DOCTOR OF PHILOSOPHY

Effects of marine recreation on bottlenose dolphins in Cardigan Bay

Vergara Peña, Alejandra

Award date:
2020

Awarding institution:
Bangor University

Bangor University

DOCTOR OF PHILOSOPHY

Effects of marine recreation on bottlenose dolphins in Cardigan Bay

Vergara Peña, Alejandra

Award date:
2020

PRIFYSGOL
BANGOR
UNIVERSITY

Effects of marine recreation on bottlenose dolphins in Cardigan Bay

Alejandra Vergara-Peña

M.Sc. Marine Biology, Bangor University (2014)

B.Sc. Biology, National University of Colombia (2012)

Submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

2020

To Ma and Pa,

La luz de mi vida

Table of Contents

Table of figures

Table of tables

Abstract

Anthropogenic activities are markedly increasing in the oceans, causing widespread concern about potential effects on marine mammals and ecosystems. In the UK, a large population of bottlenose dolphins inhabits the coastal waters of Wales, where it has experienced an increase in disturbance from human activities. The importance of the region for the species has been recognised in EU legislation through the establishment of two Special Areas of Conservation (SAC) within Cardigan Bay. Cardigan Bay SAC is located in the southern part of Cardigan Bay and Pen Llŷn a'r Sarnau SAC is located in the north of the Bay and around the Llŷn Peninsula. Conservation strategies in the area include a boating code of conduct with respect to marine mammal encounters: the southern SAC has had a code of conduct in place for several years now, with good compliance, whilst the northern SAC implemented the code of conduct for the first time in the summer of 2016, to reduce disturbance or pressure upon marine mammals in Cardigan Bay. Sea Watch Foundation has been monitoring the bottlenose dolphin population in the area since 2001. Over that period, a marked increase in human pressure has been observed, as well as a decline in bottlenose dolphin usage within the Cardigan Bay SAC. Some individuals have been found to be particularly vulnerable to local human activities, and therefore the population may no longer be at Favourable Conservation Status within the SAC. Since the Welsh bottlenose dolphin population is a central attraction for visitors, generating millions of pounds of income annually, careful management is needed in order to conserve the species whilst safeguarding its socio-economic value.

The present study aimed to evaluate effects of recreational boating and dolphin-watching activities on the bottlenose dolphins inhabiting Cardigan Bay, in order to build scientific evidence that can be used towards a better management plan. Boat-based surveys, theodolite tracking using land-watches, passive acoustic monitoring, as well as social science surveys were used to examine dolphin presence and behavioural responses during boat encounters, together with marine users' perceptions about these activities and their potential impacts, to help shape future conservation strategies.

The probability of encountering dolphins was related to the type of boat as well as the temporal scale at which this was explored. In the short-term, dolphin density decreased in relation to speed craft only. In the long-term, the probability of encountering dolphins varied in relation to the presence of all type of boats, with an increase in dolphin density in relation to fishing boats

in Cardigan Bay SAC. This shows that the presence of fishing vessels may be beneficial to dolphins, potentially by offering additional feeding opportunities Nonetheless, the fact that dolphin density decreased in relation to the presence of most boat types, shows that frequent boat activity disrupts dolphin numbers in the area, with certain boat types triggering a more significant decrease in density. This indicates the need for further management assessments and recommendations focused on minimising harassment and potential effects of vessel disturbance, avoiding a reduction in dolphin usage of certain areas (Pierpoint et al., 2009), with particularly focus on speed craft, their travel speed and numbers permitted around dolphins during an encounter.

When looking at short-term responses of bottlenose dolphins to boat encounters in Cardigan Bay, dolphin avoidance responses were found to be caused by high travel speed and close approaches by boats, but not by distance between dolphin and boat. It was evidenced that during a boat encounter, dolphins increased their swim speeds at Abersoch, where the code of conduct has been in place since 2016, but reduced it at New Quay, where the code of conduct has been in place since 2004. At Abersoch, dolphin abundance was highest during the boat encounter, whereas in New Quay dolphin numbers increased after the encounter, perhaps as an avoidance mechanism in which, to swim away from the threat source, dolphins swim faster and cluster together (covering a reduced area) to protect more individuals within the group. Dolphins maintain occupancy despite vessel presence but alter their behaviour, with greater negative responses to boats at Abersoch, which can be linked to the time that codes of conduct have been running in the SACs. This suggests that codes of conduct could have both conservation and socio-economic benefits by allowing people to encounter dolphins without causing excessive disturbance to animals and therefore compliance should be promoted across Cardigan Bay.

Evaluation of dolphin presence and foraging activity in Cardigan Bay SAC, where the boating code of conduct has been in place since 2004, suggested an increase in both when boats were in the vicinity. Bottlenose dolphins appear able to sustain the present level of boat activity, perhaps due to its constant low intensity. However, further studies at a finer scale should be implemented, because the length of time of a boat-dolphin encounter is important to characterise disruption to dolphin presence and foraging by boat activities. Further acoustic and visual-based surveys could help to predict the effects of noise disturbance, as well as the presence of different numbers and types of boat, upon bottlenose dolphin responses.

Bearing in mind that the bottlenose dolphin population in Cardigan Bay provides important economic benefits to local human communities, it is important for users to adhere to management regulations such as a boating code of conduct in order to maintain those benefits. Results from social surveys of recreational users, commercial operators, and dolphin-watching trip clients in Cardigan Bay highlighted the importance of the bottlenose dolphin population to all of them. Nonetheless, data suggested differences in knowledge of a local boating code of conduct between recreational users in both SACs, with fewer people knowing about it at Pen Llŷn a'r Sarnau SAC than at Cardigan Bay SAC. This evidences the need for further environmental education of users to improve their responses during a dolphin encounter, minimising harassment and disturbance whilst ensuring the dolphins remain in Cardigan Bay.

In conclusion, bottlenose dolphin responses to boats are different in both SACs. More neutral or positive reactions were seen in the long-standing code of conduct area (Cardigan Bay SAC), with the guidelines in place in New Quay (i.e. minimum 100 metres boat-dolphin distance, no direct approach to dolphins, and maximum 8 knots travel speed) appearing to be working. Similar management guidelines should be established on a wider scale, perhaps implementing an area-based management scheme, but with particular emphasis upon restricting the number of boats during a dolphin encounter, reducing boat speeds and modifying boat behaviour (avoiding direct approach to dolphins). Results highlight that codes of conduct can be effective if they are monitored and complied with, but education is important, particularly for recreational users. If followed, codes of conduct will not only help the bottlenose dolphin population but also facilitate a sustainable wildlife watching industry.

Acknowledgements

Words cannot express how grateful I am for the opportunity to have developed this project, and to the numerous people that have made it possible.

I would like to express my deep gratitude to Dr. Peter Evans for his patient, commitment, guidance, enthusiastic encouragement and inspiration and useful critiques during this research. He has always been supportive and for that I will be eternally grateful. My sincere gratitude also goes to Dr Line Cordes for her support, reassurance and understanding. A very special thanks goes to Dr James Waggitt, your research and statistic insight was unprecedented and without you this thesis would not have been possible. I am also thankful to Dr John Turner for helping improve my chapters.

My grateful thanks are further extended to all the SWF volunteers who collected the data used to develop this project, particularly to those who ensured that my questionnaires were filled, as well as the Gwynedd Council Beach Patrol members who likewise supported this. Additionally, I want to show gratitude to Dr Hanna Nuuttila for providing me with the data and information to develop my acoustic chapter. And thank you to all volunteers and friends that helped me during my theodolite data collection, your company meant a lot to me.

"At times, our own light goes out and is rekindled by a spark from another person. Each of us has cause to think with deep gratitude of those who have lighted the flame within us."

– Albert Schweitzer

I am grateful to all those family members and friends that always supported me and helped me light back, you all know who you are, I would have never done it without you.

Thanks to Ma, Pa, Clarita and Tatica for all their love and support and for always believing in me, los amo.

But also thanks go to those who did not believe I would achieve this, I grew stronger with your help.

CHAPTER I

General introduction

1.1 Impacts of tourism and recreational activities on terrestrial and aquatic systems

Human populations depend completely on the Earth's ecosystems and the services they provide such as water, food, disease management, climate regulation, spiritual satisfaction, and aesthetic enjoyment (Reid et al, 2005). Yet, enjoyment of nature has been documented as the most noticeable cultural ecosystem service (UNWTO, 2014), whilst its global magnitude, economic significance, and impacts on wildlife are still poorly understood, leading to widespread concern about the potential effects that they may cause on the ecosystem and wildlife populations (Hannah et al., 1994).

Annually, 3.6 million visitors frequent public lands and waters globally in order to explore our wildlife, whilst engaging in recreational activities (Tourism Concern, 2017). As this outdoor participation increases, nature managers have expressed their concern about the wellbeing of our wildlife in coexistence with the integration of policies that allow recreational use (Bell et al., 2007). Outdoor recreation is believed to be one of the leading causes of wildlife decline worldwide (Taylor & Knight, 2003), its effects reaching individuals, populations, and communities (species richness, diversity, or composition) by affecting behaviour and productivity, which in turn may alter interspecific interactions (Knight & Cole, 1991).

A global review of the literature (Larson et al., 2016) found that most studies of animal responses to recreational activities have been behavioural (45.5% of articles), followed by modification in abundance (24.1%), whilst survival and community responses have been studied least of all. Not counting survival responses (due to small sample size), the highest number of negative effects were found at the community-level (64.6 ± 6.6% of results), followed by behavioural (63.5 ± 2.8%) and physiological responses (62.5 ± 4.9%) at the individual-level. Reproductive responses at the population-level (36.7 ± 6.3%) had the fewest overall negative effects (Larson et al., 2016; Figure 1.1).

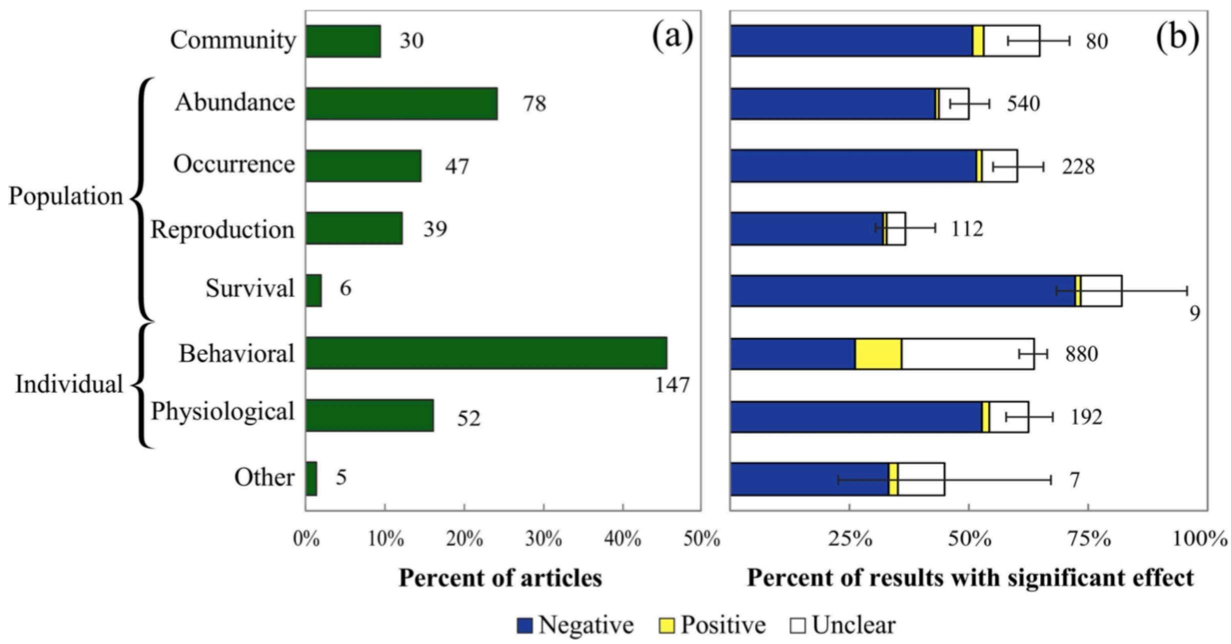


Figure 1.1 Different types of animal responses to recreational activities in the reviewed articles; a) Percentage of articles focused on each response, the numbers after the bars represent absolute number of articles; b) Percentage of results with significant effects due to recreational activities (error bars represent ± standard error), blue is for negative results, yellow for positive and white for unclear effects, numbers after the bars represent number of results (taken from Larson et al., 2016).

Evidence suggests that even though research has been conducted on all taxa, most studies have concentrated upon mammals and birds, and conservation interests towards them (Clark & May, 2002). Larson et al (2016) noted in their evaluation of 274 scientific articles assessing effects of recreation on animals at a global scale, that at the family level, Bovidae (e.g. bison, bighorn sheep) and Delphinidae (dolphins) were the ones where most effects of recreation activities were found (93.8 ± 19.3%, 70.8% ± 6.8% respectively). Some examples of impacts from recreational activities upon terrestrial and aquatic animals are shown in Table 1.1.

Certainly, it is important to continue researching and understanding different anthropogenic activities and the ways in which they cause disturbance and hence affect our wildlife species both on land and aquatic systems. Nonetheless, it is not enough to find the frequency and the level of impact and their effects, improvement on further management and mitigation actions should also be implemented from research results to protect our great biodiversity, whilst developing sustainable human activities.

Table 1.1 Examples of anthropogenic activities and their effects on different animals in terrestrial and aquatic systems

Anthropogenic activity	**Response/effect**	**Geographical location**	**Species**	**Reference**
Hunting pressure	Variation in group size, and sex and age composition	Oksbol State Forest District-Denmark	Red deer (*Cervus elaphus)*	Jeppsesen, 1987
Off-road vehicles	Decreased abundance	North Stradbroke Island-Australia	Ghost crab (Fam. Ocypodidae)	Schlacher *et al.,* 2007
Recreational boating	Moving away of affected area	Kings Bay-USA	Manatee (*Trichechus manatus latirostris*)	Buckingham *et al.,* 1999
Noise	Reduction in growth and reproduction rates	Angoulins-France	Brown shrimp (*Crangon crangon)*	Lagardere, 1982
Off-road vehicles	Mortality	Western Mojave Desert-USA	Desert tortoise (*Gopherus agassizii)*	Bury and Marlow, 1973
Pedestrian and dogs	Increase in flush and moved distance	Boulder-USA	Mule deer (*Odocoileus hemionus*)	Miller *et al.,* 2001
Aircraft noise	Nest abandonment and increase in flush distance	Jamaica Bay National Recreational Area-USA	Herring gull (*Larus argentatus*)	Burger, 1981
Hike and mountain biking	Increase in flush distance	Antelope Island State Park-USA	Bison (*Bison bison*), mule deer (*Odocoileus hemionus*), pronghorn antelope (*Antilocapra americana*)	Taylor & Knight, 2003

Travel noise	Decrease calling rate	Antarctica	Weddell seals (*Leptonychotes weddellii*)	van Polanen Petel *et al.,* 2006
Various outdoor activities	Changes in behaviour patterns	Minnesota-USA	Common loon (*Gavia immer*)	Titus & VanDruff, 1981
Helicopter overflights	Changes in behaviour patterns	Antarctica	King penguins (*Aptenodytes patagonicus)*	Hughes *et al.,* 2008
Boat presence	Changes in nesting and basking behaviours	Mississippi-USA	Yellow-blotched map turtle (*Graptemys flavimaculata)*	Moore & Seigel, 2006
Recreational fishing	Decrease in length	Balearic archipelago-Spain	Mediterranean rainbow wrasse (*Coris julis)*	Cardona *et al., 2007*

1.2 Impacts of tourism and recreational activities on marine wildlife

Due to easier accessibility, 6% of global terrestrial ecosystems have been established as conservation reserves, whilst less than 1% of seas have been protected (Carr et al., 2003), with the majority of studies focusing on recreational impacts conducted on terrestrial wildlife (Larson et al., 2016). Therefore, more research on marine systems should be undertaken, particularly bearing in mind the nature of this realm where light availability and speed of sound transmission are so different than in air. With light not reaching all depths equally whilst visibility is reduced, sound may transmit over long ranges, helping them to navigate, hunt and communicate. This is the reason why the wildlife found here relies so much upon sound, whilst there is a reduction in the importance of vision.

Human populations benefit from ocean ecosystems through the provision of numerous goods and services. This also means that both directly and indirectly, humans alter this vast ecosystem in innumerable ways. It is challenging to study a three-dimensional environment where most of the activities occur under the surface out of sight, nonetheless this system faces just as many pressures as terrestrial ones, particularly in the coastal zone which is most accessible to human contact (Ramesh et al., 2015), and where marine mammal communities in almost 50% of the world’s coastal waters are considered at high-risk (Avila et al., 2018). Therefore, research of our oceans are fundamental to reduce gaps in our understanding of this ecosystem whilst providing environmental information required to address current and emerging management needs. In this way, research helps to guarantee that ocean resources are not just managed, but managed appropriately, protecting those resources in the long-term.

In marine ecosystems, direct and indirect anthropogenic impacts such as fishing, pollution, climate change, and recreation vary in the spatial extent of their impact (Halpern et al., 2008). Recreational activities include wildlife watching and recreational boating. Even though local marine recreation may not have the same large-scale impact as pollution or climate change, the growth in recreational boating activities, as well as in commercial dolphin and whale watching since the 1990s has raised concerns for how marine mammals are affected by boat traffic (Higham et al., 2015). Although the effects of these activities are typically noticed in the short-term, it is known that cumulative effects can cause changes to populations not only in the short-term but also the long-term (Bejder et al., 2006a).

Cetaceans have important ecological roles within their ecosystems, and their absence could lead to an important modification or collapse of that ecosystem (Parsons et al., 2013). For example, blue whales fertilise phytoplankton through their defecation (Ratnarajah et al., 2016), which all sea life depends on, and dolphins control prey populations and make food available for other species (Dans et al., 2010). By studying cetaceans, the impact of anthropogenic activities on the species can be determined and management recommendations established which might also protect other species and habitats. Studies on cetaceans initially focused upon particular species, mostly mysticetes, but more recently have turned to odontocete species. Nonetheless, bottlenose dolphins have been well studied over many years and are possibly the best known of all cetaceans. This is because they occupy some of the most populated coastal areas and come into ready contact with an appreciative human population.

Due to the nature of the environment that cetaceans inhabit, they have evolved particular sensory systems to help them fulfil life functions in water. Vision in water is much reduced whilst acoustic stimuli play an important role in species interactions and communication. Even though cetacean individuals are equipped with different structures that they use underwater, they do not give the same importance to all the stimuli that they can find in the ocean, which is evidenced by their adaptations in ear structure and hearing capabilities, giving priority to their communication and navigation. Additionally, individuals are finely adjusted to specific stimuli such as those associated with predators, prey availability and/or those representing social signals. Evidence suggests that large, well-developed cetacean brain is a direct product of adaptation to a fully aquatic lifestyle (Marino, 2007). Therefore, their brains have acoustic regions, where rapid processing of sounds occurs, with particular focus on high-frequency echolocation clicks, which are directed at specific targets and help describe the surrounding environment and target objects of interest such as prey (Reynolds III et al., 2000).

Observations of collisions, where epidermal lesions, amputation of dorsal fins and/or flukes, or even death can happen, are direct evidence of the effect of vessel activities on cetaceans that are relatively easy to identify. Nonetheless, vessel presence also generates noise pollution, which may physically harm the auditory channel of cetaceans, leading to temporary or permanent hearing loss (Mooney et al., 2009), which would be a harder effect to identified. Pressure from boat traffic may also have indirect impacts on cetaceans, by acoustic, visual or physical contact. Studies have reported changes mainly in cetacean behaviour. These include foraging activities (Nowacek et al., 2001; New et al., 2013; Pirotta et al., 2015), avoidance (Bejder et al., 1999; Nowacek et al., 2001; Moore & Clarke, 2002), and variations in dive patterns/synchrony (Janik, 1996; Hastie et al., 2003; Ng & Leung, 2003). All these are examples of what we perceive as short-term effects from disturbance, but there is growing evidence that when species are continuously exposed to such disturbances, they are affected in the long-term as well. When short-term effects accumulate over a long period, ecological and evolutionary consequences for individuals can arise with population consequences, leading to decline in abundance (Bejder et al., 2006a; Scarpaci et al., 2008; Currey et al., 2009), disruption of association patterns (Lusseau, 2003b; Richardson, 2012), or movement out of the affected area (Forest, 2001; Notarbartolo di Sciara, 2002; Rako et al., 2013).

1.2.1 Short-term effects of boat activity on cetaceans

The coastal occurrence of most of the cetacean species that inhabit our seas frequently takes them into direct contact with anthropogenic activities, exposing them to potential injury or disturbance. Hoyt (2001) reported that approximately 700 to 1,000 different cetacean populations regularly interact with tour vessels; that is probably the reason why a great number of studies have focused their interest on understanding interactions between the two, including the short-term effects that cetaceans might display as a response to boat traffic. Many species display a variety of effects or behavioural responses to boat presence; some odontocetes may tolerate or even approach watercraft, whilst other species have frequently shown negative responses.

As cetaceans spend the majority of their lives underwater, in order to achieve knowledge of their reactions to vessels, observations of surfacing events are often the basis for understanding their behaviour. Studies using land-watches, vessel-based surveys, acoustic techniques and theodolite usage have reported a variety of cetacean behavioural modifications as response to boat activity. A study of Baird's beaked whale and minke whale in Tokyo Bay, for example, found modifications to the migratory routes of both species to avoid a busy traffic area (Nishiwaki & Sasao, 1977). On the other hand, research in California found that grey whales were attracted to dolphin-watching vessels and therefore would swim towards them before continuing on their original migration route (Heckel, 2001). Evaluation of dolphin reactions to boats in Porpoise Bay, New Zealand, suggested that after a relatively long period of time around vessels, Hector´s dolphins tended to swim away or ignore their presence, whilst tightening the group presumably to protect individuals from the threat that boats represent (Bejder et al., 1999). Behavioural responses of Indo-Pacific bottlenose dolphins to experimental vessel approaches were tested in regions of low and high vessel traffic in Shark Bay, Australia, with dolphins displaying stronger and longer-lasting responses in the region of low vessel traffic than those seeing in the region of high vessel traffic (Bejder et al., 2006b). Similarly, increased swim speeds by grey whales was interpreted into longitudinal avoidance (Heckel, 2001). In Hong Kong, a study of the Indo-Pacific humpback dolphin to determine behavioural responses when boats were around, found increased dive durations due to vessel presence and/or vessel approach, with responses varying depending upon the type of vessel and distance to it, with high-speed boats bringing the greatest concern (Ng & Leung, 2003). Seeking to characterise cetacean surfacing events during a boat encounter, Adimey (1995) found percussive behaviour of orcas was inhibited in the presence of vessels, although Williams et al (2009) did not find any differences between percussive behaviour in southern resident orcas with and without boats.

Cetaceans have also been the focus of studies that seek to assess social responses to boat traffic. Finless porpoises can change their social cohesion when boats are around by aggregating together (Morimura & Mori, 2019). It has also been shown that vessel activity can change cetacean vocalisations. When Pacific humpback and bottlenose dolphins came into contact with dolphin-watching boats, they displayed an increase in whistle frequency as a response to increased ambient noise that can cause signal masking (Van Parijs & Corkeron, 2001; Buckstaff, 2004). Studies of the effect of boats on vocal behaviour of beluga whales in the St. Lawrence River Estuary, Canada, found calling rates decreased as boats approached, whilst there was a shift in frequency bands to a higher frequency when the vessels were close, mitigating the noise disturbance (Lesage et al., 1999).

Changes in activities have also been shown as response to vessel traffic. Dolphins were found to interrupt socializing or resting after a boat interacted with them, whilst increasing time diving and travelling responses to elude boat presence (Lusseau, 2003a; Marley et al., 2017). Furthermore, cetaceans have been found to reduce feeding in the presence of vessels, reducing prey capture events and therefore energy intake, leading to an energy cost due to boat disturbance that might have further implication at the population level (Williams et al., 2006, Lusseau et al., 2009; Pirotta et al., 2012; Merchant et al., 2016).

1.2.2 Long-term effects of boat activity on cetaceans

Few studies have focused in detail on analysing long-term effects of recreational activities upon cetaceans. This is due to the fact that, even though accessible pre-tourism datasets from control and impact sites are available, the research design has rarely started with the intention of evaluating impacts on cetaceans. Therefore, linking the observed trends with recreational activities is often difficult and may be confounded by the effects of other human activities or ecological factors that could be involved. Nonetheless, the short-term effects described above are believed to evolve into long-term ones by accumulation over time. Short-term responses to disturbance can have unanticipated effects upon the life history of individuals exposed to those disturbances, leading to reduced reproduction and survival, thus affecting the dynamics of the population. Therefore, studies have attempted to evaluate how persistent exposure or cumulative short-term responses, can generate long-term effects on cetaceans.

Possible long-term effects of these human activities on marine mammals include reduced reproductive success through decrease in birth rates, calf mortality, offspring abandonment and decreased survival of young (Waples & Gales, 2002). They can also include, for example, avoidance or movement out of the affected area, with marine mammals seeking other less affected habitats. Several researchers have suggested that due to increased human activities, different cetacean species area usage decreases, perhaps also as part of local environmental degradation (Bryant et al., 1984, Dean et al., 1985, Evans, 2017, Forest, 2001, Jefferson, 2000). Additionally, Bejder et al. (2006) found clear habitat displacement as a result of tour vessel interactions on bottlenose dolphins in Shark Bay, Australia, with dolphin abundance decreasing in the bay, whilst it increased in an adjacent bay less frequented by vessels. These highlight the importance of the evaluation of human impacts in habitat avoidance or abandonment by cetaceans, since moving out of an affected area implies a redistribution and/or modification on species density and therefore on population dynamics if there is an increase in the frequency and the intensity of the disturbance. Therefore, it is important to be able to establish whether or not the short-term responses seen in cetaceans are linked to recreational activities or are due to some other factors, and to take those into account in the research design to arrive at accurate conclusions about the effects that vessel traffic might bring to the species in the long-term.

The suitability of short-term behavioural effects as indicators of biologically significant impacts is still under study. It is rarely known how immediate responses are modified into long-term changes in condition (individuals in poor conditions due to a decrease in feeding opportunities), habitat use (changes to overcome disturbance), or how those changes may influence reproduction, survival or population size. Therefore, examples of mortality, declines in abundance, declines in reproductive success, and disruption in association patterns in cetaceans due to recreational activities in the long-term all remain subjects to explore further. Although studies on some dolphin species have been conducted to evaluate long-term effects, additional research should be conducted to investigate ecology, behaviour, population and community dynamics of coastal bottlenose dolphins, in order to arrive at conclusions about population changes and conservation strategies to protect those cetaceans from anthropogenic impacts.

Table 1.2 Examples of cetacean responses to boat activities in other studies

Effects/Changes	Response	Geographical location	Species	Reference
Behavioural budget	Decrease in foraging and surface feeding	Faxaflói Bay, Iceland	Minke whale (*Balaenoptera acutorostrata*)	Christiansen et al., 2013b
Behavioural budget	Decrease in foraging behaviour	Bay of Plenty, North Island, New Zealand	Common dolphins (*Delphinus delphis)*	Meissner et al., 2015
Behavioural budget	Decrease in resting behaviour	Pico Island, Azores	Risso's dolphins (*Grampus griseus*)	Visser et al., 2011
Behavioural budget	Less time socializing and foraging	Galveston Ship Channel, U. S. A	Bottlenose dolphin (*Tursiops truncatus*)	Piwetz, 2019
Behavioural budget	Decrease resting behaviour and increase travelling,	Doubtful Sound, New Zealand	Bottlenose dolphin (*Tursiops truncatus*)	Lusseau et al., 2006
Dive duration	Decrease inter-breath intervals	Faxaflói Bay, Iceland	Killer whales (*Orcinus orca*)	Christiansen et al., 2013a
Dive duration	Increase synchronise movements	Cromarty Firth, Scotland	Bottlenose dolphin (*Tursiops truncatus*)	Hastie et al., 2003

Dive duration and avoidance	Changes in surface behaviour and direction of travelling	New South Wales, Australia	Bottlenose dolphin (*Tursiops truncatus*)	Lemon et al., 2006
Behaviour and Avoidance	Change in behaviour and swimming direction	Surrounding Hilton Head Island, U. S. A	Bottlenose dolphin (*Tursiops truncatus*)	Mattson et al., 2005
Horizontal avoidance	Change in swim direction	New Caledonia	Humpback whales (*Megaptera novaeangliae*)	Schaffar et al., 2013
Horizontal avoidance	Altered swim speed	Faxaflói Bay, Iceland	Minke whales (*Balaenoptera acutorostrata*)	Christiansen et al., 2014
Group cohesion and avoidance	Individuals clustering together. More erratic speeds and directions of travel.	Shark Bay,Western Australia	Bottlenose dolphin (*Tursiops* sp)	Bejder et al., 2006
Group cohesion	Spread out into smaller sub-groups	Bunbury, Australia	Bottlenose dolphin (*Tursiops truncatus*)	Arcangeli & Crosti 2009
Foraging/Vocalisation	Reduction in foraging activity (incidence of feeding buzzes)	Moray Firth, Scotland	Bottlenose dolphin (*Tursiops truncatus*)	Pirotta et al., 2015
Vocalisation	Reduce communication range	Canary Islands, Spain	Bottlenose dolphin (*Tursiops* spp)	Jensen et al., 2009

Vocalisation	Reduce communication range	Cardigan Bay, Wales	Bottlenose dolphin (*Tursiops truncatus)*	Evans et al., 1992
Vocalisation	Change in vocalisation patterns	Wildlife Refuge Gandoca-Manzanillo, Costa Rica,	Bottlenose dolphin (*Tursiops truncatus)*	May-Collado & Wartzok, 2008
Abundance	Decrease number of animals	Shark Bay, Western Australia	Bottlenose dolphin (*Tursiops truncatus)*	Bejder et al., 2006a
Abundance	Reduction in calf survival. Decline in population	Doubtful Sound, New Zealand	Bottlenose dolphin (*Tursiops truncatus)*	Currey et al., 2009
Short-term displacement	Visiting the area for shorter periods	New Zealand	Bottlenose dolphin (*Tursiops truncatus*)	Lusseau, 2005
Displacement	Avoidance of the area	Milford Sound, New Zealand	Bottlenose dolphin (*Tursiops truncatus)*	Lusseau, 2004
Survival	Reduced ability to produce and successfully rear offspring	Shark Bay, Australia	Bottlenose dolphin (*Tursiops truncatus*)	Bejder, 2005

1.3 Knowledge gaps

Given that the determination of short-term impacts of vessel activity and their potential to trigger long-term effects currently are major research questions for better management and conservation of cetaceans - important species for the ecosystem as well as socio-economic development, and given that boat traffic has been found to be increasing worldwide, this thesis will address marine recreational activities and their effects on coastal bottlenose dolphin *Tursiops truncatus* to aid better conservation of the species alongside a viable recreational industry.

1.4 Thesis structure and aims

The results of monitoring between 2001 and 2019 suggest a recent decline in the abundance of the semi-resident population of bottlenose dolphins within Cardigan Bay SAC (Lohrengel et al., 2018), for which the species is a primary feature. This, together with reports that anthropogenic activities are increasing in Cardigan Bay, provide the perfect setting to evaluate effects of those human activities (recreational boating and dolphin-watching) on this species, in order to build scientific evidence that can be used to guide management recommendations, facilitate consenting decisions for marine development and design targeted monitoring.

The study first introduces the environmental features of Cardigan Bay and summarises information on the bottlenose dolphin population there (*Chapter II*). It then identifies regions where human activities and disturbance are likely to impact the Welsh bottlenose dolphin population, helping to direct management recommendations towards the conservation of this species in the bay. Therefore, it aims to analyse boat activity and its possible effects upon the bottlenose dolphin population across Cardigan Bay over the past 12 years, to answer: i) is there a relationship between dolphin density and boat density and is any relationship dependent on the type of boat?; ii) is there a relationship between dolphin density and boat density and is any relationship dependant on the area (whether or not code of conduct compliance has been applied over a number of years)?; and iii) have dolphin reactions and/or density changed over time? (*Chapter III).*

Due to the presence of management plans with different levels of code of conduct compliance between the two SACs, the study aims to evaluate immediate behavioural responses of dolphins and boats during encounters, in areas with different management compliance. The following hypotheses are tested: i) short-term behavioural attraction responses by bottlenose dolphins to boat presence are more likely to happen in an area of strong code of conduct compliance, than in an area where boats are less compliant; and ii) there is less compliance in areas of Cardigan Bay where the code of conduct was established in 2016, than in areas where the code of conduct has been in place since 2004. The research was conducted using land-based surveys, in order to avoid possible disturbance from the researcher during the data collection (*Chapter IV).*

Based on previous studies, there is evidence suggesting that boats can cause short-term behavioural changes on bottlenose dolphins, which can lead to change in activity budgets. Nonetheless, it is much more difficult to establish whether these have longer-term population level effects. One way to infer a population consequence of disturbance is if boat exposure can reduce foraging time, which in turn will affect energy intake, with potential implications for an individual's energy balance, physiological conditions/vital rate (such as increased heart rate and decreased body mass), which may reduce individual fitness and survival and could ultimately have population-level consequences in the long-term. Acoustics is a useful method to assess foraging through animals click buzz rates (which have been shown to indicate the exploration and targeting of potential prey). Therefore, the aim of this study is to characterise the effect of boat disturbance on the activity of bottlenose dolphin in Cardigan Bay SAC whilst assessing code of conduct success, by testing: i) is dolphin presence affected by boat presence? and ii) how does boat presence affect foraging activity? (*Chapter V).*

To examine whether knowledge about the code of conduct, as well as compliance to its guidelines (in terms of the duration, range and response at the moment of an encounter) differ between SACs in Cardigan Bay, questionnaire surveys of different groups were undertaken. This provides the occasion to evaluate boat user perceptions, interests, awareness and, most important, adherence to a code of conduct. The aim of this study was to ensure that management recommendations provided the correct balance between bottlenose dolphin conservation and a viable use of wildlife resources in Cardigan Bay by taking into account users' perceptions and needs. Thus, the study seeks to answer: i) are recreational users aware of, and do they follow the code of conduct?; ii) how important is the presence of bottlenose dolphins to recreational users and dolphin-watching clients when visiting Cardigan Bay? iii) what are the main interests of locals and visitors when going on a wildlife-watching tour? and iv) what is clients' awareness of the potential benefits and impacts on the environment and specifically to bottlenose dolphins of wildlife-watching trips? (*Chapter VI).*

The general discussion (*Chapter VII*) reviews key findings and their consequences in terms of impacts from boat activities on bottlenose dolphins in Cardigan Bay, whilst directing management recommendations.

1.5 References

Adimey, N. M. (1995). A descriptive study of the percussive behavior of orcas, *Orcinus orca*, in Johnstone Strait, British Columbia. MSc Thesis, Nova Southeastern University, Fort Lauderdale, Florida.

Arcangeli, A., Crosti, R., del Leviatano, A., & Rome, I. (2009). The short-term impact of dolphin-watching on the behaviour of bottlenose dolphins (*Tursiops truncatus*) in Western Australia. *Journal of Marine Animals and their Ecology*, 2(1), 3-9.

Avila I. C., Kaschner K., & Dormann C. F. (2018). Current global risks to marine mammals: taking stock of the threats. *Biological Conservation,* 221, 44–58.

Bejder, L. (2005). Linking short and long-term effects of nature-based tourism on cetaceans. PhD Thesis, Dalhousie University, Halifax, Nova Scotia.

Bejder, L., Dawson, S. M., & Harraway, J. A. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science,* 15(3), 738-750. https://doi.org/10.1111/j.1748-7692.1999.tb00840.x

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C. & Kruetzen, M. (2006a). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, 20(6), 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x

Bejder, L., Samuels, A., Whitehead, H., & Gales, N. (2006b). Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal behaviour*, 72(5), 1149-1158. https://doi.org/10.1016/j.anbehav.2006.04.003

Bell, S., Tyrväinen, L., Sievänen, T., Pröbstl, U., & Simpson, M. (2007). Outdoor recreation and nature tourism: A European perspective. *Living Reviews in Landscape Research,* 1(2), 1-46.

Bryant, P. J., Lafferty, C. M., & Lafferty, S. K. (1984) Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by Gray Whales. Pp. 375-387. In: Jones, M.L., Swartz, S.L. & Leatherwood, S. The Gray Whale *Eschrichtius robustus*. *Academic Press*, Orlando, FL.

Buckingham, C. A., Lefebvre, L. W., Schaefer, J. M., & Kochman, H. I. (1999). Manatee response to boating activity in a thermal refuge. *Wildlife Society Bulletin*, 27, 514-522.

Buckstaff, K. C. (2004). Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay Florida, *Marine Mammal Science,* 20, 709–725.

Burger, J. (1981). Behavioural responses of Herring Gulls *Larus argentatus* to aircraft noise. *Environmental Pollution Series* A*, Ecological and Biological*, 24(3), 177-184.

Bury, R. B., & Marlow, R. W. (1973). The desert tortoise: Will it survive? *Natural Parks Conservation Magazine,* 47(6). 9-12.

Cardona, L., López, D., Sales, M., De Caralt, S., & Díez, I. (2007). Effects of recreational fishing on three fish species from the Posidonia oceanica meadows off Minorca (Balearic archipelago, western Mediterranean). *Scientia Marina*, 71(4), 811-820.

Carr, M. H., Neigel, J. E., Estes, J. A., Andelman, S., Warner, R. R., & Largier, J. L. (2003). Comparing marine and terrestrial ecosystems: implications for the design of coastal marine reserves. *Ecological Applications*, 13(sp1), 90-107.

Christiansen, F., Rasmussen, M., & Lusseau, D. (2013a). Whale watching disrupts feeding activities of minke whales on a feeding ground. *Marine Ecology Progress Series*, 478, 239-251.

Christiansen F., Rasmussen M. H., & Lusseau, D. (2013b). Inferring activity budgets in wild animals to estimate the consequences of disturbances. *Behavioral Ecology*, 24,1415-1425.

Christiansen, F., Rasmussen, M. H., & Lusseau, D. (2014). Inferring energy expenditure from respiration rates in minke whales to measure the effects of whale watching boat interactions. *Journal of Experimental Marine Biology and Ecology*, 459, 96-104.

Clark, J. A., & May, R. M. (2002). Taxonomic bias in conservation research. *Science*, 297(5579), 191-192.

Currey, R., Dawson, S., Slooten, E., Schneider, K., Lusseau, D., Boisseau, O., & Williams, A. (2009). Survival rates for a declining population of bottlenose dolphins in Doubtful Sound, New Zealand: an information theoretic approach to assessing the role of human impacts. *Aquatic Conservation: Marine and Freshwater Ecosystem*s, 19, 658–670.

https://doi.org/10.1002/aqc

Dans, S. L., Crespo, E. A., Koen-Alonso, M., Markowitz, T. M., Vera, B. B., & Dahood, A. D. (2010). Dusky dolphin trophic ecology: their role in the food web. In The Dusky Dolphin (pp. 49-74). Academic Press.

Dean, F. C., Jurasz, C. M., Palmer, V. P., Curby, C. H., & Thomas, D. L. (1985). Analysis of humpback whale *(Megaptera novaeangliae)* blow interval data, Glacier Bay, Alaska, 1976-1979. *Reports from Alaska, Fairbanks, for U. S. National Park Service,* Anchorage, AK. 224pp.

Evans, P. G. H. (2017). Habitat pressures. pp 441-446. In: Würsig, B., Thewissen, J. G. M., & Kovacs, K. M. Encyclopedia of Marine Mammals. 3rd Edition. *Academic Press*, San Diego. pp 1157.

Evans, P. G. H., Canwell, P. J. & Lewis, E. J. (1992). An experimental study of the effects of pleasure craft noise upon bottle-nosed dolphins in Cardigan Bay, West Wales. *European Research on Cetaceans,* 6, 43-46.

Forest, A. (2001). The Hawaiian spinner dolphin, *Stenella longirostris*: effects of tourism. MSc Thesis, Texas A& M University, Galveston, Texas.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V, Micheli, F., D'Agrosa, C., & Watson, R. (2008). A Global Map of Human Impact on Marine Ecosystems. *Science*, 948–953. https://doi.org/10.1111/2041-210X.12109

Hannah, L., Lohse, D., Hutchinson, C., Carr, J. L., & Lankerani, A. (1996). A preliminary inventory of human disturbance of world ecosystems. *Biological Conservation*, 76(2), 209. https://doi.org/10.1016/0006-3207(96)83209-5

Hastie, G. D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2003). Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science*, 19(1), 74–84. https://doi.org/10.1111/j.1748-7692.2003.tb01093.x

Heckel, G. (2001). The influence of whalewatching on the behaviour of gray whales (*Eschrichtius robustus*) in Todos Santos Bay, Baja California, and surrounding waters: Management plan proposal. *Journal of Cetacean Research and Management*, 3(3), 227–237.

Higham, J. E., Bejder, L., Allen, S. J., Corkeron, P. J., & Lusseau, D. (2015). Managing whale-watching as a non-lethal consumptive activity. *Journal of sustainable tourism,* 24(1), 73-90.

Hoyt, E. (2001). Whale Watching 2000: Worldwide tourism numbers, expenditures, and expanding socioeconomic benefits. *International Fund for Animal Welfare*, Yarmouth, MA. pp 165.

Hughes, K. A., Waluda, C. M., Stone, R. E., Ridout, M. S., & Shears, J. R. (2008). Short-term responses of king penguins *Aptenodytes patagonicu*s to helicopter disturbance at South Georgia. *Polar Biology*, 31(12), 1521-1530.

Janik, V. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12, 597–602.

Jefferson, T. A. (2000). Population biology of the Indo-Pacific hump-backed dolphin in Hong Kong waters. *Wildlife Monographs*, 64(4), 1-65.

Jensen, F. H., Bejder, L., Wahlberg, M., Soto, N. A., Johnson, M., & Madsen, P. T. (2009). Vessel noise effects on delphinid communication. *Marine Ecology Progress Series*, 395, 161–175. https://doi.org/10.3354/meps08204

Jeppesen, J. L. (1987). Seasonal variation in group size, and sex and age composition in a Danish red deer (*Cervus elaphus*) population under heavy hunting pressure. *Danish Review of Game Biology,* 13, 1–19

Knight, R. L., & Cole, D. N. (1991). Effects of Recreational Activity on Wildlife in Wildlands. *Transactions of the North American Wildlife and Natural Resources Conference*, 56, 238-247.

Lagardère, J. P. (1982). Effects of noise on growth and reproduction of *Crangon crangon* in rearing tanks. *Marine Biology*, 71(2), 177-185.

Larson, C. L., Reed, S. E., Merenlender, A. M. & Crooks, K. R. (2016). Effects of recreation on animals revealed as widespread through a global systematic review. *PLoS ONE*, 11(12), pp 21. doi:10.1371/journal.pone.0167259

Lemon, M., Lynch, T. P., Cato, D. H., & Harcourt, R. G. (2006). Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. *Biological Conservation*, 127(4), 363–372. https://doi.org/10.1016/j.biocon.2005.08.016

Lesage, V., Barrette, C., Kingsley, M. C. S., & Sjare, B. (1999). The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River estuary, Canada. *Marine Mammal Science*, 15(1), 65–84. https://doi.org/10.1111/j.1748-7692.1999.tb00782.x

Lohrengel, K., & Evans, P. G. H. (2015). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2015. *Sea Watch Foundation, Interim Report*, (February). pp 86.

Lusseau, D. (2003a). Effects of tour boats on the behavior of bottlenose dolphins: Using Markov chains to model anthropogenic impacts. *Conservation Biology*, 17(6), 1785–1793. https://doi.org/10.1111/j.1523-1739.2003.00054.x

Lusseau, D. (2003b). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series*, 257, 267–274. https://doi.org/10.3354/meps257267

Lusseau, D. (2004). The hidden cost of tourism: Detecting long-term effects of tourism using behavioral information. *Ecology and Society*, 9(1), 2. http://www.ecologyandsociety.org/vol9/iss1/art2/

Lusseau, D. (2005). Residency pattern of bottlenose dolphins *Tursiops* spp. in Milford Sound, New Zealand, is related to boat traffic. *Marine Ecology Progress Series*, 295, 265–272.

Lusseau, D. (2006). The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Marine Mammal Science*, 22(4), 802–818. https://doi.org/10.1111/j.1748-7692.2006.00052.x

Lusseau, D., Bain, D. E., Williams, R., & Smith, J. C. (2009). Vessel traffic disrupts the foraging behavior of southern resident killer whales *Orcinus orca*. *Endangered Species Research*, 6(3), 211–221. https://doi.org/10.3354/esr00154

Lusseau, D., Slooten, L., & Currey, R. J. C. (2006). Unsustainable dolphin-watching tourism in Fiordland, New Zealand. *Tourism in Marine Environments*, 3(2), 173–178. https://doi.org/10.3727/154427306779435184

Marino, L. (2007). Cetacean brains: how aquatic are they? Advances in Integrative Anatomy and Evolutionary Biology. *The Anatomical Record*, 290(6), 694-700.

Marley, S. A., Salgado Kent, C. P., Erbe, C., & Parnum, I. M. (2017). Effects of vessel traffic and underwater noise on the movement, behaviour and vocalisations of bottlenose dolphins in an urbanised estuary. *Scientific Reports*, 7(1), 1–14. https://doi.org/10.1038/s41598-017-13252-z

Mattson, M. C., Thomas, J. A., & St. Aubin, D. (2005). Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquatic Mammals*, 31(1), 133–140. https://doi.org/10.1578/am.31.1.2005.133

May-Collado, L. J., & Wartzok, D. (2008). A comparison of bottlenose dolphin whistles in the Atlantic Ocean: Factors promoting whistle variation. *Journal of Mammalogy*, 89(5), 1229–1240. https://doi.org/10.1644/07-mamm-a-310.1

Meissner, A. M., Christiansen, F., Martinez, E., Pawley, M. D., Orams, M. B., & Stockin, K. A. (2015). Behavioural effects of tourism on oceanic common dolphins, *Delphinus* spp., in New Zealand: the effects of Markov analysis variations and current tour operator compliance with regulations. *PLoS One*,10:e0116962.

Merchant, N. D., Pirotta, E., Barton, T. R., & Thompson, P. M. (2016). Soundscape and noise exposure monitoring in a Marine Protected Area using shipping data and time-lapse footage. *Advances in Experimental Medicine and Biology*, 875, 705–712. https://doi.org/10.1007/978-1-4939-2981-8

Miller, S. G., Knight, R. L., & Miller, C. K. (2001). Wildlife responses to pedestrians and dogs. *Wildlife Society Bulletin*, 29(1), 124-132.

Reid, W. V., Mooney, H. A., Cropper, A., Capistrano, D., Carpenter, S. R., Chopra, K., Dasgupta, P., Dietz, T., Duraiappah, A. K., Hassan, R. & Kasperson, R. (2005). Ecosystems and human well-being, Synthesis. A report of the Millennium Ecosystem Assessment. Island Press. https://doi.org/10.5822/978-1-61091-484-0_1

Mooney, T. A., Nachtigall, P. E., & Vlachos, S. (2009). Sonar-induced temporary hearing loss in dolphins. *Biology Letters*, (June 2014). https://doi.org/10.1098/rsbl.2009.00

Moore, S. E., & Clarke, J. T. (2002). Potential impact of offshore human activities on gray whales. *Journal of Cetacean Research & Management*, 4(1), 19–25.

Moore, M. J., & Seigel, R. A. (2006). No place to nest or bask: effects of human disturbance on the nesting and basking habits of yellow-blotched map turtles (*Graptemys flavimaculata*). *Biological Conservation*, 130(3), 386-393.

Morimura, N., & Mori, Y. (2019). Social responses of travelling finless porpoises to boat traffic risk in Misumi West Port, Ariake Sound, Japan. *PLoS ONE*, 14(1), 1–16. https://doi.org/10.1371/journal.pone.0208754

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., & Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, 27(2), 314–322. https://doi.org/10.1111/1365-2435.12052

Ng, S. L., & Leung, S. (2003). Behavioral response of Indo-Pacific humpback dolphin (*Sousa* *chinensis*) to vessel traffic. *Marine Environmental Research*, 56(5), 555–567. https://doi.org/10.1016/S0141-1136(03)00041-2

Nishiwaki, M., & Sasao, A. (1977). Human activities disturbing natural migration routes of whales. *Scientific Reports of the Whales Research Institute Tokyo*, 29, 113–120.

Notarbartolo di Sciara, G. (2002). Cetaceans of the Mediterranean and Black Seas State. *A Report to the Permanent Secretariat of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area -ACCOBAMS-*, 1–259. Retrieved from http://www.rne.tn/upload/files/Cetaceans of the Mediterranean and Black Seas_ State of knowledge and conservation strategies.pdf#page=118

Nowacek, D. P., Tyack, P. L., & Wells, R. S. (2001). A platform for continuous behavioral and acoustic observation of free-ranging marine mammals: Overhead video combined with underwater audio. *Marine Mammal Science*, 17(1), 191–199. https://doi.org/10.1111/j.1748-7692.2001.tb00992.x

Parsons, E. C. M., Bauer, A., Simmonds, M. P., Wright, A. J., & McCafferty, D. (2013). An Introduction to Marine Mammal Biology and Conservation. *Jones & Bartlett Publishers*. pp 345.

Pirotta, E., Harwood, J., Thompson, P. M., New, L., Cheney, B., Arso, M., Hammond, P. S., Donovan, C. & Lusseau, D. (2015). Predicting the effects of human developments on individual dolphins to understand potential long-term population consequences. *Proceedings of the Royal Society B: Biological Sciences*, 282(1818). https://doi.org/10.1098/rspb.2015.2109

Pirotta, E., Milor, R., Quick, N., Moretti, D., Di Marzio, N., Tyack, P., & Hastie, G. (2012). Vessel noise affects beaked whale behavior: Results of a dedicated acoustic response study. *PLoS ONE*, 7(8). https://doi.org/10.1371/journal.pone.0042535

Piwetz, S. (2019). Common bottlenose dolphin (*Tursiops truncatus*) behavior in an active narrow seaport. *PLoS ONE*, 14(2), 1–23. https://doi.org/10.1371/journal.pone.0211971

Rako, N., Fortuna, C. M., Holcer, D. Š., Mackelworth, P., Nimak-Wood, M., Pleslić, G., & Picciulin, M. (2013). Leisure boating noise as a trigger for the displacement of the bottlenose dolphins of the Cres-LoŠinj archipelago (northern Adriatic Sea, Croatia). *Marine Pollution Bulletin*, 68(1–2), 77–84. https://doi.org/10.1016/j.marpolbul.2012.12.019

Ramesh R., Chen Z., Cummins V., Day J., D'Elia C., Dennison B., Forbes D. L., Glaeser B., Glaser M., Glavocic B., Kremer H., Lange M., Larsen J. N., Le Tissier M., Newton A., Pelling M., Purvaja R., & Wolanski E. (2015). Land–ocean interactions in the coastal zone: past, present & future. *Anthropocene,* 12, 85–98

Ratnarajah, L., Melbourne-Thomas, J., Marzloff, M. P., Lannuzel, D., Meiners, K. M., Chever, F., Nicol, S. & Bowie, A. R. (2016). A preliminary model of iron fertilisation by baleen whales and Antarctic krill in the Southern Ocean: sensitivity of primary productivity estimates to parameter uncertainty. *Ecological modelling*, 320, 203-212.

Reynolds III, J., E., Wells, R., S. & Eide, S., D. (2000). The bottlenose dolphin. Biology and Conservation. *University Press of California*. U. S. A. pp 76.

Richardson, H. (2012). The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus*) of Cardigan Bay in Wales. MSc Thesis, University College London. pp 71.

Scarpaci, C., Parsons, E. C. M., & Lück, M. (2008). Recent advances in whale-watching research: 2006-2007. *Tourism in Marine Environments*, 5, 55–66. https://doi.org/10.3727/154427308785855288

Schaffar, A., Madon, B., Garrigue, C., & Constantine, R. (2013). Behavioural effects of whale-watching activities on an endangered population of humpback whales wintering in New Caledonia. *Endangered Species Research*, 19, 245-254.

Schlacher, T. A., Thompson, L., & Price, S. (2007). Vehicles versus conservation of invertebrates on sandy beaches: mortalities inflicted by off-road vehicles on ghost crabs. *Marine Ecology*, 28(3), 354-367.

Taylor, A. R., & Knight, R. L. (2003). Wildlife responses to recreation and associated visitor perceptions. *Ecological Applications*, 13(4), 951–963. https://doi.org/10.1890/1051-0761(2003)13[951:WRTRAA]2.0.CO;2

Titus, J. R., & VanDruff, L. W. (1981). Response of the common loon to recreational pressure in the boundary waters Canoe Area, northeastern Minnesota. *Wildlife Monographs*, 79, 3-59.

Tourism Concern. (2017). *Action for Ethical Toursim*, Research briefing. Available from www.tourismconcern.org.uk

UNWTO. (2014). UNWTO Tourism Highlights. World Tourism Organization. Available from http://mkt.unwto.org/publication/unwto-tourism-highlights-2014-edition

Van Parijs, S., & Corkeron, P. (2001). Boat traffic affects the acoustic behaviour of Pacific humpback dolphins, *Sousa chinensis*. *Journal of the Marine Biological Association of the United Kingdom*, 81, 533–538.

van Polanen Petel, T. D., Terhune, J. M., Hindell, M. A., & Giese, M. A. (2006). An assessment of the audibility of sound from human transport by breeding Weddell seals (*Leptonychotes weddelli*i). *Wildlife Researc*h, 33(4), 275-291.

Visser, F., Hartman, K. L., Rood, E. J. J., Hendriks, A. J. E., Zult, D. B., Wolff, W. J., Huisman, J., & Pierce, G. J. (2011). Risso's dolphins alter daily resting pattern in response to whale watching at the Azores. *Marine Mammal Scienc*e, 27, 366-381.

Waples, K. A., & Gales, N. J. (2002). Evaluating and minimising social stress in the care of captive bottlenose dolphins (*Tursiops aduncus*). *Zoo Biology*, 21(1), 5–26. https://doi.org/10.1002/zoo.10004

Williams, R., Bain, D. E., Smith, J. C., & Lusseau, D. (2009). Effects of vessel on behaviour patterns of individual southern resident killer whales *Orcinus orca*. *Endangered Species Research*, 6(3), 199–209. https://doi.org/10.3354/esr00150

Williams, R., Lusseau, D., & Hammond, P. S. (2006). Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation*, 133(3), 301–311. https://doi.org/10.1016/j.biocon.2006.06.010

CHAPTER II

Cardigan Bay and the bottlenose dolphin population

2.1 Cardigan Bay and the bottlenose dolphin population

2.1.1 Cardigan Bay

Cardigan Bay is the largest bay in the United Kingdom, covering an area of approximately 5500 km^2 (CCC et al., 2001). The bay spans over 100 km from the Llŷn Peninsula and Bardsey Island in the north to Saint David's Head in the south. It is a shallow bay, with maximum depths reaching 60 metres, becoming shallower from west to east. The substrate of Cardigan Bay is extremely heterogeneous, varying from fine sand and broken shell to gravel, shingle and muddy sand. The sediments are shaped by tides and currents. Where the current is strong, more gravel is present but when current decreases, this is replaced by mud (Evans, C.D.R., 1995) (Figure 2.1). The region is frequently exposed to winds coming mostly from the south-west and west, and gales can arise often during the period between October and March. These gales can produce substantial swells, and this may be a reason for some northward facing bays such as New Quay, Mwnt and Ynys Lochtyn offering shelter for bottlenose dolphins during parts of the year (Evans, P.G.H, 1995; Pesante et al., 2008a; Feingold & Evans, 2014a).

Sea surface temperatures in Cardigan Bay vary depending upon the season, the shallow seabed and input of freshwater coming from rainfall and rivers. Sea surface temperatures are higher during August and September with between 14° and 16°C in offshore waters and 20°C in inshore waters, whilst between February and March temperatures are lower, with values ranging from 5° to 8.5°C (Evans, C.D.R., 1995). The average salinity of the waters in Cardigan Bay is approximately 34 parts per thousand, indicating an influence of saltwater coming from the Atlantic and freshwater coming from different rivers; as a result, salinity decreases towards the coast, and increases during summer months (CCC et al., 2008).

Shaped by its physical characteristics, Cardigan Bay exhibits an extensive variety of marine habitats, ranging from estuarine, littoral and sub-littoral together with more offshore habitats characterised by depth and substratum of the area. This is the reason why Cardigan Bay holds an abundant and rich flora and fauna, including diverse species of marine invertebrates, fish, seabirds, and marine mammals. In fact, there are records of dolphins thought to be bottlenose in Cardigan Bay going back to the eighteenth century (Evans & Scanlan, 1989), and regular records since the 1920's (Evans & Scanlan, 1989; Lamb, 2004; Pierpoint et al., 2009).

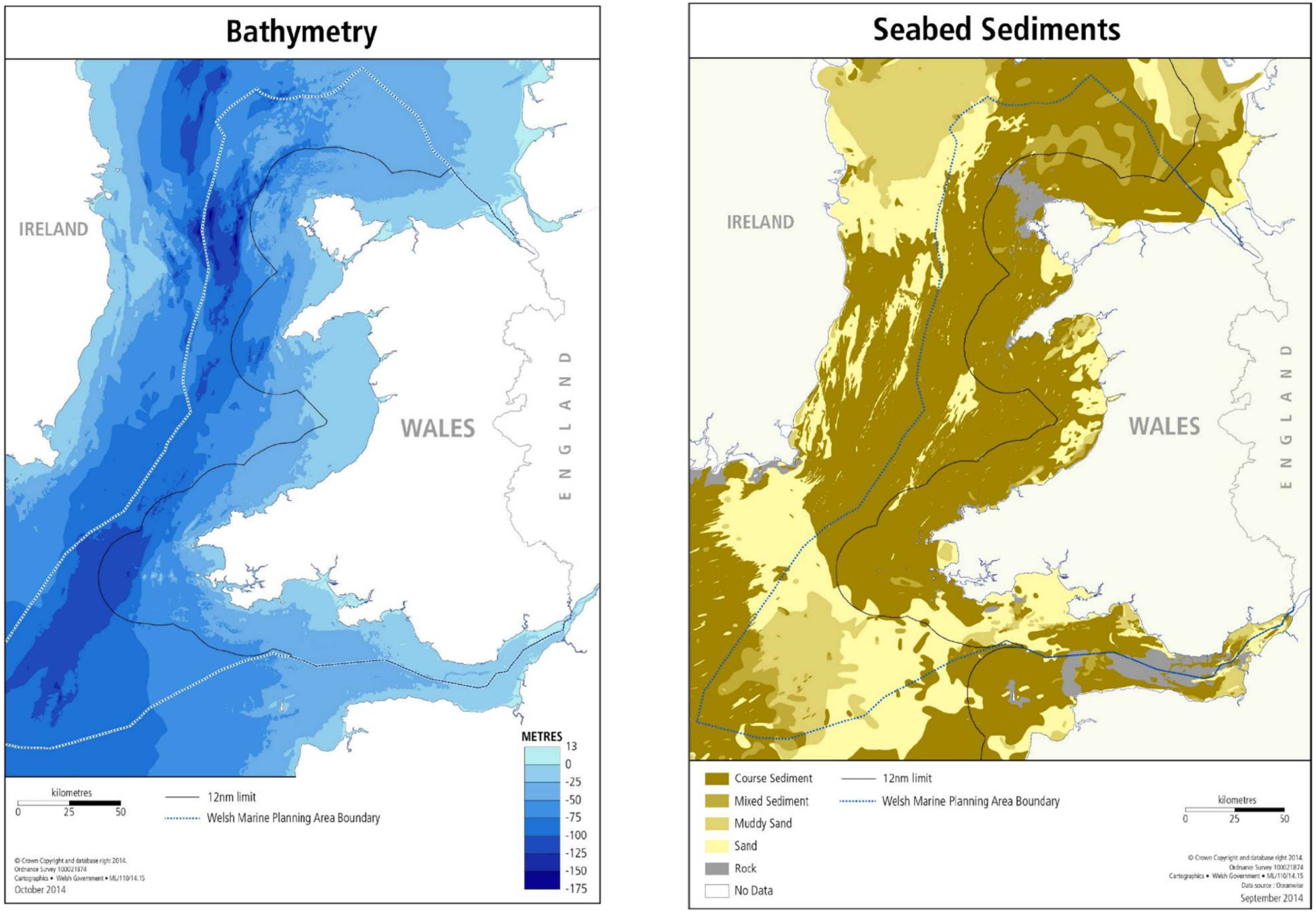


Figure 2.1 Bathymetry and seabed sediments of Welsh waters (taken from Wales' Marine Evidence Report, 2015).

2.1.2 The Bottlenose Dolphin

Bottlenose dolphins belong to the sub-order Odontoceti and family Delphinidae within the Infraorder Cetacea. The species has a cosmopolitan distribution being found in nearly all oceans around the world except at very high latitudes, favouring temperate and tropical waters with sea surface temperatures ranging from 10 to 32 degrees Celsius (Reeves et al., 2002; Jefferson et al., 2015). Therefore, individuals of the species reach a wide range of habitats, from deep waters of the open ocean beyond the continental shelf, to the coastal zone including bays and estuaries (Leatherwood & Reeves, 1990; Wells & Scott, 1999; Reynolds III et al., 2000; Wells & Scott, 2018). In a number of regions, coastal and offshore populations appear to form separate ecotypes, as revealed from differentiation of genetic and cranial features (Mead & Potter, 1995; Hoelzel et al., 1998; Perrin et al., 2011). In some areas, particularly offshore, bottlenose dolphins can be migratory whilst in coastal and estuarine areas, the species appears to be often sedentary with a limited home range (Jefferson et al., 1993; Toth et al., 2011; Taylor et al., 2016; Wells & Scott, 2018). In addition, coastal populations are frequently small (usually less than 200 individuals), making them particularly vulnerable to anthropogenic pressures (ICES, 2016).

Habitat studies have related bottlenose dolphin distribution not only to depth but also to other environmental features including sea surface temperature, salinity, bottom topography, substrate type, and distance from shore (Wells & Scott, 1999; Teixeira-Moreno, 2005; Cubero-Pardo, 2007; Gómez De Segura et al., 2008; Lopes, 2017). Bottlenose dolphins appear to have quite catholic diets, they are able to exploit diverse food resources in different geographical areas, likely in response to the local availability of potential prey (Blanco et al., 2001). Individuals have been recorded taking a range of pelagic, demersal and benthic prey species, mainly fish but also cephalopods and crustaceans (Blanco et al., 2001; Santos et al., 2007). Associations with prey availability have been examined with mixed results. Gómez De Segura et al. (2008) found no relationship between dolphin presence and prey availability in a Spanish study whereas prey availability was found to be associated with bottlenose dolphin distribution in a study in Texas (Teixeira-Moreno, 2005). In order to reach more accurate conclusions on how cetaceans interact and use their environment, anthropogenic pressures also need to be evaluated, since these additional factors can affect cetacean distributions in both the short- and long-term. Studies such as those referred to above provide evidence towards the need for identifying important habitats for local populations so that areas of conservation can be established for their protection.

Bottlenose dolphins are a social species, commonly occurring in groups of between 2 and 25 individuals, although they can on occasions number some tens or even low hundreds of animals (Reid et al., 2003). Studies of coastal bottlenose dolphins suggest they live in a relatively open society (Wells & Scott, 1999; Connor et al., 2000). The life history of the species has been well-studied in a number of regions. At birth, calves measure between 0.8 and 1.4 metres following a gestation period of around 12 months (Wells & Scott, 1999, 2018). During the lactation period which can last between one and a half and two years, calves achieve most of their growth (Wells & Scott, 2018). At approximately 250 cm length (at least for warm temperate/subtropical populations), physical and sexual maturity is reached, corresponding to between 5 and 13 years of age in females and between 9 and 14 years in males (Wells & Scott, 1999, 2018). Females can still breed up to an age of approximately 48 years, with calves born typically at intervals of between 3 and 6 years (Wells et al., 1987; Wells & Scott, 1999, 2018). Bottlenose dolphins are long-lived, with females living to more than 67 years and males up to 52 years (Wells & Scott, 2018).

Previous studies have found that bottlenose dolphins use different types of vocalizations, which are associated with specific behaviours. The species creates squawks, pops and yelps by using wide-band pulse sounds. These sounds are believed to be used in a social context, in which dolphins can produce or show different types of emotions, such as aggression or sexual play (Lammers, 2003). Dolphins also use broad-band short duration clicks during echolocation to hunt, orientate and navigate. These sounds are useful for discrimination of targets, detecting small details of different objects such as prey type and availability (Au, 2004), as well as bottom topography and presence of predators (Reynolds III et al., 2000). Narrow-band frequency whistles are thought to be used by bottlenose dolphins also in a social context, for individual recognition and communication. They can be divided into two groups: Variant whistles are responsible for keeping the group together when individuals need to communicate during foraging and travel over long distances. These are not individual-specific, which gives them a less stable characteristic than signature whistles (May-Collado & Wartzok, 2008). The latter, also referred to as contact calls, are, by contrast, individual-specific and used over time, promoting group cohesion (May-Collado & Wartzok, 2008). Previous research has found that the type of whistle can be affected by such aspects as water depth, seabed substrate, behaviour, group size and presence of mother-calf pairs, all of which can alter the structure and frequency of a particular signal (Caldwell & Caldwell, 1965; Baron et al., 2008; Cook et al., 2004).

2.1.3 Bottlenose dolphin population in Cardigan Bay

Cardigan Bay is one of two main coastal areas of British waters where a semi-resident bottlenose dolphin population can be found, with between 200 and 300 individuals (Baines & Evans, 2012; Feingold & Evans, 2014b), the other being the Moray Firth in East Scotland. From April to October, dolphins are found regularly, displaying a seasonal highest incidence during summer months, visiting frequently the inshore waters of Cardigan Bay (Figure 2.2), with the aim of foraging and nursing young (Pesante et al., 2008b; Feingold & Evans, 2014a; Lohrengel et al., 2018). This region of Wales is the focus of biological studies on the bottlenose dolphin population and potential impacts from human activities, particularly recreation, given the great attraction that marine mammals provide to the area.

The distribution of bottlenose dolphin depends on the availability and abundance of suitable prey species. In Cardigan Bay, dolphin prey includes flatfish, dragonet, sand eel, pollock, wrasse and blennies (Dunn & Pawson, 2002). Low levels of scallop dredging have been taking place in Cardigan Bay over 30 years now (Evans & Hintner, 2010). After few studies focusing on the impacts that this fishery could have on the environment in the zone, in 2009 the activity was closed (Simmonds et al., 2013). Following different assessments, in 2010 the activity was re-opened with a significant part of the bay declared off limits to the fishery (Simmonds et al., 2013). The potential threat from scallop dredging to bottlenose dolphin, porpoises, and benthic organisms that provide prey for fish on which dolphins feed in the area is still under study. Nonetheless, it is considered that under the current technical conservation measures in place there was no risk to the bay's bottlenose dolphins, despite the disturbance from this activity, including noise and boat presence, which can also affect dolphins prey availability (CEFAS, 2011).

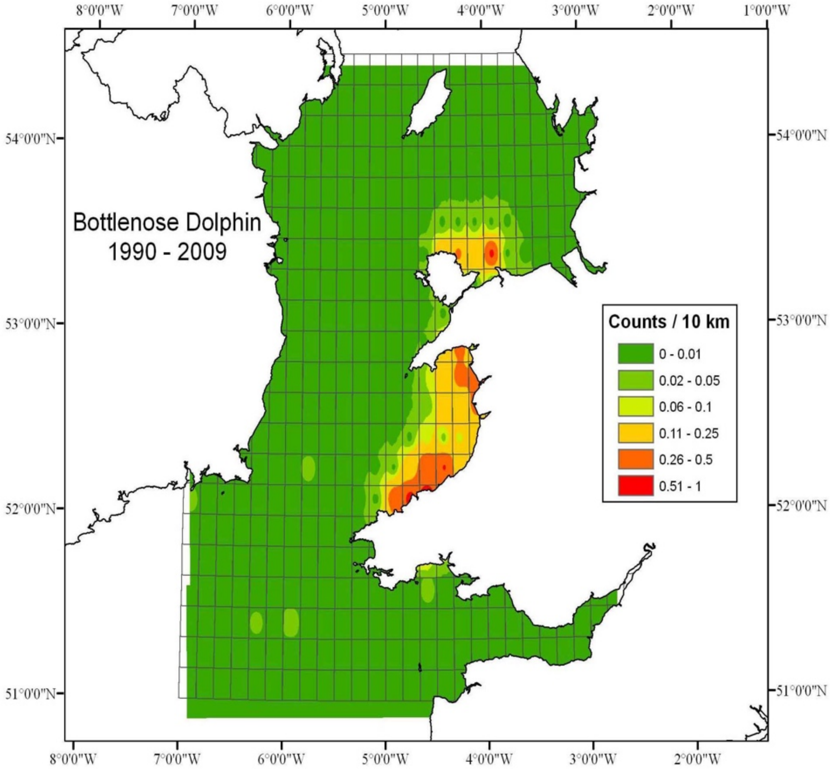


Figure 2.2 Distribution of bottlenose dolphins in the southern Irish Sea, based on data collected from 1990 to 2009 (from Baines & Evans, 2012).

For the protection of the bottlenose dolphin population that inhabits these waters, two SACs have been created in West Wales under the EU Habitats Directive (Figure 2.3). Cardigan Bay SAC is located in the county of Ceredigion, and was established in 2001, after being proposed as a SAC in 1996 to protect a number of vulnerable marine habitats and species, notably the bottlenose dolphin found here. With the joint efforts of nine statutory organizations, a management scheme was developed for the area (CCC et al., 2001), Cardigan Bay SAC was then formally designated. The aim of the marine protected area is to preserve richness and diversity of marine life, and to manage human activities in an environmentally sustainable manner. The area extends nearly 20 kilometres from the coast, protecting the wildlife that inhabits an area of around 1000 kilometres square of sea (CCC et al., 2008) (Table 2.1).

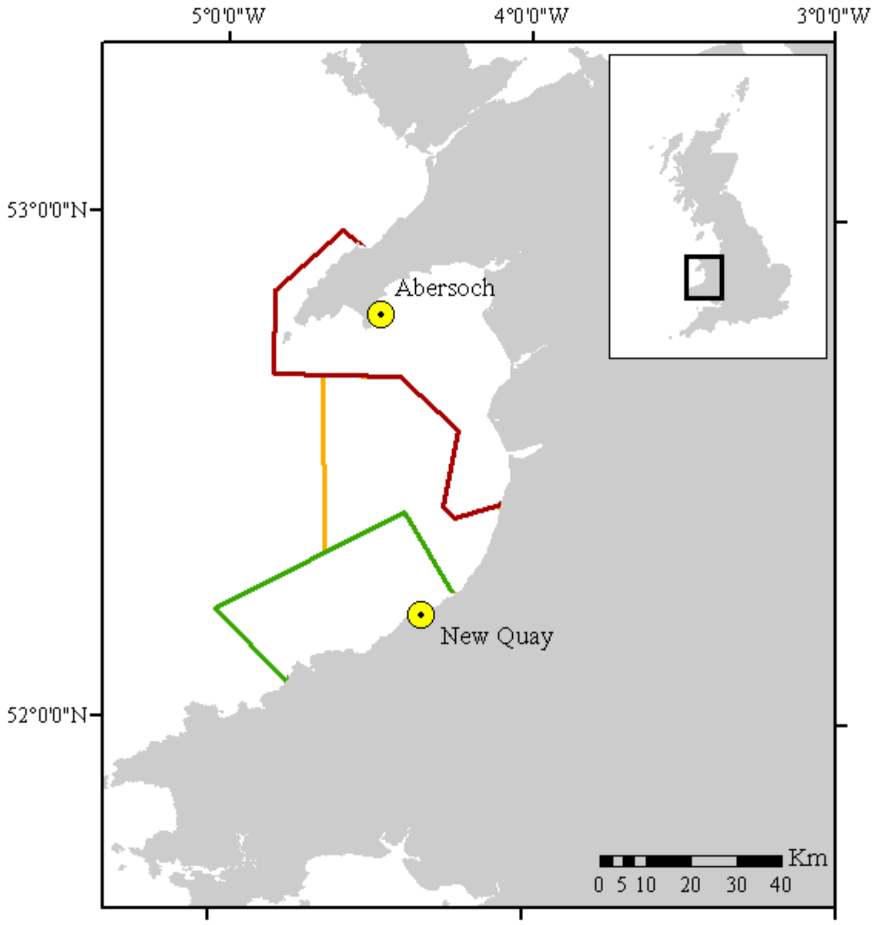


Figure 2.3 The study area, Cardigan Bay, within the UK. The red line delimits the Pen Llŷn a'r Sarnau SAC, the orange line delimits the mid-area and the green line delimits Cardigan Bay SAC. Sites at Abersoch and New Quay (within Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC, respectively) will be used in analyses in later chapters.

Besides bottlenose dolphins, Cardigan Bay SAC protects also lampreys, grey seals, reefs, caves and sand-banks that are found here. In the northern zone of Cardigan Bay, the Pen Llŷn a'r Sarnau SAC has also been established. This SAC covers a large area of 230 square kilometres between the Llŷn Peninsula and Sarnau reefs of North Wales; it extends 24 kilometres from the coast, covering and protecting reefs, estuaries, coastal lagoons, rocky shores, sandy seabeds and caves, as well as grey seals, otters and bottlenose dolphins. The management plan for this SAC is run under a number of competent authorities that seek to recognise threats from human activities, in order to manage them appropriately, minimising their effects and ultimately maintaining diversity (CCC et al., 2001) (Table 2.1).

2.1.4 Boating code of conduct

The Cardigan Bay SAC management scheme includes a code of conduct that was first introduced in 1992 by the Ceredigion County Council for the Ceredigion Heritage Coast; when the SAC was proposed, the code of conduct was kept, and it is still operational nowadays (Table 2.1). The code of conduct states that any recreational vessel needs to be aware of the important bottlenose dolphin feeding areas and should travel slowly to avoid any disturbance. In case of an encounter, the code restricts the distance to the animals (minimum100 metres), the time spending with them (maximum 15 minutes), avoidable noise, as well as the boat's travel speed. Boat passengers are advised not to attempt to touch, feed or swim with the dolphins. The code highlights that any disturbance to a protected species is a criminal offence and therefore, if a boat is found not to be following the code, Ceredigion County Council have authorisation to remove the boat's permit (Ceredigion Marine Code, 2008). Previous studies have evaluated the success of the code of conduct, concluding that by using this, a reduction in the chances that passengers will affect the behaviour of bottlenose dolphin can be observed (CCC et al., 2008; Pierpoint et al., 2009). For the other marine protected area in Cardigan Bay, Pen Llŷn a'r Sarnau SAC, a code of conduct has only been implemented from the recreational season of 2016, by Gwynedd Council, also with the aim of reducing any disturbance or pressure upon the wildlife (Figure 2.4).

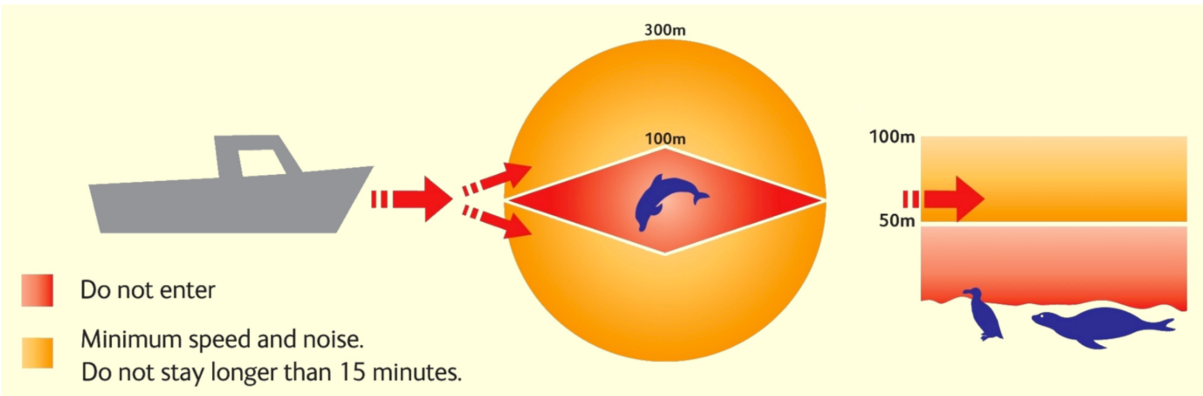


Figure 2.4 Ceredigion and Gwynedd marine code of conduct. In general, users should keep a good look out, they should not approach marine mammals, but allow the animals to come to them. In case of an encounter they should keep their distance (minimum 100 metres) and they should leave the cetaceans 15 minutes into the encounter (from Ceredigion Marine Code, 2008).

Previous studies analysed vessel traffic across Cardigan Bay including the southern SAC with a code of conduct and apparently good compliance, and the northern Pen Llŷn a'r Sarnau SAC which at the time did not have a code of conduct. They concluded that the existing management scheme in the north required a code of conduct, particularly for general recreational craft such as speedboats (Lohrengel et al., 2012; Richardson, 2012). Further studies were recommended throughout Cardigan Bay to provide scientific evidence whilst achieving a greater perception of how disturbance may be impacting the dolphin population and, ultimately, contributing towards a better management plan in both SACs and the wider area (Richardson, 2012; Feingold & Evans, 2014a).

Table 2.1 Characteristics of the three different zones used for further analyses with information regarding area, distance of coastline, SAC establishment date (if applicable), code of conduct establishment date (if applicable) and boat usage.

Area name	Area (Km^2)	Distance of coastline (Km)	SAC establishment	Code of conduct establishment	General use
Pen Llŷn a'r Sarnau SAC	1460	230	2004	2016	Large jet ski usage
Mid-area	1076	23	N/A	N/A	N/A
Cardigan Bay SAC	959	48	2004	2004	Large dolphin-watching usage

Sea Watch Foundation is a British marine environmental research organisation, forming a partnership between scientists and the public through a national volunteer observer network, to conserve and protect whales, dolphins and porpoises in British and Irish waters. It routinely monitors populations of dolphins, porpoises and whales in UK seas, with the idea of gaining valuable knowledge about the health of the marine environment and the possible effects that human activities (over-fishing, accidental capture in fishing gear, pollution, disturbance from noise, and climate change) might have upon cetacean populations. Sea Watch Foundation has been monitoring the Welsh bottlenose dolphin population over a period of 18 years, in collaboration with the Countryside Council for Wales/Natural Resources Wales.

In Cardigan Bay, bottlenose dolphins are concentrated in coastal waters during summer but are uncommon there during winter (Pesante et al., 2008b; Simon et al., 2010; Baines & Evans, 2012). Between November and April, individuals identified as having spent the summer in Cardigan Bay have been photographed occurring regularly further north off the coasts of Anglesey and mainland North Wales, as well as in Liverpool Bay and around the Isle of Man (Feingold & Evans, 2014b; Lohrengel et al., 2018). Group sizes in winter number in the tens of animals, occasionally reaching up to 150 individuals. Within Cardigan Bay, the most common group size is 3-5 animals (mean 4.5, range 1-33), with groups consistently slightly larger in the north, and during spring and autumn (Lohrengel et al., 2018).

Identified females observed in both North Wales and Cardigan Bay are likely to spend the summer in Cardigan Bay during the year of calving and the subsequent year, suggesting that the latter serves as an important calving and nursery area (Duckett, 2018). Although calf births can occur in most months of the year, 65% of them have been recorded between July and September (Lohrengel et al., 2018).

The presence of the species in bays, harbours, and waters around headlands attracts boat users in summer. The regular use of these inshore waters and transit routes results in higher levels of boating at specific sites, but significantly lower dolphin sighting rates when more boats are present (Pierpoint et al., 2009). Therefore, whilst human pressure upon the dolphins increases markedly, this may be the reason for a reduction in the dolphin usage of the area (Pierpoint et al., 2009). Annual birth rates of known females vary widely between years from 1.5-8.5% of the population, with no particular part of Cardigan Bay apparently favoured (Lohrengel et al., 2018). Adult females give birth every 2-7 years (with three years being the most common calving interval) (Lohrengel et al., 2018). Thirty-nine percent of dolphin calves apparently die by 3 years of age (Lohrengel et al., 2018).

Monitoring of abundance has been undertaken by Sea Watch Foundation since 2001 in Cardigan Bay SAC and since 2007 over the wider bay using both line transect surveys with Distance sampling and Capture-Mark-Recapture analysis of photo-ID data (Pesante et al., 2008a; Feingold & Evans, 2014a; Lohrengel et al., 2018). There has been no significant trend in numbers for Cardigan Bay SAC between 2001 and 2016, but a decline in the last 10 years

(2007-2016), significant at the 90% level. For the wider Cardigan Bay there has been a significant negative trend over the ten years since 2007 when surveys started (Lohrengel et al., 2018).

1. Evidence of effects of boat activity on bottlenose dolphin within Cardigan Bay

Previous research in Cardigan Bay has found different impacts of boat traffic on bottlenose dolphins: Boat encounters have affected dolphin behaviour, with decreased surfacing intervals (time spent at the surface between dives) in the presence of vessels, resulting in both vertical and horizontal evasion (Hudson, 2014). Vessels changing course erratically led to greatest avoidance reactions, whilst boats not following the cetaceans, but slowing down or stopping, resulted in only a slight response by the dolphins (Veneruso et al., 2011). Group size has been found to be smaller when boats, mostly motorised vessels, were in the vicinity (Koroza, 2018), whilst a social network analysis found that individuals formed looser bonds with many others in areas of high vessel activity, compared to low vessel activity areas where dolphins showed very strong bonds within a small number of individuals (Richardson, 2012). Additionally, animals displaying resting behaviour were more susceptible to disturbance and responded by changing their behaviour at the moment of a boat encounter; in contrast, animals that were foraging were not significantly affected by boat presence (Veneruso et al., 2011). In order to evaluate whether boat type had an effect upon bottlenose dolphin responses, Bristow & Rees (2001) evaluated different boats, finding that negative responses such as avoidance were mostly displayed towards power boats, whereas yachts and small fishing boats were found to trigger positive responses such as bow-riding. Similarly, Koroza (2018) found that small motor-boats and speed boats were the ones triggering dolphin avoidance behavioural responses, whilst attraction responses were found to boats complying with the management guidelines in the area, such as visitor passenger boats.

There may be a longer-term impact on the local bottlenose dolphin population given that dolphin abundance has decreased over recent years, whilst boat traffic has been continuously increasing (Lohrengel et al., 2018). Pierpoint et al (2009) presenting results of shore watches in southern Cardigan Bay between 1994 and 2007, reported an inverse relationship between the number of boats counted and number of dolphins.

In order to arrive at a more correct conclusion concerning the short-term effects that boat disturbance could have, as well as long-term consequences upon species reproductive success and in turn upon sustainability of the bottlenose dolphin population in Cardigan Bay, it is necessary to continue monitoring dolphin activity in the study area, collecting data that will help to develop an area-based management scheme that promotes bottlenose dolphin conservation alongside a sustainable ecotourism industry.

2.2 References

Au, W. (2004). The sonar of dolphins. *Acoustics Australia*, 32(2), 1-4.

Baines, M. E., & Evans, P. G. H. (2012). Atlas of the Marine Mammals of Wales. *CCW Monitoring Report No. 68*, (2nd edition). pp 143.

Baron, S. C., Martinez, A., Garrison, L. P., & Keith, E. O. (2008). Differences in acoustic signals from Delphinids in the western North Atlantic and northern Gulf of Mexico. *Marine Mammal Science*, 24(1), 42–56. https://doi.org/10.1111/j.1748-7692.2007.00168.x

Blanco, C., Salomón, O., & Raga, J. A. (2001). Diet of the bottlenose dolphin (*Tursiops truncatus*) in the Western Mediterranean Sea. *Journal of the Marine Biological Association of the UK*, 81. 1053 - 1058. 10.1017/S0025315401005057.

Bristow, T., & Rees, E. I. S. (2001). Site fidelity and behaviour of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, Wales. *Aquatic Mammals,* 27(1), 1-10.

Caldwell, M. C., & Caldwell, D. K. (1965). Individualized whistle contours in bottle-nosed dolphins (*Tursiops truncatus). Nature*, 207(4995), 434-435.

CCC (Ceredigion County Council), Countryside Council of Wales, Dŵr Cymru Welsh Water, Environment Agency, Gwynedd Council, North Western and North Wales Sea Fisheries Committee, Powys County Council, Severn Trent Water, Snowdonia National Park Authority, and Trinity House Lighthouse Authority. (2001). *Pen Llŷn a'r Sarnau candidate Special Area of Conservation Action Plan*. Ceredigion County Council, Aberystwyth. pp 40.

CCC (Ceredigion County Council), Countryside Council of Wales, Environment Agency Wales, North Western and North Wales Sea Fisheries Committee, Pembrokeshire Coast

National Park Authority, Pembrokeshire County Council, South Wales Sea Fisheries Committee, Trinity House, and Welsh Water. (2008). *Cardigan Bay Special Area of Conservation (SAC) Management Scheme.* Ceredigion County Council, Aberystwyth. pp 179.

CEFAS - Centre for Environment Aquaculture and Fisheries Science. (2011). Scallop dredging in the Cardigan Bay SAC: Potential effects on bottle-nosed dolphins and grey seals. Peer review to Welsh Government.

Connor, R. C., Wells, R. S., Mann, J., & Read, A. J. (2000). The bottlenose dolphin: Social relationships in a fission-fusion society. Pp. 91-126. In: Cetacean Societies: field studies of dolphins and whales. *University of Chicago Press,* Chicago, USA.

Cook, M., Sayigh, L., Blum, J., & Wells, R. (2004). Signature-whistle production in undisturbed free-ranging bottlenose dolphins (*Tursiops truncatus*). *Proceedings of the Royal Society B: Biological Sciences*, 271, 1043–1049. https://doi.org/10.1098/rspb.2003.2610

Cubero-Pardo, P. (2007). Environmental factors governing the distribution of the bottlenose (*Tursiops truncatus*) and the spotted dolphin (*Stenella attenuata*) in Golfo Dulce, South Pacific, off Costa Rica. *Investigaciones Marinas*, 35(2), 15–23. https://doi.org/10.4067/S0717-71782007000200002

Duckett, A. (2018) Cardigan Bay bottlenose dolphin *Tursiops truncatus* connectivity within and beyond marine protected areas. MSc Thesis, University of Bangor. pp 76.

Dunn, M. R., & Pawson, M. G. (2002). The stock structure and migrations of plaice populations on the west coast of England and Wales. *Journal of Fish Biology*, 61(2), 360-393.

Evans, C. D. R. (1995). Chapters 2.1, 2.2, 2,3. Coastal Geology, Offshore Environment, Wind and Water. In: Eds. Barne, J. H., Robson, C. F., Kaznowska, S. S. & Doody, J. P. Coasts and seas of the United Kingdom. Region 12 Wales: Margam to Little Orme. *Joint Nature Conservation Committee*, Peterborough. pp 239.

Evans, P. G. H. (1995). Chapter 5.15. Whales, dolphins and porpoises. pp 137-140. In: Eds. Barne, J. H., Robson, C. F., Kaznowska, S. S. & Doody, J. P. Coasts and Seas of the United Kingdom. Region 12 Wales: Margam to Little Orme. *Joint Nature Conservation Committee*, Peterborough. pp 239.

Evans, P. G. H., & Hintner, K. (2010). A review of the direct and indirect impacts of fishing activities on marine mammals in Welsh Waters. CCW Policy Research Report No. 104. pp 160.

Evans, P. G. H., & Scanlan, G. M. (1989). Historical review of cetaceans in British and Irish waters. *Greenpeace Environmental Trust*, London. pp 120.

Feingold, D. & Evans, P. G. H. (2014a). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2011-2013. *Natural Resources Wales Evidence Report Series No. 4*, 1-124.

Feingold, D. & Evans, P. G. H. (2014b). Connectivity of bottlenose dolphins in Welsh Waters: North Wales photo-monitoring report. *Natural Resources Wales Research Report*. pp 15.

Gómez De Segura, A., Hammond, P. S., & Raga, J. A. (2008). Influence of environmental factors on small cetacean distribution in the Spanish Mediterranean. *Journal of the Marine Biological Association of the United Kingdom*, 88(6), 1185–1192. https://doi.org/10.1017/S0025315408000386

Hanson, M. & Defran, R. (1993). The behaviour and feeding ecology of the Pacific coast bottlenose dolphin, *Tursiops truncatus*. *Aquatic Mammals* 19 (3), 127142.

Hoelzel, A. R., Potter, C. W., & Best, P. B. (1998). Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. *Proceedings of the Royal Society of London. Series B, Biological Sciences*, 265, 1177–1183.

Hudson, T. (2014). Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay. MSc Thesis, University of Bangor. pp 79.

ICES. (2016). OSPAR request on indicator assessment of coastal bottlenose dolphins. ICES Special Request Advice. Northeast Atlantic Ecoregion. ICES, Copenhagen. pp 14.

Jefferson, T. A., Leatherwood, S., & Webber, M. A. (1993). FAO species identification guide. Marine mammals of the world. *Food and Agriculture Organization of the United Nations*, Rome.

Jefferson, T. C., Webber, M. A., & Pitman, R. L. (2015). Marine mammals of the World. *Academic Press*, London & San Diego. pp 608.

Koroza, A. A. (2018). Habitat use and effects of boat traffic on bottlenose dolphins at New Quay Harbour, Cardigan Bay. MSc Thesis, University of Bangor. pp 93.

Lamb, J. (2004). Relationships between presence of bottlenose dolphins, environmental variables and boat traffic; visual and acoustic surveys in New Quay Bay, Wales. MSc Thesis, University of Bangor.

Lammers, M., Au, W., & Herzing, D. (2003). The broadband social acoustic signaling behavior of spinner and spotted dolphins. *Journal of the Acoustical Society of America,* 114(3), 1629–1639. https://doi.org/10.1121/1.1596173

Leatherwood, S. & Reeves, R. R. (1990). The bottlenose dolphin. *Academic Press,* San Diego, CA, USA. pp 653.

Lohrengel, K., Evans, P. G. H., Lindenbaum, C. P., Morris, C. W., & Stringell, T. B. (2018). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2014-17. *Natural Resources Wales Evidence Report No: 191.* 1-154.

Lohrengel, K., Veneruso, G., Feingold, D., Pesante, G., Ugarte, F., & Evans, P. G. H. (2012). Boat traffic trends and effects on bottlenose dolphin sighting rates in Cardigan Bay, Wales. Poster at: *Annual Conference of the European Cetacean Society*, Galway, Ireland.

Lopes, K. F. C. F. (2017). Habitat preference of bottlenose dolphin (*Tursiops truncatus*) in Cardigan Bay. MSc Thesis, University of Bangor. pp 54.

May-Collado, L. J., & Wartzok, D. (2008). A Comparison of bottlenose dolphin whistles in the Atlantic Ocean: Factors promoting whistle variation. *Journal of Mammalogy,* 89(5), 1229–1240. https://doi.org/10.1644/07-mamm-a-310.1

Mead J. C., & Potter C. W. (1995). Recognizing two populations of the bottlenose dolphin (*Tursiops truncatus*) of the Atlantic coast of North America - morphologic and ecologic considerations. *IBI Reports-International Marine Biological Research Institute,* 5, 31–44.

Perrin W. F., Thieleking J. L, Walker W. A., Archer F. I., & Robertson K. M. (2011). Common bottlenose dolphins (*Tursiops truncatus*) in California waters: Cranial differentiation of coastal and offshore ecotypes. *Marine Mammal Science,* 27, 769–792.

Pesante, G., Evans, P. G. H., Anderwald, P., Powell, D., & McMath, M. (2008). Connectivity of bottlenose dolphins in Wales: North Wales photo-monitoring interim report 2008. *CCW Marine Monitoring Report No. 62*, 1-42.

Pesante, G., Evans, P. G. H., Baines, M. E., & McMath, M. (2008). Abundance and life history parameters of bottlenose dolphin in Cardigan Bay: Monitoring 2005-2007. *CCW Marine Monitoring Report No. 61*, 1-75.

Pierpoint, C., Allan, L., Arnold, H., Evans, P., Perry, S., Wilberforce, L., & Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan Bay, UK. *Journal of the Marine Biological Association of the United Kingdom,* 89(5), 1033–1043. https://doi.org/10.1017/S0025315409000885

Reeves, R. R., Stewart, B. S., Clapham, P. J., & Powell, J. A. (2002). Sea mammals of the world: A complete guide to whales, dolphins, seals, sea lions and sea cows. *A & C Black,* London & New York.

Reid, J., Evans, P. G. H., & Northridge, S. P. (2003). Atlas of cetacean distribution in north west European waters. *Joint Nature Conservation Committee*, Peterborough.

Reynolds III, J. E., Wells, R. S., & Eide, S. D. (2000). The bottlenose dolphin. Biology and Conservation. *California University Press,* USA. pp 76.

Richardson, H. (2012). The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus*) of Cardigan Bay in Wales. MSc Thesis, University College London. pp 71.

Santos, M. B., Fernandez, R., López, A., Martínez, J. A., & Pierce, G. J. (2007). Variability in the diet of bottlenose dolphin, *Tursiops truncatus*, in Galician waters, north-western Spain, 1990–2005. *Journal of the Marine Biological Association of the United Kingdom*, 87(1), 231-241.

Simon, M., Nuuttila, H., Reyes-Zamudio, M. M., Ugarte, F., Verfuß, U., & Evans, P. G. H. (2010). Passive acoustic monitoring of bottlenose dolphin and harbour porpoise with implications for habitat use and partitioning. *Journal of the Marine Biological Association of the United Kingdom*, 90, 1539-1546.

Simmonds, M. P., Green, M., James, V. I. C. K. I., Eisfeld, S., & Lott, R. (2013). Assessing the Cardigan Bay bottlenose dolphin SACs. *Ecos*, 34(3-4), 46-55.

Taylor, A. R., Schacke, J. H., Speakman, T. R., Castleberry, S. B., & Chandler, R. B. (2016). Factors related to common bottlenose dolphin (*Tursiops truncatus*) seasonal migration along South Carolina and Georgia coasts, USA. *Animal Migration,* 3(1), 14–26. https://doi.org/10.1515/ami-2016-0002.

Teixeira-Moreno, M. P. (2005). Environmental predictors of bottlenose dolphin distribution and core feeding densities in Galveston Bay, Texas. PhD thesis, Texas A&M University. pp 102.

Toth, J. L., Hohn, A. A., Able, K. W., & Gorgone, A. M. (2011). Patterns of seasonal occurrence, distribution, and site fidelity of coastal bottlenose dolphins (Tursiops truncatus) in southern New Jersey, U.S.A. Marine Mammal Science, 27(1), 94–110. https://doi.org/10.1111/j.1748-7692.2010.00396.x

Veneruso, G., Magileviciute, E., Nuuttila, H., & Evans, P. G. H. (2011). Habitat use and effects of boat traffic on bottlenose dolphins at New Quay Harbour, Cardigan Bay. Poster at: *Annual Conference of the European Cetacean Society*, Cadiz, Spain.

Wells, R. S. & Scott, M. D. (1999). Bottlenose dolphin *Tursiops truncatus* (Montagu, 1921) In: Ridgway, S.H. & Harrison, R J. Handbook of Marine Mammals. Volume 6. *Academic Press,* London & San Diego. ISBN 0-12-588506-7.

Wells, R.S. & Scott, M.D. (2018). Bottlenose dolphin *Tursiops truncatus*. Pp. 118-125. In: Würsig, B., Thewissen, J.G.M., & Kovacs, K. Encyclopedia of Marine Mammals. 3rd Edition. *Academic Press*, New York. pp 1157.

Wells, R. S., Scott, M. D., & Irvine, A. B. (1987). The social structure of free-ranging bottlenose dolphins. pp 247-305. In: Genoways, H.H. Current Mammalogy. *Plenum Press*, London & New York.

CHAPTER III

Using vessel-based sighting data to predict both short- and long-term effects of boat activity on bottlenose dolphin distributions

3.1 Abstract

The noticeable growth of anthropogenic activities in the oceans, and their potential effects on marine mammals and the ecosystems have triggered extensive concerns about wildlife conservation. A large population of bottlenose dolphins occupies the coastal waters of Wales - UK, where it has experienced increased pressure from social activities. The importance of the region for the species has been acknowledged through the establishment of two Special Areas of Conservation (SAC) within Cardigan Bay. In the southern region a boating code of conduct has been functioning for many years, whilst in the north, it has only very recently been initiated. The Welsh bottlenose dolphin population is a central attraction for visitors, generating millions of pounds of income annually. Nonetheless, careful management is needed in order to conserve the species whilst safeguarding its socio-economic value. This study aimed to analyse boat activity and its possible effects on the bottlenose dolphin population in Cardigan Bay over the past years. Twelve years of data collected during boat-based surveys were used, covering both SACs and the wider area of Cardigan Bay. The study identifies regions where human activities and disturbance are likely to impact the Welsh bottlenose dolphin population, helping to direct management recommendations towards the conservation of this species in the bay. In the short-term only speed craft impacted dolphin density, whilst in the long-term, the presence of fishing boats, non-motorised craft and motorised craft affected the probability of encountering dolphins. An increase in dolphin density as a response to fishing boat usage in Cardigan Bay SAC suggests that management guidelines and compliance seem to be working with dolphins staying in the area, whilst the decrease in dolphin density found in Pen Llŷn a'r Sarnau SAC indicates the need for more management compliance. As such, these findings suggest the need for a further review of management approaches and recommendation of measures that may help to minimise potential effects of vessel disturbance and harassment, thereby avoiding a reduction in dolphin usage of certain areas (Pierpoint et al., 2009).

3.2 Introduction

Human interactions with the natural environment have increased worldwide over the past few decades; as human populations continue to grow, migration to the coasts as well as demand for ocean space and resources is increasing (Halpern et al., 2008; Halpern et al., 2015; Maxwell et al., 2013). Marine and coastal ecosystems provide a variety of goods and services that are used by humans. Leisure activities are part of these good and services, including recreation and tourism. Due to the increase in marine leisure activities (such as fishing, boating, diving, and whale and dolphin watching), concerns have arisen over the possible effects that such activities could have on marine animal populations and individuals. Therefore, a more comprehensive approach to quantify marine species distributions is required to understand the role of external drivers, such as environmental factors as well as human-made influences, given that these variables may determine temporal and spatial variations in those species distributions. In the case of cetaceans that are highly mobile, predicting species distribution models is challenging due to their wide habitat range, and should also take account of anthropogenic pressures such as vessel presence.

Studies on cetaceans have reported short-term effects from vessel disturbance, such as decrease in foraging activities (Nowacek et al., 2001; New et al., 2013; Pirotta et al., 2015), avoidance (Bejder et al., 1999; Nowacek et al., 2001; Moore & Clarke, 2002) and variations in dive patterns (Janik, 1996; Hastie et al., 2003; Ng & Leung, 2003). There is also growing evidence that when species are continuously exposed to such disturbances, they are affected in the long-term as well. This in turn will have ecological consequences for individuals' fitness, with further population consequences leading to declines in abundance (Bejder et al., 2006; Scarpaci et al., 2008; Currey et al., 2009), disruption of association patterns (Lusseau, 2003; Richardson, 2012), or movement out of the affected area (Forest, 2001; Notarbartolo, 2002; Rako et al., 2013).

In Cardigan Bay (Wales, UK), two SACs have been established, namely Pen Llŷn a'r Sarnau SAC in the north and Cardigan Bay SAC in the south, to protect the semi-resident population of bottlenose dolphin. The SACs differ in their boating code of conduct (see Chapter II), however, the wider area in the bay is not under any management plan. In addition, over the past decade human pressures including boat disturbance have increased markedly which may be the reason for a reduction in the dolphin usage of certain areas (Pierpoint et al., 2009).

Previous studies have focused their efforts on the bottlenose dolphin habitat preferences in Cardigan Bay (Baines et al., 2005; Villaescusa et al., 2007; Lopes, 2017). Less focus has been placed on understanding the impacts of vessel activity on dolphin distribution in the long-term. Therefore, it is important to assess the distribution of the different type of vessels that visit the bay and their possible effects on the presence and density of bottlenose dolphins in the short- (this is how dolphins responded to boats that were present at that specific time or “co-occurrence”) and long-term (how dolphins responded to boats after being exposed to the accumulated disturbance or persistence). In order to evaluate the current conservation strategies in the bay, it is necessary to identify regions where human activities and disturbance are likely to influence the distribution of the bottlenose dolphin population in Cardigan Bay.

This study aimed to analyse boat activity and its possible effects on the bottlenose dolphin population in Cardigan Bay over the past years. 12 years of data collected during boat-based surveys were used, covering both SACs and the wider area of Cardigan Bay to answer three questions: i) Is there a relationship between dolphin density and boat density? If so, is the relationship dependant on ii) the type of boat, and iii) area (due to differences in boating code of conduct compliance)? Finally, iv) have dolphin reactions and/or density changed over time?

3.3 Methods

3.3.1 Study area

The study area was embedded in Cardigan Bay, an area of approximately 5500 km^2 (Baines *et al.,* 2000). The bay runs from the north in the western tip of the Llŷn Peninsula at 52˚ 47’ 45’’ N, 004˚ 46’ 00’’ W to the south at St David’s Head at 51˚ 54’ 10’’ N, 005˚ 18’ 54’’ W, encompassing two SACs, one in the north, Pen Llŷn a’r Sarnau and one in the south, Cardigan Bay, and the mid-area, the wider zone of the bay between the northern and southern SACs (Figure 2.3) (see Chapter II).

3.3.2 Vessel-based surveys

Boat-based surveys were conducted during April to October, between 2005 and 2016 in the study area. Surveys were conducted under favourable weather conditions (including Beaufort Sea state ≤ 3 and good visibility (>1 km)), therefore, survey effort varies every year depending on the climate (Figure 3.1). Surveys were carried out by trained staff (in order to provide standardised and scientifically accurate data) at Sea Watch Foundation.

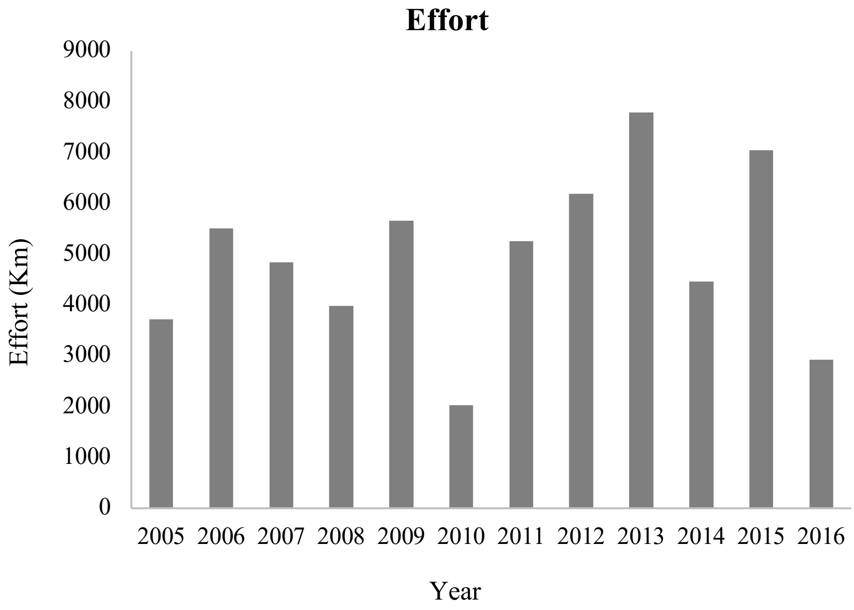


Figure 3.1 Survey effort (in kilometre) conducted in Cardigan Bay by Sea Watch Foundation in the period 2005-2016.

Surveys followed specific previously determined transects (performed standardised by Sea Watch Foundation in previous years to provide cetacean estimates in Cardigan Bay), which were put in place in order to guarantee equal coverage per survey (Figure 3.2). During the moment of a boat or bottlenose dolphin encounter, GPS positions, time, number of dolphins, as well as number and type of boats were recorded.

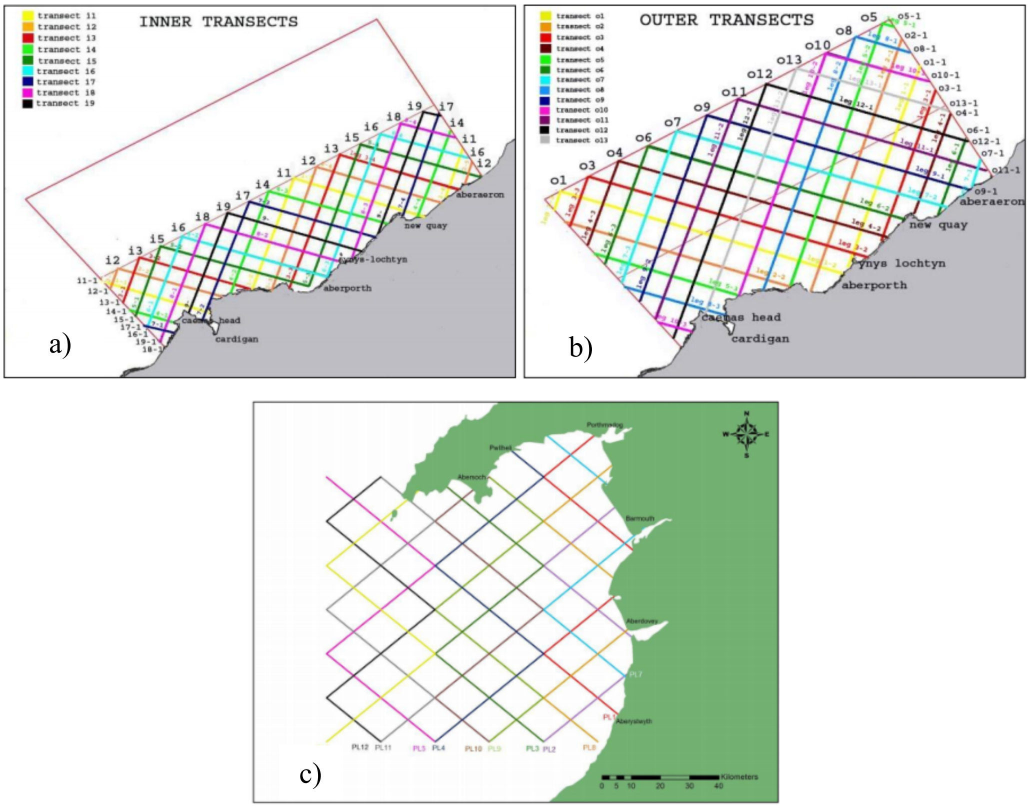


Figure 3.2. Transect lines used for line-transect surveys in a) inner Cardigan Bay SAC, b) outer Cardigan Bay SAC and c) Pen Llŷn a'r Sarnau SAC and outer Cardigan Bay (taken from Lohrengel & Evans, 2015).

3.3.3 Statistical analyses

3.3.3.1 Data processing

Boat types were categorised based on the size and potential travel speed, resulting in four categories including speed craft (SC, power boats, jet skis, RIBs, and motorised boats operating at speeds of c. 15 knots or more), non-motorised craft (QC, mainly sail boats but also small numbers of kayaks and row boats), motorised craft (MC, all motorised boats operating at speeds of <15 knots) and fishing boats (FI) based on the activity and how this can improve prey availability (Table 3.1).

Table 3.1. Boat types were grouped into four categories, based on the size and potential travel speed of those craft recorded during vessel-based surveys in Cardigan Bay from 2005 to 2016.

Boat type	Boat category	Abbreviations
Fishing boat	Fishing boat	FI
Sail boats Rowing boats	Non-motorised craft	QC
Small and medium motorboats Visitor passenger boats	Motorised craft	MC
Speed boats Jet skis	Speed craft	SC

In order to test differences in dolphin density between areas with different management compliance in Cardigan Bay, boundaries between SACs and the wider area/ mid-area were determined using ArcGIS. Additionally, to explore changes in boat and dolphin distribution patterns during the years of the study, and based on differences on effort through the study years (with 2009-2012 displaying the highest effort and therefore more probability of dolphin sightings and boat encounters, whilst there are fewer data in other years), three periods each of 4 years were created to assess bottlenose dolphin and boat categories sightings.

To investigate impacts from boat aggregations on the distribution of bottlenose dolphin, the influence of habitat needed to be accounted for. For instance, bottlenose may favour certain habitats, and not accounting for this could prevent any impact of boat traffic from being detected. Based upon previous studies, distance to land was chosen as habitat variable, since it captures spatial patterns and all environmental gradients.

Survey area was allocated with cells, a systematic superimposed grid of 5 km by 5 km, which provided a reliable data summary from the surveys. Each survey transect was divided into 1 km length portions to predict accurate effort estimates per grid cell from the transect surveys. Boats seen were allocated to the beginning of the transect in order to standardise the data.

3.3.3.2 Short-term analysis

Dolphin short-term responses to vessel co-occurrence (this is how dolphins responded to boats that were present at that specific time) were evaluated. Non-motorised craft were square root transformed to account for outliers. Generalised additive models GAMs were used to model nonlinear relationships between dolphins and habitat covariates. The response variable was the count of dolphins and the explanatory variables were effort, distance to land and count of each boat category. The latter was modelled separately, with motorised craft, fishing boats and non-motorised craft in addition per area. Distance to land was considered a dimensional smoother and the natural logarithm of the area surveyed was included as an offset to account for both varying segment lengths and varying detection probabilities based on recorded sighting conditions during the surveys. The models were run using a Gaussian family due to the normal distribution of the data. Backwards model selection based on AIC values to assess best fitted models was used. The levels within the variable area (Pen Llŷn a'r Sarnau SAC, Cardigan Bay SAC and the mid-area) were re-ordered (re-levelled) in order to be able to compare all areas and significance differences in dolphin density. The models' residuals showed no evidence of extreme temporal autocorrelation (Supplementary material 8.1.1.1), therefore more advanced statistical approaches accounting for temporal autocorrelation were considered unnecessary (Zuur et al., 2009). Statistical analyses were performed using "mgcv" package fitted in 'R Studio' (Version 1.0.136 – © 2009-2016 RStudio, Inc.).

3.3.3.3 Long-term analysis

To test the relationship between bottlenose dolphin and boat distributions, concurrent densities of bottlenose dolphin and boats were used, these are, mean number of animals and vessels per cell (25 Km^2). Therefore, response variables were the mean number of dolphins per cell and the explanatory variables were mean number of different types of boats per cell, effort and distance to land. Boat category was modelled separately, with motorised craft, fishing boats and non-motorised craft in addition per area. Distance to land was considered a dimensional smoother. The natural logarithm of the area surveyed was included as an offset to account for both varying segment lengths and varying detection probabilities based on recorded sighting conditions during the surveys. A Gaussian family was used due to the continuous decimal data with normal distribution, whilst using a backwards model selection based on AIC. These GAMs were run with “mgcv” package in ‘R Studio’ (Version 1.0.136 – © 2009-2016 RStudio, Inc.). Furthermore, re-levelling was used to check for significant differences in dolphin density between the three areas. No evidence of extreme temporal autocorrelation was found based on the models’ residuals (Supplementary material 8.1.1.2), therefore it was considered unnecessary to run more advanced statistical approaches accounting for temporal autocorrelation (Zuur et al., 2009).

3.4 Results

Surveys were conducted for 1125 days, over the course of 86 months within the study period 2005-2016. In total, 63,109 km of survey effort was analysed (Figure 3.3), with 1,590 bottlenose dolphin, 2205 fishing boats, 2295 non-motorised craft, 3476 motorised craft and 748 speed craft sightings to test in the models (Table 3.2; Figure 3.4).

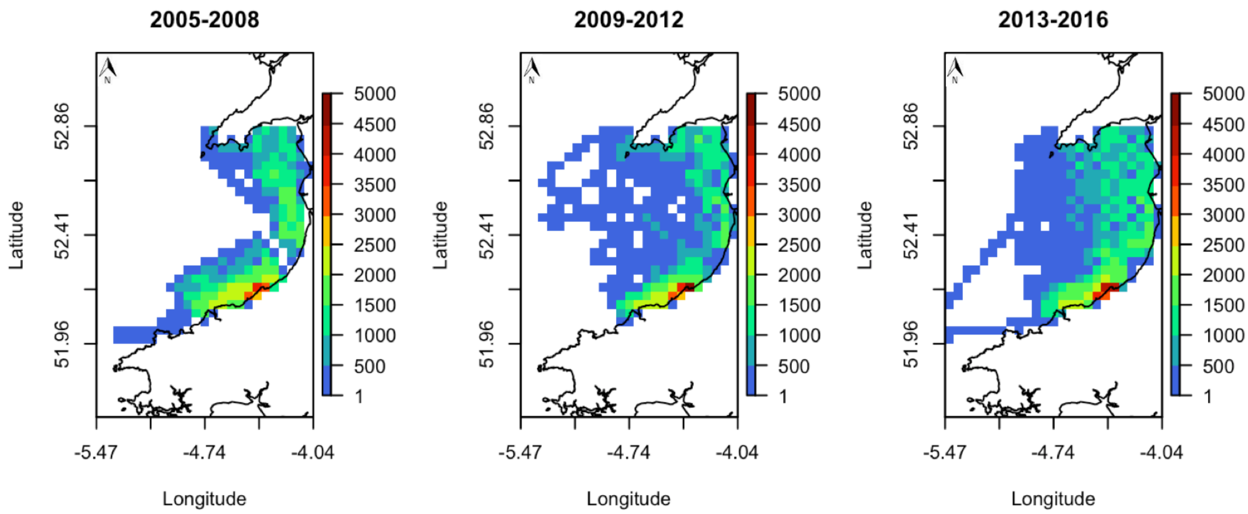


Figure 3.3 Vessel-based effort (kilometre per cell) conducted in Cardigan Bay by Sea Watch Foundation during periods 2005-2008, 2009-2012 and 2013-2016. Cells are 5 x 5 km resolution.

Table 3.2 Sample size for dolphin, fishing boat, non-motorised craft, motorised craft and speed craft to be used in further short- and long-term analyses.

	Sample size (for short-term analysis)	Sample size (for long-term analysis)
Dolphins	1589	207
Fishing boat	77	330
Non-motorised craft	86	373
Motorised craft	148	338
Speed craft	31	148

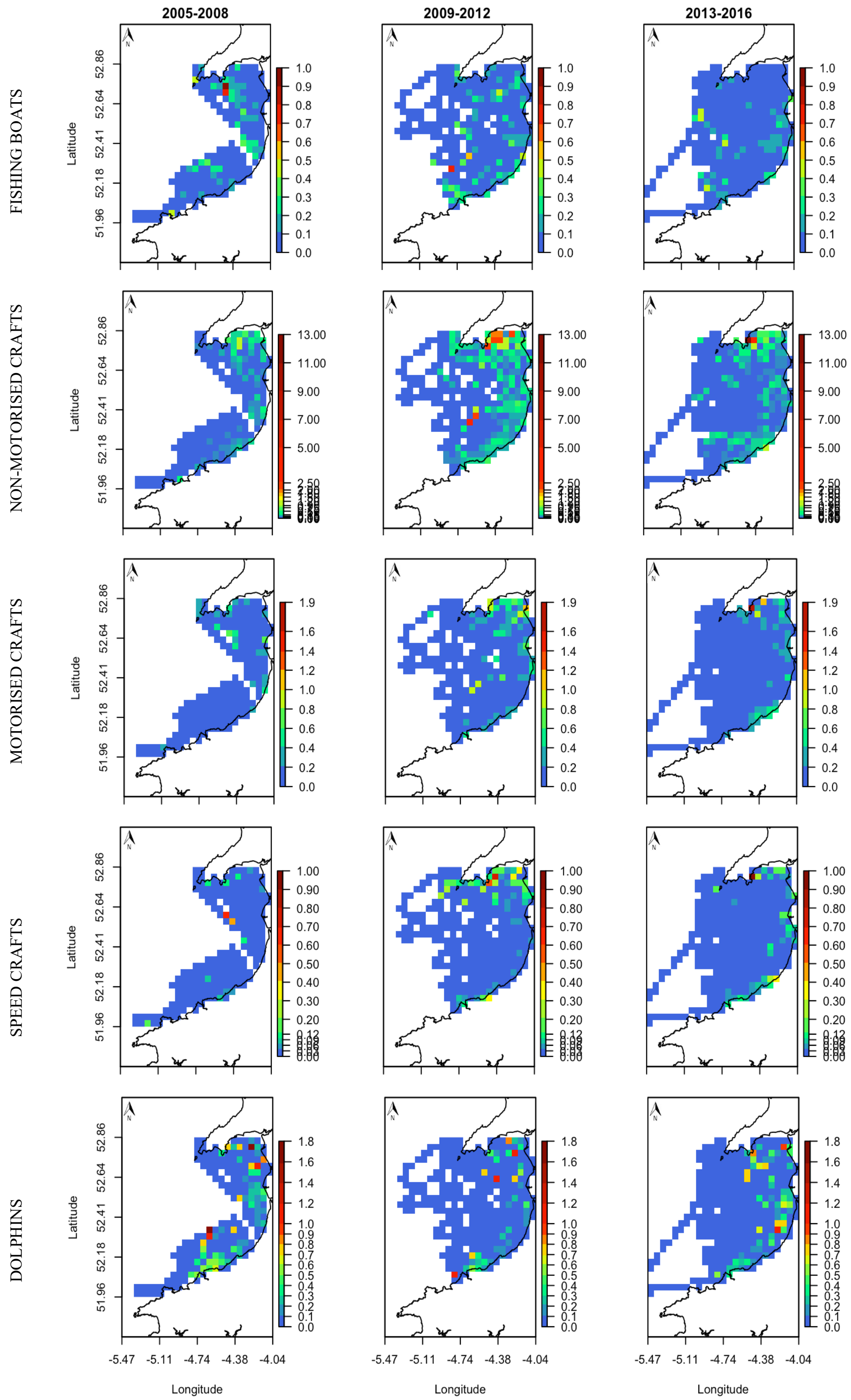


Figure 3.4 Mean number of fishing boats (FI), non-motorised craft (QC), motorised craft (MC), speed craft (SC), and dolphins per cell during periods 2005-2008, 2009-2012 and 2013-2016. Cells are 5 x 5 km resolution.

3.4.1 Bottlenose dolphin density related to boat activity in the short-term

To predict dolphin density in the short-term, GAMs selected corresponded to those where the different boat categories were included, together with distance to land and effort, based on AIC values. Nonetheless, counts of motorised craft (t= -2.813, mean ± SD: 1.545 ± 0.654), fishing boats (t= -2.702, mean ± SD: 1.698 ± 0.324) and non-motorised craft (t= -4.259, mean ± SD: 2.148 ± 1.29) were not found to be significant when predicting dolphin number per area and therefore only speed craft was retained in the results. Dolphin density was found to decrease when speed craft were in the vicinity (t= -5.063, mean ± SD: 2.029 ± 0.253) (Figure 3.5). The best-fitting model for dolphin presence explained 18.7% of the deviance using a Gaussian distribution with a product smooth of distance to land (see Supplementary material 8.1.1.1).

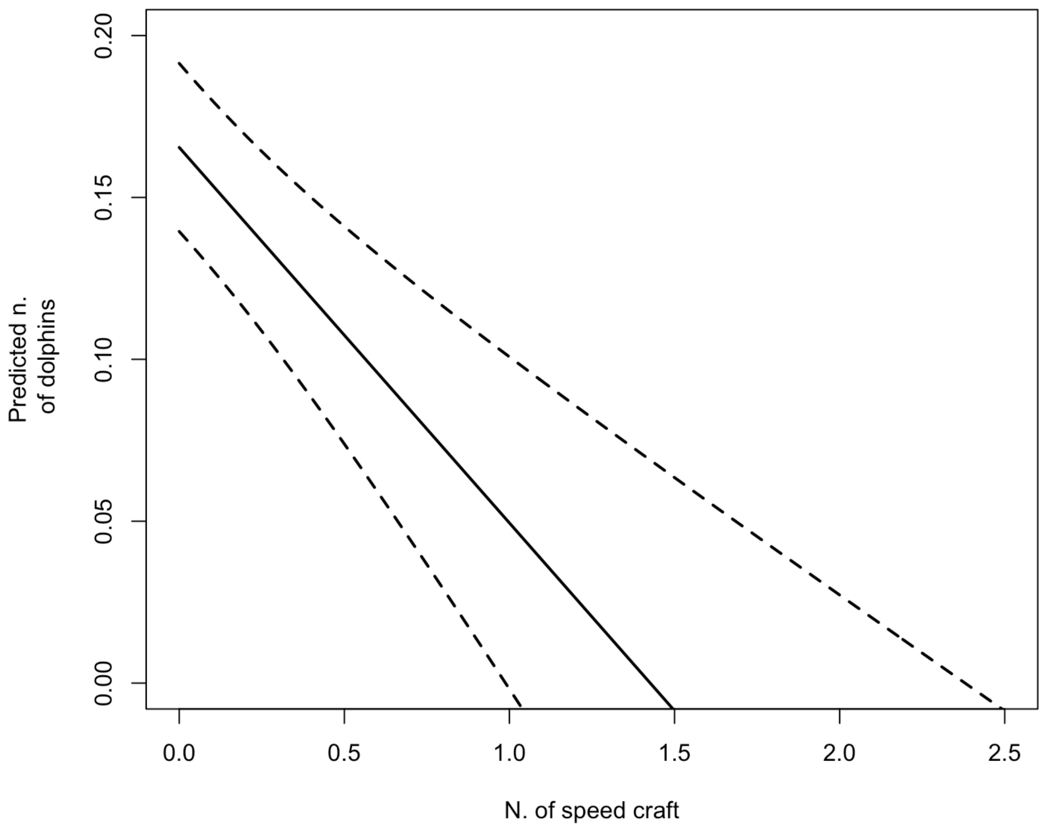


Figure 3.5 Modelled prediction of dolphin abundance in relation to speed craft abundance, within Cardigan Bay from 2005 to 2016. Relationships were quantified from GAM with a gaussian distribution. Dashed lines represent 95% confidence intervals.

3.4.2 Bottlenose dolphin density related to boat activity in the long-term

Dolphin density predictions from GAMs in the long-term included speed craft, fishing boats, non-motorised craft and motorised craft, effort, distance to land, as well as area during the years of the study (Table 3.3, see Supplementary material 8.1.1.2). Although the probability of encountering a pod of bottlenose dolphin is similar in the whole of Cardigan Bay, when evaluating the effect of the presence of different boats in different areas, changes in dolphin density can be seen (Figure 3.6).

Table 3.3 Results from GAMs for the effects of different boat categories on dolphin density at Pen Llŷn a'r Sarnau SAC (PLaS), Cardigan Bay SAC (CB) and the mid-area (M).

Boat type	Area	Estimate	2.5% CI	97.5% CI
Fishing boat	PLaS-M	**-0.303**	**-0.046**	**-0.559**
	PLaS-CB	**-1.117**	**-0.907**	**-1.326**
	M-CB	**-0.814**	**-0.582**	**-1.046**
Non-motorised craft	PLaS-M	**-0.312**	**-0.054**	**-0.569**
	PLaS-CB	**-1.134**	**-0.923**	**-1.346**
	M-CB	**-0.823**	**-0.590**	**-1.055**
Motorised craft	PLaS-M	**-0.350**	**-0.096**	**-0.604**
	PLaS-CB	**-1.218**	**-1.006**	**-1.429**
	M-CB	**-0.867**	**-0.637**	**-1.097**
Speed craft	-	-1.010	0.283	-2.303

Confidence intervals that indicate a significant effect are in **bold** text

At Pen Llŷn a'r Sarnau SAC, where a management scheme was only recently put in place, when fishing boats, non-motorised and motorised craft were present, dolphin density was affected negatively, although this was most noticeable when motorised craft appeared (Figure 3.6). In the mid area, where no management plan has been established, dolphin density did not display any change in presence of non-motorised craft. The effect of motorised craft and fishing boats upon dolphin density was negative, with such an effect being most noticeable as response to fishing boats (Figure 3.6). At Cardigan Bay SAC, dolphin density did not show any changes in the presence of non-motorised craft. In addition, dolphin density decreased when motorised craft were around. On the contrary, dolphin density showed an increase during fishing boats encounters. Speed craft presence during the years of the study showed a negative effect on dolphin density, with numbers of dolphins decreasing during encounters with speed craft (Figure 3.6).

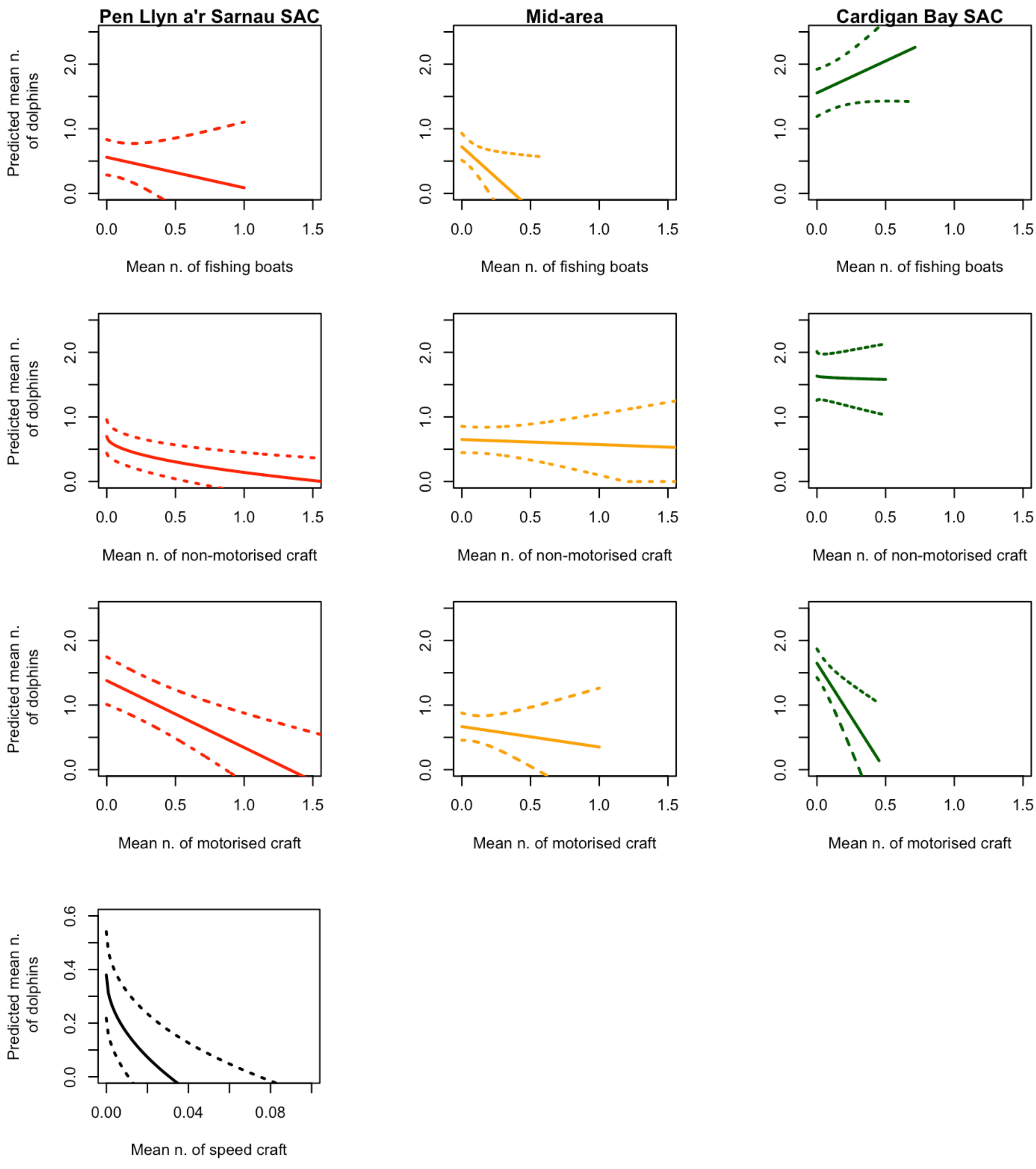


Figure 3.6 Modelled prediction of mean number of dolphins in Pen Llŷn a'r Sarnau SAC, mid-area and Cardigan Bay SAC as a function of mean number of fishing boats, non-motorised craft and motorised craft per area, and mean number of speed craft, during the period 2005-2016. Relationships were quantified from GAMs with a gaussian distribution. Dashed lines represent 95% confidence intervals.

3.5 Discussion

This study aimed to analyse boat traffic and its possible effects on the bottlenose dolphin population in the long- and short-term in Cardigan Bay, in order to find the probability of encountering dolphins or pods. There were three main findings: i) in the long-term, the probability of encountering dolphins is variably related to the presence of all type of boats at different areas, ii) in the short-term, dolphin density decreased in relation to speed craft, iii) an increase in dolphin density as response to fishing boats in Cardigan Bay SAC suggest that management guidelines and compliance to it seem to be working, whilst negative responses found in Pen Llŷn a'r Sarnau SAC indicate the need for more management compliance. Combined, these outcomes show that frequent boat activity disrupts dolphin density in the area, with certain boat types decreasing dolphin density, indicating the need for further management recommendations, awareness and compliance. The possible reasons for these findings and the implications for habitat usage and management of the species in different areas of Cardigan Bay are discussed below.

Importance of boat activity in influencing cetacean habitat preferences

In order to determine species distribution, relationships with different environmental variables such as depth, current speed and sea surface temperature among other factors that represent habitat characteristics, have been used previously. Species-habitat relationships can help to assess species preferences (Becker et al., 2014; Forney et al., 2012; Gilles et al., 2016). However, even if different studies include what they considered were all relevant factors to determine species distribution by identifying the best proxy variables, increasing the power of the analysis, variables that are relevant are not always used or available (Gilles et al., 2016). Therefore, habitat mapping has been recently improved with studies identifying the importance of other variables: Research has found that further variables that are likely to affect marine mammal populations should be included, such as human activities. Consequently, since fisheries may cause direct effects on cetacean acoustic habitat, as well as causing by-catch or vessel strikes, and even prey depletion, the effects of fisheries or presence of fishing boats have been recommended to be added to cetacean habitat modelling (Alter et al., 2010), as well as other anthropogenic pressures such as seismic surveys (Gregr et al., 2014). This in turn suggests that habitat mapping is based on a biological rationale that can set the basis for conservation science, by identifying different areas where possible management zones or guidelines are needed (Day, 2002).

The current study allowed us to prove that the environmental variables commonly used in habitat preferences of cetaceans are insufficient for this purpose, anthropogenic factors should also be added to the modelling process, since they alter cetacean behaviour especially at a fine scale, reduce animals' food intake, displace them from some areas, and in the long-term, reduce their population size (Halpern et al., 2015).

Bottlenose dolphin density related to boat activity

In Cardigan Bay SAC a decrease in dolphin density (negative response) was found during encounters with motorised craft, whilst no change in dolphin numbers per area (neutral response) was found during non-motorised craft presence. On the contrary, when fishing boats were around, dolphin density increased (positive response). These findings together suggest that the implementation of the guidelines and boat compliance are working in this SAC. Negative responses of dolphins to motorised craft can relate to previous studies in which unpredictable boat routes, such as those conducted by small and medium motored vessels, seemed to be the most influential boat feature affecting number of dolphins (Zapetis, 2017). Even though visitor passenger boats are part of this category, whilst being the vessels that comply the most with the boating code of conduct in Cardigan Bay SAC, the negative response seeing may be also caused by the lowest observed compliance from small and medium motor boats (Koroza, 2018), which are actually increasing in number in the area due to easy access from growing leisure activities (Lemon et al., 2006). In addition, dolphin neutral responses towards non-motorised craft (kayaks or yachts under sail) could be explained by a mix of responses: the fact that these are non-engine vessels that may display a silence approach, prevents the cetaceans to track the vessel movements after the initial encounter, and therefore animals may have decided to swim away or scatter to avoid a further startle approach. Such negative responses were seen towards kayaks and sailing boats in other studies (Gregory & Rowden, 2001). Nonetheless, neutral effects that kayaks and yacht under sail had may be due to dolphin habituation to this type of boat: dolphins are able to detect them only at short distances and after recognising their presence and due to non-motorised vessels compliance to code of conduct, animals decide to stay around (Bristow & Rees, 2001). Positive response from dolphins to fishing boats could be explained by the fact that dolphins can obtain easy prey by gathering around and following this vessel type (Ansmann et al., 2012). Previously, it was found that in moments of prey depletions, dolphins would alter their behaviour and increase the number of close interactions with fishing boats in order to obtain food easily (Powell & Wells, 2011). Also, this current positive relationship may be due either to the low number of these vessels in the southern SAC or the awareness of users who try to protect the cetaceans whilst mitigating dolphin disturbance.

In the mid area, where there are no management regulations, negative responses from dolphins were seeing during encounters with fishing boats and motorised craft. Perhaps, due to the fact that the area is not recognised as an important feeding and nursery area, as Cardigan Bay SAC has (CCC et al., 2008), dolphins do not visit this area to feed and therefore they do not follow the fishing boats to easily find prey or on the contrary, prey availability is high and there is no need to approach fishing boats to improve feeding. On the other hand, the fact that motorised craft also had a negative effect on the number of dolphins seeing int the mid-area may be due to small and medium motorboats causing a change in dolphin behaviour whilst triggering travelling (Mattson et al, 2005). A neutral response to non-motorised craft was also found in the mid-area, similar to that found in Cardigan Bay SAC, with dolphins displaying possible habituation due to the absence of previous collisions or dangerous approaches from these vessels (Bristow & Rees, 2001).

At Pen Llŷn a'r Sarnau SAC all type of boats triggered a decrease in dolphin numbers. Considering that fishing boats and motorised boats are vessels that usually travel at significant speeds whilst not following any particular routes, the current finding can be corroborated by previous outcomes where these characteristics were the most influential vessel features on dolphin negative responses (Zapetis, 2017). Other studies suggested that bottlenose dolphins react more strongly to motorised boats than non-motorised vessels due to the presence of engines and their noise (Mattson et al., 2005). Nonetheless, in this northern area, regattas are a common activity, in which many visitors from all over the UK come to the area to use their recreational sailing vessels. Therefore, a great number of these kind of vessels are present in the area, and due to the absence of engine noise that can help dolphins to locate them, the chance of collision with dolphins increases, whilst triggering a decrease in the number of animals.

Consequently, even though in 2016 the boating code of conduct was implemented in this area, more focus should be placed on maximising the number of people that are aware of the guidelines and comply with them, to protect the dolphins.

Speed craft had a negative effect on dolphin density across Cardigan Bay. Since speed craft did not have a large enough sample size to be calculated per area, it is not possible to evaluate specific effects that can relate to the management plans operating in each area within Cardigan Bay. Nonetheless, at Pen Llŷn a'r Sarnau SAC and the mid-area, speed boats included jet skis - high speed craft with loud engine noise and erratic movements. These craft could pose severe pressure on bottlenose dolphins, a species that spends a large amount of time at the surface, by making them spend longer periods underwater seeking avoidance or improved communication (Mattson et al., 2005). Thus, dolphins could extend their range or surface less, showing a reduced number in the site of the encounter. In addition, perhaps speed is not the variable to account for when recommending management guidelines to protect the bottlenose dolphin in the area, but the number of these type of boats around them, as suggested in other studies (Bejder et al., 2006; Lusseau, 2005; Mattson et al., 2005; Williams et al., 2009).

In the short-term analysis, speed craft were found to be the only type of boat affecting dolphin density, with the number of dolphins decreasing in an encounter with this type of vessel. Speed craft often approach dolphins with erratic movements, at high speeds, and loud engine noise whilst displaying little guideline compliance (Mattson et al., 2005; Simmonds, 2009). Nonetheless, the sample size was not large enough to evaluate responses per area to assess conservation strategies. Further studies aiming to evaluate differences per area could help to assess the effect of this type of boat more appropriately, perhaps providing recommendations on the establishment of restricted zones, or setting a limit on the number of speed craft permitted during a dolphin encounter.

Preferences of dolphins in the long-term versus in the short-term appeared to differ. In the long-term, the probability of encountering a large number of dolphins is related to the presence of fishing boats in the area with a long-standing code of conduct: in Pen Llŷn a'r Sarnau SAC, all type of boats had a negative relationship with dolphin density. In the mid-area, dolphin responses to fishing and motorised craft were negative, and a neutral effect was seeing with non-motorised craft, whilst in Cardigan Bay SAC, with the only positive response, dolphin density increased with fishing boats around, whilst displaying a neutral reaction to non-motorised craft. Therefore, motorised boats were the vessels with a major negative impact on dolphin density in the long-term in different areas of Cardigan Bay. On the other hand, in the short-term, dolphin density was negatively related to speed craft only, which shows that in the short period of time dolphins are behaving negatively to the presence of these vessels and large pods are not habituating to them in the long- term with possible long-term population impacts, such as movement out of the affected area.

Implications of studies on boat activity and bottlenose dolphin density

This study presents the analyses of the effects of boat type on bottlenose dolphin density in Cardigan Bay, West Wales, whilst intending to inform the management of anthropogenic activities that are currently in place (boating code of conduct). Results demonstrate the need for monitoring the dolphin population together with vessel activity in the different zones within the bay, whilst increasing people guidelines awareness. The primary goal was to determine how boat traffic affects the distribution of dolphins because it has implications for habitat usage, population estimates and management. Currently, evidence suggests that if environmental factors are not under consideration, areas of high boat density overlap with the distribution of the studied species, whilst fewer dolphins are present in those areas, indicating that human activities are reducing the available habitat for them, which in turn can have greater implications in the long-term.

The fact that less boat activity is found in the mid areas, compared with the two SACs, together with evidence of greater dolphin density, show that animals might not change their density following boating codes of conduct, but they might respond by changing their distribution (Pierpoint et al., 2009). Therefore, management guidelines and compliance to them in southern areas of Cardigan Bay are applicable to other zones and could help improve the status of the population; guidelines such as the area of boat operations, their travel speed, number of vessels interacting with dolphins, and maximum time permitted interacting with the dolphins, could be put in place across the wider area, whilst supporting an area-based management. In this way, when finding positive dolphin responses to vessels, it could be ensure that disturbance is not being displaced to the vicinity of the protected area, but that the conservation area is large enough, covering important zones, whilst managing threats from boat activity in the whole extend (Slooten, 2013). Keeping in mind that the bottlenose dolphin population in Welsh waters also has an important economic benefit to local human communities (CCC et al., 2001), it is important for users to adhere to management regulations, which have been previously found not only to reduce negative effects on dolphin behaviour but also increase the probability of having an encounter with dolphins (Meissner et al., 2015), whilst safeguarding the dolphin-watching industry.

Conclusions

Human activities need to be considered in species density mapping and the confirmation for this is that if an area is visited and the trip happens to coincide with a large number of boats and no dolphin sightings, results will show no presence of dolphins related to the specific environmental variables in the zone, whilst disregarding the potential effect of the great boat activity seeing, giving a biased estimate of the population in the area. Bottlenose dolphins seemed to respond differently to boats in different areas of the bay both in the short- and long-term. Even though there are different management guidelines between zones, it is important to account for the fact that the dolphin population in the area is a mixture of residents, semi-residents and transient, and therefore some individuals travel around the entire bay, being exposed to different disturbances and magnitudes of it, perhaps changing their behaviour and therefore their energy budget in different regions (Hudson, 2014; Lohrengel et al., 2018), which could be improved by the establishment of an area-based management. Therefore, results highlight the value of enforcing regulations, particularly in the northern of Cardigan Bay, contributing to an area-based management scheme that promotes species conservation alongside a sustainable ecotourism-industry, seeking a sustainable development that can provide gains in biodiversity and human livelihoods across the whole of Cardigan Bay.

Future research should aim to improve the analyses regarding boat categories in order to assess possible effects that visitor passenger boats might trigger. In addition, analysing engine noise could add important parameters to have in mind when evaluating effects of boat disturbance, besides boat presence, on dolphin presence. Furthermore, analyses of individual/specific responses to certain recognisable vessels should be implemented to evaluate whether certain boat types with a different engine or unusual travel behaviour have a greater impact on the dolphins.

3.6 References

Alter, S., Simmonds, M. P., & Brandon, J. R. (2010). Forecasting the consequences of climate-driven shifts in human behavior on cetaceans. *Marine Policy*, 34(5), 943–954. https://doi.org/10.1016/j.marpol.2010.01.026

Ansmann, I. C., Parra, G. J., Chilvers, B. L., & Lanyon, J. M. (2012). Dolphins restructure social system after reduction of commercial fisheries. *Animal Behaviour,* 84(3), 575–581. https://doi.org/10.1016/j.anbehav.2012.06.009

Baines, M., Reichelt, M., & Evans, P. G. H. (2005). Investigation of harbour porpoise and bottlenose dolphin ecology in Cardigan Bay, UK, using model based spatial analyses. Unpublished report to EU INTERREG Programme, Sea Watch Foundation, Oxford, UK.

Becker, E., Forney, K., Moore, T., Barlow, J., Foley, D., & Smith, R. (2014). Predicting seasonal density patterns of California cetaceans based on habitat models. *Endangered Species Research*, 23(1), 1–22. https://doi.org/10.3354/esr00548

Bejder, L., Dawson, S. M., & Harraway, J. A. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise bay, New Zealand. *Marine Mammal Science,* 15(3), 738–750. https://doi.org/10.1111/j.1748-7692.1999.tb00840.x

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., & Kruetzen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, 20(6), 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x

Bristow, T., & Rees, E. I. S. (2001). Site fidelity and behaviour of bottlenose dolphins (*Tursiops tmncatus*) in Cardigan Bay, Wales. *Aquatic Mammals*, 27, 1-10.

CCC (Ceredigion County Council), Countryside Council of Wales, Environment Agency Wales, North Western and North Wales Sea Fisheries Committee, Pembrokeshire Coast National Park Authority, Pembrokeshire County Council, South Wales Sea Fisheries Committee, Trinity House, and Dŵr Cymru Welsh Water. (2001). Cardigan Bay cSAC Management Plan. Ceredigion County Council, Aberystwyth. pp 203.

CCC (Ceredigion County Council), Countryside Council of Wales, Environment Agency Wales, North Western and North Wales Sea Fisheries Committee, Pembrokeshire Coast National Park Authority, Pembrokeshire County Council, South Wales Sea Fisheries Committee, Trinity House, and Welsh Water. (2008). Cardigan Bay Special Area of Conservation (SAC) Management Scheme. Ceredigion County Council, Aberystwyth. pp 179.

Currey, R., Dawson, S., Slooten, E., Schneider, K., Lusseau, D., Boisseau, O., & Williams, A. (2009). Survival rates for a declining population of bottlenose dolphins in Doubtful Sound, New Zealand: an information theoretic approach to assessing the role of human impacts. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 19, 658–670. https://doi.org/10.1002/aqc

Day, J.C. (2002). Zoning-lessons from the Great Barrier Reef Marine Park. *Ocean & Coastal Management*, 45, 139–156.

Forest, A. (2001). The Hawaiian spinner dolphin, *Stenella longirostris*: effects of tourism. MSc Thesis, Texas A& M University, Galveston, Texas.

Forney, K. A., Ferguson, M. C., Becker, E. A., Fiedler, P. C., Redfern, J. V., Barlow, J., & Ballance, L. T. (2012). Habitat-based spatial models of cetacean density in the eastern Pacific Ocean. *Endangered Species Research*, 16(2), 113–133. https://doi.org/10.3354/esr00393

Gilles, A., Viquerat, S., Becker, E. A., Forney, K. A., Geelhoed, S. C. V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., & Van Beest, F. M. (2016). Seasonal habitat-based density models for a marine top predator, the harbor porpoise, in a dynamic environment. *Ecosphere*, 7(6), 1–22. https://doi.org/10.1002/ecs2.1367

Gregory, P. R., & Rowden, A. A. (2001). Behaviour patterns of bottlenose dolphins (*Tursiops truncatus*) relative to tidal state, time-to-day, and boat traffic in Cardigan Bay, West Wales. *Aquatic Mammals*, 27(2), 105–113.

Gregr, E. J., Baumgartner, M. F., Laidre, K. L., & Palacios, D. M. (2014). Marine mammal habitat models come of age: The emergence of ecological and management relevance. *Endangered Species Research*, 22(3), 205–212. https://doi.org/10.3354/esr00476

Halpern, B. S., Frazier, M., Potapenko, J., Casey, K. S., Koenig, K., Longo, C., Lowndes, J. S., Rockwood, R. C., Selig, E. R., Selkoe, K. A,. & Walbridge, S. (2015). Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications,* 6(May), 1–7. https://doi.org/10.1038/ncomms8615

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., & Fujita, R. (2008). A global map of human impact on marine ecosystems. *Science,* pp 948–953. https://doi.org/10.1111/2041-210X.12109

Hastie, G. D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2003). Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science*, 19(1), 74–84. https://doi.org/10.1111/j.1748-7692.2003.tb01093.x

Hudson, T. (2014). Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay. MSc Thesis, Bangor University.

Janik, V. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12, 597–602.

Knight, R. L., & Cole, D. N. (1991). Effects of recreational activity on wildlife in wildlands. *Transactions of the North American Wildlife and Natural Resources Conference*, 56, 238-247.

Koroza, A. A. (2018). Habitat use and effects of boat traffic on bottlenose dolphins at New Quay Harbour, Cardigan Bay. MSc Thesis, Bangor University. pp 68.

Lemon, M., Lynch, T. P., Cato, D. H., & Harcourt, R. G. (2006). Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. *Biological Conservation*, 127(4), 363–372. https://doi.org/10.1016/j.biocon.2005.08.016

Lohrengel, K., & Evans, P. G. H. (2015). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2015. *Sea Watch Foundation, Interim Report*, (February), pp 86.

Lohrengel, K., Evans, P. G. H., Lindenbaum, C. P., Morris, C. W., & Stringell, T. B. (2018). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2014-17. *Natural Resources Wales Evidence Report* No: 191. pp 154.

Lopes, K. C. F. (2017). Habitat Preference of bottlenose dolphin (*Tursiops truncatus*) in Cardigan Bay. MSc Thesis, Bangor University.

Lusseau, D. (2003). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series,* 257, 267–274. https://doi.org/10.3354/meps257267

Lusseau, D. (2005). Residency pattern of bottlenose dolphins *Tursiops* spp. in Milford Sound, New Zealand, is related to boat traffic. *Marine Ecology Progress Series*, 295, 265–272.

Mattson, M. C., Thomas, J. A., & St. Aubin, D. (2005). Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquatic Mammals,* 31(1), 133–140. https://doi.org/10.1578/am.31.1.2005.133

Maxwell, S. M., Hazen, E. L., Bograd, S. J., Halpern, B. S., Breed, G. A., Nickel, B., Teutschel, N. M., Crowder, L. B., Benson, S., Dutton, P. H. & Bailey, H. (2013). Cumulative human impacts on marine predators. *Nature communications*, 4, 2688.

Meissner, A. M., Christiansen, F., Martinez, E., Pawley, M. D. M., Orams, M. B., & Stockin, K. A. (2015). Behavioural effects of tourism on oceanic common dolphins, Delphinus sp., in New Zealand: The effects of markov analysis variations and current tour operator compliance with regulations. *PLoS ONE*, 10(1), 1–23. https://doi.org/10.1371/journal.pone.0116962

Moore, S. E., & Clarke, J. T. (2002). Potential impact of offshore human activities on gray whales. *Journal of Cetacean Research & Management*, 4(1), 19–25.

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., Thompson, P. M., Cheney, B., Scott-Hayward, L., & Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, 27(2), 314–322. https://doi.org/10.1111/1365-2435.12052

Ng, S. L., & Leung, S. (2003). Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis)* to vessel traffic. *Marine Environmental Research*, 56(5), 555–567. https://doi.org/10.1016/S0141-1136(03)00041-2

Notarbartolo di Sciara, G. (2002). Cetaceans of the Mediterranean and Black Seas State. *A Report to the Permanent Secretariat of the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area -ACCOBAMS-*, 1–259. Retrieved from http://www.rne.tn/upload/files/Cetaceans of the Mediterranean and Black Seas_ State of knowledge and conservation strategies.pdf#page=118

Nowacek, D. P., Tyack, P. L., & Wells, R. S. (2001). A platform for continuous behavioral and acoustic observation of free-ranging marine mammals: Overhead video combined with underwater audio. *Marine Mammal Science,* 17(1), 191–199. https://doi.org/10.1111/j.1748-7692.2001.tb00992.x

Pierpoint, C., Allan, L., Arnold, H., Evans, P., Perry, S., Wilberforce, L., & Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan bay, UK. *Journal of the Marine Biological Association of the United Kingdom,* 89(5), 1033–1043. https://doi.org/10.1017/S0025315409000885

Pirotta, E., Merchant, N. D., Thompson, P. M., Barton, T. R., & Lusseau, D. (2015). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. *Biological Conservation,* 181, 82–89. https://doi.org/10.1016/j.biocon.2014.11.003

Powell, J. R., & Wells, R. S. (2011). Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Marine Mammal Science,* 27(1), 111-129.

R Studio. Version 1.0.136 – © 2009-2016 RStudio, Inc.

Rako, N., Fortuna, C. M., Holcer, D. Š., Mackelworth, P., Nimak-Wood, M., Pleslić, G., & Picciulin, M. (2013). Leisure boating noise as a trigger for the displacement of the bottlenose dolphins of the Cres-LoŠinj archipelago (northern Adriatic Sea, Croatia). *Marine Pollution Bulletin*, 68(1–2), 77–84. https://doi.org/10.1016/j.marpolbul.2012.12.019

Richardson, H. (2012). The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus)* of Cardigan Bay in Wales. MSc thesis, University College London. pp 71.

Scarpaci, C., Parsons, E. C. M., & Lück, M. (2008). Recent advances in whale-watching research : 2006-2007. *Tourism in Marine Environments*, 5(1), 55–66. https://doi.org/10.3727/154427308785855288

Simmonds, M. P. (2009). Chasing dolphins. *Whale and Dolphin Conservation Society*, Chippenham, UK. Retrieved from http://www.wdcs.co.uk/media/submissions_bin/chasingdolphins.pdf

Slooten, E. (2013). Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin. *Endangered Species Research*, 20(2), 121–130. https://doi.org/10.3354/esr00483

Villaescusa, L., Pesante, G., Anderwald, P., & Evans, P. G. H. (2007). Distribution and habitat preference of bottlenose dolphins in Cardigan Bay, Wales. *Marine Ecology*, 83(1), 2.

Williams, R., Bain, D. E., Smith, J. C., & Lusseau, D. (2009). Effects of vessel on behaviour patterns of individual southern resident killer whales *Orcinus orca*. *Endangered Species Research*, 6(3), 199–209. https://doi.org/10.3354/esr00150

Zapetis, M. (2017). The effect of boat presence on the behavior of bottlenose dolphins (*Tursiops Truncatus*) in the Mississippi Sound. MSc Thesis, University of Southern Mississippi. pp 437.

Zuur, A. F., Ieno, E. N., Walker, N., Saveliev, A. A., & Smith, G. M. (2009). Mixed Effects Models and Extensions in Ecology with R. *Springer*, New York, USA.

CHAPTER IV

Short-term effects of boat disturbance on the behaviour of bottlenose dolphins

4.1 Abstract

In many parts of the world, recreational activities pose a threat to coastal dolphins. In the UK, three Special Areas of Conservation have been established to protect bottlenose dolphins. However, over the past decade, human pressures have increased markedly and at two of those sites may be the reason for a reduction in their usage of the area. Careful management is needed to conserve the bottlenose dolphin population whilst safeguarding its socio-economic value. This study aimed to examine the success of management plans in two SACs (where a code of conduct was implemented at different times), which experience different levels of disturbance, evaluating behavioural impacts relative to vessel proximities. Theodolite tracking of dolphins and boats covering both SACs, were conducted to assess responses of different boat types (including distance, speed and direction in relation to dolphins) at the moment of encounter, and dolphin responses (changes in swim speed, orientation and abundance). Results show differences in boat responses between SACs, boats keeping greater distances from dolphins irrespective of boat type in the site with a long-standing code of conduct, whereas at the recently established one, speed craft came closer to dolphins than other boats. At both sites, dolphins remained present during periods of high vessel traffic, but with significant increase in swim speeds, larger number of dolphins, as well as movements directly away from vessels at the site with a recent code of conduct establishment. It is concluded that dolphins maintain occupancy despite vessel presence but alter their behaviour during periods of high traffic, which is linked to the time that codes of conduct have been running in the SACs. Results highlight the value of enforcing regulations, contributing to an area-based management scheme that promotes species conservation alongside a sustainable ecotourism industry.

4.2 Introduction

Coastal marine mammal populations are found worldwide. All populations are exposed to a wide range of anthropogenic disturbances including construction and operation of wind farms (Bailey et al., 2014) and presence of various types of vessels (Acevedo, 1991; Mattson et al., 2005). Increasing boat traffic has raised concerns about its consequences on wildlife (Douglas & Alie, 2014). Major threats from these activities have been found to be direct vessel strikes, which can lead to injury or in extreme cases, death (Read et al., 2006), interference from noise, masking communication (Guerra et al., 2014) and disrupting feeding (Pirotta et al., 2015) and social activities (Papale et al., 2012). Physical evidence of the effects that vessel activities may have upon marine mammals include epidermal lesions, amputations of dorsal fins and/or flukes, or even direct death (Read et al., 2006). On the other hand, estimating non-lethal effects from those activities can be extremely challenging. Recurrent exposure can cause direct modifications in the short-term behaviour of individuals, triggering subsequent changes to their vital rates, and causing indirect long-term effects at the population level (Lusseau, 2004; New et al., 2013). Numerous studies have found evidence regarding boat responses triggering changes to cetacean behaviour at the moment of an encounter. In order to manage the disturbance, different species develop responses including horizontal avoidance, increased dive intervals, increased swim speed, and variations in vocalizations (Janik, 1996; Hastie et al., 2003; Buckstaff, 2004; Bejder et al., 2006; Lemon et al., 2006; Lusseau, 2006). Nonetheless, it seems that whales and dolphins tend to avoid motorised boats when the conduct of those is not predictable (Nowacek et al., 2001). The predictability of vessels appears to be the main aspect explaining such avoidance strategies (Lusseau, 2003). Therefore, management strategies including boating codes of conduct, which specify boat manoeuvre guidelines at the moment of a whale or dolphin encounter may achieve predictability of vessels, contributing to species conservation.

In recent years, recreational boat use has increased in Cardigan Bay, with evidence suggesting that high traffic can temporarily displace animals from this area (Lohrengel et al., 2012; Pierpoint et al., 2009), whilst also impacting group structure (Richardson, 2012). However, little is known about the short-term changes in behavioural patterns of bottlenose dolphin due to boat disturbance in both SACs. This is an important gap in our knowledge, since knowing the effects of the disturbance can help to mitigate it and protect the bottlenose dolphin population that inhabits the area (see Chapter II).

One form of mitigation against vessel disturbance that has been introduced to protect these cetaceans is to put codes of conduct in place. The southern SAC has had a code of conduct in place for several years now, with good compliance (CCC et al., 2001; Pierpoint et al., 2009; Koroza, 2018). The northern SAC implemented the code of conduct for the first time in the summer of 2016, in order to diminish any disturbance or pressure upon the wildlife. In both cases, the code of conduct states that any recreational vessel needs to be aware of the important bottlenose dolphin feeding areas and should travel slowly through these areas to avoid any disturbance. In case of an encounter, the code restricts distance to the animals (100 metres), time spent with them (maximum 15 minutes), vessel travel speed (maximum 8 knots), travel direction (no direct approach to dolphins) and avoidable noise (CCC et al., 2001). In addition, in Cardigan Bay SAC, jet skis are not allowed, whilst there is a strong presence of visitor passenger boats, in contrast to Pen Llŷn a’r Sarnau SAC where other types of recreational vessels (sailboats, speed boats and personal watercraft) dominate (see Chapter 2). Based on previous information from long-term monitoring of the dolphins (Pesante et al., 2008; Feingold & Evans, 2014; Lohrengel et al., 2018), and in order to evaluate immediate behavioural responses of both dolphins and boats during encounters in areas where a code of conduct has been established for different lengths of time, visual tracking of the movements of the dolphins was undertaken from land using a theodolite.

The Welsh semi-resident population of bottlenose dolphin, the continued disturbance of this resource by recreational users as well as the tourism industry, and the presence of a management plan with differences in the code of conduct establishment, make Cardigan Bay a suitable location for the investigation of 1) the state of compliance and success of management plans in both SACs, and 2) bottlenose dolphin behavioural changes resulting from boat encounters.

The aim of this study was to evaluate immediate behavioural responses of dolphins and boats during encounters in areas with different management plan establishment in Cardigan Bay, West Wales. The following questions were investigated: i) are boats failing the code of conduct in some areas of Cardigan Bay; and ii) are short-term behavioural responses in bottlenose dolphins to boat presence more positive in an area of long-lasting code of conduct establishment, than in an area with recently established one?

4.3 Methods

4.3.1 Study area

Cardigan Bay is the largest bay in the UK, covering an area of approximately 5500 square kilometres (CCC et al., 2001) (Figure 4.1). Bottlenose dolphins have long been present in the bay, with records over the last century going back at least to the 1920s (Evans, 1980). With the idea of protecting the bottlenose dolphin population that inhabits Welsh waters, two SACs have been created, Pen Llŷn a'r Sarnau SAC in the north and Cardigan Bay SAC in the south (see Chapter II).

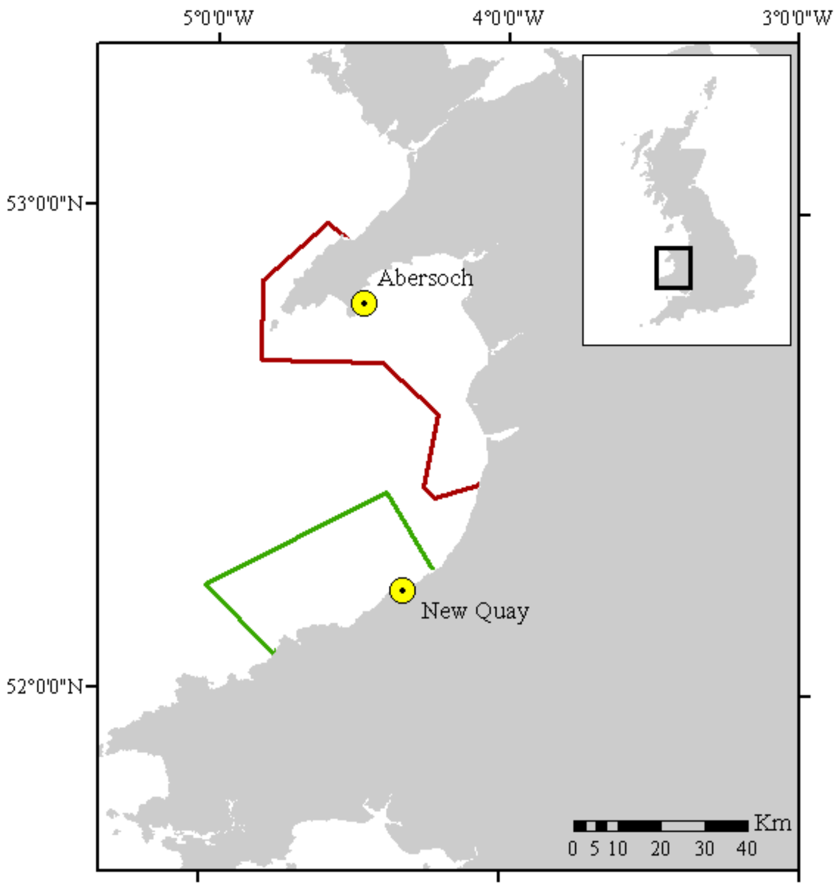


Figure 4.1 Cardigan Bay: area used for the present study showing Pen Llŷn a'r Sarnau SAC (red), Cardigan Bay SAC (green) and the sites (Abersoch and New Quay) where data were collected.

Study sites (Abersoch and New Quay)

Two elevated observation points were chosen to collect data in order to compare short-term responses of bottlenose dolphins to boat presence, at locations with high vessel activity - New Quay and Abersoch, the former with demonstrable compliance of a strong and long-standing code of conduct and the latter with a recently code implemented so that compliance is weak (Koroza, 2018) (Table 4.1).

Table 4.1 Study sites within Welsh SACs with code of conduct establishment date and main boat usage.

Site	SAC	Code of conduct establishment	Main boat usage
Abersoch	Pen Llŷn a'r Sarnau	2016	Jet skis
New Quay	Cardigan Bay	2004	Dolphin-watching tour

4.3.2 Land-based theodolite surveys

Regular electronic digital theodolite surveys (SOKKIA DT500A, SOKKIA Co., Ltd) of dolphins and boats were conducted from April to October of 2016 and 2017, weather and light dependent. From each site, the area was scanned and variables that were used in the subsequent analysis were collected. These shore-based watches were used to simultaneously track the movements of animals and boats, allowing responses to one another to be identified. This non-invasive method prevents the observer presence altering the behaviour of animals and boats, providing an unbiased indication of any responses.

From each watch point, horizontal and vertical angles of both dolphins and vessels were recorded every 3 minutes using the theodolite. It was important to accurately record the theodolite height in metres, accounting for tidal fluctuations, as well as precise latitude and longitude for each survey site (Figure 4.2). A second point was used at each site, as a reference point with specific coordinates. In addition, date, time, environmental data such as visibility, Beaufort Sea state, and swell height were recorded in order to guarantee appropriate survey conditions and provide temporal information useful for further analyses. When dolphins were spotted, an individual focal follow was conducted, and the individual's movements were followed using binoculars. Sighting information was recorded, including overall number of dolphins, number of calves, and behaviour. Alongside this information, boat presence was recorded, along with boat number and boat type.

Figure 4.2 The angle and distances used to calculate the position of a marine mammal using a theodolite. (i) theodolite height, (ii) height of the survey site, (iii) tidal height, (h) theodolite height above the current sea level, (VA) vertical angle.

4.3.3 Theodolite processing data

Using the horizontal and vertical angles derived from the theodolite readings every 3 minutes, and knowing the exact height of the theodolite above sea level (accounting for tidal fluctuations), as well as the specific position of a reference point, trigonometric formulae as used by Lerczak & Hobbs (1998) were used to convert data into specific coordinates for further plotting and analyses (Formulae 4.1). As a result, boat and dolphin theodolite tracking at both sites were possible (Figure 4.3).

Formulae 4.1. Trigonometric equations used to obtain geographical positions based on theodolite readings (VA= vertical angle; DistTheoPoint= distance from theodolite to observation point; HA= horizontal angle; Bearing= reference point bearing):

$$Interpolated\ tidal\ height = Predicted\ tidal\ height\ at\ hour\ + (Tidal\ difference\ per\ min * min)$$

$$Theodolite\ height = Total\ theodolite\ height - interpolated\ tidal\ height$$

$$\theta_O = 180 - \boldsymbol{VA}$$

$$DistTheoPoint = TAN(RADIANS(\theta\_O)) * Theodolite\ height$$

$$X = IF\ ((\boldsymbol{HA} < Bearing), DistTheoPoint * cos(radians(90° - Bearing) + \boldsymbol{HA})), DistTheoPoint * cos(radians(ABS(90° - Bearing) - (360 - \boldsymbol{HA})))))$$

$$Y = IF\ ((\boldsymbol{HA} < Bearing), DistTheoPoint * sin(radians(-90° - Bearing) + \boldsymbol{HA})), DistTheoPoint * sin(radians((-90° - Bearing) - (-360 + \boldsymbol{HA})))))$$

$$EASTING = Theodolite\ easting + X$$

$$NORTHING = Theodolite\ northing + Y$$

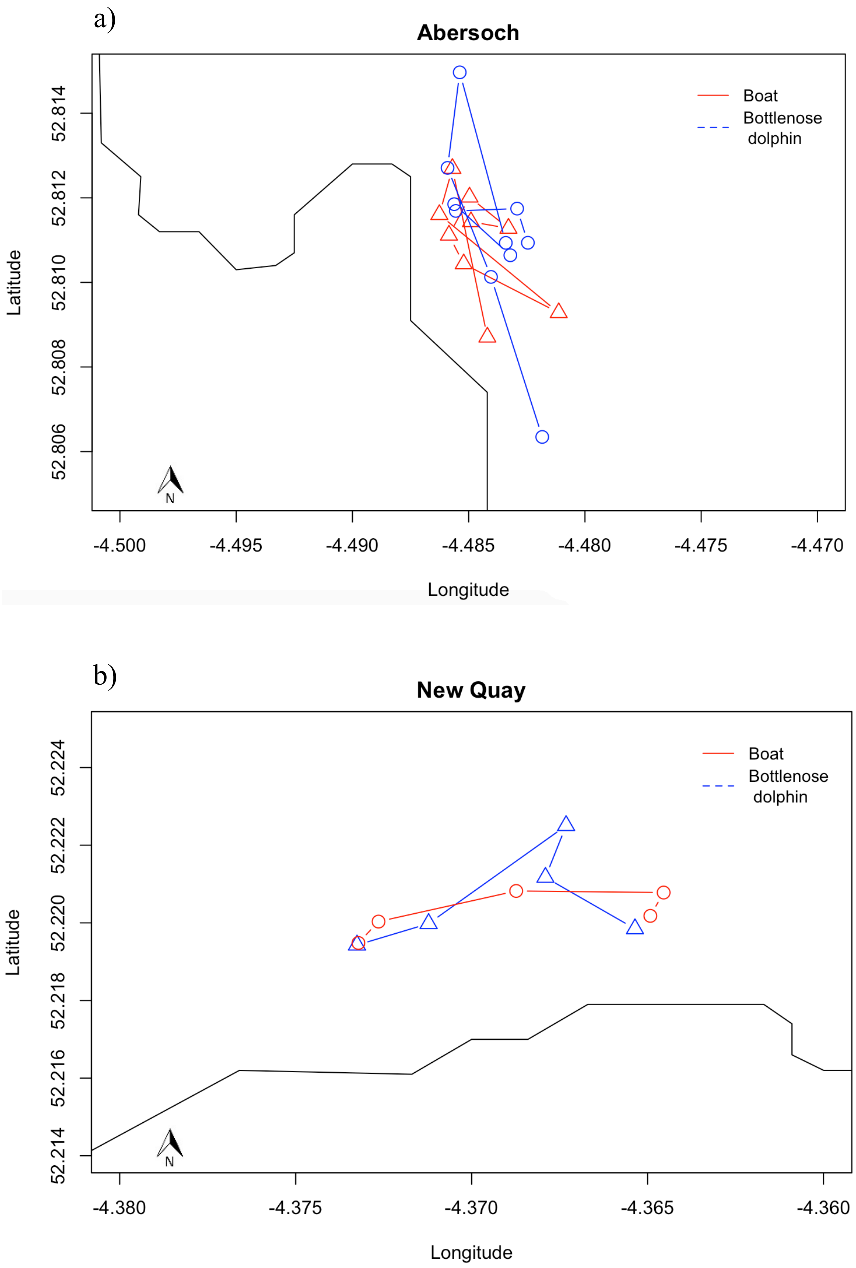


Figure 4.3 Examples of dolphin-boat encounter tracking (geographical positions) based on theodolite readings at a) Abersoch and b) New Quay.

Using these coordinates (easting and northing) extracted from consecutive theodolite readings, the distance between dolphins and boats, direction of movement of the dolphins, direction of the movement of the boats, and speeds of both dolphins and boats were also extracted (Figure 4.4). The speed of both focal dolphin and boat was estimated using the distance (in metres) between each pair of positions divided by the number of seconds taken between each reading (3 min=180sec). Dolphin direction in relation to boat position (Figure 4.5a,b) was defined as the angle calculated by the heading of each "vector" of pod movement relative to the boat position, where a "vector" was defined by two consecutive theodolite readings of movement of the dolphin. This was also applied to determine boat direction in relation to dolphin position (Figure 4.5c,d).

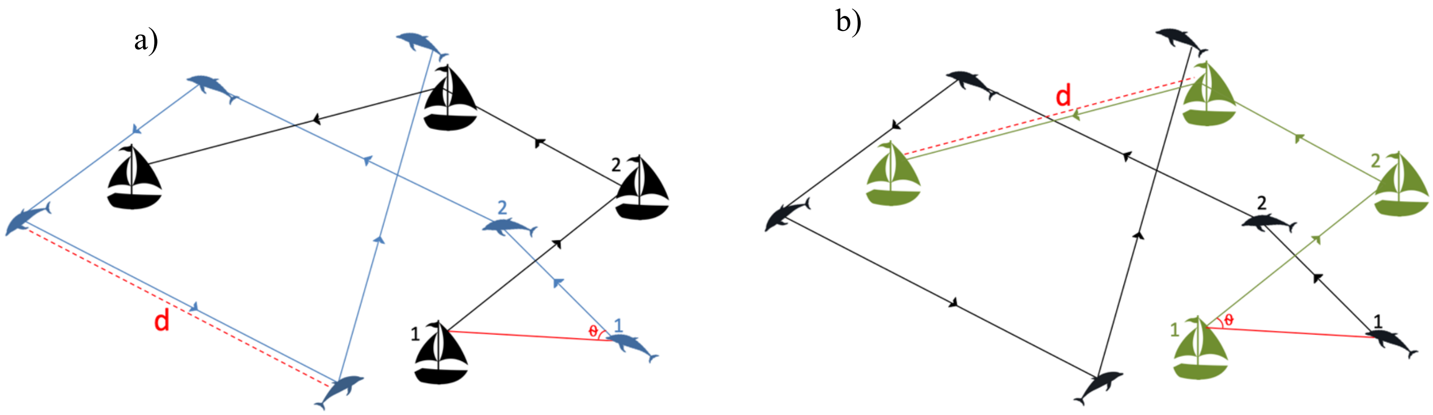


Figure 4.4 Diagram of dolphin-boat encounter theodolite tracking. Continued theodolite readings allowed the following to be determined: a) distance, d, between consecutive dolphin sighting locations, and dolphin swim direction in relation to boat, θ; b) distance, d, between consecutive boat sighting locations, and boat travel direction in relation to dolphin, θ.

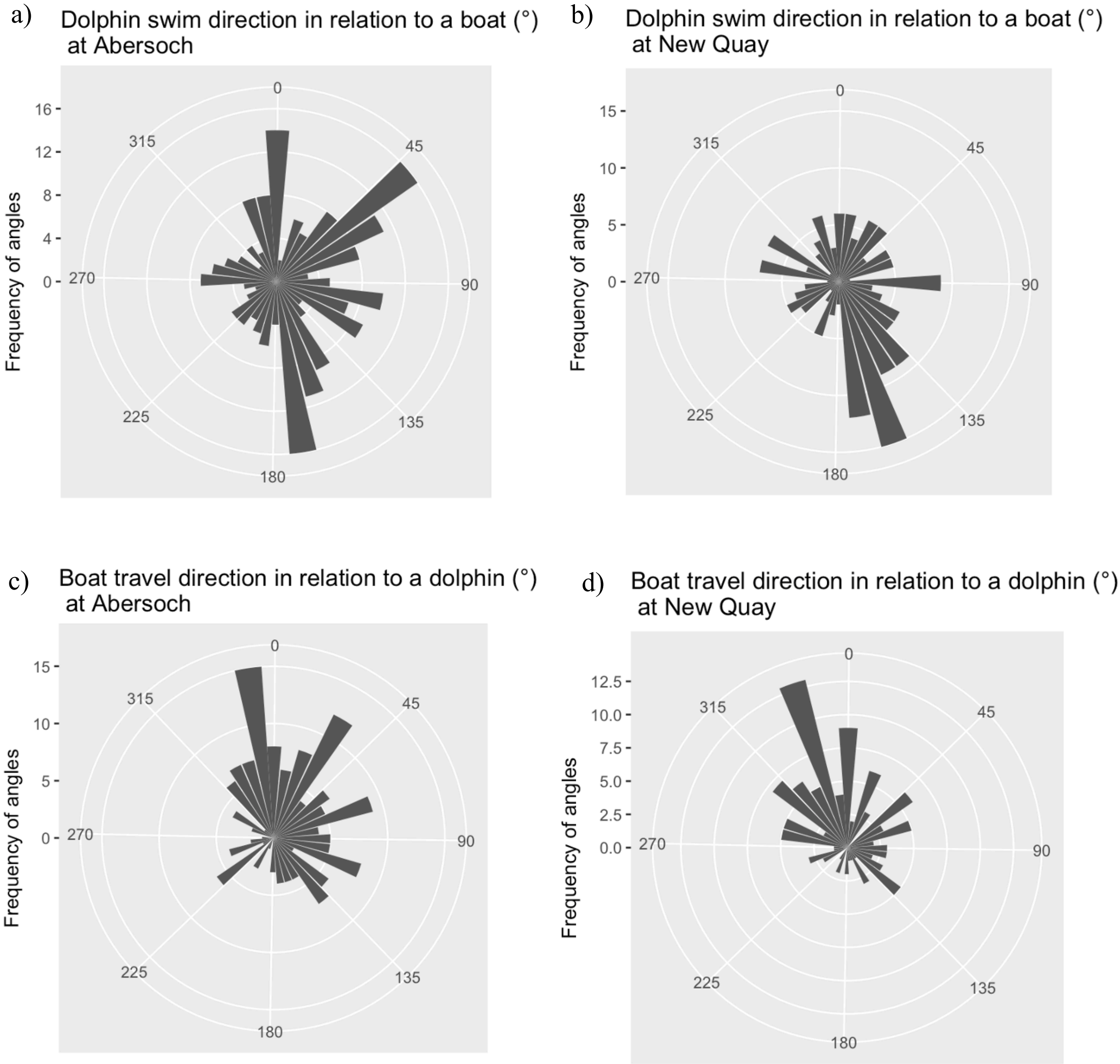


Figure 4.5 Frequency of angles for dolphin swim direction in relation to boats at a) Abersoch and b) New Quay; and boat travel direction in relation to dolphins at c) Abersoch and d) New Quay.

Dolphin direction in relation to boat position, and boat direction in relation to dolphin position, were converted into 0º to 180º only (since whether movements were to the right or left was not relevant) where 0º in a circumference represents moving towards and 180° is moving away (leaving). Therefore, angles between 315º and 360º (converted to 45º and 0º, respectively) and 0º and 45º were categorised as approaching, angles between 226º and 314º (converted to 134º and 46º, respectively) and 46º and 134º were considered a neutral response (where dolphins do not necessarily displayed avoidance behaviour, but were equivocal toward the boat) and the rest of the circumference was considered as leaving (Bejder et al., 1999) (Figure 4.6).

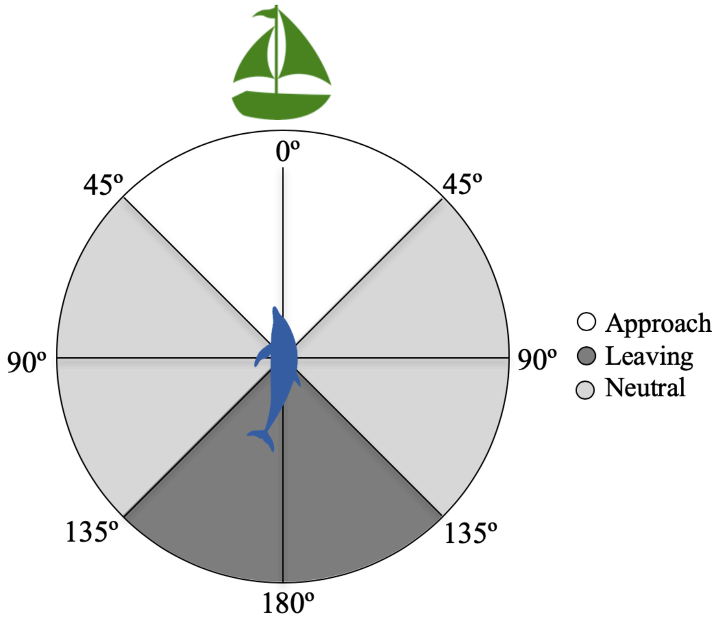


Figure 4.6 Classification of dolphin-boat encounter direction (approach, leaving or neutral). In this example, which considers dolphin swim direction in relation to the boat, the boat is at 0°, which means the dolphin is approaching it. This classification also applies to boat direction in relation to dolphin location.

4.3.4 Statistical analyses

In relation to the code of conduct guidelines, boat behaviour was analysed. GLMs were used in order to explain differences between areas in regard to boat travel speed and distance between dolphin and boat at the moment of an encounter. For travel speed, a Gaussian family and log transformation were used and for distance between dolphin and boat a quasiPoisson family was used (to account for overdispersion of the residuals). Boat category and site were used as explanatory variables. Analyses were completed in 'R Studio' (Version 1.0.136 – © 2009-2016 RStudio, Inc.) (See Supplementary material 8.1.2.1).

Dolphin short-term behavioural responses at each site were evaluated at different moments of a boat encounter. Paired t-tests were used to evaluate differences in dolphin swim speed and number of dolphins (abundance) in scanned area every 3 minutes at three different stages of the boat encounter: before (previous to the boat arriving to the vicinity of the dolphin), during (when boat and dolphin were together at the same time), and after (moment where dolphin is left alone following a boat encounter).

The probability of detecting short-term changes in dolphin behaviour was evaluated as response to boat conduct. Linear mixed models (LMM) were used to account for temporal autocorrelation between dolphin responses and explanatory variables due to dolphin movement. Additionally, the model included site (*Site*), number of boats (*B_numb*), boat category (*B_cat*), boat speed (*B_spd*), boat travel direction (*B_dir*) and distance (*DIST*) as explanatory variables (Table 4.2). Response variables were dolphin swim speed, swim direction, and abundance every 3 minutes, all evaluated with Gaussian family. In all LMMs, encounter identification number (*ENC)* was modelled as a random effect to account for temporal autocorrelation. The models' residuals showed no evidence of further temporal autocorrelation, therefore more advanced statistical approaches accounting for those were considered unnecessary (See Supplementary material 8.1.2.2) (Zuur et al., 2009). Models were run with "mgcv" package in 'R Studio' (Version 1.0.136 – © 2009-2016 RStudio, Inc.).

Backwards model selection based on AIC values was performed. Beginning with a full model including all possible fixed effects, AIC values were used to find the smallest value of those models that could better predict the response variables. Models with the lowest AIC value for each response variable were then used to see which fixed effect better predicted each response variable.

Table 4.2 Description of explanatory variables used in the linear mixed-effect model

Explanatory variables	Description	Abbreviation
Site	Sites used to collect data	*Site*
Number of vessels	Maximum number of vessels present during a dolphin encounter	*B_numb*
Boat category	Category of the vessel interacting with the dolphins: motorised boats (MB), rowing boats (RB), speed motor (SM), visitor passenger boat (VPB) and sailing boat (YA).	*B_cat*
Vessel speed	Boat speed measured between *t and t+1*	*B_spd*
Vessel direction	Boat direction measured in relation to dolphin position	*B_dir*
Distance to pod	Distance measured between the boat and the pod	*DIST*
Encounter identification number	Encounter identification number, defined by the specific date and time of survey and number of encounter, to account for potential effects.	*ENC*

4.4 Results

With 338.75 effort hours, 190 dolphin encounters and 111 dolphin-boat encounters (Table 4.3), successful theodolite tracking allowed one to identify different positions of dolphins and boats, as well as distances between them, the swim and travel direction and speeds respectively at Abersoch and New Quay. An example of consecutive pod swim direction during a boat encounter can be seen in Figure 4.7.

Table 4.3 Summary of land watches at Abersoch and New Quay.

Site	Number of visits	Hours watched	Dolphin encounters	Dolphin-boat encounters
Abersoch	31	135.75	87	57
New Quay	30	148.5	98	54

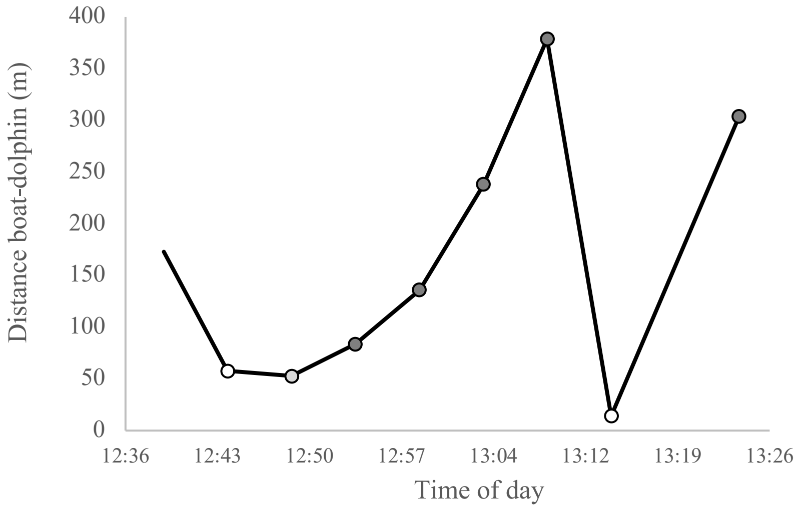


Figure 4.7 Example of dolphin pod movement in relation to boat position during an encounter (represented by increasing / decreasing distance between boat and dolphin), based on theodolite tracking. ○ = pod movement towards boat; ● = pod movement away from boat; ◦ = pod movement neutral to boat.

4.4.1 Boat responses around dolphins

The distances that boats keep from dolphins were significantly shorter at Abersoch *(t*= 49.48, mean ± SD: 208.77 ± 0.15m) than New Quay *(t*= 3.30, mean ± SD: 341.05± 0.10m) (Figure 4.8a). However, when evaluating distance of dolphin-boat per boat category, at Abersoch it varied among boat categories, with speed craft approaching significantly closer to dolphins (*t*=-5.59, mean ± SD: 200 ± 0.09m), accounting for 75.2% of the vessels that did not follow the 100-metre guideline (Figure 4.8b). On the other hand, at New Quay, rowboats came closer to the cetaceans (*t*=-2.18, mean ± SD: 208 ± 0.18m), whilst visitor passenger boats represented 55% of the boats that approached cetaceans more than the code of conduct specified (Figure 4.8c).

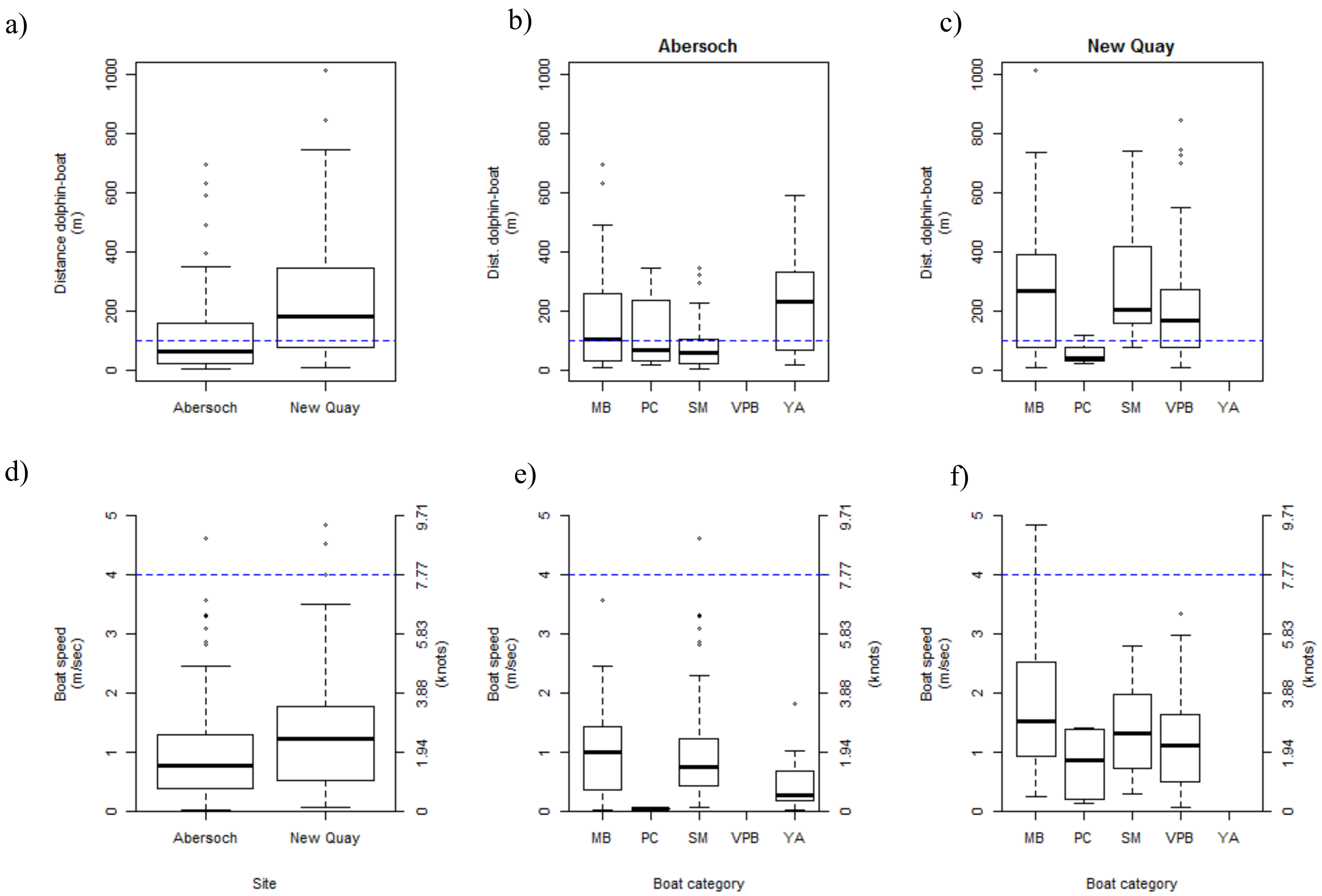


Figure 4.8 Dolphin-boat encounter distance (blue dotted line representing the 100m guideline) a) per site, b) at Abersoch per boat category, and c) at New Quay per boat category. Boat speed at the moment of an encounter (blue dotted line representing the 8 knots guideline) d) per site, e) at Abersoch per boat category, and f) at New Quay per boat category. (MB: Motorboat, PC: Rowboat, SM: Speedboat, VPB: Visitor passenger boat, YA: Sailboat).

In addition to the distances between dolphin and boat, vessel speed was evaluated at the moment of an encounter at each site (Figure 4.8d). At New Quay, all boat categories were travelling around the same speed (Figure 4.8e), but speedboats were significantly faster than other vessels at Abersoch, (t=4.83, mean ± SD: 20.64± 0.18 m/sec) (Figure 4.8f).

4.4.2 Dolphin behaviour around boats

4.4.2.1 Before, during and after a dolphin-boat encounter

From dolphin and dolphin-boat encounters, dolphins were observed "Before" (Abersoch, n=145, New Quay, n=218), "During" (Abersoch, n=306, New Quay, n=212), and "After" (Abersoch, n=56, New Quay, n=89) the boat encounter to assess the effect of vessel interactions on dolphin responses (Table 4.4). These analyses for each stage of the encounter were run under the assumption of a common scenario where, on average, bottlenose dolphins behave similarly before the arrival of boats/disturbance, displaying consistent swim speed and abundance. Therefore, when evaluating responses after the encounter, even from different sightings, it is assumed they are comparable, such that differences from normal behaviour at any stage of the encounter are indicative of impacts of boats.

Table 4.4 Summary of theodolite readings of dolphin swim speed, direction and distance to boat before, during and after boat encounters.

	Before	During	After
Abundance (n)	363	518	145
Swim speed (n)	243	262	140
Swim direction (n)	--	407	--
Distance to boat (n)	--	232	--

A significant decrease in dolphin swim speed before and after the encounter was found at New Quay and at Abersoch (Figure 4.9a; Table 4.5). In addition, although the number of dolphins in the scanned area is similar at both sites, the presence of boats triggered an increase in number of dolphins, but at different moments of the encounter at the two sites (Figure 4.9b). Number of dolphins was significantly smaller before an encounter (than during or after) at Abersoch, with an increase between before and after, and before and during the encounter (Table 4.5). On the other hand, at New Quay, the number of dolphins was highest after the boat encounter, with significant differences between before and after, during and after, and before and during the encounter (Table 4.5).

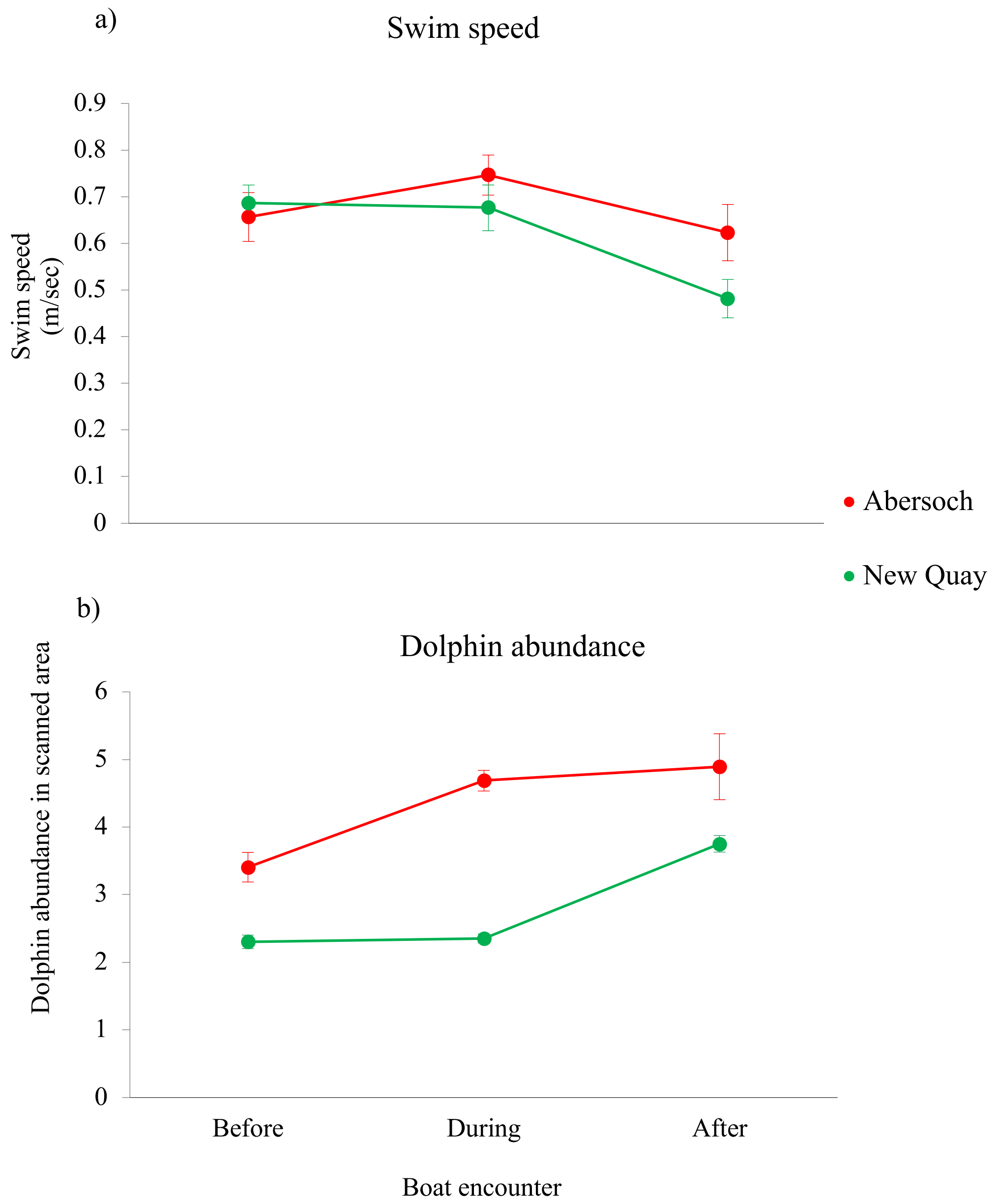


Figure 4.9 Observed a) dolphin swim speed and b) dolphin abundance in scanned area before, during and after a boat encounter at Abersoch and New Quay.

Table 4.5 p-values from paired t-tests for dolphin swim speed and abundance in the scanned area before (B), during (D) and after(A) a vessel encounter at Abersoch and New Quay.

		Vessel encounter	t-statistic	p-value
Abersoch	Swim speed	B-D	-19.69	**<0.05**
		B-A	-14.26	**<0.05**
		D-A	-18.56	**<0.05**
	Abundance	B-D	-17.651	**<0.05**
		B-A	-8.735	**<0.05**
		D-A	-15.126	**<0.05**
New Quay	Swim speed	B-D	-21.317	**<0.05**
		B-A	-19.861	**<0.05**
		D-A	-16.234	**<0.05**
	Abundance	B-D	-10.448	**<0.05**
		B-A	-9.354	**<0.05**
		D-A	-3.26	**<0.05**

p-values that indicate a significant effect are in **bold** text

4.4.2.2 Dolphin behaviour in relation to boat responses

The predicted probability of dolphins changing their swim direction (modification in the swim orientation/angle), swim speed and abundance from LMM is presented in Table 4.6. Dolphin direction was significantly affected by boat direction according to the best-fit model (t= 16.486, mean ± SD: 94.03 ± 55.03º) (Table 4.6; Figure 4.10). In addition, boat speed did not have a significant effect upon the dolphin swim direction as response to a boat encounter.

According to the best-fit model, an increase in boat speed significantly increased dolphin swim speed (t= 6.82, mean ± SD: 0.66 ± 0.50 m/sec) (Table 4.6; Figure 4.11). At both sites, distance of boat to pod and boat travel direction did not affect significantly the speed at which dolphins swam.

Fewer dolphins were found in New Quay compared with Abersoch (Table 4.6). Number of dolphins found in New Quay were consistently small (t= 5.5 mean ± SD: 2.48± 1.65), whereas at Abersoch numbers were occasionally large (t= 4, mean ± SD: 3.98± 2.68). Boat speed and direction did not significantly affect abundance in the scanned area, contrary to the previous response variables evaluated.

Table 4.6 Results from linear mixed effect model for dolphin swim direction, speed and abundance in scanned area.

Response	Model	Variable	Variable type	F	p-value
Dolphin direction	B_spd,B_dir	B_dir	Linear	**38.349**	**$5.4e^{-09}$**
		B_spd	Linear	0.037	0.848
Dolphin swim speed	B_spd,B_dir,DIST	B_spd	Linear	**6.232**	**0.014**
		B_dir	Linear	0.137	0.712
		DIST	Linear	2.29	0.134
Abundance	B_spd,B_dir,B_cat,Site	B_spd	Linear	6.468	0.112
		B_dir	Linear	0.194	0.66
		B_cat	Categorical	**3.652**	**0.007**
		Site	Categorical	**6.255**	**0.013**

Confidence intervals that indicate a significant effect are in **bold** text

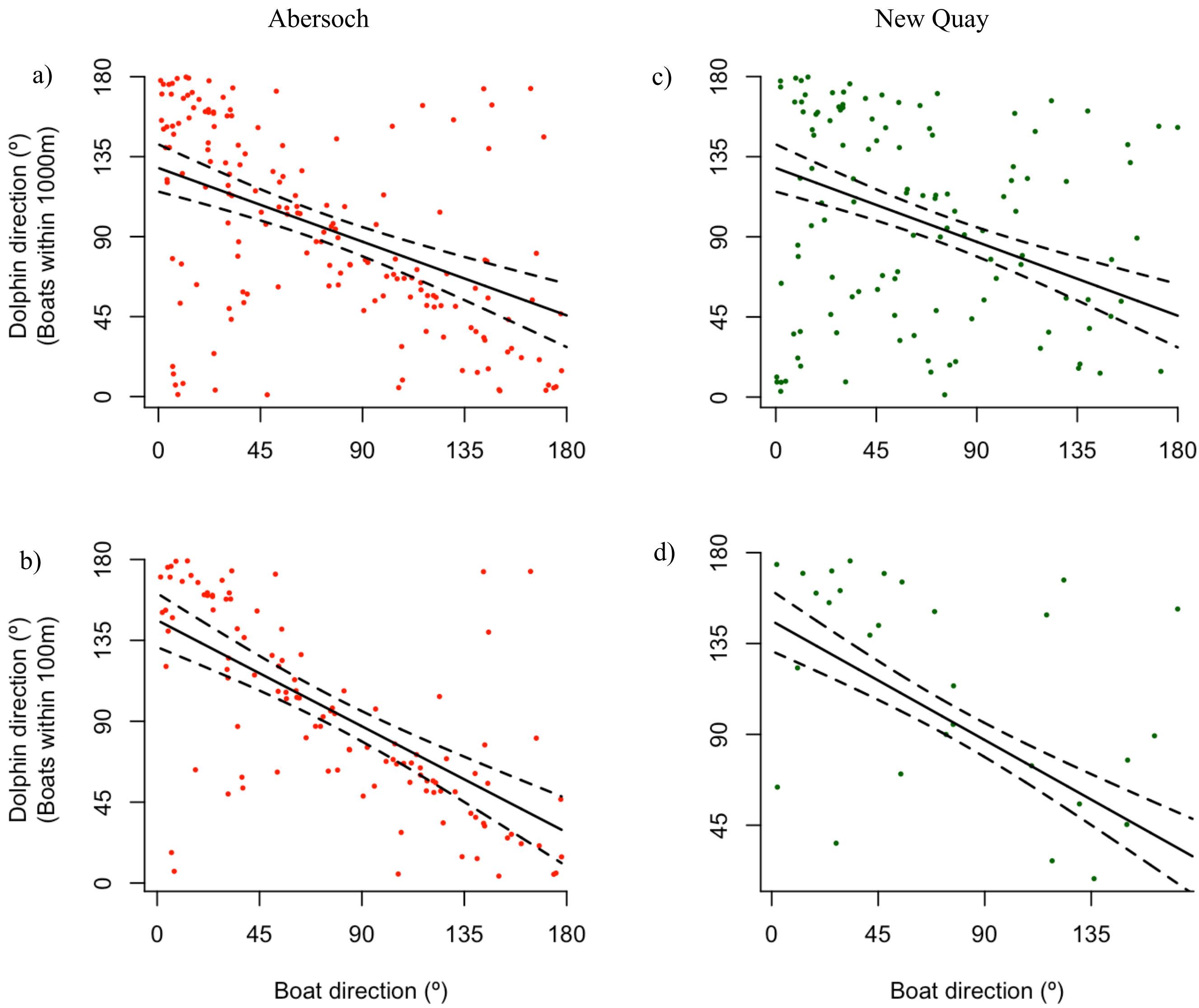


Figure 4.10 Dolphin swim direction in relation to boat travel direction at the moment of an encounter at a) Abersoch (boats within 1000m of the dolphin), b) Abersoch (boats within 100m), c) New Quay (boats within 1000m) and d) New Quay (boats within 100m). Lines represent the predicted effect of boat travel direction on dolphin swim direction and dash lines are 95% confidence intervals. Data points represent raw data.

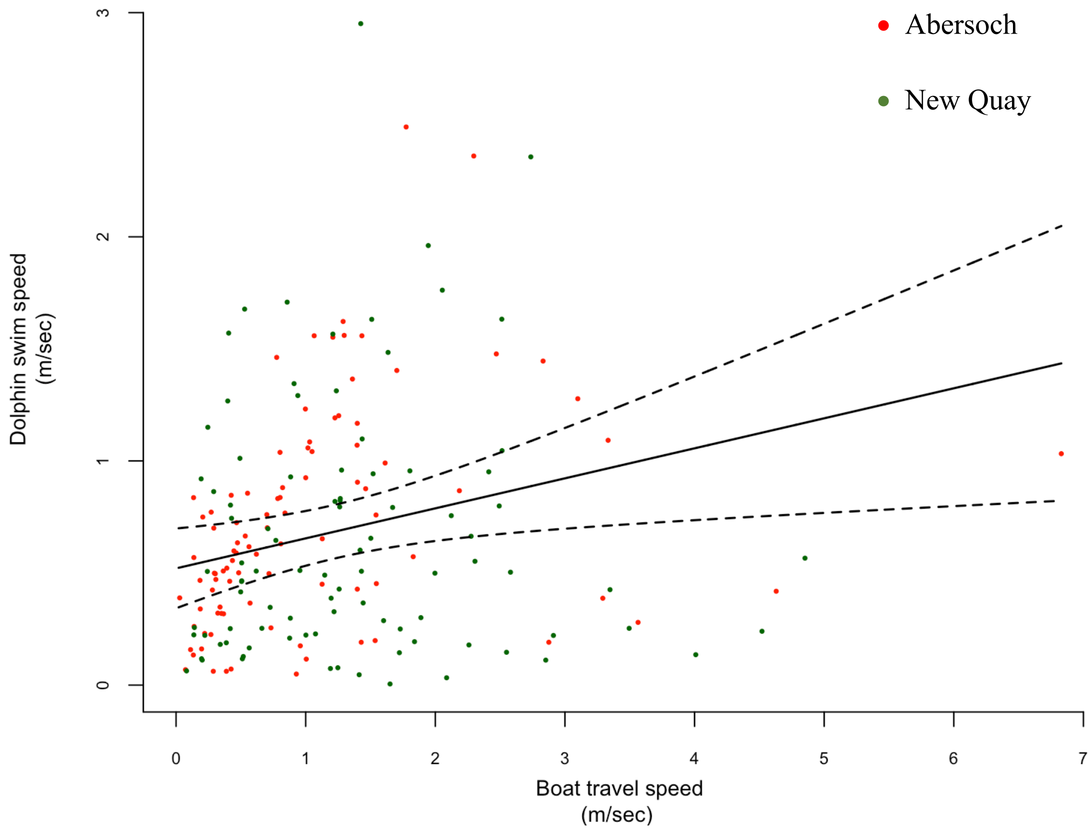


Figure 4.11 Dolphin speed in relation to boat speed at the moment of an encounter at both sites. Lines represent the predicted effect of boat travel speed on dolphin swim speed and dash lines are 95% confidence intervals. Data points represent raw data for Abersoch and New Quay. Significance differences from LMM are denoted by asterisk (*= p<0.05; **= p<0.01; ***= p<0.001).

4.5 Discussion

The current study sought to investigate responses of bottlenose dolphins to boat encounters, as well as to evaluate compliance to boat codes of conduct following SAC management in Welsh waters. There were three principal results: i) when boats were around, dolphin increased their swim speeds at Abersoch, but reduced swim speed at New Quay; at Abersoch, dolphin abundance was highest during the boat encounter, whilst in New Quay abundance increased after an encounter; ii) bottlenose dolphin avoidance responses were triggered by boat speed and travel direction, but not by distance between dolphin and boat; iii) the guidelines in place in New Quay (i.e. minimum 100 metres boat-dolphin distance, no direct approach to dolphins, and max 8 knots travel speed) appear to be working, with vessels keeping greater distances from dolphins in New Quay compared with Abersoch, whilst boats also travelled faster at Abersoch than New Quay. Overall, these findings show that the management plan operating in New Quay appears to be effective, with slower boats having no negative short-term effect on dolphins. Therefore, guidelines should be established on a wider scale, with particular emphasis upon reducing boat speeds and modifying boat behaviour (avoiding direct approach to dolphins). The following discussion will explore the different variables that influence these findings.

Boat responses around dolphins

We found differences in dolphin-boat distances, with boats staying further away at New Quay. Conversely, at Abersoch, boats approached closer than the 100m guidelines. At New Quay all types of vessels seemed to follow the code and respect the established minimum distance, whereas at Abersoch the distance varied among boat categories, with speed craft approaching closer to dolphins. Therefore, an established code of conduct influences the greater adherence at New Quay. The fact that Abersoch displays more erratic boat use (which means less code of conduct compliance), whilst speedboats are much less regulated than in New Quay (with great jet skis usage), explains such differences in distance. Thus, the guidelines in place in New Quay, which have been in place much longer, seem to be working, and should be established on a wider scale. Even though in the present study, the distance between boat and dolphin did not affect the cetacean response at the moment of an encounter, previous findings suggest that cetaceans show greater evasive responses to boats when they are at closer distances (Polacheck & Thorpe, 1990).

Dolphin behaviour before, during and after a boat encounter

Dolphin swim speed increased upon the arrival of boats at Abersoch. This response has been observed elsewhere in humpback whales (Bauer et al., 1986; Scheidat et al., 2004; Morete et al., 2008; Schaffar et al., 2013), where fast swim speeds allow the animals to avoid the disturbance, acting as an escape mechanism. Additionally, at Abersoch the number of dolphins increased when boats were around. During situations that can involve a threat or danger, dolphins are known to group together, the number of animals seem to increase since they cover a smaller area or move into the immediate undisturbed area, which helps them protect each individual in the group (Johnson and Norris, 1986). Similar responses to approaching vessels may support this particular finding of the study. The fact that boats in Abersoch are mainly recreational and may instinctively respond to dolphin encounters by approaching animals at faster speeds, whilst dolphins respond by swimming faster and clustering together to protect the individuals in the group, suggest that aggressive approaches such at the ones observed here have an avoidance (negative) impact on the cetaceans. Additionally, concerns have also arisen since faster dolphin swim speeds are likely to lead to an increase in energy expenditure.

By contrast, no such increase in dolphin swim speeds was found in New Quay as response to boat encounters, and dolphin abundance did not change when boats arrived in the area. This may be explained by the fact that boats in New Quay are mainly visitor passenger boats, that follow the same routes, displaying greater adherence to the code of conduct than boats in Abersoch. Therefore, animals may be accustomed to this type of boat, reducing their avoidance responses. Thus, when boats are acting according to management plans during a dolphin encounter, using cautious approaches, individuals do not avoid vessels, which is seen as them displaying no negative responses.

Dolphin behaviour related to boat response

Dolphin swim speed, direction and abundance were significantly affected by boat travel speeds and direction. This indicates that neither the characteristics of the boat, i.e. boat category, nor the number of vessels, and the distance that they keep between them and the cetaceans affect dolphin reactions, whereas the behaviour of the boats in terms of travel speed and direction, were found to have a significant effect. This study found that dolphins moved directly away from vessels approaching them, which suggests that the individuals viewed the boats as a threat. When the distance between dolphin and boat was less than 100 metres and when boats attempted to approach dolphins, dolphins always responded by swimming away. In other odontocete species, similar findings have shown that animals change their swim direction in order to avoid approaching vessels (Richardson et al., 1995; Mattson et al., 2005).

Dolphin swim speed increased in response to an increase in boat speed at all sites. Other studies have found similar responses from other cetaceans in order to avoid motorised vessels (Bauer et al., 1986; Au & Green, 2002; Scheidat et al., 2004). Nonetheless, the fact that in New Quay most of the boats are usually the same visitor passenger boats, which travel often the same routes and generally at the same speeds, implies that dolphins could be more habituated to them and would not perceive them as a threat.

Previous studies have found that dolphin abundance was affected by the number of boats interacting with them (Bejder et al., 2006; Mattson et al., 2005). In addition, in Cardigan Bay Richardson (2012) suggested that the number of vessels around bottlenose dolphins could change their behaviour, with individuals clustering together in areas of high vessel traffic, resulting in small number of dolphins, whereas in low vessel traffic areas, there were larger numbers with more dispersed individuals. Nonetheless, the current study has shown that the number of vessels interacting with dolphins does not seem to have a significant effect on the reactions by dolphins when in an encounter, but it is influenced by the behaviour that those boats display.

Conclusions

Differences between Abersoch and New Quay appear to be linked to the differences in the code of conduct compliance, which in turn is related to the type of boats that frequent both areas. The more established code of conduct in New Quay has encouraged all types of vessels to remain further away (distance and direction) from dolphins. The nature of the encounters and the reaction of boats during it (i.e. boat travel speed and direction), rather than boat type, number of vessels and/or distance to cetaceans, determine bottlenose dolphin responses. Therefore, boat practices in New Quay could reduce the number of negative responses by dolphins to vessels, even during close encounters. This in turn suggests that codes of conduct could have both conservation and socio-economic benefits by allowing people to encounter dolphins without causing excessive disturbance to animals and therefore compliance should be promoted in the wider bay.

In order to arrive at robust conclusions concerning the short-term effects that boat disturbance may have on bottlenose dolphins, and potential long-term consequences on species reproductive success and thus population sustainability of bottlenose dolphins in Cardigan Bay, it is necessary to determine if a code of conduct over a wider area could work, by complementing it with spatio-temporal analysis of dolphins and boats, to see how they are distributed in the study area (see chapter III). Results from this study suggest that boats at Abersoch and New Quay affect the behaviour of bottlenose dolphins by increasing their swim speeds when boats are present, which in turn can lead to more energy being expended. Therefore, potential changes in their energy budget triggered by a possible decrease in feeding behaviour, should be assessed in the presence of boats (see chapter V). Finally, given that boat behaviour affects dolphin responses, it is necessary to evaluate people's perceptions and increase their environmental awareness, in order to determine possible reasons for why there might be poor compliance to the code of conduct in northern Cardigan Bay, including what sectors of the recreational industry is most involved, and what can be done about it, in order to improve dolphin conservation whilst safeguarding their socio-economic value in Wales (see chapter VI).

4.6 References

Acevedo, A. (1991). Interactions between boats and bottlenose dolphin, *Tursiops truncatus*, in the entrance to Ensenada De La Paz, Mexico. *Aquatic Mammals*, 17(3), 120-124.

Au, W. W. L., & Green, M. (2002). Acoustic interaction of humpback whales and whale-watching boats off Maui, Hawaii. *Journal of the Acoustical Society of America*, 102(5), 3177–3177. https://doi.org/10.1121/1.420824

Bailey, H., Brookes, K. L., & Thompson, P. M. (2014). Assessing environmental impacts of offshore wind farms: Lessons learned and recommendations for the future. *Aquatic Biosystems*, 10(1), 1–13. https://doi.org/10.1186/2046-9063-10-8

Bauer, G. B. & Herman, L. M. (1986). Effects of vessel traffic on the behavior of humpback whales in Hawaii. Report from Kewalo Basin Marine Mammal Laboratory, Univ. Hawaii, Honolulu, for the US National Marine Fisheries Service.

Bejder, L., Samuels, A., Whitehead, H., & Gales, N. (2006). Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour*, 72(5), 1149–1158. https://doi.org/10.1016/j.anbehav.2006.04.003

Buckstaff, K. C. (2004). Effects of watercraft noise on the acoustic behavior of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay Florida. *Marine Mammal Science*, 20(4), 709–725.

CCC (Ceredigion County Council), Countryside Council of Wales, Environment Agency Wales, North Western and North Wales Sea Fisheries Committee, Pembrokeshire Coast National Park Authority, Pembrokeshire County Council, South Wales Sea Fisheries Committee, Trinity House, and Dŵr Cymru Welsh Water (2001) Cardigan Bay cSAC Management Plan. Ceredigion County Council, Aberystwyth. pp 203.

Douglas, L. R., & Alie, K. (2014). High-value natural resources: Linking wildlife conservation to international conflict, insecurity, and development concerns. *Biological Conservation*, 171, 270–277. https://doi.org/10.1016/j.biocon.2014.01.031

Evans, P. G. H. (1980). Cetaceans in British waters. *Mammal Review*, 10(1), 1–52. https://doi.org/10.1111/j.1365-2907.1980.tb00232.x

Feingold, D., & Evans, P. G. H. (2014). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2011-2013. Natural Resources Wales Evidence Report Series No. 4. pp 124.

Guerra, M., Dawson, S. M., Brough, T. E., & Rayment, W. J. (2014). Effects of boats on the surface and acoustic behaviour of an endangered population of bottlenose dolphins. *Endangered Species Research*, 24(3), 221–236. https://doi.org/10.3354/esr00598

Hastie, G. D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2003). Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science*, 19(1), 74–084. https://doi.org/10.1111/j.1748-7692.2003.tb01093.x

Janik, V. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12, 597–602.

Johnson, M., & Norris, K. (1986). Delphinid social organization and social behavior. pp 335-

346. In: R. Schusterman, J. Thomas, & F. Wood (Eds.), Dolphin cognition and behavior: A comparative approach. Lawrance Erlbaum, Hillsdale, NJ.

Koroza, A. A. (2018). Habitat use and effects of boat traffic on bottlenose dolphins at New Quay Harbour, Cardigan Bay. MSc Thesis, Bangor University. pp 93.

Lemon, M., Lynch, T. P., Cato, D. H., & Harcourt, R. G. (2006). Response of travelling bottlenose dolphins (*Tursiops aduncus*) to experimental approaches by a powerboat in Jervis Bay, New South Wales, Australia. *Biological Conservation*, 127(4), 363–372. https://doi.org/10.1016/j.biocon.2005.08.016

Lerczak, J. A., & Hobbs, R. C. (1998). Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. *Marine Mammal Science,* 14(3), 590–598. https://doi.org/10.1111/j.1748-7692.1998.tb00745.x

Lohrengel, K., Evans, P. G. H., Lindenbaum, C. P., Morris, C. W. & Stringell, T. B. (2018). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2014-16. NRW Evidence Report No: 191. Natural Resources Wales, Bangor. pp 154.

Lohrengel, K., Veneruso, G., Feingold, D., Pesante, G., Ugarte, F. & Evans, P. G. H. (2012). Boat traffic trends and effects on bottlenose dolphin sighting rates in Cardigan Bay, Wales. Poster, European Cetacean Society Annual Conference, Galway, Ireland.

Lusseau, D. (2004). The hidden cost of tourism: Detecting long-term effects of tourism using behavioral information. *Ecology and Society*, 9(1), http://www.ecologyandsociety.org/vol9/iss1/art2/

Lusseau, D. (2003). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series,* 257, 267–274. https://doi.org/10.3354/meps257267

Lusseau, D. (2006). The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Marine Mammal Science*, 22(4), 802–818. https://doi.org/10.1111/j.1748-7692.2006.00052.x

Mattson, M. C., Thomas, J. A., & St. Aubin, D. (2005). Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquatic Mammals*, 31(1), 133–140. https://doi.org/10.1578/am.31.1.2005.133

Morete, M. E., Bisi, T. L., & Rosso, S. (2008). Mother and calf humpback whale responses to vessels around the Abrolhos Archipelago, Bahia , Brazil. *Journal of Cetacean Research & Management*, 9(3), 241–248.

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., Thompson, P. M., Cheney, B., Scott-Hayward, L., & Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, 27(2), 314–322. https://doi.org/10.1111/1365-2435.12052

Nowacek, D. P., Tyack, P. L., & Wells, R. S. (2001). A platform for continuous behavioral and acoustic observation of free-ranging marine mammals: Overhead video combined with underwater audio. *Marine Mammal Science*, 17(1), 191–199. https://doi.org/10.1111/j.1748-7692.2001.tb00992.x

Papale, E., Azzolin, M., & Giacoma, C. (2012). Vessel traffic affects bottlenose dolphin (*Tursiops truncatus*) behaviour in waters surrounding Lampedusa Island, south Italy. *Journal of the Marine Biological Association of the United Kingdom*, 92(8), 1877–1885. https://doi.org/10.1017/S002531541100083X

Pesante, G., Evans, P. G. H., Baines, M. E., & McMath, M. (2008). Abundance and life history parameters of bottlenose dolphin in Cardigan Bay: Monitoring 2005-2007. Countryside Council for Wales Marine Monitoring Report, (61), 75pp.

Pierpoint, C., Allan, L., Arnold, H., Evans, P. G. H., Perry, S., Wilberforce, L., & Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan bay, UK. *Journal of the Marine Biological Association of the United Kingdom*, 89(5), 1033–1043. https://doi.org/10.1017/S0025315409000885

Pirotta, E., Merchant, N. D., Thompson, P. M., Barton, T. R., & Lusseau, D. (2015). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. *Biological Conservation*, 181, 82–89. https://doi.org/10.1016/j.biocon.2014.11.003

Polacheck, T., & Thorpe, L. (1990). The swimming direction of harbor porpoise in relation to survey vessel. Reports of the International Whaling Commission, 40, 463-470.

R Studio. Version 1.0.136 – © 2009-2016 RStudio, Inc.

Read, A. J., Drinker, P., & Northridge, S. (2006). Bycatch of marine mammals in U.S. and global fisheries. *Conservation Biology*, 20(1), 163–169. https://doi.org/10.1111/j.1523-

1739.2006.00338.x

Richardson, W. J., Greene, C. R. Jr., Malme, C. I., & Thomson, D. H. (1995). Marine mammals and noise. *Academic Press*, San Diego, California, USA. pp 576.

Richardson, H. (2012). The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus)* of Cardigan Bay in Wales. MSc Thesis, University College London. pp 71.

Schaffar, A., Madon, B., Garrigue, C., & Constantine, R. (2013). Behavioural effects of whale-watching activities on an endangered population of humpback whales wintering in New Caledonia. *Endangered Species Research*, 19(3), 245–254. https://doi.org/10.3354/esr00466

Scheidat, M., Castro, C., Gonzalez, J., & Rob, W. (2004). Behavioural responses of humpback whales (*Megaptera novaeangliae*) to whalewatching boats near Isla de la Plata, Machalilla National Park, Ecuador. *Journal of Cetacean Research and Management*, 6(1), 63–68.

Zuur, A. F., Ieno, E. N., Walker, N., Saveliev, A. A., & Smith, G. M. (2009). Mixed Effects Models and Extensions in Ecology with R. *Springer*, New York, USA.

CHAPTER V

Effects of boat activity on bottlenose dolphin foraging behaviour assessed by acoustics

5.1 Abstract

In many parts of the world, impacts of recreational activities have focused on displacement of cetaceans from the affected area. Nonetheless, changes in behavioural patterns of cetaceans that remain may also pose a threat. In Cardigan Bay, UK, two Special Areas of Conservation have been established to protect bottlenose dolphins. However, over the past decade, human pressures have increased markedly. Careful management is needed, including a sustainable recreational industry, to conserve this population whilst safeguarding its socio-economic value.

This study aimed to evaluate possible effects of boat disturbance on bottlenose dolphin presence and foraging activity in the southern SAC, where a long-standing code of conduct has been in place, yet compliance varies between sites. This study analysed dolphin echolocation clicks and boat noise recorded by T-PODS at ten sites with different levels of compliance with the code of conduct within Cardigan Bay SAC between April and October from 2005-2008 to evaluate how boat disturbance affected bottlenose dolphin occurrence and foraging activity. Generalised linear models (GLM) were used to test bottlenose dolphin presence (click occurrence) and foraging behaviour (buzz occurrence) and the effect of noise level during a boat encounter at different sites.

Results show increased bottlenose dolphin presence and foraging activity when boats are around. In addition, when looking at boat-time passage at a finer scale, negative responses to boats (that is, a decrease in dolphin presence) at sites with low code of conduct compliance indicate that management guidelines could be improved, whilst neutral responses (that is, no changes in dolphin presence) found at New Quay suggest that compliance to management guidelines seem to be working. Therefore, time into boat-dolphin encounter is important to characterise how boat activity affects dolphin presence and foraging activity in the SAC. In conclusion, dolphins maintain occupancy at a site with high code of conduct compliance but alter their foraging behaviour during the boat encounter at all sites. Results highlight the value of enforcing regulations, promoting species conservation alongside a sustainable ecotourism industry.

5.2 Introduction

Understanding and characterising the effects of boat disturbance on bottlenose dolphin presence and foraging activity is fundamental to assess management plans and recommendations. Worldwide, increasing boat traffic has raised concerns about the consequences for wildlife whilst allowing a sustainable use of natural resources (Douglas & Alie, 2014). Commercial shipping is growing globally, as industrial development takes place, contributing significantly to worldwide ocean noise (Hildebrand, 2009). Boat numbers have also increased in coastal areas, as a result of the development of recreational activities at accessible inshore areas, which are predicted to continue growing (McCarthy, 2007).

Detrimental impacts on marine mammals from boat activity can include lethal effects or physical injuries. They may also include subtle effects, such as short-term behavioural changes, which are challenging to assess although essential to understand and protect the wildlife (Pirotta et al., 2015). Typical negative short-term behavioural responses from marine mammals to boat activities have been found to include evasion, in which individuals might decide to flee the area (Bejder et al., 2006). When staying in the disturbed area, individuals may develop changes in travel direction (Nowacek et al., 2001; see also Chapter 3) or dive duration (Janik, 1996; Lusseau, 2003b) and in behaviour, such as decrease in feeding or resting (Constantine et., 2004; Lusseau 2003a). These responses to disturbance have been found to affect energy budgets (Ellison et al., 2012; New et al., 2013), which if prolonged can affect individual fitness, reproduction success, birth rates, and develop into long-term consequence at the population level.

Additionally, recreational boats, including small motorised crafts, produce relatively low levels of noise depending upon speed and operational characteristics (OSPAR, 2009), whilst their sound generally belongs to high frequency bands (over 1,000 Hz) (Dyndo et al., 2015; Pollara et al., 2017). At that level recreational boat noise is unlikely to cause physical injury to marine mammals. However, it can cause changes in vocalisation responses in animals, because its characterised high frequency may mask important acoustic cues (Guerra et al., 2014; Pirotta et al., 2015; Marley et al., 2017; Tsujii et al., 2018). Based on this, there has been growing interest on how boat noise could impact dolphin echolocation. Boat noise can mask important acoustic signals (sounds specific to social interactions, courtship, agonistic behaviour, travel and foraging - Erbe et al., 2016); it can cause physiological stress responses (Wright et al., 2007); and moreover, it can affect the behaviour of the dolphins (Pirotta et al., 2015; Wisniewska et al., 2018) and/or their prey (Popper & Hastings, 2009). In addition, based on acoustic data, boat disturbance has been found to have an effect on foraging activity: the presence of boats was found to be associated with a decrease in dolphin foraging behaviour; which in turn was inferred to lead to changes or reduction in feeding, resulting in less energy intake (Pirotta et al., 2015). Therefore, a new framework to study energy budgets has arisen, due to alterations in foraging activities and in energy intake potentially bringing consequences in survival and reproduction of individuals and ultimately into population dynamics (Lusseau & Bejder, 2006). Acoustic techniques are a suitable method for measuring underwater behaviour, such as foraging, using buzz rates of individuals, which have been shown to indicate the exploration and targeting of potential prey (Barrett-Lennard et al., 1996).

In the case of dolphins, highly mobile species, it is essential to assess important areas where feeding or breeding activities take place (Hoyt, 2005) and determine which anthropogenic factors might drive these preferences, so one can improve understanding the processes that affect habitat use and movements, informing management and conservation strategies (Pirotta et al., 2015). Bottlenose dolphins are susceptible to disturbance by boats within the coastal zone (Janik, 1996; Nowacek et al., 2001; Constantine et al., 2004). Consequently, a Special Area of Conservation (SAC) in Cardigan Bay, West Wales has been established in the southern area to protect a semi-resident population of bottlenose dolphins (Pesante et al., 2008; Feingold & Evans, 2014) (see Chapter II). Cardigan Bay SAC has had a boating code of conduct for several years now. Within it, New Quay has been the only site with high compliance, whilst other sites in the SAC (Cemaes Head, Cardigan Island, Mwnt,, Aberporth and Ynys Lochtyn), have had less compliance (Pierpoint et al., 2009; Koroza, 2018). In Cardigan Bay SAC, studies have focused on visual data to assess bottlenose dolphin-boat encounters, evaluating reactions to different boat type (such as kayaks and motorised boats) and code of conduct compliance (Hudson, 2014; Koroza, 2018). Nonetheless, none have focused on acoustic data, whilst evaluating foraging activities and comparing dolphin responses in areas with different code of conduct compliance.

The responses of bottlenose dolphin to boat activity were recorded using a past dataset from acoustic data loggers deployed from April to October, 2005-2008. Datasets were merged to address three questions: i) Does boat presence increase dolphin presence; ii) does boat presence increase dolphin foraging activity; iii) is code of conduct compliance working to protect bottlenose dolphin within Cardigan Bay SAC?

5.3 Methods

5.3.1 Study area

This study was undertaken within the Cardigan Bay SAC (Figure 5.1). The area is important both for bottlenose dolphin feeding and breeding (Feingold & Evans, 2014; Lohrengel et al., 2018). Consequently, it is popular for commercial dolphin watching trips whilst also used for other recreational boating activities such as sailing and kayaking (Pierpoint & Allan, 2004; CCC et al., 2008) (see Chapter II). Based on bottlenose dolphin usage of feeding sites within Cardigan Bay SAC, six coastal locations were chosen to conduct acoustic analyses: Cemaes Head, Cardigan Island, Mwnt, Aberporth, Ynys Lochtyn and New Quay.

5.3.2 Recording bottlenose dolphin vocalisations

Acoustic data were recorded using static acoustic click detectors called T-PODs (http://www.chelonia.co.uk), which contain a hydrophone, together with an amplifier, a number of band-pass filters and a data logger with a timer, all inside a plastic watertight tube. Ten T-PODs were deployed at a depth of 12 to 25 m, collecting acoustic data year-round from 2005 to 2008 (see Figure 5.1 and Table 5.1 for specific locations). At Ynys Lochtyn, Cardigan Island, New Quay fish factory and New Quay reef only one T-POD was installed at each site (300 m from the coast). At Cemaes Head, Mwnt, Aberporth and and, T-PODs were deployed inshore (300 m from the coast) and offshore (800-1,000 m from the coast). Loggers were retrieved every 4 to 7 weeks to download data, replace batteries and redeploy. An echolocation click is only recorded by the TPOD if the energy received by the target filter (set at the peak frequency of the species of interest) is higher than the energy received by the reference filter (outside the target frequency). In this study, three of the six scans that T-PODs used were set to detect bottlenose dolphin (since the other three scans are used to detect harbour porpoises) with target filter at 50 kHz and reference filter at 70 kHz (Philpott et al., 2007; Bailey et al., 2010; Simon et al., 2010). In addition, since most other signals emitted underwater contain energy, T-PODs also record boat noise, which although of similar frequency range, have a longer duration, lower peak frequencies, and a regular pattern. Thus, by using all T-POD scans and setting the filter to ‘Boat’ we were able to detect boat noise sources at the same time as dolphin acoustic encounters.

Table 5.1 Locations of T-POD data loggers within Cardigan Bay SAC, and the code of conduct compliance at each location.

T-POD location	Distance from shore (m)	Code of conduct compliance
Cemaes Head inshore	<300	Low
Cemaes Head offshore	800-1000	Low
Cardigan Island	<300	Low
Mwnt inshore	<300	Low
Mwnt offshore	800-1000	Low
Aberporth inshore	<300	Low
Aberporth offshore	800-1000	Low
Ynys Lochtyn	<300	Low
New Quay reef	<300	High
New Quay fish factory	<300	High

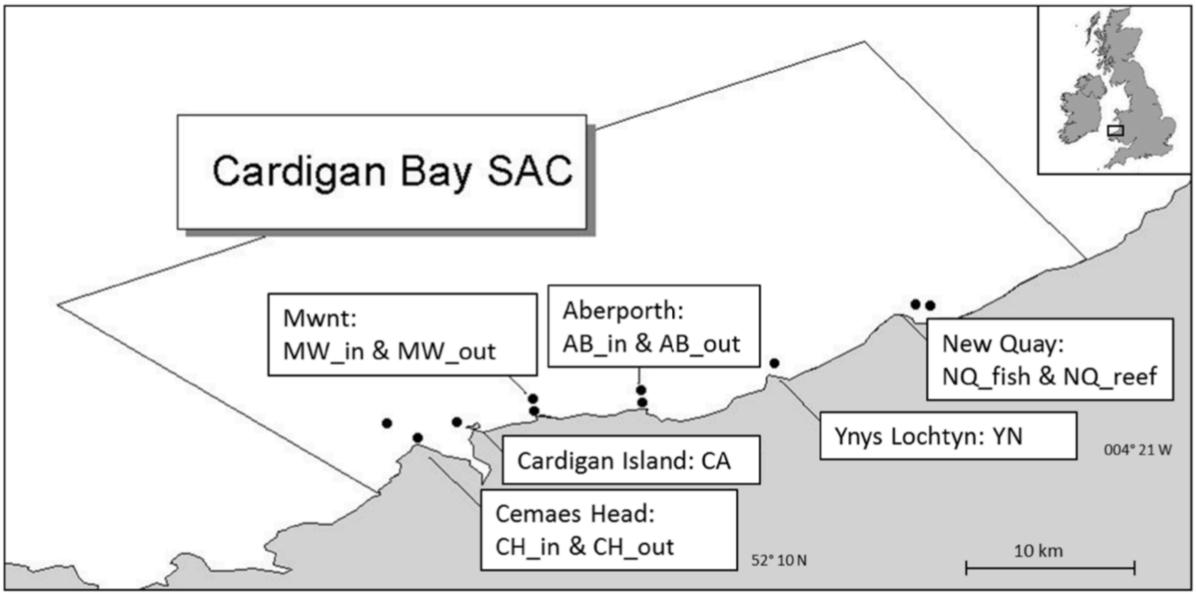


Figure 5.1 Cardigan Bay SAC boundary, represented by the rectangle. Points indicate the different sites where T-PODs were deployed during 2005-2008, between April and October (From west to east: Cemaes Head inshore and offshore, Cardigan Island, Mwnt inshore and offshore, Aberporth inshore and offshore, Ynys Lochtyn, New Quay fish factory and New Quay reef) (taken from Nuuttila et al., 2017).

5.3.3 Data processing

Acoustic data between April and October were downloaded using TPOD.exe software (version 8.24; Chelonia Ltd, Cornwall, UK, http://www.chelonia.co.uk), which classifies click trains into classes (e.g cetaceans and/or boats). For the purpose of this study and to minimise the risk of including false positive detections, only those classes with high probability of belonging to a cetacean (called "Cet all") were used to assess bottlenose dolphin vocalisations, whilst those categorised as coming from boat sonars (Chelonia, 2007) were used to assess vessel presence. Those trains classified by the software as unreliable ('Doubtful') were excluded for further analyses since they are believed to contain multiple clicks in clusters, with non-cetacean origin (Chelonia, 2007). The software calculated train details by providing a click rate (pulse repetition frequency, PRF) per train. Following previous studies and the T-POD user guide, foraging buzzes were defined as those with PRF above 200 per second (Chelonia, 2007; Luís et al., 2016).

The two exported data sets were trains where bottlenose dolphin clicks were detected and where boat noise was recorded. Nonetheless, in order to fulfil the objectives, dolphin clicks, boat noise and foraging buzzes per trains were reorganised every 10 minutes and then aggregated to a new blank data frame created every 10 minutes too. The new data set allowed to have presence (1) and absence (0) of each variable every 10 minutes, providing a more appropriate way to evaluate potential relationships between them. Therefore, click occurrence was later used to analyse dolphin presence and buzz occurrence was used to analyse dolphin foraging behaviour.

In addition, using boat presence and absence (1 and 0) every 10 minutes, a boat status was created to evaluate the effects of boat presence on dolphins at a finer time scale. Therefore, when a boat was absent (0) at two consecutive periods of time it was called 'no boat' (NB), when boats were present (1) at two consecutive periods of time it was called 'boat present' (BtP), when a boat was present (1) first and it was absent (0) in the next period of time it was called 'boat leaving' (BtL), and when a boat was absent (0) first but then present (1) in the next period of time, it was called 'boat arriving' (BtA).

Due to low boat activity in the more westerly sites (those being Cemaes Head in and offshore, Cardigan Island, Mwnt in and offshore, Aberporth in and offshore and Ynys Lochtyn) and using mean boat noise detections at each site, it was decided to analyse the data using New Quay (fish factory and reef) versus the other sites, since the total amount of boat activity at the more westerly sites was more or less equivalent to that around New Quay (Figure 5.2).

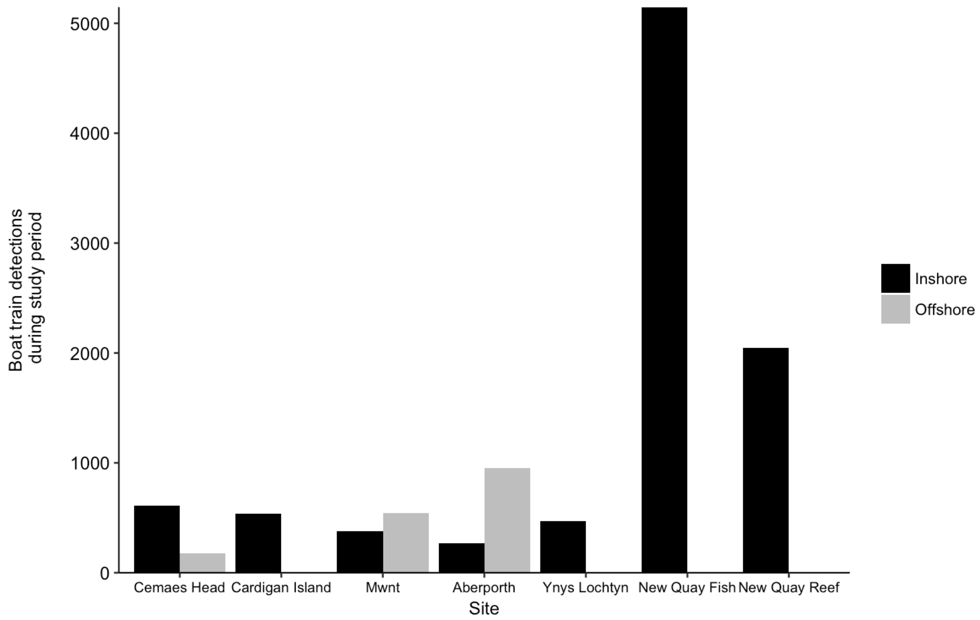


Figure 5.2 Number of boat train detections per site (Cemaes Head inshore and offshore, Cardigan Island, Mwnt inshore and offshore, Aberporth inshore and offshore, Ynys Lochtyn, New Quay fish factory and New Quay reef; no offshore deployments were made in Cardigan Island, Ynys Lochtyn, New Quay fish factory and New Quay reef) during the period 2005-2008, between April and October.

5.3.4 Statistical analysis

Generalised linear models GLMs were run in order to model relationships between dolphin presence (occurrence of clicks) and boat presence in each ten-minute period, and between boat status in consecutive ten-minute periods (See Supplementary material 8.1.3.1). The same GLMs were used to test the effect of the explanatory variables on dolphin foraging behaviour (occurrence of buzzes) in each ten-minute period where at least one click was detected, and boat presence and between boat status in consecutive ten-minute periods (See Supplementary material 8.1.3.2). Response variables were the presence/absence of dolphins and presence/absence of foraging activity. Explanatory variables were 1) presence/absence of boats and how they depend upon site and 2) boat status (absent, arriving, present, leaving) and how they depend upon site. A binomial family was used to account for the use of presence-absence data whilst model selection was based on Akaike's information criterion with a correction for small sample sizes (AICc) values and weighting using "AICcmodavg" package. These GLMs were run in 'R Studio' (Version 1.0.136 – © 2009-2016 RStudio, Inc.).

5.4 Results

The T-PODs recorded for 18,360 hours, across 765 days, in the course of 25 months within the study period 2005-2008 between the months of April and October. In total, 126,076 click trains were analysed, with 25,265 bottlenose dolphin 'positive 10-minutes' of acoustic data and 11,141 boat 'positive 10-minutes' noise to test in the models.

5.4.1 Effect of boat presence on bottlenose dolphin click occurrence

The final GLMs for dolphin presence included site and the interaction effect with boat presence, and site and the interaction effect with boat status (Table 5.2). The analyses of the acoustic data showed that presence of boats significantly increased the probability of dolphin occurrence, with the positive effect being larger at other sites compared to New Quay (Figure 5.3a,b).

Table 5.2 AIC values for GLM selections for dolphin presence and dolphin foraging activity.

Response	Model	AICc	Difference in AIC	Weight
Dolphin presence (occurrence of clicks)	Site*Boat	219649.90	0	1
	Site+Boat	219994.20	344.39	0
	Boat	220030.70	380.82	0
	Null	221849.00	2199.19	0
	Site	221851.00	2201.18	0
	Site*Boat status	218401.90	0	1
	Site+ Boat status	218821.50	419.63	0
	Boat status	218891.70	489.82	0
	Null	221849.00	3447.14	0
	Site	221851.00	3449.13	0
Dolphin foraging activity (occurrence of buzzes)	Site+Boat	19095.05	0	0.72
	Site*Boat	19097.01	1.96	0.27
	Boat	19105.67	10.62	0
	Site	19129.66	34.61	0
	Null	19144.53	49.48	0
	Site+ Boat status	19083.01	0	0.58
	Site* Boat status	19083.66	0.65	0.42
	Boat status	19093.00	10.00	0
	Site	19129.66	46.65	0
	Null	19144.53	61.52	0

An examination of a possible relationship between boat status and dolphin clicks showed differences between sites, with greater impact at other sites than at New Quay: At those other sites the probability of dolphin presence was much higher on the arrival of boats compared to when boats were absent. However, the probability of a dolphin encounter was lower when boats were in the area and when they were leaving compared to when boats were arriving (Figure 5.3c). At New Quay, after an increase in the probability of dolphin presence when boats arrived, the effect of boats was the same during the boat encounter as when the boat was departing (Figure 5.3d; Table 5.3).

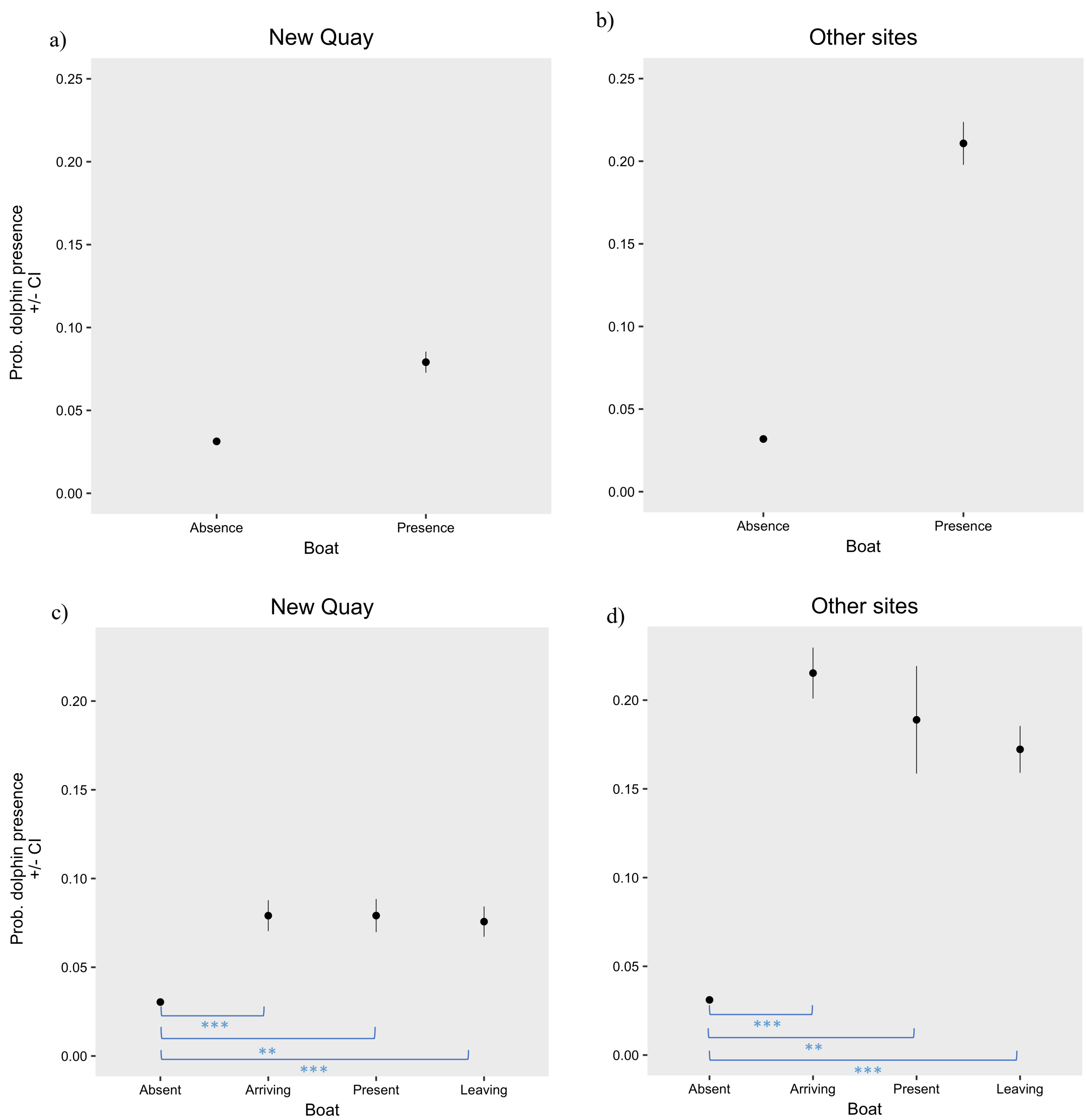


Figure 5.3 Probability of dolphin presence (click occurrence) related to boat presence (noise) at a) New Quay and b) other sites (Cemaes Head inshore and offshore, Cardigan Island, Mwnt inshore and offshore, Aberporth inshore and offshore and Ynys Lochtyn); and related to boat status at c) New Quay and d) other sites. Significance differences from GLM are denoted by asterisk (*= p<0.05; **= p<0.01; ***= p<0.001).

5.4.2 Effect of boat presence on bottlenose dolphin buzz occurrence

The final GLMs for dolphin foraging behaviour included site and boat presence and site and boat status, using a binomial family (Table 5.3). The analysis of occurrence of buzzes as a proxy for foraging behaviour showed that the presence of boats had a slight positive effect on the probability of occurrence of dolphin foraging activity throughout the study area (Figure 5.4a,b). When investigating the effect of boat status in more detail, the probability of foraging was found to be higher when boats arrived compared to when boats were absent. Nonetheless, after that first rise, the foraging activity of the dolphins decreased at all sites by the time of boat departure (Figure 5.4c,d; Table 5.3).

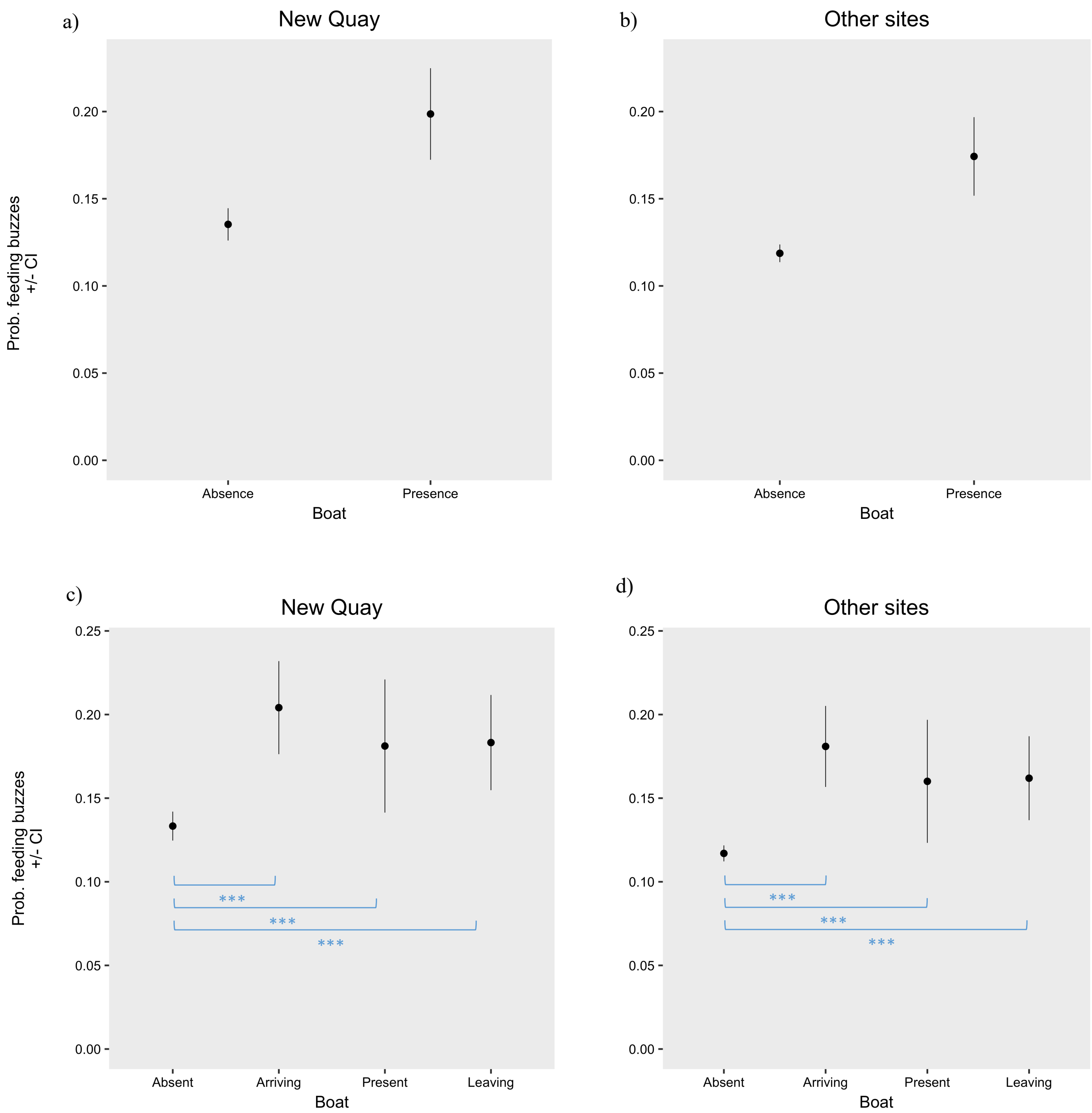


Figure 5.4 Probability of foraging behaviour (buzz occurrence) related to boat presence (noise) at a) New Quay and b) other sites (Cemaes Head inshore and offshore, Cardigan Island, Mwnt inshore and offshore, Aberporth inshore and offshore and Ynys Lochtyn); and related to boat status c) at New Quay and d) other sites. Significance differences from GLM are denoted by asterisk (*= p<0.05; **= p<0.01; ***= p<0.001).

Table 5.3 GLM results for dolphin presence (clicks) and foraging behaviour (buzzes) related to boat presence and boat status.

	Variable	Estimate	95% Confidence Limit	
			Lower	Upper
Clicks	New Quay-Other sites	0.019	0.048	-0.011
	Boat	**1.116**	**1.235**	**0.997**
	New Quay-Other sites	**0.232**	**0.262**	**0.201**
	Boat Absent- Boat Arriving	**1.138**	**1.285**	**0.991**
	Boat Absent- Boat Present	**0.974**	**1.207**	**0.741**
	Boat Absent- Boat Leaving	**0.909**	**1.062**	**0.756**
	Boat Arriving- Boat Present	-0.164	0.108	-0.436
	Boat Arriving- Boat Leaving	**-0.229**	**-0.021**	**-0.436**
	Boat Present- Boat Leaving	-0.065	0.211	-0.340
Buzzes	New Quay-Other sites	**-0.152**	**-0.069**	**-0.236**
	Boat	**0.454**	**0.596**	**0.313**
	New Quay-Other sites	**-0.149**	**-0.066**	**-0.233**
	Boat Absent- Boat Arriving	**0.511**	**0.674**	**0.349**
	Boat Absent- Boat Present	**0.364**	**0.631**	**0.096**
	Boat Absent- Boat Leaving	**0.377**	**0.561**	**0.194**
	Boat Arriving- Boat Present	-0.148	0.160	-0.455
	Boat Arriving- Boat Leaving	-0.134	0.105	-0.372
	Boat Present- Boat Leaving	0.014	0.332	-0.304

Confidence intervals that indicate a significant effect are in **bold** text

5.5 Discussion

This study aimed to explore the effect of boat activity on bottlenose dolphin presence and foraging activity in Cardigan Bay SAC using acoustic data. There were three main findings: i) the probability of dolphin presence was higher upon boat arrival at all sites, whilst the presence and departure of vessels triggered a different dolphin response at New Quay compared with other sites; ii) dolphin foraging behaviour was higher across all sites when boats arrived, but decreased again when boats stayed and by the time they left the area; and iii) dolphin presence did not respond to boat presence and departure at New Quay which suggests that compliance to management guidelines seem to be working with dolphins responding neutrally to vessels, whilst less neutral responses found at the other sites at the same boat status suggest the need for greater management compliance. Therefore, time into boat-dolphin encounter plays an important role, with boat presence appearing to disrupt dolphin presence at sites having less code of conduct compliance, whilst disrupting foraging activity at all sites monitored within the SAC, indicating the need for further management compliance and recommendations. The potential causes of these findings and the implications for bottlenose dolphin management in different areas of Cardigan Bay SAC and over the wider area are discussed below.

Influence of boats on dolphin presence

Evidence based upon visual data suggests that boat traffic decreases bottlenose dolphin presence at New Quay, where vessel activity is greater than at other sites in Cardigan Bay SAC (Pierpoint et al., 2009; see also Chapter III). However, results here showed that an increase in dolphin occurrence happens with an increase in vessel presence at all sites. This finding could be explained by the fact that boats respond to sighting dolphins, by approaching them and therefore the motorised crafts come within acoustic range. Also, dolphins might interrupt their activity to increase their distance from the source of disturbance (Lusseau, 2003a), which in turn might represent an approach to shallow areas, increasing the probability of getting closer to the T-POD and making the acoustic data logger detection greater, detecting, in turn, more dolphins, displaying a positive response on dolphin presence to boat presence.

Differences in bottlenose dolphin responses to vessels between sites can be assessed when considering boat presence at finer temporal scales. Despite the increase in dolphin presence when boats arrived, when vessels remained and when they left there was no change in dolphin presence at New Quay. On the contrary, the probability of recording clicks at other sites decreased with boat status. These differences could be explained by the fact that the response of the source of disturbance usually influences the perceived risk: a vessel actively associating with the dolphins will be more disturbing than one travelling a predictable route (Lusseau, 2003b). Since it has been reported that at New Quay there is a constant low level of disturbance (during summer months), mainly represented by the same boats, which in turn generally adhere to guidelines relating to boat behaviour (distance to maintain, duration and how to manoeuvre around the animals) when they encounter dolphins (displaying the highest code of conduct compliance in the SAC) (Pierpoint & Allan, 2004; Pierpoint et al., 2009; Koroza, 2018), dolphins do not respond negatively to them by leaving the area or changing swim direction and speed (Baker et al., 1982; see also Chapter IV). This suggests a habituation in which boats become predictable as individuals become accustomed to vessels they know (Wright et al., 2007), resulting in the perception of the threat being lower. This would also explain why at the other sites, where vessels are not adhering to the code of conduct guidelines and are prolonging their cetacean encounter, vessel time passages triggered a decrease in dolphin presence. In addition, the less neutral responses of dolphins to them can be explained by the fact that dolphins are not accustomed to particular vessels since the crafts are not constant/frequent.

A number of studies in the region using visual data to evaluate the effects of different boat types on bottlenose dolphin presence have found a significant negative effect on dolphins to motorised boats (Hudson 2014; Koroza 2018), as well as to unmotorized craft, such as kayaks (Lusseau, 2006). Koroza (2018) found that responses varied not only with boat type but also between individual boats, possibly due to the specific noise source and behaviour of the vessel. Thus, the visual identification of the effect of boat types would probably support the idea that acoustic data should be evaluated together with visual data to reach robust results, such as those found by Pirotta et al (2015). They reinforce the fact that beyond noise, the physical presence of boats has a more significant impact on dolphin presence. Likewise, the effects of boat noise on the detection and classification of the acoustic vocalisations need to be assessed, since individuals might not leave, but they could cease their clicks (Marques et al., 2013). In the absence of visual based data, results could overestimate the intensity and duration of the effect of boats on dolphins, which could result in misleading management recommendations (Pirotta et al., 2015).

Influence of boats on dolphin foraging activity

A previous land-based study conducted in New Quay found a decrease in socialising and resting behaviours but an increase in foraging behaviour when boats were present (Koroza, 2018). These findings can be linked together, indicating that bottlenose dolphins may decide to increase feeding when boats arrive in the area because watercraft affect their ability to socialise and rest. Nonetheless, this can also be explained by the fact that when dolphins are stationary in an area foraging, they are more likely to be spotted by boats, which are in the area looking for dolphins and which will then respond by going towards them. The current study supports the idea that dolphins have higher foraging activity in the presence of boats at all sampled sites. One cannot discount the possibility that, due to the constant low level of disturbance in the area, dolphins adjust their foraging activities to compensate for boat noise, once it has reached a threshold level (Foote et al., 2004) and therefore dolphins continue foraging even with vessels around. In addition, due to boat noise and its high frequency, important acoustic cues may be masked (Guerra et al., 2014; Pirotta et al., 2015; Marley et al., 2017; Tsujii et al., 2018), to which dolphins, accustomed to the boat disturbance, instead of leaving the area may increase their vocalisation rate, displaying an increase in the foraging buzzes.

Despite the higher buzz detection when boats are present, observations of dolphin acoustic responses to boat passage time at a finer temporal scale, showed a decrease in buzz occurrence at all sites when boats were present compared to when they arrived, which can be linked to the individuals perceiving boats as a risk, particularly those that are seeking direct contact with the animals (such as dolphin-watching vessels). This could have greater consequences, as it is known that repeated disruption of foraging activities is likely to result in reduced energy intake (New et al., 2013), ultimately affecting the animal's overall energy budget and fitness.

These ambiguities demonstrate the need to comprehensively understand in more detail the effects of boats on bottlenose dolphin foraging behaviour. Previously, when assessing behavioural effects based exclusively upon received sound levels, inconclusive results were also obtained (Southall et al., 2007). Therefore, in order to describe and predict cetacean responses based on the level of risk perceived, it is necessary to combine measures of boat type, behaviour, noise and context, since they interact together in relation to disturbance (Ellison et al., 2012). Combining all these factors would help evaluate and compare whether dolphin behaviour is different between sites as a result of variation in code of conduct compliance. In addition, this would help determine whether results are linked to the subject of the disturbance (in this case, a vessel) being known to the individuals, triggering a weaker response, which could happen in New Quay where the same boats are frequent and always follow the same routes, or if the cetaceans are actually forced to reduce their time foraging due to more persistent disturbance from a variety of vessels that are not following a code of conduct, as at other sites away from New Quay.

Additionally, the uncertainties found could demonstrate the need for further data analyses. Independence between successive observations was assumed in the statistical analyses of dolphin clicks and buzzes (see supplementary material 8.1.3). Nonetheless, the quantification of more extensive temporal autocorrelation might be significant for understanding and predicting dolphin behaviour and the impact of vessel presence. As has been shown with boat presence and boat status, the introduction of finer scale boat-related factors is likely to refine the results. Adding a further time variable to the models (this could be month, date or time of the day) could account for possible temporal autocorrelation, allowing for a more accurate prediction of how boat status (boat absent, arriving, present and leaving) may impact dolphins clicks and buzzes. However, due to the large data sample size, adding a temporal variable, such as time of the day, would increase data resolution and therefore data analyses would require equipment with high processing power to run the models.

In order to forecast the impact of boat activity (engine noise) on dolphin presence (clicks) and foraging activities (buzzes) at different times of an encounter, a time series analysis could be more accurate than the previous GLMs. Time series methods would evaluate clicks and buzzes recorded at different points, ordered in time (Shumway & Stoffer, 2000). This would allow evaluation of adjacent points whilst accounting for temporal autocorrelation in a continuous series. The precision offered by this method may help to avoid missing information that could be otherwise lost due to the handling of the continuous data. The current study did not include a continuous data series, due to the differing times of deployment (and redeployment following battery exchange) of T-PODs at each site. In order to be able to use this method with the present data, it would be important to maximize the number of observations using constant time intervals to increase the accuracy and precision of estimates (De Solla et al., 1999), probably by evaluating sites separately and creating a series where the frequency is known at all sites. This approach could increase the efficiency of analysis and provide reliable dolphin responses to boat status (absent, arriving, present and leaving).

Conclusions

This study found increased dolphin presence and foraging activity when boats were in the vicinity in Cardigan Bay SAC. Bottlenose dolphins seem to be able to sustain the present level of boat activity, perhaps due to its constant low intensity. However, more effort is needed to be able to predict the effects of boat disturbance and its different intensity upon bottlenose dolphin responses, as well as the ability of dolphins to compensate for potential lost foraging activities.

At a finer temporal scale, differences in dolphin presence between sites were found to relate to the boat passage time. This highlights the importance of examining fine-scale behavioural responses, since large-scale approaches are likely to miss subtle changes in activity budgets, which in turn might have the potential to impact energy intake. The combined findings suggest that the code of conduct is working in areas with high compliance, but there is need for greater compliance and awareness across sites in Cardigan Bay SAC, and this involves also continued monitoring of boat traffic levels, more environmental education for boat users to encourage them to adhere to the guidelines, and subsequent enforcement of the code of conduct to ensure the long-term welfare of Cardigan Bay bottlenose dolphins.

5.6 References

Au W. W. L., Fay R. R., & Popper A. N. (2000) Hearing by whales and dolphins. *Springer Handbook of Auditory Research*, Vol 12. Springer, New York. 242-364

Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G., & Thompson, P. M. (2010). Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Marine Pollution Bulletin*, 60(6), 888–897. https://doi.org/10.1016/j.marpolbul.2010.01.003

Baker, C. S., Herman, L., Bays, B., & Stifel, W. (1982). The impact of vessel traffic on the behavior of humpback whales in Southern Alaska. (University of Hawaii at Manoa Report to NMFS). *National Marine Fisheries Service,* Seattle, USA. pp 78.

Barrett-Lennard, L. G., Ford, J. K. B., & Heise, K. A. (1996). The mixed blessing of echolocation: Differences in sonar use by fish-eating and mammal-eating killer whales. *Animal Behaviour,* 51(3), 553–565. https://doi.org/10.1006/anbe.1996.0059

Bejder, L., Samuels, A., Whitehead, H., Finn, H., & Allen, S. (2009). Impact assessment research: Use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. *Marine Ecology Progress Series*, 395, 177–185. https://doi.org/10.3354/meps07979

Bejder, L., Samuels, A., Flaherty, C., Watson-Capps, J., Gales, N., Krutzen, M., Mann, J., Whitehead, H., Connor, R., & Heithaus, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, 20(6), 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x

CCC (Ceredigion County Council), Countryside Council of Wales, Environment Agency Wales, North Western and North Wales Sea Fisheries Committee, Pembrokeshire Coast National Park Authority, Pembrokeshire County Council, South Wales Sea Fisheries Committee, Trinity House, and Welsh Water (2008) Cardigan Bay Special Area of Conservation (SAC) Management Scheme. Ceredigion County Council, Aberystwyth. pp 179.

Chelonia Limited. (2007). T - POD Reference Guide, 2007. Chelonia Ltd, Penzance, Cornwall.

Constantine, R., Brunton, D. H., & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation*, 117(3), 299–307. https://doi.org/10.1016/j.biocon.2003.12.009

De Solla, S. R., Bonduriansky, R., & Brooks, R. J. (1999). Eliminating autocorrelation reduces biological relevance of home range estimates. *Journal of animal ecology*, 68(2), 221-234.

Dyndo, M., Wisniewska, D. M., Rojano-Donate, L., & Madsen, P. T. (2015). Harbour porpoises react to low levels of high frequency vessel boise. *Scientific Reports*, 5, 11083. https://doi.org/10.1038/srep11083

Douglas, L. R., & Alie, K. (2014). High-value natural resources: Linking wildlife conservation to international conflict, insecurity, and development concerns. *Biological Conservation*, 171, 270–277. https://doi.org/10.1016/j.biocon.2014.01.031

Ellison, W. T., Southall, B. L., Clark, C. W., & Frankel, A. S. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conservation Biology*, 26(1), 21–28. https://doi.org/10.1111/j.1523-1739.2011.01803.x

Erbe, C., Reichmuth, C., Cunningham, K., Lucke, K., & Dooling, R. (2016). Communication masking in marine mammals: A review and research strategy. *Marine Pollution Bulletin*, 103(1–2), 15–38. https://doi.org/10.1016/j.marpolbul.2015.12.007

Feingold, D., & Evans, P. G. H. (2014). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2011-2013. Natural Resources Wales Evidence Report Series No. 4. pp 124.

Foote, A. D., Osborne, R. W., & Hoelzel, A. R. (2004). Whale-call response to masking boat noise. *Nature*, 428(6986), 910-910.

Guerra, M., Dawson, S. M., Brough, T. E., & Rayment, W. J. (2014). Effects of boats on the surface and acoustic behaviour of an endangered population of bottlenose dolphins. *Endangered Species Research*, 24(3), 221–236. https://doi.org/10.3354/esr00598

Hildebrand, J. A. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series*, 395, 5–20. https://doi.org/10.3354/meps08353

Hoyt, E. (2005). Marine Protected Areas for whales, dolphins and porpoises. A World Handbook for Cetacean Habitat Conservation. Earthscan, London. pp 492.

Hudson, T. (2014). Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay. MSc Thesis, University of Bangor. pp 79.

Janik, V. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12, 597–602.

Johnson, M., & Norris, K. (1986). Delphinid social organization and social behavior. pp 335-346. In: R. Schusterman, J. Thomas, & F. Wood (Eds.), Dolphin cognition and behavior: A comparative approach. Lawrance Erlbaum, Hillsdale, NJ.

Koroza, A. A. (2018). Habitat use and effects of boat traffic on bBottlenose dolphins at New Quay Harbour, Cardigan Bay. MSc Thesis, University of Bangor. pp 93.

Lohrengel, K., Evans, P. G. H., Lindenbaum, C. P., Morris, C. W. & Stringell, T. B. (2018). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2014-16. NRW Evidence Report No: 191. Natural Resources Wales, Bangor. pp 154.

Luís, A. R., Couchinho, M. N., & Dos Santos, M. E. (2016). A quantitative analysis of pulsed signals emitted by wild bottlenose dolphins. *PLoS ONE*, 11(7), 1–11. https://doi.org/10.1371/journal.pone.0157781

Lusseau, D. (2003a). Effects of tour boats on the behavior of bottlenose dolphins: Using Markov Chains to model anthropogenic impacts. *Conservation Biology*, 17(6), 1785–1793. https://doi.org/10.1111/j.1523-1739.2003.00054.x

Lusseau, D. (2003b). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series,* 257, 267–274. https://doi.org/10.3354/meps257267

Lusseau, D. (2006). The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Marine Mammal Science*, 22(4), 802–818. https://doi.org/10.1111/j.1748-7692.2006.00052.x

Lusseau, D., & Bejder, L. (2006). The long-term consequences of short-term responses to disturbance experiences from whalewatching impact assessment. *Journal of Comparative Psychology*, 20(2), 228–236.

Marley, S. A., Salgado Kent, C. P., Erbe, C., & Parnum, I. M. (2017). Effects of vessel traffic and underwater noise on the movement, behaviour and vocalisations of bottlenose dolphins in an urbanised estuary. *Scientific Reports*, 7(1), 1–14. https://doi.org/10.1038/s41598-017-13252-z

Marques, T. A., Thomas, L., Martin, S. W., Mellinger, D. K., Ward, J. A., Moretti, D. J., Harris, D., & Tyack, P.L. (2013). Estimating animal population density using passive acoustics. *Biological Reviews*, 88, 287–309. https://doi.org/10.1111/brv.12001

McCarthy, E. (2007). International regulation of underwater sound: establishing rules and standards to address ocean noise pollution. Springer Science & Business Media. pp 287.

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., Thompson, P. M., Cheney, B., Scott-Hayward, L., & Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, 27(2), 314–322. https://doi.org/10.1111/1365-2435.12052

Nowacek, D. P., Tyack, P. L., & Wells, R. S. (2001). A platform for continuous behavioral and acoustic observation of free-ranging marine mammals: Overhead video combined with underwater audio. *Marine Mammal Science*, 17(1), 191–199. https://doi.org/10.1111/j.1748-7692.2001.tb00992.x

Nuuttila, H K., Courtene-Jones, W., Baulch, S., Simon, M., & Evans, P. G. H. (2017). Don't forget the porpoise: acoustic monitoring reveals fine scale temporal variation between bottlenose dolphin and harbour porpoise in Cardigan Bay SAC. *Marine Biology*, 164(3), 50. https://doi.org/10.1007/s00227-017-3081-5

OSPAR. (2009). Assessment of the environmental impact of underwater noise. OSPAR Biodiversity Series, 1–41.

R Studio. Version 1.0.136 – © 2009-2016 RStudio, Inc.

Pesante, G., Evans, P. G. H., Baines, M. E., & Mcmath, M. (2008). Abundance and life history parameters of bottlenose dolphin in Cardigan Bay : Monitoring 2005-2007. CCW Marine Monitoring Report, (61), pp 75.

Philpott, E., Englund, A., Ingram, S., & Rogan, E. (2007). Using T-PODs to investigate the echolocation of coastal bottlenose dolphins. *Journal of the Marine Biological Association of the United Kingdom*, 87(1), 11–17. https://doi.org/10.1017/S002531540705494X

Pierpoint, C., & Allan, L. (2004). Boat traffic on the Ceredigion Marine Heritage Coast, West Wales. Report , Ceredigion County Council, Aberaeron, Ceredigion. pp 44.

Pierpoint, C., Allan, L., Arnold, H., Evans, P., Perry, S., Wilberforce, L., & Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan bay, UK. *Journal of the Marine Biological Association of the United Kingdom*, 89(5), 1033–1043. https://doi.org/10.1017/S0025315409000885

Pirotta, E., Merchant, N. D., Thompson, P. M., Barton, T. R., & Lusseau, D. (2015). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. *Biological Conservation*, 181, 82–89. https://doi.org/10.1016/j.biocon.2014.11.003

Pollara, A., Sutin, A., & Sailoum, H. (2017). Modulation of high frequency noise by Enghien tones of small boats. *Journal of the Acoustical Society of America*, 142, EL30 (2017); doi: 10.1121/1.4991345.

Popper, A. N., & Hastings, M. C. (2009). The effects of human-generated sound on fish. *Integrative Zoology*, 4(1), 43–52. https://doi.org/10.1111/j.1749-4877.2008.00134.x

Shumway, R. H., & Stoffer, D. S. (2000). Time series analysis and its applications: with R examples. Springer

Simon, M., Nuuttila, H., Reyes-Zamudio, M. M., Ugarte, F., Verfuß, U., and Evans, P. G. H. (2010). Passive acoustic monitoring of bottlenose dolphin and harbour porpoise with implications for habitat use and partitioning. *Journal of the Marine Biological Association of the United Kingdom*, 90: 1539-1546.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Jr, C. R. G., Kastak, D., Ketten, D R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A. & Tyack, P. L. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals*, 33(4), 411–521. ttps://doi.org/10.1578/AM.33.4.2007.411

Tsujii, K., Akamatsu, T., Okamoto, R., Mori, K., Mitani, Y., & Umeda, N. (2018). Change in singing behavior of humpback whales caused by shipping noise. *PLoS ONE*, 13(10), 1–16. https://doi.org/10.1371/journal.pone.0204112

Wisniewska, D. M., Johnson, M., Beedholm, K., Wahlberg, M., & Madsen, P. T. (2012). Acoustic gaze adjustments during active target selection in echolocating porpoises. *Journal of Experimental Biology*, 215(24), 4358–4373. https://doi.org/10.1242/jeb.074013

Wisniewska, D. M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., & Madsen, P. T. (2018). High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). *Proceedings of the Royal Society B: Biological Sciences*, 285(1872). https://doi.org/10.1098/rspb.2017.2314

Wright, A., Soto, A. J., Aguilar Baldwin, N., & Linda, A. (2007). Do marine mammals experience stress related to anthropogenic noise? *Journal of Comparative Psychology*, 20(2) 274-316.

CHAPTER VI

Recreational and dolphin-watching trip users' perceptions of bottlenose dolphin, evaluating current conservation management

6.1 Abstract

Anthropogenic activities are markedly increasing in the oceans, causing widespread concern for potential effects on marine mammals and ecosystems. In the UK, a large population of bottlenose dolphins inhabits the coastal waters of Wales, where it has experienced increased pressure from human activities. The importance of the region for the species has been recognised through EU legislation with the establishment of two Special Areas of Conservation (SAC) within Cardigan Bay. A boating code of conduct has been in operation in the southern region for many years, whereas in the north, it has only very recently been introduced. The Welsh bottlenose dolphin population is a central attraction for visitors, generating millions of pounds of income annually. Nonetheless, careful management is needed in order to conserve the species whilst safeguarding its socio-economic value.

Integrating the understanding and knowledge of people into conservation will help empower them whilst seeking local solutions to environmental issues, at the same time as safeguarding wildlife-based local activities. This study aimed to ensure that future management recommendations in Cardigan Bay balance bottlenose dolphin conservation interests against a sustainable commercial tourism industry. Results from 96 questionnaires completed by recreational users, 4 interviews with the main commercial operators, and 153 questionnaires completed by clients on dolphin-watching trips in Cardigan Bay highlighted the importance of the bottlenose dolphin population to all of them. Data suggested differences in knowledge of a local code of conduct between recreational users in both SACs, with fewer people knowing about it at Pen Llŷn a'r Sarnau SAC compared to Cardigan Bay SAC, evidencing the need for further environmental education of users to improve their responses during a dolphin encounter minimising harassment and disturbance, whilst reducing the reasons why dolphins are thought to be leaving the bay. Both local and visitor clients agreed that dolphin-watching trips bring economic opportunities for local communities and raise participants' marine conservation awareness, whilst visitors agreeing slightly more than locals about the activity helping to protect dolphins through education of participants. Thus, environmental education together with the experience of being on a dolphin-watching trip play an important role in protect dolphins and ultimately, the marine ecosystem.

6.2 Introduction

The current recognition of the impacts of anthropogenic activities on marine ecosystems has led to stronger conservation initiatives that involve not only scientists and policy makers, but also stakeholders and local communities that are engaged in such activities. The development and diversification of human activities in the marine ecosystem (Halpern et al., 2008), has included an increasing recreational boating occupation (O'Connor et al., 2009), whilst among the different types of natural-area tourism activities that are conducted worldwide, whale- and dolphin-watching are growing the fastest of all, with companies continually emerging (Hoyt, 2001; Higham & Lück, 2007; O'Connor et al., 2009; Larson et al., 2016). The rapid growth of these activities has raised concerns amongst scientists about how recreational boating and whale- and dolphin-watching may be affecting various aspects of whale and dolphin biology, with evidence suggesting short-term changes in social, reproductive, feeding and other behavioural activities (Janik, 1996; Lusseau, 2003b, 2003a; Constantine et al., 2004; Mattson et al., 2005; Bejder et al., 2006a; Hastie et al., 2006; Ellison et al., 2012; New et al., 2013; Nowacek et al., 2015; Pirotta et al., 2015; see also Chapters IV and V). Furthermore, long-term effects of wildlife-watching on cetacean presence and abundance have been demonstrated, with disturbance causing animals to move away from the affected area (see, for example, Bejder et al., 2006b; Lusseau & Bejder, 2007; Higham et al., 2008).

Nature-based tourism, involving not only experiencing the scenery but also interactions with nature (Newsome et al., 2005), provides the opportunity for people to become more conservation-inclined, seeking to contribute to the protection of ecosystems and species (Forestell & Kaufman, 1991). Nature-based tourism tends to be used interchangeably with ecotourism; nonetheless, evidence suggests that nature-based tourism does not necessarily maintain environmental quality, whilst ecotourism requires the seeing of nature to be environmentally sustainable with minimal environmental impact (Goodwin, 1996). As such, focus should be placed upon the latter, incorporating an educational component. In marine ecosystems, marine recreational tourism and marine mammal watching are important for increasing people's awareness about cetacean conservation (Corkeron, 2004; Andersen & Miller, 2006). Further regulations may be required, whilst including recreational users, commercial-boat skippers, guides and visitors, together with government and regulatory authorities, to engage all the parties, to ensure there is understanding of the reasoning for potential further management guidelines and recommendations (Walker, 2018).

Accordingly, ecologists recently have been using a variety of social science techniques to assess human behaviour that might have an impact on ecological systems, in particular social surveys such as questionnaires (to collect information from large numbers of people in standardised form) and/or interviews (to collect information from individuals) (White et al., 2005). Using these approaches, studies have found evidence that suggest that the key to the success of activities aiming at boat-wildlife encounters is environmental education where public appreciation of the marine environment is important to fulfil cetacean conservation (Orams, 2000). Environmental education describes a process aimed at improving biological and cultural knowledge, awareness of environmental problems, and generating reasons to act responsibly towards the environment (O'Hearn, 1982). Environmental education has been found to be an effective tool that promotes management objectives (Orams, 1997, 2000; Reynolds & Braithwaite, 2001; Lück, 2003; Stamation et al., 2007).

Using social science approaches, scientists have highlighted the importance of understanding the social and ecological context in which activities take place, as cultural and social norms differ between communities (Vaske & Donnelly, 1999). Integrating the understanding and knowledge of local people into conservation will help empower them whilst seeking local solutions to their environmental problems, at the same time as safeguarding their wildlife-based activities (Danielsen et al., 2005).

In the UK, recreational activities, particularly using personal watercraft (such as kayaks, jet skis and paddle boards) are becoming more popular every day, whilst commercial marine mammal watching is also growing. In Wales, this increase in usage has shown different impacts on marine mammals (Pierpoint et al., 2009; Richardson, 2012; Hudson, 2014; Koroza, 2018; chapters III and IV). Cardigan Bay in West Wales, an area inhabited by a semi-resident population of bottlenose dolphins, is a bay protected by the establishment of two Special Areas of Conservation (SACs) (see Chapter II). Approximately 45,000 tourists visit Cardigan Bay to see the bottlenose dolphins annually on trips or recreational boats, generating more than four million pounds of income a year through ticket sales, local accommodation, purchase of food and merchandise (Lambert & Evans, 2012). A boating code of conduct to protect the species in the bay has been implemented in both SACs: in the southern region the code has been in operation for many years, pre-dating the establishment of the marine protected area, whereas in the north, it has only very recently been introduced. Therefore, knowledge about these regulations, as well as compliance to the guidelines (in terms of the duration, range and response at the moment of an encounter) differ between the two SACs. This provides an opportunity to ensure that future management recommendations in the bay include the correct balance between bottlenose dolphin conservation and a sustainable use of wildlife resources in the whole Cardigan Bay, whilst evaluating: i) what the recreational boat users' perceptions and interests are when out in the bay, and whether they are aware and follow the code of conduct to protect bottlenose dolphins; ii), how important bottlenose dolphins are to commercial operators; and iii) what dolphin-watching boat clients' perceptions and interests are when going on a dolphin-watching trip, and how engaged they are with conservation?

6.3 Methods

6.3.1 Study area

Located in the northern part of Cardigan Bay within Pen Llŷn a'r Sarnau SAC, Pwllheli Marina and Abersoch were chosen due to the high recreational boat activity they both receive. Additionally, in the southern Cardigan Bay SAC, New Quay was the focus of questionnaire surveys being the main coastal town in Cardigan Bay from which dolphin-watching boats operate (see Chapter II).

6.3.2 Interview and questionnaire surveys

Three separate surveys were undertaken: questionnaires for recreational users (users of private boats) and dolphin-watching boat clients, and interviews with dolphin-watching boat operators. To ensure confidentiality, all the questionnaires were treated anonymously. Demographic characteristics were assessed through statements on age, gender and residency status of the participants. A pilot study was conducted prior to the research to know people better, developing a carefully designed survey that assures people understand the questions whilst prompting truthful, accurate responses. Additionally, in order to avoid leading questions, neutral wording was used.

6.3.2.1 Questionnaire to recreational users

Besides demographic information, this survey included three open-ended and twelve closed questions (see Supplementary material 8.1). Closed questions included five checklist questions with Yes/No answers and five with longer multiple-choice lists. A set of likert-scale type (rating scale) and a horizontal scale question (giving the option of three opposing statements) were used. The first set of questions covered information about vessel type and its temporal usage in the area. A Yes/No checklist was used to evaluate the number of users that are registered with the Ceredigion/Gwynedd scheme (every craft that launches on Gwynedd and Ceridigion's coast has to register with the Councils) and those that own a property in Cardigan Bay. Additionally, users' expectations when operating a recreational craft were assessed by likert-scale with 1 being not important and 5 being very important. Moreover, three Yes/No questions and a percentage list were used to assess users' perceptions of bottlenose dolphin population, management and impact from boats: did users observe interference from other vessels when out at sea, have they perceived changes in dolphin numbers over the long-term, do they know of the existence of any guidelines protecting bottlenose dolphins in Cardigan Bay, and what percentage of trips had bottlenose dolphin encounters, respectively. Assessment of adherence to a code of conduct was based on three questions following the three main guidelines: Time spent during an encounter and distance between dolphin and boat that recreational users followed were evaluated with closed long list logical categories (0-5min, 6-15min, 16-30min, 31-60 min, >60min; 0-20m, 21-50m, 51-100m, 101-200, >200m; respectively); moreover, in order to evaluate manoeuvre approach, a horizontal scale was used with opposing statements (slow down vs speed up, stop vs move away and move towards vs continue its course), based on the code of conduct guidelines on how boats should manoeuvre. The code stipulates that when encountering dolphins, boats should slow down gradually to a minimum speed and they must not make sudden changes in speed or course.

From May 2017 to September 2018, recreational users were approached at random at the study sites and invited to participate. People were handed the questionnaire sheet and a pen so they could fill in the survey themselves. In order to increase sample size, Gwynedd Council beach patrol, as well as staff and volunteers from Sea Watch Foundation contributed by approaching users and inviting them to complete the survey. The questionnaire was also created on an Online Survey website, enabling the link to be shared on other relevant scientific monitoring, environmental protection, and marine mammal websites, as well as Facebook groups, over the period July 2017 to May 2018.

Using information provided concerning the locations from which recreational users launch their craft, data were categorised according to SAC (Pen Llŷn a'r Sarnau SAC vs Cardigan Bay SAC), in order to compare awareness and compliance for their respective codes of conduct. Residency information was used in order to organise the data into locals (those that live in Wales. Sample size was not enough to divide the residency at a smaller scale) and visitors (those that live outside Wales).

Closed questions regarding boat distances and durations at an encounter, which were long lists of logical categories by metres and minutes respectively were translated into a binomial category (0-1), following the guidelines and adherence to the local code of conduct: For those participants that recorded spending between 0 and 15 minutes with the dolphins, the variable was translated as 1 (since they followed the guidelines), whilst a duration of 16 to greater than 60 minutes was translated as 0 (since they did not adhere to the code). Consistently, for those recreational users approaching dolphins between 0 to 100 metres, the variable was treated as 0, and for those approaching them between 101 to more than 200 metres, the variable was treated as 1. Evaluating boat manoeuvres in the moment of an encounter involved a horizontal scale, with six options organised in three columns, and instructions to participants to choose one option per column, since each column had opposing statements (slow down vs speed up, stop vs move away, and move towards vs continue its course) following the code of conduct manoeuvre guidelines (slow down gradually to minimum speed; do not make sudden changes in speed or course). The variable was later also translated into a binomial category, with 1 being the combination of slow down, stop and continue its course, whilst 0 involved the rest of the options, which implied that boats were not following the code of conduct statements.

6.3.2.2 Interviews with dolphin-watching boat operators

The interview consisted of two open-ended and six closed questions (see Supplementary material 8.2). Closed questions involved four Yes/No checklists and two sets of likert-scale type questions. Temporal usage of boats undertaking dolphin-watching trips was assessed. Additionally, operators' perceptions were evaluated, starting with views about interference from other vessels during their operation, and changes in the number of clients and in bottlenose dolphin sightings over the time of their operation. Considerations about the current regulations and the balance between conservation and dolphin-watching trip activities were assessed with a Yes/No checklist, followed by an open-ended question where participants could develop their thoughts about the existing guidelines. The importance to the commercial operation of scenery, being on a boat, photographs/videos, seabirds, fishing, dolphins, porpoises and seals, as well as the importance of a healthy bottlenose dolphin population to their business, were covered using a likert-scale with score 1=not important and 5=very important. An initial email contact was made with the operators in order to engage them with the current study and the survey. Later meetings were arranged to conduct the interviews, which took place during May and November of 2017.

6.3.2.3 Questionnaire with dolphin-watching boat clients

The survey included one open- and 10 closed questions (see Supplementary material 8.3). Closed questions included five checklist questions with three Yes/No options, one different scale question (where 2 options were given, with 2 opposing terms), and a longer list question. Four sets of likert-scale type questions were used. The seasonality and frequency of participants' dolphin-watching trip experiences was first assessed. A Yes/No checklist was used to determine whether participants owned a property in the Cardigan Bay region, if they had bottlenose dolphin sightings during their trip, and if they were interested in returning to the area for dolphin-watching. The two questions with opposing terms assessed whether the dolphin-watching trip was the main reason for their visit or if it was a spur of the moment decision, whilst the longer list question was used to assess users' perceptions regarding the percentage of interference from other vessels during the dolphin-watching trip. Likert scale questions were used to evaluate clients' perceptions before and after their experience: the main reasons to go on the trip (classified from 1 to 5, with 1=not important and 5=very important); rating of the dolphin-watching trip based on expectations (score 1 to 5 with 1=much worse and 5=much better), potential benefits and negative impacts (two types of scoring, 1=strongly disagree and 5=strongly agree; 1=very negative and 5=very positive and 6=not sure).

The Sea Watch Foundation contacted dolphin-watching operators to get consent to conduct questionnaires with their clients. Then from April to October 2018, Sea Watch interns approached clients at random after their dolphin-watching trip, inviting them to participate and providing a questionnaire sheet and pen on authorised vessels. With all recreational user questionnaires, residency information was collected in order to organise the data into locals (those that live in Wales. Sample size was not enough to divide the residency at a smaller scale) and visitors (those that live outside Wales).

6.3.3 Data analyses

6.3.3.1 Recreational user questionnaire

Kruskal-Wallis tests were conducted to determine significant differences between the scores of the likert-scale questions assessing the importance of different reasons for participants when using a recreational craft. These were run for all the data set and additionally for Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC separately. When significant differences were found, a further post hoc Dunn's test or pairwise multiple comparison test was used to determine which levels of the independent variable differ from each other level. These post hoc tests were run with "PMCMR" package in 'R Studio' (Version 1.0.136 – © 2009-2016 RStudio, Inc.).
Recreational users' adherence to the code of conduct was determined. Thus, generalised linear models (GLMs) were used to evaluate how the code of conduct guidelines are affected by the explanatory variables. The response variables were boat responses on a dolphin encounter: distance, type of manoeuvre and time, with binomial family due to data previously converted into 0-1 (No-Yes) to account for code of conduct adherence. The explanatory variables chosen were the knowledge of the existence of the code of conduct, having a property in Cardigan Bay, and the place of residency. A further marginal effect was run due to the GLM allowing one only to interpret the sign of the coefficients, and therefore, to know how much a particular variable influences the code of conduct adherence, marginal effects were calculated. These GLMs with marginal effects were run with "mfx" package in 'R Studio' (Version 1.0.136 – © 2009-2016 RStudio, Inc.).

Variations of boat responses on a dolphin encounter (distance, manoeuvre and time) were not assessed per site with a GLM (due to sample size) and therefore two tailed t-tests with unequal variances (due to the idiosyncratic features of the units observed in the sample), were run for each variable, in order to identify differences between Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC.

6.3.3.2 Operator interviews

A frequency table, as well as mean values from likert-scale questions, were used to report the importance of different categories to operators, in order to assess their interests. In addition, Yes/No questions (experiencing interference from other vessels, noting any changes in the number of people going on dolphin-watching tours, and noting changes in the number of bottlenose dolphin encounters during commercial trips) were quantified by reporting percentages in order to assess operators' perceptions.

6.3.3.3 Client questionnaires

Similar to the recreational users' questionnaires, client data to evaluate the main reasons for participants to go on a dolphin-watching trip, were used; Kruskal-Wallis tests were run to determine significant differences between the scores, for the entire dataset and for locals and visitors separately. When significant differences were found, pairwise multiple comparison tests were used to determine which levels of the independent variable differ from each other. These post hoc tests were run with "PMCMR" package in 'R Studio' (Version 1.0.136 – © 2009-2016 R Studio, Inc.). Variations in the opinions of participants regarding potential benefits and negative impacts of dolphin-watching trips in Cardigan Bay were assessed via two tailed t-tests with unequal variances (due to the idiosyncratic characteristics of the units observed in the sample), in order to identify differences between locals and visitors.

6.4 Results

From the surveys used, 96 people participated in the recreational user questionnaires, and 153 participated in the dolphin-watching boat client questionnaires. Additionally, four of the main dolphin-watching operators in Cardigan Bay were interviewed.

6.4.1 Recreational boat user questionnaires

6.4.1.1 Demographics of recreational boat users

Of the 96 respondents who agreed to complete the survey, 39% (n=36) were female and 61% (n=57) male, resulting in a 1.6:1 male to female sex ratio. The sex ratio was 1.9:1 at Pen Llŷn a'r Sarnau SAC, and 1:1 at Cardigan Bay SAC. The majority of the participants belonged to the age group >45years old.

6.4.1.2 Temporal usage of recreational boat users

Recreational users in Cardigan Bay have gradually increased their visits to the area in the last six years, with 2011 representing 14% (n=53) and 2016, 20% (n=76) (Figure 6.1a). In addition, when looking into more detail at the visits in the last six years, July and August were the months with the greater amount of recreational boat activity, with 21% (n=54) and 24% (n=70) respectively (Figure 6.1b). Results show that recreational users visit Cardigan Bay the most during weekends (33%, n=79), followed by school holidays (26%, n=62), weekdays (23%, n=55), and bank holidays (19%, n=47) (Figure 6.1c).

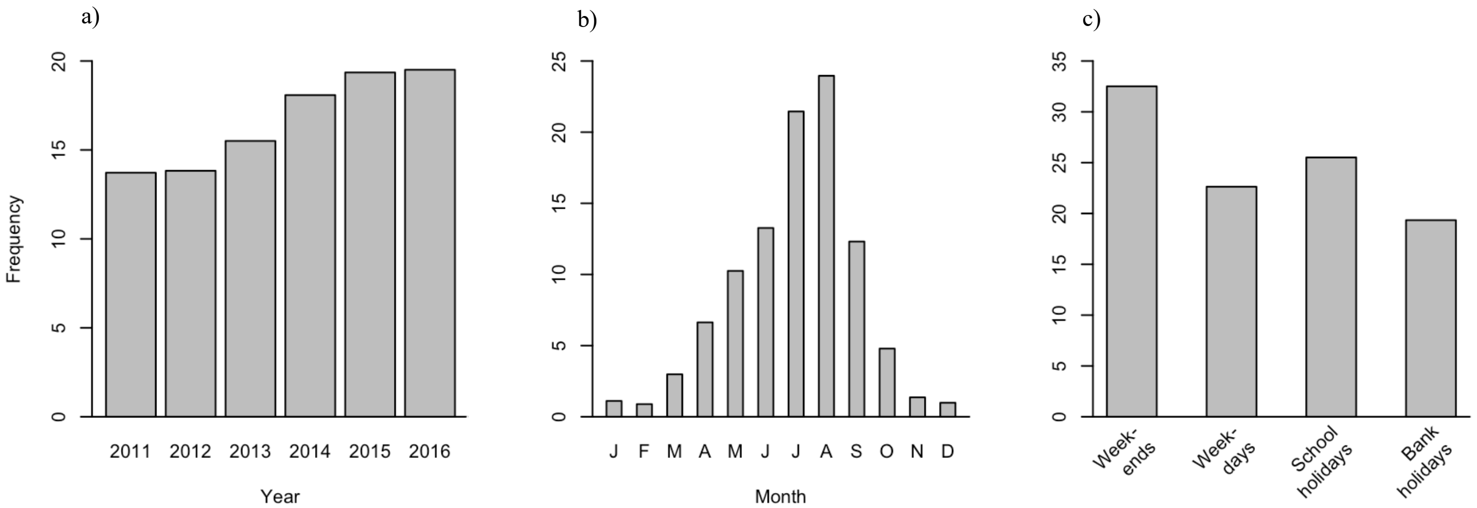


Figure 6.1 Frequency of visits by questionnaire participants using recreational craft at Cardigan Bay, with a) visits by year during the period 2011 to 2016; b) visits per month during the period 2011 to 2016; and c) visits by work day status.

6.4.1.3 Perceptions of recreational boat users

Differences in the reasons why recreational users visit Cardigan Bay on their craft were tested. Post-hoc Dunn tests found that taking photographs/videos (p<0.001), fishing (p<0.001) and seeing seabirds (p<0.001) were less important than visiting to see dolphins (Figure 6.2). Differences between the reasons why recreational users use their crafts at both SACs were tested, but with no significant results (Pen Llŷn a'r Sarnau SAC: Kruskal-Wallis chi-squared=8.24, p-value=0.14; Cardigan Bay SAC: Kruskal-Wallis chi-squared=6.64, p-value=0.24).

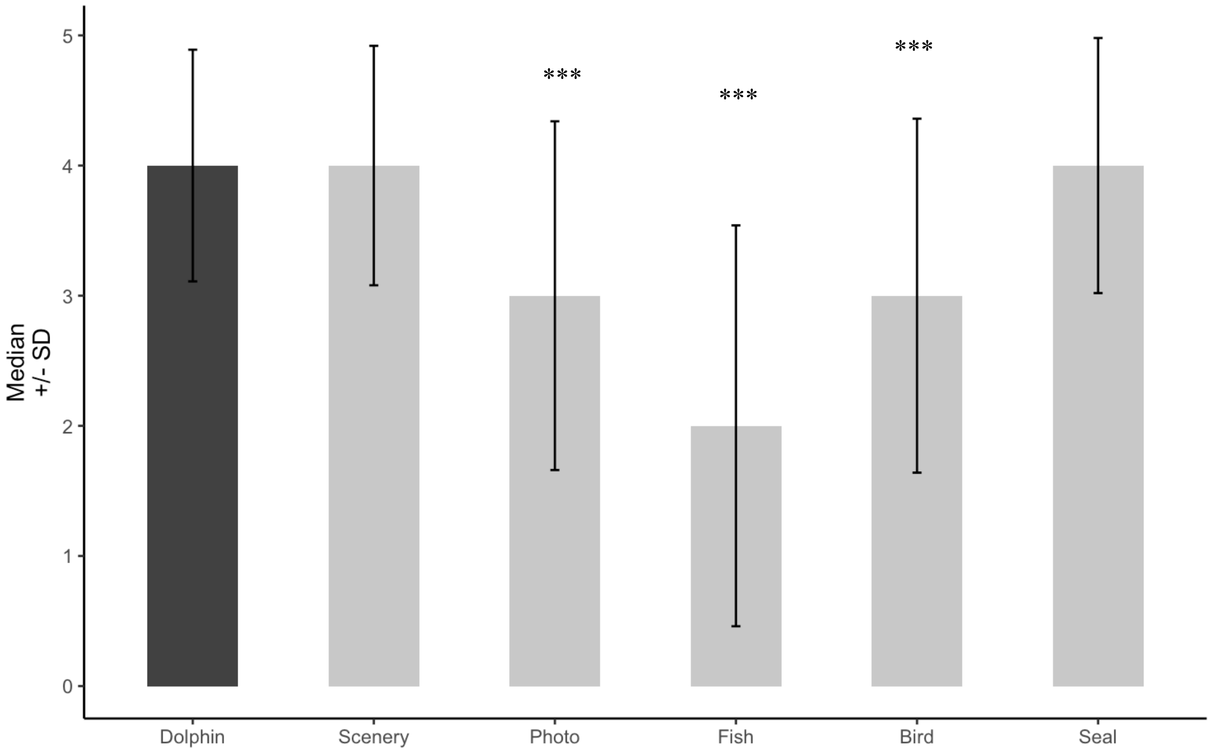


Figure 6.2 Median likert scale values of the importance of different factors for recreational boat users (1 being not important and 5 being very important). Significant differences between the importance of seeing dolphins and other factors using a post-hoc Dunn test are denoted by asterisks (*= p<0.05; **= p<0.01; ***= p<0.001).

Recreational users encountered bottlenose dolphins on 36.8% (n=91) of their trips. On a minority of those trips they experienced interference from other vessels (28%, n=27), with 34% (n=32) being commercial boats and 66% (n=61) being recreational craft. Of those recreational users that participated in the questionnaire and that have visited Cardigan Bay for more than 6 years, 40% (n=28) registered a change in the number of dolphin encounters during their trips in Cardigan Bay, perceiving the number of individuals increasing in the area (79%, n=22) which they believed were due to an increase in food availability, attraction by boats and/or legislation (n=11).

6.4.1.4 Recreational boat users adherence to the code of conduct

When asked about the existence of a guideline that protects the bottlenose dolphin in Cardigan Bay, 55% of the participants did not know of it, while 42% were aware of the existence of the guideline. Knowledge of a code of conduct differed between Pen Llŷn a'r Sarnau SAC and Cardigan Bay SAC. At Pen Llŷn a'r Sarnau SAC, 27% of participants knew about the code, whilst 69% had no knowledge of it. By contrast, at Cardigan Bay SAC, the majority (79%) of the participants knew about the code of conduct, whereas 21% were unaware of its existence (Table 6.1).

Table 6.1 Responses to questions assessing participants' knowledge about the code of conduct in the whole of Cardigan Bay and at Pen Llŷn a'r Sarnau (PLaS) SAC and Cardigan Bay (CB) SAC.

	All participants (n=96)			Participants at PLaS SAC (n=64)			Participants at CB SAC (n=28)		
Do users:	Yes (%)	No (%)	No answer (%)	Yes (%)	No (%)	No answer (%)	Yes (%)	No (%)	No answer (%)
know of any guideline that protects bottlenose dolphins in Cardigan Bay?	42	55	3	27	69	4	79	21	0
follow code of conduct manoeuvre guideline during a dolphin encounter?	49	11	40	45	16	39	64	4	32
follow code of conduct time guideline during a dolphin encounter?	81	16	3	76	19	5	93	7	0
follow code of conduct distance guideline during a dolphin encounter?	20	76	4	11	84	5	40	57	3
have a property in Cardigan Bay?	53	41	6	53	39	8	54	43	3
live in Wales?	46	54	0	42	58	0	57	43	0

Differences in the probability of recreational users following the guidelines that the code of conduct established regarding boat manoeuvres, distance to dolphins and time spent with any dolphin encounter from GLMs and marginal effects calculated, are reported in Table 6.2. Participants following the appropriate manoeuvre was significantly related to residency of the user, with visitors having 25% less chance compared with locals of following this aspect of the code of conduct according to the best-fit model (Table 6.2). According to the best-fit model, recreational users following the recommended time spent with the dolphins, was not related to whether they knew about the code of conduct, having a property in Cardigan Bay, nor to living in Wales (Table 6.2). On the other hand, the probability of users following the 100-metre distance guideline was significantly related to whether participants had previous knowledge of the code of conduct, with the probability of people adhering to the distance guideline increasing by 21% (Table 6.2).

Table 6.2 GLMs of questionnaire responses by participants using recreational boats from July 2017 to May 2018, to test adherence to manoeuvre, time and distance guidelines related to: the code of conduct knowledge; having a property in Cardigan Bay; and residency information (CC_knowledge: Knowing about the code of conduct; CB_Prop: Having a property in Cardigan Bay).

Response variable	Explanatory variable	Estimate	2.5% CI	97.5% CI	Marginal effect	p-value
Manoeuvre	CC_knowledge	-0.11	1.59	-1.81	-0.010	0.89
	CB_Prop	-0.31	1.37	-1.99	-0.02	0.71
	Residency	2.51	4.77	0.25	0.27	**0.01**
Time	CC_knowledge	0.02	1.25	-1.21	0.002	0.9
	CB_Prop	0.62	1.90	-0.65	0.08	0.3
	Residency	-0.27	0.99	-1.52	-0.03	0.6
Distance	CC_knowledge	1.32	2.50	0.14	0.21	**0.02**
	CB_Prop	-0.82	0.45	-2.09	-0.13	0.21
	Residency	0.84	2.11	-0.43	0.12	0.18

Significant values ($p<0.05$) are denoted in **bold**.

6.4.2 Dolphin-watching boat operator interviews

Four operators participated in the interview (representing 100% of the active boat operators), informing about their vessels, their characteristics and passenger capacity. Two of them have been operating in Cardigan Bay for at least 30 years, whilst the other two have been running for 10 years, all visiting different areas but mainly Cardigan Bay SAC in the neighbourhood of New Quay.

6.4.2.1 Perceptions of dolphin-watching boat operators

Operators were asked about their reasons for their commercial operation, with dolphins being the most important element (mean score = 5). Cetacean interest was followed by scenery (mean score = 4.5), taking photographs/videos (mean = 4.5), seals (mean = 4.5), and enjoying being on a boat (mean = 4.3). Seabirds (mean = 3.8) and porpoises (mean = 3.8) were less important, with fishing (mean = 1.8) the least important motivation for their commercial operation.

When asked about experiencing interference from other craft when out on the sea, only one operator recorded this happening, with 50% being from recreational users and 50% being from other operators. All participants recorded that having a healthy bottlenose dolphin population in Cardigan Bay was very important to their business. Moreover, when asked about perceiving changes in the number of people going on dolphin-watching boat tours in Cardigan Bay, 100% of them reported an increase, with the perception that this might be due to more advertising in the media and greater awareness of the bottlenose dolphin population in New Quay. When asked about any perceived changes in the number of bottlenose dolphin encounters during commercial trips in Cardigan Bay, the opinion was divided, with 50% noting an increase and 50% recording similar numbers.

Operators were asked whether the current regulations provided a good way to obtain the right balance between conservation and dolphin-watching tourism activities, with two of them agreeing with this statement, whilst suggesting further management of the total number of vessels permitted in any given area. One operator did not concur with the previous statement, affirming that a limit to the overall number of commercial boats should be incorporated, whilst also believing that a stronger code of conduct was needed which when broken could elicit withdrawal of the operator's permit. The operator that was unsure about this statement considered that there was no point in having a code of conduct since no one checked if it had been followed. He felt it was more important to know other operators' perceptions about dolphin reactions during a boat encounter to agree on the proper way they should behave/react when in an encounter.

6.4.3 Dolphin-watching boat client questionnaires

6.4.3.1 Demographics of dolphin-watching boat clients

There were 153 dolphin-watching boat clients who participated in the current study. Of those, 136 recorded their gender, giving a 7:10 male to female sex ratio. The majority of participants were over the age of 25 years, with 50% in the age range of 26-45 years and 37% being over 45 years. Additionally, of those who took part in the survey, 78% were visitors from outside Wales.

6.4.3.2 Clients' use of dolphin-watching boats

152 participants responded concerning whether this was their first dolphin-watching experience of this nature, with 82% (n=124) being new to dolphin watching and 18% (n=28) being previous dolphin-watching clients. The majority of participants went on a dolphin-watching trip for the first time less than 5 years before the survey (78%), with 22% first visiting Cardigan Bay between 6 to 15 years ago. July and August were the months when most participants were involved in dolphin-watching trips, with 22% (n=28) and 27% (n=34) respectively (Figure 6.3).

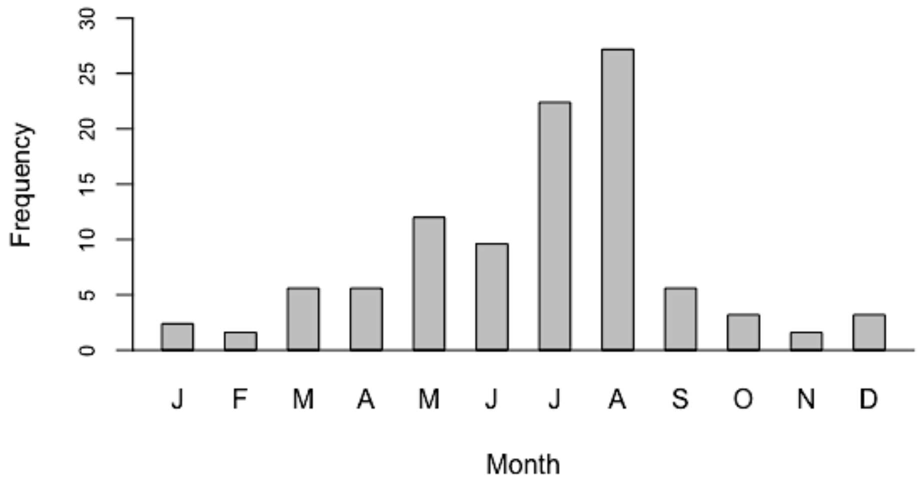


Figure 6.3 Frequency of dolphin-watching visits by questionnaire participants in Cardigan Bay per month during 2016.

6.4.3.3 Perceptions of dolphin-watching boat clients

Participants were asked for the reason why they went on a dolphin-watching trip (n=136), to which 42% (n=57) said it was a spur of the moment decision and 58% (n=70) reported this was their main reason for visiting the area. Differences between the reasons why clients went on a dolphin-watching trip in Cardigan Bay were analysed. Post-hoc Dunn tests showed that seeing dolphins was the main reason for going on a dolphin-watching trip, with significantly more persons stating this compared with being outdoors ($p<0.001$), fishing ($p<0.001$), seeing the scenery ($p<0.001$), seeing seabirds ($p<0.001$), seeing seals ($p<0.001$), or taking photos/videos ($p<0.001$) (Figure 6.4). Differences between reasons to go on the trips were also found for participants living in Wales compared with those who were visitors to the country (Kruskal-Wallis=11.88, p-value=0.03). Pairwise comparisons showed that dolphins were more important than fishing ($p<0.001$), seeing seabirds ($p<0.001$) and taking photos/videos ($p<0.001$) for people living in Wales. Dissimilarities were found within visitors too (Kruskal-Wallis chi-squared=26.29, p-value=$7.81e^{-5}$), with seeing dolphins being more important than being outside ($p<0.001$), fishing ($p<0.001$) scenery ($p<0.001$), seeing seabirds ($p<0.001$), seeing seals ($p<0.001$) and taking photos/videos ($p<0.001$).

Table 6.3 Responses to questions assessing the main reasons of participants for going on dolphin-watching trips in Cardigan Bay in 2017.

	All participants (n=153)					Locals (n=28)					Visitors (n=98)				
	Not important (%)	Slightly important (%)	Moderate important (%)	Important (%)	Very important (%)	Not important (%)	Slightly important (%)	Moderate important (%)	Important (%)	Very important (%)	Not important (%)	Slightly important (%)	Moderate important (%)	Important (%)	Very important (%)
Scenery	3	7	22	41	27	0	0	18	56	26	3	11	22	38	26
Being outside	2	9	14	48	27	0	11	11	52	26	2	10	15	45	28
Photographs/videos	17	14	24	24	21	9	14	41	22	14	18	13	22	25	22
Fishing	13	24	27	22	14	17	8	25	29	21	8	26	29	25	12
Seeing birds	83	6	3	4	4	75	0	10	5	10	84	6	3	4	3
Seeing dolphins	1	1	3	21	74	0	0	3	36	61	1	1	2	17	79
Seeing seals	2	4	14	40	40	0	0	12	42	46	2	4	16	40	38

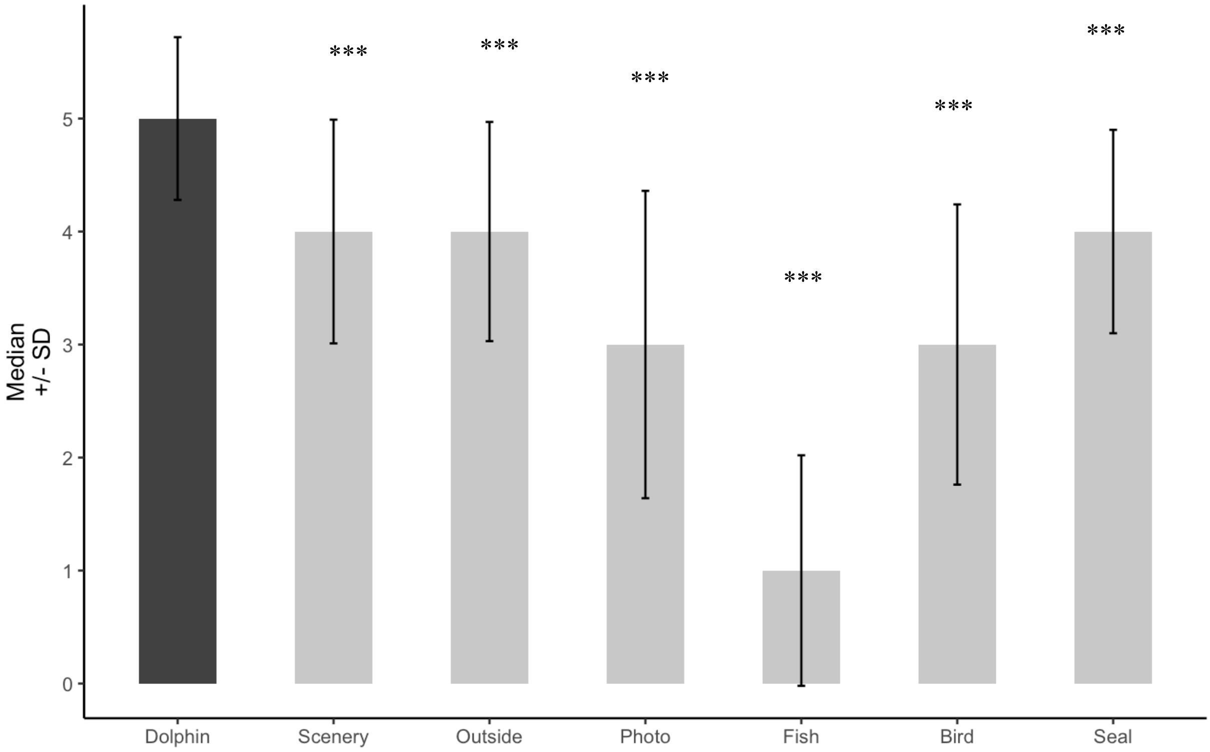


Figure 6.4 Median likert scale values of the main reasons for clients going on a dolphin-watching trip (1 being not important and 5 being very important). Significant differences between the importance of seeing dolphins and other factors using Post hoc Dunn test are denoted by asterisk (*= p<0.05; **= p<0.01; ***= p<0.001).

A small percentage of clients reported interference from other vessels during a dolphin encounter (18%, n=24). Such interference was reported mainly from speedboats (38%, n=8), fishing boats (29%, n=6), and sail boats (19%, n=4).

Participants were asked whether they had dolphin sightings on their trip. 85% (n=127) said they encountered cetaceans during their trip, with only 15% (n=22) not having sightings. In order to evaluate the importance of a dolphin sighting to them, clients were asked to rate their dolphin-watching experience. This resulted in a mean value of 4 (n=113), which translates into somewhat better than their expectations. These perceptions were also supplemented with the thoughts of participants concerning returning to Cardigan Bay specifically for dolphin watching, with 80% (n=109) being interested in coming back, 6% (n=8) not interested, and 14% (n=20) unsure.

6.4.3.4 Dolphin-watching boat clients' conservation awareness

Six statements measured awareness of the potential benefits and negative impacts of dolphin-watching trips in Cardigan Bay. t-tests showed the following: dolphin-watching boat clients, both locals and visitors, agreed that the activity brings economic opportunities for local communities. Residency did not have a significant impact when agreeing on whether dolphin-watching trips raised awareness of participants for marine conservation issues in general. Moreover, both locals and visitors perceived that dolphin-watching was somewhat positive to the dolphins in Cardigan Bay. Nonetheless, significant differences were found between locals and visitors towards the idea of education of participants in helping to protect dolphins, with visitors agreeing more strongly than locals. Significant differences were also found regarding whether dolphin-watching trips had a negative impact on the marine environment and on dolphins, with locals having a neutral view, whereas visitors disagreed with this (Table 6.4).

Table 6.4 Results of t-tests for differences between question responses by locals and visitors on the perceptions of benefits and negative impacts of dolphin-watching trips in Cardigan Bay.

	Local (mean)	**Visitor (mean)**	**Diff**	**t-statistic**	**p-value**
a. Economic opportunities for local communities	4.270	4.270	0.00	0.024	0.980
b. Education of participants, which helps to protect dolphins	4.27	4.45	-0.180	-1.3621	**0.024**
c. Negative impact on the marine environment	2.769	2.204	0.570	2.458	**0.019**
d. Negative impact on dolphins	2.653	2.173	0.480	2.111	**0.041**
e. Raise of awareness of participants for marine conservation issues in general	4.307	4.322	-0.010	-0.103	0.918
f. Impact on dolphins of dolphin-watching	3.923	4.206	-0.280	-1.393	0.170

L and V values for a-e: 1=Strongly Disagree, 2=Disagree, 3= Neutral, 4=Agree, 5= Strongly Agree.

L and V values for f: 1= Very negative, 2= Somewhat negative, 3= Neutral, 4= Somewhat positive, 5= Very positive, 6= Not sure.

Significant values ($p<0.05$) are denoted in **bold**.

6.5 Discussion

This study provides a qualitative and quantitative analyses of social aspects of marine recreational and dolphin-watching activities in Cardigan Bay, their potential to improve environmental education and, ultimately, bottlenose dolphin and marine environment conservation awareness. While most studies focus upon the impact of recreational and dolphin-watching activities on the cetaceans themselves (Forestell & Kaufman, 1991; Janik, 1996; Constantine et al., 2004; Danielsen et al., 2005; Hastie et al., 2006; Lusseau, 2006; Williams et al., 2009; Pirotta et al., 2015), this study gathered i) data on the interests of the public (recreational users and dolphin-watching trip clients) and their perceptions regarding such activities; ii) commercial operators interests; and iii) information evaluating people's conservation awareness in Cardigan Bay.

Recreational activities in Cardigan Bay

Results suggest that users go on their recreational vessels in Cardigan Bay to enjoy the scenery, and the presence of dolphins and seals. This highlights the importance of the bottlenose dolphin population in Cardigan Bay even to recreational users; they also perceived the cetacean population as increasing in numbers. Recreational users might be aware of the potential impacts of their own activities on the dolphins, as well as on other species and the environment in general, and this means, they could improve their responses during a dolphin encounter to minimise harassment and disturbance, whilst ensuring the dolphins remain in the bay (Chapters III and IV). Similarly, recreational users perceived greater interference from other recreational users than from commercial tourist boats during a dolphin encounter, suggesting greater disturbance to dolphins from this type of activity, and therefore the need for improved management focused on these users (Higham & Lück, 2007). This can also be linked to knowledge and adherence to a local boating code of conduct: the majority of recreational users were aware of such regulations in the southern SAC, but in the northern SAC and the wider bay, most of the participants did not recognise it. Consequently, awareness of the importance of a code of conduct and adherence to it should be raised through environmental education in Cardigan Bay since the dolphins travel over the whole bay, visiting both SACs. This requires users in the wider area to be conscious about the guidelines and to follow them, whilst protecting the species and ensuring that their numbers remain stable. If dolphin numbers do not cease, this will encourage users to keep visiting the region, which not only improves their wellbeing (Higham & Lück, 2007) but also brings economic benefits to the area (Garcia-Hernandez, 2015).

The fact that boating code of conduct guidelines are not followed to the same extent by visitors as by locals, suggests a lack of awareness of the guidelines, and the code itself. It is possible that some guidelines are followed only because they seem to be the appropriate response towards the dolphins and are not necessarily related to actual knowledge of the guidelines. Also, the fact that visitors were less likely to follow the manoeuvre guidelines during a dolphin encounter suggests that locals are more aware of this and adhere to it better, minimising disturbance. These findings are similar to those assessed in previous studies elsewhere, with residents living in areas where tourism activities take place being more aware of potential positive and negative environmental impacts, which they associate with their social and economic wellbeing (Liu et al., 1987).

There is a clear need to improve the number of recreational users that are aware of the code of conduct guidelines, including both locals and visitors, and this will only be possible by increasing environmental education and awareness. Several studies emphasise that education is, or should be, a principal component of 'ecotourism' experiences (see, for example, Orams, 2000; Reynolds & Braithwaite, 2001; Walker, 2018). By increasing environmental education and awareness of codes of conduct, people can be encouraged to reduce their impact through a more efficient use, increasing the probability that they will adhere to the guidelines, safeguarding dolphins and the marine environment in general. Environmental education should not only being increased, but also it has to be done effectively, the way that people is approached should be improved, whilst users understand the benefits that they can get if they act responsible, whilst adopting attitudes and collaborating to make informed decisions that are beneficial to the community. Additionally, as part of the environmental education programme, notice boards could be implemented at beaches and launch places, specifying each set of guidelines, to promote a boating code of conduct and, ultimately, dolphin conservation (see Figure 6.5 as an example). Similarly, taking into account the results presented here and the fact that recreational activities are greater in northern Cardigan Bay, priority to the management, this is code of conduct guidelines and awareness should be given in that area. Particularly, speed craft (which are the majority of recreational users in Pen Llŷn a'r Sarnau SAC) measures should be implemented, such as, number of craft around the dolphins during an encounter and falling to follow the code of conduct resulting in fines or more legal procedures, to encourage people to act accordingly to protect the bottlenose dolphin and the wildlife in the area.

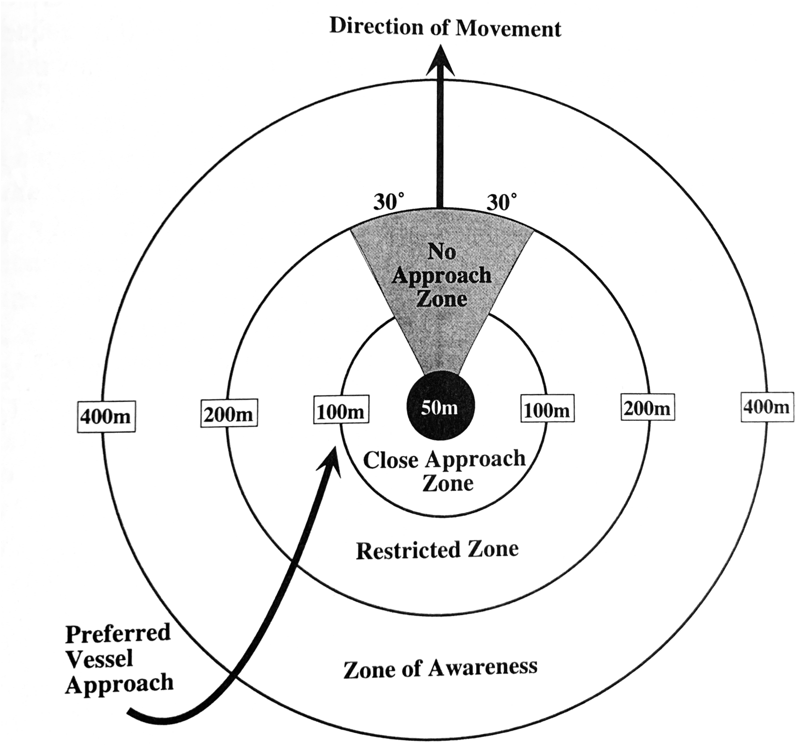


Figure 6.5. Diagram of recommended vessel approach to cetaceans (taken from Würsig & Evans, 2001).

Commercial dolphin-watching in Cardigan Bay

As with the interests of recreational users, dolphin-watching boat operators reported dolphins as the most important motivation for their commercial operations, which is also supported by a 100% response to the importance of a healthy bottlenose population in Cardigan Bay for their business. In addition, operators are aware of the presence of dolphins attracting visitors on their boats, with numbers increasing in the last decade due to greater advertising of the dolphins in New Quay on both radio and TV. Therefore, operators will benefit by minimising disruption, protecting dolphins, and avoiding further disturbance that might make the animals flee, which will keep bringing people on their trips and helping their economy.

Operators were divided in their opinion regarding the code of conduct and whether it provides the right balance between conservation and dolphin-watching activities. This was also supported by their perception that interference from recreational users and dolphin-watching boats was about the same. Therefore, stakeholders are aware of the comparable potential disturbance that recreational boats and dolphin-watching activities may trigger on the local bottlenose dolphins, whilst acknowledging room for improvements in the code of conduct and adherence to it. Consequently, although dolphin-watching boats seemed to have a less negative impact on the dolphins (Chapter IV), there is still scope for improving compliance among operators. Despite the fact that operators' knowledge of the current regulations that protect bottlenose dolphins in Cardigan Bay is greater than that of recreational users (mainly in the northern part of the bay), they still consider that there is need for more policing, enforcement and sustained compliance, including legal implications for those not adhering to the regulations (such as removal of boat permit or fines). Thus, operators are a key source of information towards management recommendations. During summer, they undertake their activities almost every day and this ensures that they are the ones regularly witnessing not only dolphin and boat presence, but also dolphin responses to vessels as well as boat behaviour towards the dolphins. On the other hand, it is also suggested that besides a stronger code of conduct, in those cases where multiple skippers are in charge of the operations, additional education is needed (Walker, 2018). This will ensure that people are not using the activity only for profit, but always in a sustainable way, balancing tourism activities with bottlenose dolphin conservation.

Regarding dolphin-watching boat clients, it is reassuring that the bottlenose dolphin population in Cardigan Bay is the main reason for people to go on the dolphin-watching trips. Consequently, protecting bottlenose dolphins around New Quay is important to retain the principal interests of visitors and ensuring they continue visiting the area, whilst contributing to the commercial tourism industry. Nonetheless, the fact that significant differences were found between interest in dolphins and the other possible interests suggests the need for improving the knowledge of the marine environment in general, with dolphins being not the only important species having a role in the energy flux of oceans and as indicators of the productivity of the ecosystem (Katona & Whitehead, 1988), but also being part of a wider system encompassing more benefits to visitors. Like recreational users, clients also perceived that during a dolphin encounter there is more interference from recreational craft than from commercial tourism boats. The fact that dolphin-watching activities are perceived as not disturbing suggests the need for greater awareness by clients of potential boat disturbance, since all vessels, if not responding properly and, in this case, not adhering to the code of conduct, may disturb wildlife. Additionally, this can be translated into clients not feeling responsible for the consequences of their actions and threats to the marine environment, as has been found in other studies (García-Cegarra & Pacheco, 2017).

In addition, similar opinions from locals and visitors concerning whether dolphin-watching trips raise awareness of participants for marine conservation issues in general, supports the idea that dolphin-watching activities in New Quay are perceived as an important tool to increase knowledge about the marine environment and its preservation. Therefore, education and awareness, being different processes, are linked together to reach successful marine management and conservation, and so participants need to be more conscious of this to effectively know the guidelines and act according to them to protect dolphins in the area.

Differences in the perception of whether dolphin-watching trips involve negative impacts on the marine environment and dolphins, with a general neutral reaction from locals but disagreement from visitors, suggests a slightly greater awareness from people living in Wales towards potential adverse effects that dolphin-watching activities can generate on dolphins and the marine environment. Thus, locals appear to be more aware of the human impacts on the marine environment. Further analyses treating those living within the county of Ceredigion separately to the rest of Wales could have shown greater differences. Nonetheless, in order to increase this knowledge for visitors, so they are more likely to adhere to the aims of a sustainable dolphin-watching industry, it is necessary to improve education, including cetacean approach conditions and regulations, through brochures and advertisements, ensuring that participants are much more aware of what is and what is not allowed, and more importantly, the reasons for such regulations (Walker, 2018). In contrast, the fact that both visitors and locals evaluated the impact on dolphins of dolphin-watching as somewhat positive is evidence that locals consider dolphin-watching beneficial, even though they do perceive some negative effects. This finding is similar to other studies of dolphin watching impacts on bottlenose dolphins that have elicited local population declines (Bejder et al., 2006b). On the other hand, visitors do not perceive such negative threats and therefore incorporation of an explanation of the threats to dolphins and other wildlife species should be adequately addressed whilst providing opportunities for participants to help towards conservation (García-Cegarra & Pacheco, 2017). When asked about dolphin-watching trips in Cardigan Bay and the benefit to economic opportunities for local communities, both locals and visitors strongly agreed. In general, people are aware that tourism has the potential to generate income for resident communities, whilst linking local economic development and environmental conservation (Alexander, 2000; Sekhar, 2003).

Conclusions

The wider area of Cardigan Bay has more pressure from general recreational activities, but less so from targeted dolphin-watching, and, therefore, personal water craft (RIBs, jet skis, small motor-boats) should be examined more closely to ensure less disturbance on bottlenose dolphins from these type of vessels (Walker, 2018). Additionally, bearing in mind that dolphin-watching management involves the control of human access to dolphins, the establishment of codes of conduct and better education in marine tourism have become more essential, leading to international workshops on the educational values of marine mammal watching, whilst promoting this activity as an educational and environmentally friendly industry (Lück, 2003).

Changing people's behaviour towards the marine environment involves a big challenge for conservation science. Consequently, regulation is necessary, but it is not sufficient on its own for species protection. Rules can only be effective if they are known, understood and followed by people participating in dolphin-watching activities (Keane et al., 2011). Therefore, legislation, regulation and enforcement are needed in order to protect the bottlenose dolphins inhabiting Cardigan Bay. In this respect, training and education in codes of conduct are needed to reduce boat disturbance in the bay. Furthermore, in order to ensure compliance, the implementation of wardens at different launch places, who not only could be promoting the code of conduct, but also could be controlling boats' responses (and assuring those that do not stick to the rules are legalise in some way) could improve adherence to guidelines and regulations.

An effective environmental education needs to be increased in Cardigan Bay. It is important to make marine users (recreational and dolphin-watching) understand their benefits from acting responsibly, whilst adopting attitudes and collaborating to make informed decisions that are beneficial to the community. Incorporating the understanding and knowledge of users involved in the recreational industry towards management, has a value beyond the potential quantitative assessment, this can empower people to seek local solutions to environmental problems. People need to be aware of our wildlife, the marine environment, the planet, they are increasingly being encroached upon and our responses can keep them from dwindling.

6.6 References

Alexander, S. E. (2000). Resident attitudes towards conservation and black howler monkeys in Belize: The Community Baboon Sanctuary. *Environmental Conservation*, 27(4), 341–350. https://doi.org/10.1017/S0376892900000394

Andersen, M. S., & Miller, M. L. (2006). Onboard marine environmental education: Whale watching in the San Juan Islands, Washington. *Tourism in Marine Environments*, 2(2), 111–118. https://doi.org/10.3727/154427306779436327

Bejder, L., Samuels, A., Whitehead, H., & Gales, N. (2006a). Interpreting short-term behavioural responses to disturbance within a longitudinal perspective. *Animal Behaviour*, 72(5), 1149–1158. https://doi.org/10.1016/j.anbehav.2006.04.003

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C. & Kruetzen, M. (2006b). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, 20(6), 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x

Constantine, R., Brunton, D. H., & Dennis, T. (2004). Dolphin-watching tour boats change bottlenose dolphin (*Tursiops truncatus*) behaviour. *Biological Conservation*, 117(3), 299–307. https://doi.org/10.1016/j.biocon.2003.12.009

Corkeron, P. J. (2004). Whale watching, iconography, and marine conservation. *Society for Conservation Biology*, 18(3), 847–849.

Danielsen, F., Burgess, N. D., & Balmford, A. (2005). Monitoring matters: Examining the potential of locally-based approaches. *Biodiversity and Conservation* (Vol. 14). https://doi.org/10.1007/s10531-005-8375-0

Ellison, W. T., Southall, B. L., Clark, C. W., & Frankel, A. S. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. *Conservation Biology*, 26(1), 21–28. https://doi.org/10.1111/j.1523-1739.2011.01803.x

Forestell, P. H., & Kaufman, G. (1991). Whalewatching in Hawaii enhances appreciation for endangered species and the marine environment, proceedings of The Congress on Coastal and Marine Tourism, May 25-31, 1990: Honolulu, HI. 1–9.

García-Cegarra, A. M., & Pacheco, A. S. (2017). Whale-watching trips in Peru lead to increases in tourist knowledge, pro-conservation intentions and tourist concern for the impacts of whale-watching on humpback whales. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 1–10. https://doi.org/10.1002/aqc.2754

Garcia-Hernandez, O. (2015). Economic impacts of sustainable marine tourism in the local economy, case study: Dolphin watching activity in New Quay, Cardigan, Wales. M.Phil. Thesis, Aberystwyth University. pp 228.

Goodwin, H. (1996). In pursuit of ecotourism. *Biodiversity and Conservation*, 5(3), 277–291.

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., D'agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E. & Fujita, R. (2008). A global map of human impact on marine ecosystems. *Science*, 319(5865), 948–953. https://doi.org/10.1111/2041-210X.12109

Hastie, G. D., Wilson, B., Tufft, L. H., & Thompson, P. M. (2006). Bottlenose dolphins increase breathing synchrony in response to boat traffic. *Marine Mammal Science*, 19(1), 74–084. https://doi.org/10.1111/j.1748-7692.2003.tb01093.x

Higham, J. & Lück, M. (2007). Marine wildlife and tourism management: Insights from the Natural and Social Sciences. CABI Publishing, Wallingford. pp 41.

Higham, J. E. S., Bejder, L., & Lusseau, D. (2008). An integrated and adaptive management model to address the long-term sustainability of tourist interactions with cetaceans. *Environmental Conservation*, 35(4), 294-302.

Hoyt, E. (2001). Whale Watching 2000: Worldwide tourism numbers, expenditures and expanding socioeconomic benefits. International Fund for Animal Welfare, Yarmouth, MA. pp 165.

Hudson, T. (2014). Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay. MSc Thesis, University of Bangor. pp 79.

Janik, V. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12, 597–602.

Katona, S., & Whitehead, H. (1988). Are Cetacea ecologically important? Oceanography and Marine Biology Annual Review, 26, 553–568.

Keane, A., Ramarolahy, A. A., Jones, J. P. G., & Milner-Gulland, E. J. (2011). Evidence for the effects of environmental engagement and education on knowledge of wildlife laws in Madagascar. *Conservation Letters*, 4(1), 55–63. https://doi.org/10.1111/j.1755-263X.2010.00144.x

Koroza, A. A. (2018). Habitat use and effects of boat traffic on bottlenose dolphins at New Quay Harbour, Cardigan Bay. MSc Thesis, University of Bangor. pp 93.

Lambert, R. and Evans, P. G. H. (2012). The socio-economic value of whale watching to local Welsh communities. Poster at the 26th Annual Conference of the European Cetacean Society, Galway, Ireland, 2012.

Larson, C. L., Reed, S. E., Merenlender, A. M., & Crooks, K. R. (2016). Effects of recreation on animals revealed as widespread through a global systematic review. *PLoS ONE*, 11(12), 1–21. https://doi.org/10.1371/journal.pone.0167259

Liu, J. C., Sheldon, P. J., & Var, T. (1987). Resident perception of the environmental impacts of tourism. *Journal of Travel Research*, 14(1), 17–37. https://doi.org/10.1177/004728758702600151

Lusseau, D. (2003a). Effects of tour boats on the behavior of bottlenose dolphins: Using Markov Chains to model anthropogenic impacts. *Conservation Biology*, 17(6), 1785–1793. https://doi.org/10.1111/j.1523-1739.2003.00054.x

Lusseau, D. (2003b). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress Series*, 257, 267–274. https://doi.org/10.3354/meps257267

Lusseau, D. (2006). The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. *Marine Mammal Science*, 22(4), 802–818. https://doi.org/10.1111/j.1748-7692.2006.00052.x

Lusseau, D., & Bejder, L. (2007). The long-term consequences of short-term responses to disturbance experiences from whalewatching impact assessment. *International Journal of Comparative Psychology*, 20(2). 228-236.

Lück, M. (2003). Education on marine mammal tours as agent for conservation - But do tourists want to be educated? *Ocean and Coastal Management*, 46(9–10), 943–956. https://doi.org/10.1016/S0964-5691(03)00071-1

Mattson, M. C., Thomas, J. A., & St. Aubin, D. (2005). Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters surrounding Hilton Head Island, South Carolina. *Aquatic Mammals*, 31(1), 133–140. https://doi.org/10.1578/am.31.1.2005.133

New, L. F., Harwood, J., Thomas, L., Donovan, C., Clark, J. S., Hastie, G., Thompson, P. M., Cheney, B., Scott-Hayward, L. & Lusseau, D. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. *Functional Ecology*, 27(2), 314–322. https://doi.org/10.1111/1365-2435.12052

Newsome, D., Dowling, R. K., & Moore, S. A. (2005). *Wildlife tourism* (Vol. 24). Channel View Publications. Bristol-UK.

Nowacek, D. P., Clark, C. W., Mann, D., Miller, P. J., Rosenbaum, H. C., Golden, J. S., Jasny, M., Kraska, J. & Southall, B. L. (2015). Marine seismic surveys and ocean noise: Time for coordinated and prudent planning. *Frontiers in Ecology and the Environment,* 13(7), 378–386. https://doi.org/10.1890/130286

O'Connor, S., Campbell, R., Cortez, H., & Knowles, T. (2009). Whale watching worldwide: tourism numbers, expenditures and expanding economic benefits. International Fund for Animal Welfare. Yarmouth MA, USA, Prepared by Economists at Large. Retrieved from http://www.wildfordolphins.com/Resources/PDF/IFAW09_whale watching worldwide.pdf

O'Hearn, G. T. (1982). What is the Purpose of Evaluation? *The Journal of Environmental Education*. 13(4). 1-3.

Orams, M. B. (1997). The effectiveness of environmental education: can we turn tourists into "greenies"? *Progress in Tourism and Hospitality Research*, 3(4), 295–306. https://doi.org/10.1002/(sici)1099-1603(199712)3:4<295::aid-pth85>3.3.co;2-4

Orams, M. B. (2000). Tourists getting close to whales, is it what whale-watching is all about? *Tourism Management,* 21(6), 561–569. https://doi.org/10.1016/S0261-5177(00)00006-6

Pierpoint, C., Allan, L., Arnold, H., Evans, P., Perry, S., Wilberforce, L., & Baxter, J. (2009).

Monitoring important coastal sites for bottlenose dolphin in Cardigan bay, UK. *Journal of the Marine Biological Association of the United Kingdom*, 89(5), 1033–1043. https://doi.org/10.1017/S0025315409000885

Pirotta, E., Merchant, N. D., Thompson, P. M., Barton, T. R., & Lusseau, D. (2015). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. *Biological Conservation*, 181, 82–89. https://doi.org/10.1016/j.biocon.2014.11.003

R Studio. Version 1.0.136 – © 2009-2016 RStudio, Inc.

Reynolds, P. C., & Braithwaite, D. (2001). Towards a conceptual framework for wildlife tourism. *Tourism Management*, 22(1), 31–42. https://doi.org/10.1016/S0261-5177(00)00018-2

Richardson, H. (2012). The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus*) of Cardigan Bay in Wales. MSc Thesis, University College London. pp 71.

Sekhar, N. U. (2003). Local people's attitudes towards conservation and wildlife tourism around Sariska Tiger Reserve, India. *Journal of Environmental Management*, 69(4), 339–347. https://doi.org/10.1016/j.jenvman.2003.09.002

Stamation, K. A., Croft, D. B., Shaughnessy, P. D., Waples, K. A., & Briggs, S. V. (2007). Educational and conservation value of whale watching. *Tourism in Marine Environments*, 4(1), 41–55. https://doi.org/10.3727/154427307784835660

Vaske, J. J., & Donnelly, M. P. (1999). A value-attitude-behavior model predicting wildland preservation voting intentions. *Society and Natural Resources*, 12(6), 523–537. https://doi.org/10.1080/089419299279425

Walker, R. (2018). Evaluating marine mammal watching legislation, regulation and codes of conduct. Wiunston Churchill Memorial Trust Report. pp 50.

White, P. C. L., Jennings, N. V., Renwick, A. R., & Barker, N. H. L. (2005). Questionnaires in ecology: A review of past use and recommendations for best practice. *Journal of Applied Ecology*, 42(3), 421–430. https://doi.org/10.1111/j.1365-2664.2005.01032.x

Williams, R., Bain, D. E., Smith, J. C., & Lusseau, D. (2009). Effects of vessel on behaviour patterns of individual southern resident killer whales *Orcinus orca*. *Endangered Species Research*, 6(3), 199–209. https://doi.org/10.3354/esr00150

Würsig, B. & Evans, P. G. H. (2001). Cetaceans and humans: influences of noise. Pp. 555-576. In: Marine Mammals: Biology and Conservation (Editors P.G.H. Evans and J.A. Raga).

Kluwer Academic/Plenum Press, London. pp 630.

CHAPTER VII

General discussion

The present study aimed to evaluate effects of recreational boating and dolphin-watching activities on the bottlenose dolphins inhabiting Cardigan Bay, in order to build scientific evidence that can be used towards a better management plan if needed, such as establishment of an area-based management, establishment of restricted zones, or setting a limit on the number of certain craft permitted during a dolphin encounter. Boat-based surveys, theodolite tracking using land-watches, passive acoustic monitoring, as well as social science surveys were used to examine dolphin presence and behavioural responses during boat encounters, together with marine users' perceptions about these activities and their potential impacts, to help shape future conservation strategies.

Impacts of recreational activities on wildlife

Outdoor recreation has been found to be increasing worldwide, whilst lack of compatibility with biodiversity conservation raises concerns. Recently, more studies have focused their efforts on understanding the interactions between human activities and animals, with strong evidence of negative impacts from recreation on animals (Larson et al., 2016). Additionally, main research has been interested in understanding short-term effects of such activities on individuals. Nonetheless, with the evidence of these activities being happening for long now, whilst they continue disturbing, more long-term effect of such interactions on the wildlife should be assessed.

The fact that different studies evaluating the effects of the interactions between wildlife and recreational activities have found opposite reactions, such as the case of Baird's beaked whale and minke whale in Tokyo Bay where individuals modified their migratory routes to avoid a heavily trafficked area (Nishiwaki & Sasao, 1977), whilst gray whales in California were found to be attracted to vessels and therefore would swim towards them before continuing on their original migration route (Heckel, 2001), denotes the importance of evaluating the characteristics of the interaction. This means that, although studies and management recommendations can usually be interpolated to other areas and species, there are many other factors cooperating in the interaction, and therefore they need to be taken into account when evaluating the effects of recreation on cetaceans and other wildlife.

Public interest in wildlife results in a demand for activities and infrastructure that allows people to be "in contact" with it, therefore it is important to evaluate the interactions and the recreational industry and ensure a sustainable development that can still bring socio-economic benefits, but will not endanger the species.

Bottlenose dolphin and recreational activities interactions

Given the great focus of research conducted on bottlenose dolphin population due to its coastal distribution allowing easy access for the studies, and due to the species being identified as a charismatic, intelligent and focus of not only scientific research but also of the general community, this study aimed to evaluate effects of human activities on the species in order to build scientific evidence that can be used towards a better management plan. A potential conflict occurs in Cardigan Bay between both recreational activities and dolphin-watching trips and the semi-resident bottlenose dolphin population (Chapter III). Evidence suggests that the dolphin population, particularly within the Cardigan Bay SAC, has decreased lately, with some animals emigrating permanently from Cardigan Bay (Feingold & Evans, 2014; Lohrengel et al., 2018). One possible reason is that these human activities are having a negative impact on the dolphins; Building upon past studies (Richardson, 2012; Hudson, 2014; Koroza, 2018), I investigated short-term effects of boats on dolphins to examine more closely interactions between them (chapter IV). Theodolite tracking was conducted of both dolphins and boats to assess vessel responses and dolphin behaviour during the moment of an encounter. Findings demonstrated negative dolphin reactions to boats, such as increase in swim speed and changes in swim direction to avoid vessels at Pen Llŷn a'r Sarnau SAC, where a boating code of conduct has only recently been in place. This does not tell if there is a long-term impact, nonetheless, given the negative behavioural findings due to vessel activity and having in mind that in the southern SAC a decrease in number of individuals has been proved, if the magnitude and the characteristics of the disturbance continue, there could be consequences at the population level. Therefore, spatial distribution, acoustic and energy budget analyses could inform us of potential long-term consequences, since how animals have distributed themselves might have been affected in the long-term by those human activities (Bejder, 2005; Bejder et al., 2006; Lussean, 2004; Lusseau, 2003; Williams et al., 2006; chapters III and V), whilst changes in energy intake could have consequences for individual fitness and in the long-term in reproduction and survival. Using vessel-based surveys and acoustic techniques to evaluate dolphin presence and foraging activities showed that, in the long-term, dolphin presence varies in response to different boat types, with foraging behaviour decreasing during the vessel encounter.

Cardigan Bay and the bottlenose dolphin – recreational activities interactions

In Cardigan Bay SAC, particularly around New Quay, bottlenose dolphins appear to find favourable conditions and recognised animals remain there year-round (Simon et al., 2010; Nuuttila et al., 2017). Nonetheless, there are dolphin short-term reactions to boats in the area, as found by Koroza (2018) and Lohrengel et al. (2018), similar to those observed by Pirotta et al., (2015) in the Moray Firth SAC in North-east Scotland, where there is evidence of disturbance, whilst dolphin numbers remain the same. Thus, it is thought that recognised animals are still in the New Quay area despite any vessel disturbance because the area provides good feeding opportunities (Lopes, 2017), and resident individuals have learned to tolerate vessels and live with the human activity. Some individuals display more positive reactions to certain boats than others, particularly to regular vessels to which the dolphins have become habituated (Koroza, 2018), which might still have an effect on their behaviour, but this is overridden by their desire to be there. Over the wider part of Cardigan Bay SAC, mark-recapture analysis indicates that the dolphin population is declining, with some animals that had been resident in the area for several years leaving it permanently (Lohrengel et al., 2018), perhaps because of too much pressure from boats away from sites where the code of conduct is followed, or because food availability may not be sufficient.

In the widest part of Cardigan Bay, encompassing Pen Llŷn a'r Sarnau SAC, the population also appears to have declined and that too may be due to increased boat disturbance or lack of food. In northern Cardigan Bay, vessels did not follow the boating code of conduct (little compliance) and there was more evidence of a disturbance effect (chapters III and IV). In contrast, in the vicinity of New Quay itself, vessels followed the boating code of conduct (compliance is very high- Koroza, 2018), further away in the SAC it is recorded as lower (Pierpoint et al., 2009), whilst it is clear that dolphin-watching operators comply better than the normal recreational vessel users. In northern Cardigan Bay, where there is no tradition of commercial dolphin-watching boats, and the majority of boats are recreational (speedboats and jet skis), there is little compliance and there is evidence they are causing disturbance on the dolphins there (chapters III and IV). Although from this study, it remains impossible to show that bottlenose dolphin numbers have declined in the area due to boat activity, there is evidence that boat activity is having negative impacts on the dolphins, and that may be one of the factors causing some of the dolphins to move away.

There is indication that female dolphins use Cardigan Bay to give birth and nurse their calf through the first year of life (Duckett, 2018). The shallowness of the area means that mothers do not have to leave the calf unattended for long whilst going to the seabed to feed. This also means that the area is an appropriate place for the calf to learn to dive. Therefore, the area provides advantages as a birthing and nursing ground, particularly if there is predictable food around the coast (Evans et al., 2001; Baines & Evans, 2012). It could be that some food resources become over exploited and disappeared, and therefore this is causing the dolphins to move away to try to find their prey elsewhere (Bear, 2014). Also, since it is known that females tend to stay with their calves only for one or two years, after that they may disperse to somewhere else or range over a wider area. The nature of the dynamic of the species in Cardigan Bay, this is resident and transient individuals, could account for why more transient dolphins are less habituated to individual boats and are more likely to respond negatively to this disturbance.

In chapter III it is shown that areas of high boat density overlap with the distribution of the bottlenose dolphins in Cardigan Bay, but where there was direct overlap, fewer individuals were present, indicating that human activities are reducing the available habitat for them, which in turn may have greater implications in the long-term. Additionally, positive dolphin responses seeing in the vicinity of New Quay suggest that management guidelines there seem to be working, whilst negative responses found in Pen Llŷn a'r Sarnau SAC indicate the need for better management compliance there. Combined, these outcomes show that frequent boat activity decreases dolphin presence in the whole of Cardigan Bay, evidencing the need for further management assessments and recommendations, such as establishment of an area-based management, establishment of restricted zones, or setting a limit on the number of certain craft permitted during a dolphin encounter.

Moreover, results show differences in boat responses between SACs, with boats keeping greater distances from dolphins irrespective of boat type in Cardigan Bay SAC where a long-standing code of conduct has been running, whereas at Pen Llŷn a'r Sarnau SAC, a recently code of conduct established site, speed craft came closer to dolphins than other boats. At both sites, dolphins remained present during periods of high vessel traffic, but with a significant increase in swim speeds and larger number of dolphins at the recent code of conduct established site, as well as movements directly away from vessels. Additionally, the current study shows that the quantity of boats interacting with dolphins does not seem to have a significant effect on the reactions by dolphins when in an encounter but is more influenced by the behaviour that those boats display, such as travel speed and direction (Chapter IV).

In the southern SAC, where there is a long-lasting boating code of conduct, although different sites within it display different levels of compliance to the management guidelines (Pierpoint et al., 2009), results show increased bottlenose dolphin presence and foraging activity when boats are around, perhaps due to dolphin habituation to vessels. In addition, when looking at boat passage-time at a finer scale, neutral responses found at New Quay (where there is greatest compliance to the code of conduct within Cardigan Bay SAC) suggest that adherence to management guidelines seem to be working, whilst decreased on dolphin presence as response to boats at sites with low code of conduct compliance within the SAC indicate that management guidelines could be improved. Therefore, dolphins maintain occupancy at a site with high code of conduct compliance, contrary to a reduction at other sites (less compliance) but decreased their foraging behaviour between boat arrival and departure at all sites within Cardigan Bay SAC. These findings highlight the importance of enforcing regulations, supporting dolphin conservation alongside a sustainable tourism industry (Chapter V).

Information gathered from people’s knowledge and perceptions of the bottlenose dolphin population together with the human activities in Cardigan Bay suggest the need of greater awareness of boating codes of conduct to protect the species throughout Cardigan Bay. There should be attention focused upon recreational users, particularly in northern Cardigan Bay, since, being a numerous group, and usually not resident, they are a more difficult sector to reach and engage with. Although greater effort is needed to engage with them, they should be a priority in this northern SAC. In the southern SAC, the amount of commercial dolphin-watching probably needs to continue being monitored closely, because even though at the moment these vessels do not seem to have an impact, they may do so in the long-term as the number of dolphin watching trips continues to increase (chapter VI). Consequently, improved education and awareness amongst recreational users is needed, including for example, the installation of noticeboards explaining the boating code of conduct and providing information on how to behave around dolphins. Potential sites include New Quay, Aberporth, Aberystwyth, Barmouth, Pwllheli Marina, and Abersoch, where there is a high vessel traffic. To improve compliance to the boating code of conduct in the area, operation of wardens would be helpful, since there is a need for policing whilst ensuring compliance. There also remains some scope for improved compliance to the boating code of conduct even among commercial dolphin-watching operators. Regarding the present code of conduct guidelines, vessel travel speed is not the only issue of concern; it should include a more specific behavioural response from boats around the animals to mitigate harassment (Chapter IV). There is also need for users to recognise different dolphin behaviours to better understand how to react to their responses, which can presumably be reached by environmental education.

Study limitations and suggestions for future work

Future research should aim to improve the analyses regarding the characteristics of individual boats in order to assess possible effects that regular boats (notably visitor passenger vessels) might trigger. For example, analysis of engine noise could be an important parameter to have in mind when evaluating effects of boat on dolphin behaviour. Furthermore, analysis of individual/specific responses to certain recognisable vessels should be implemented to evaluate whether certain boats with unusual travel behaviour have a greater impact on the dolphins. Consequently, further acoustic assessment together with visual techniques should be implemented in order to evaluate effects of specific vessels, as well as their physical presence, and not solely the noise of those vessels.

Additional analysis of bottlenose dolphin behaviour could be implemented to assess further short-term and long-term effects of disturbance: further dive duration, synchrony as well as mother and calf analyses could improve knowledge towards the analysis of longer-term consequences of disturbance. Additional assessment of behaviour patterns, including evaluating behavioural budgets and modifications to energy intake, could improve knowledge of long-term impacts from continuous short-term effects, not only in New Quay but also in the wider area, taking account of the fact that the population includes a mixture of transient, semi-resident and resident animals.

Finally, the development of further client questionnaires on board of more than one commercial vessel to assess how people respond based on their experiences could improve our knowledge of people's perceptions and their conservation awareness. Further recreational user questionnaires aiming at participants across the wider Cardigan Bay area could improve our understanding of people's knowledge, perceptions and adherence to local boating codes of conduct, since dolphin travel along the whole bay and disturbance at other sites may cause impact in different areas within it.

The bottlenose dolphin population of Cardigan Bay is a nationally important wildlife attraction, bringing large numbers of visitors to the region and generating significant income as well as providing jobs. Human pressures from those activities are likely to increase, and therefore it is important that appropriate management measures are put in place throughout the region to mitigate any negative effects. Raising awareness, education and guidance alongside enforcement of compliance to boating codes of conduct, perhaps with the implementation of an area-based management, will go a long way to ensuring a sustainable dolphin watching activity alongside a healthy bottlenose dolphin population.

Conclusions

Overall, the findings of this study show that the management plan operating around New Quay appears to be effective, and therefore similar management guidelines should be established at a wider scale and not only within SACs. An area-based management scheme could improve conservation efforts, emphasising a reduction in boat speeds and modification of boat behaviour (i.e. avoiding direct approach to dolphins), and promoting species conservation alongside a viable ecotourism-industry, thus seeking sustainable development that can provide gains in biodiversity and human livelihoods across the whole of Cardigan Bay.

Boating codes of conduct can be effective if they are monitored and complied with, but education is important, particularly for recreational users. Without this, such measures are less likely to be effective, as shown by the negative responses of dolphins to boats in Pen Llŷn a'r Sarnau (where the boating code of conduct was established in 2016 and there is less awareness by users). If codes of conduct become well established and followed, they will not only help the bottlenose dolphin population by reducing disturbance and potential short- and long-term effects but will also facilitate a sustainable wildlife watching industry.

7.1 References

Baines, M. E., & Evans, P. G. H. (2012). Atlas of the Marine Mammals of Wales. CCW Monitoring Report No. 68 (2nd edition). pp 143.

Bear, C. (2014). Governance of the seas: a more-than-human perspective on the Cardigan Bay scallop fishery. In Water Worlds: Human Geographies of the Ocean. *Taylor & Francis*.

Bejder, L. (2005). Linking short and long-term effects of nature-based tourism on cetaceans. PhD Thesis, Dalhousie University, Halifax, Canada.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C. & Kruetzen, M. (2006). Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. *Conservation Biology*, 20(6), 1791–1798. https://doi.org/10.1111/j.1523-1739.2006.00540.x

Duckett, A. (2018). Cardigan Bay bottlenose dolphin *Tursiops truncatus* connectivity within and beyond marine protected areas. MSc Thesis, University of Bangor. pp 76.

Evans, P. G. H., Baines, M. E. & Shepherd, B. (2001). Bottlenose dolphin prey and habitat sampling trials in Cardigan Bay. Report for the Countryside Council for Wales. Sea Watch Foundation, Oxford. pp 67.

Feingold, D. & Evans, P. G. H. (2014). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation 2011-2013. Natural Resources Wales Evidence Report Series No. 4. pp 124.

Heckel, G. (2001). The influence of whalewatching on the behaviour of gray whales (*Eschrichtius robustus*) in Todos Santos Bay, Baja California, and surrounding waters: Management plan proposal. *Journal of Cetacean Research and Management*, 3(3), 227–237.

Hudson, T. (2014). Bottlenose dolphin (*Tursiops truncatus*) responses to vessel activities in New Quay Bay. MSc Thesis, University of Bangor. pp 79.

Koroza, A. A. (2018). Habitat use and effects of boat traffic on bottlenose dolphins at New Quay Harbour, Cardigan Bay. MSc Thesis, University of Bangor. pp 93.

Larson, C. L., Reed, S. E., Merenlender, A. M., & Crooks, K. R. (2016). Effects of recreation on animals revealed as widespread through a global systematic review. *PLoS ONE*, 11(12): e0167259. doi:10.1371/journal.pone.0167259

Lohrengel, K., Evans, P. G. H., Lindenbaum, C. P., Morris, C. W. & Stringell, T. B. (2018). Bottlenose dolphin and harbour porpoise monitoring in Cardigan Bay and Pen Llŷn a'r Sarnau Special Areas of Conservation, 2014-17. Natural Resources Wales Evidence Report No: 191. pp 154.

Lopes, K. C. F. (2017). Habitat preference of bottlenose dolphin (*Tursiops truncatus*) in Cardigan Bay. MSc Thesis, University of Bangor. pp 54.

Lusseau, D. (2003). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. Marine *Ecology Progress Series*, 257, 267–274. https://doi.org/10.3354/meps257267

Lusseau, D. (2004). The hidden cost of tourism: Detecting long-term effects of tourism using behavioral information. *Ecology and Society*, 9(1). https://doi.org/10.5751/es-00614-090102

Nishiwaki, M., & Sasao, A. (1977). Human activities disturbing natural migration routes of whales. *Scientific Reports of the Whales Research Institute Tokyo*, 29, 113–120.

Nuuttila, H. K., Courtene-Jones, W., Baulch, S., Simon, M., & Evans, P. G. H. (2017). Don't forget the porpoise: acoustic monitoring reveals fine scale temporal variation between bottlenose dolphin and harbour porpoise in Cardigan Bay SAC. Marine Biology, 164(3), 50. https://doi.org/10.1007/s00227-017-3081-5

Pierpoint, C., Allan, L., Arnold, H., Evans, P., Perry, S., Wilberforce, L., & Baxter, J. (2009). Monitoring important coastal sites for bottlenose dolphin in Cardigan Bay, UK. *Journal of the Marine Biological Association of the United Kingdom*, 89(5), 1033–1043. https://doi.org/10.1017/S0025315409000885

Pirotta, E., Harwood, J., Thompson, P. M., New, L., Cheney, B., Arso, M., Hammond, P. S., Donovan, C. & Lusseau, D. (2015). Predicting the effects of human developments on individual dolphins to understand potential long-term population consequences. *Proceedings of the Royal Society B: Biological Sciences*, 282(1818). https://doi.org/10.1098/rspb.2015.2109

Richardson, H. (2012). The effect of boat disturbance on the bottlenose dolphin (*Tursiops truncatus*) of Cardigan Bay in Wales. MSc Thesis, University College London. pp 71.

Simon, M., Nuuttila, H., Reyes-Zamudio, M. M., Ugarte, F., Verfuß, U., & Evans, P. G. H. (2010). Passive acoustic monitoring of bottlenose dolphin and harbour porpoise with implications for habitat use and partitioning. *Journal of the Marine Biological Association of the United Kingdom*, 90: 1539-1546.

Williams, R., Lusseau, D., & Hammond, P. S. (2006). Estimating relative energetic costs of human disturbance to killer whales (*Orcinus orca*). *Biological Conservation*, 133(3), 301–311. https://doi.org/10.1016/j.biocon.2006.06.010

Supplementary material

8.1 Models validation

8.1.1 Chapter III

8.1.1.1 Short-term analyses

- M2<-gam(Dolphins~offset(log(Effort))+s(LND)+SC, family=gaussian, data=stats)

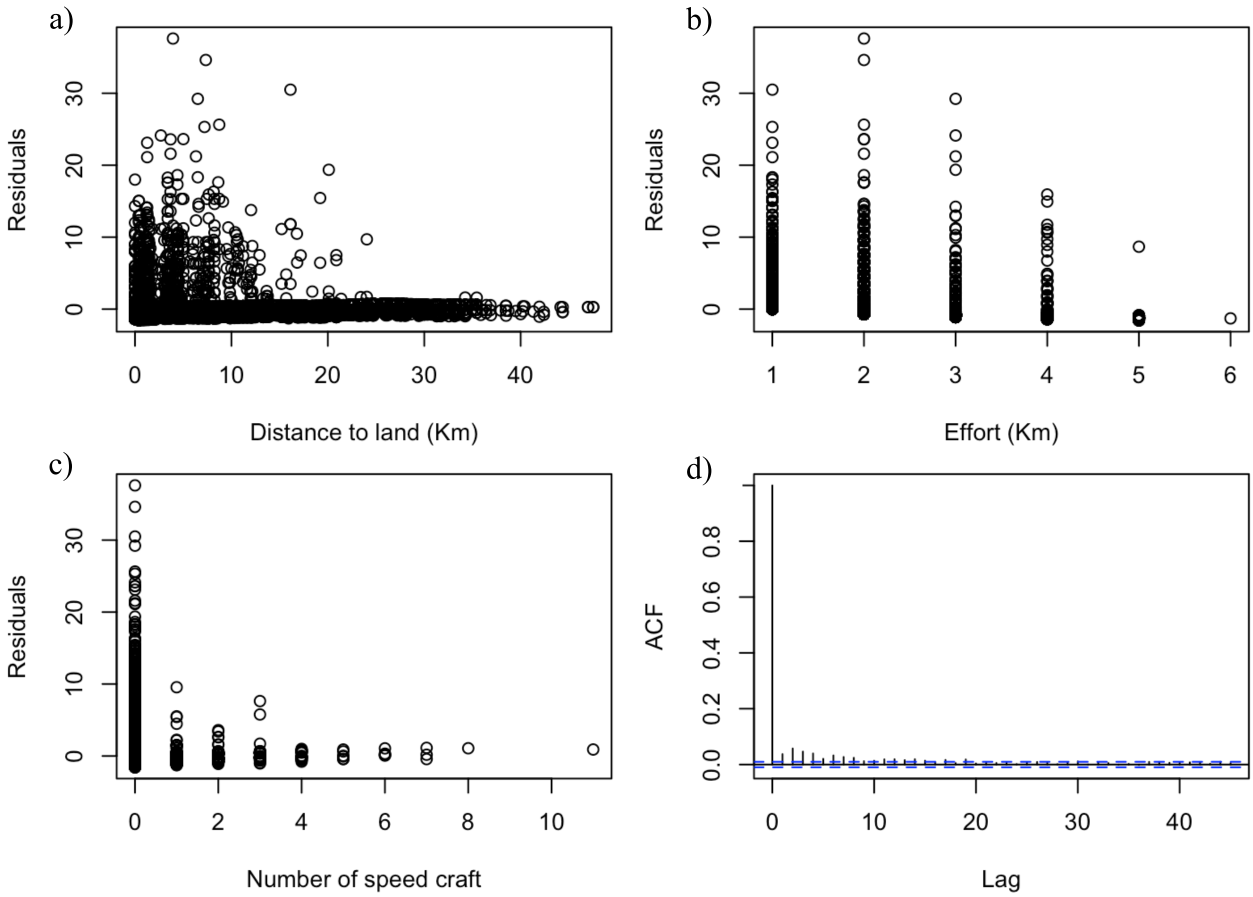


Figure S1 Model validation graphs. a) Distance to land (Km) versus residuals. b) Effort (Km) versus residuals. c) Number of speed craft versus residuals. d) Correlation of model residuals as a function of time (sequence of surveys).

8.1.1.2 Long-term analyses

- M2<-gam(Dolphinsm~FIm+s(LND)+offset(log(Effort))+AREA, family=gaussian, data=data)

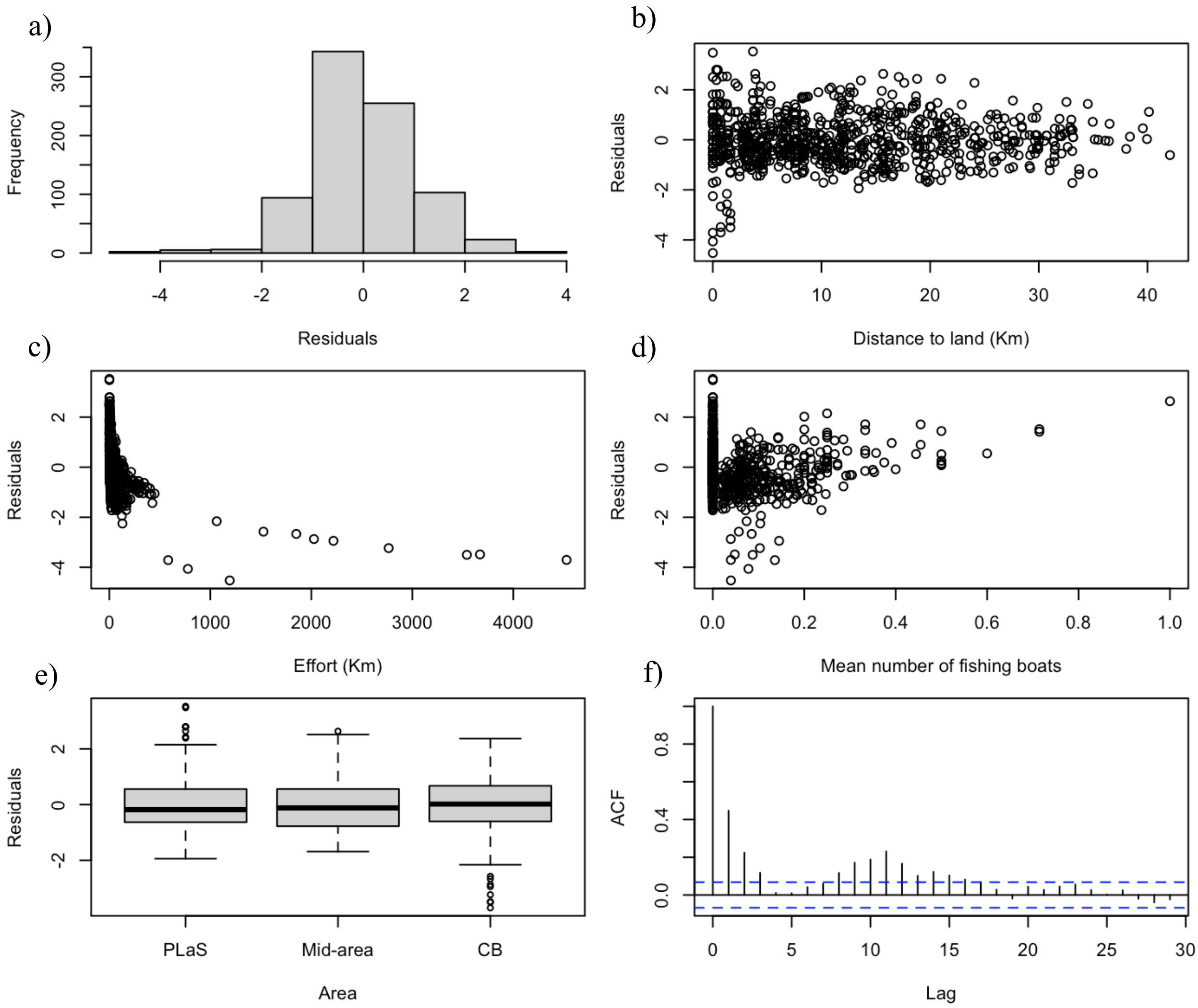


Figure S2 Model validation graphs. a) Histogram of the residuals (normality). b) Distance to land (Km) versus residuals. c) Effort (Km) versus residuals. d) Mean number of fishing boats versus residuals. e) Area versus residuals. f) Correlation of model residuals as a function of time (sequence of surveys).

- M2<-gam(Dolphinsm~QCm+s(LND)+offset(log(Effort))+AREA, family=gaussian, data=data)

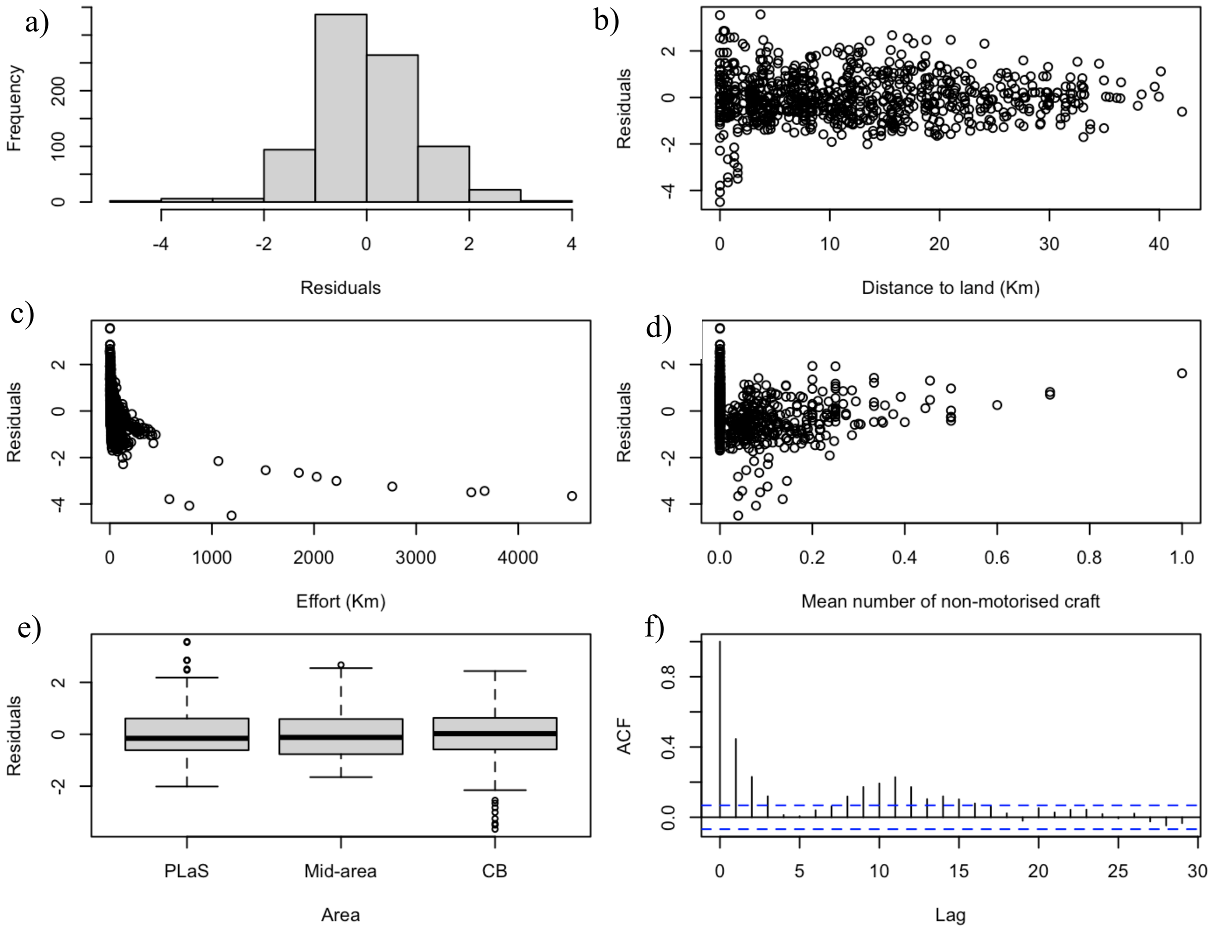


Figure S3 Model validation graphs. a) Histogram of the residuals (normality). b) Distance to land (Km) versus residuals. c) Effort (Km) versus residuals. d) Mean number of non-motorised craft versus residuals. e) Area versus residuals. f) Correlation of model residuals as a function of time (sequence of surveys).

- M2<-gam(Dolphinsm~MCm+s(LND)+offset(log(Effort))+AREA, family=gaussian, data=data)

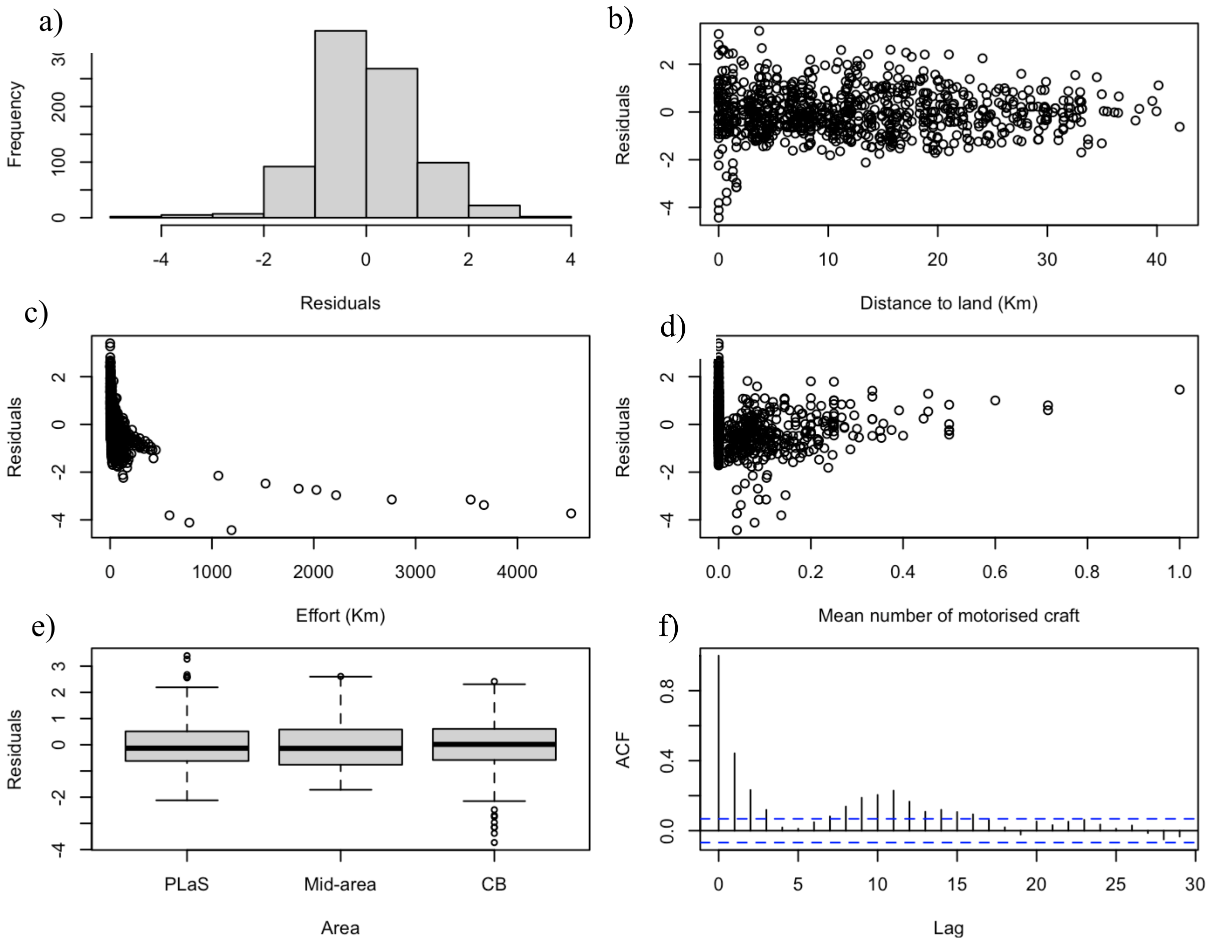


Figure S4 Model validation graphs. a) Histogram of the residuals (normality). b) Distance to land (Km) versus residuals. c) Effort (Km) versus residuals. d) Mean number of motorised craft versus residuals. e) Area versus residuals. f) Correlation of model residuals as a function of time (sequence of surveys).

- M2<-gam(Dolphinsm~SCm+s(LND)+offset(log(Effort)), family=gaussian, data=data)

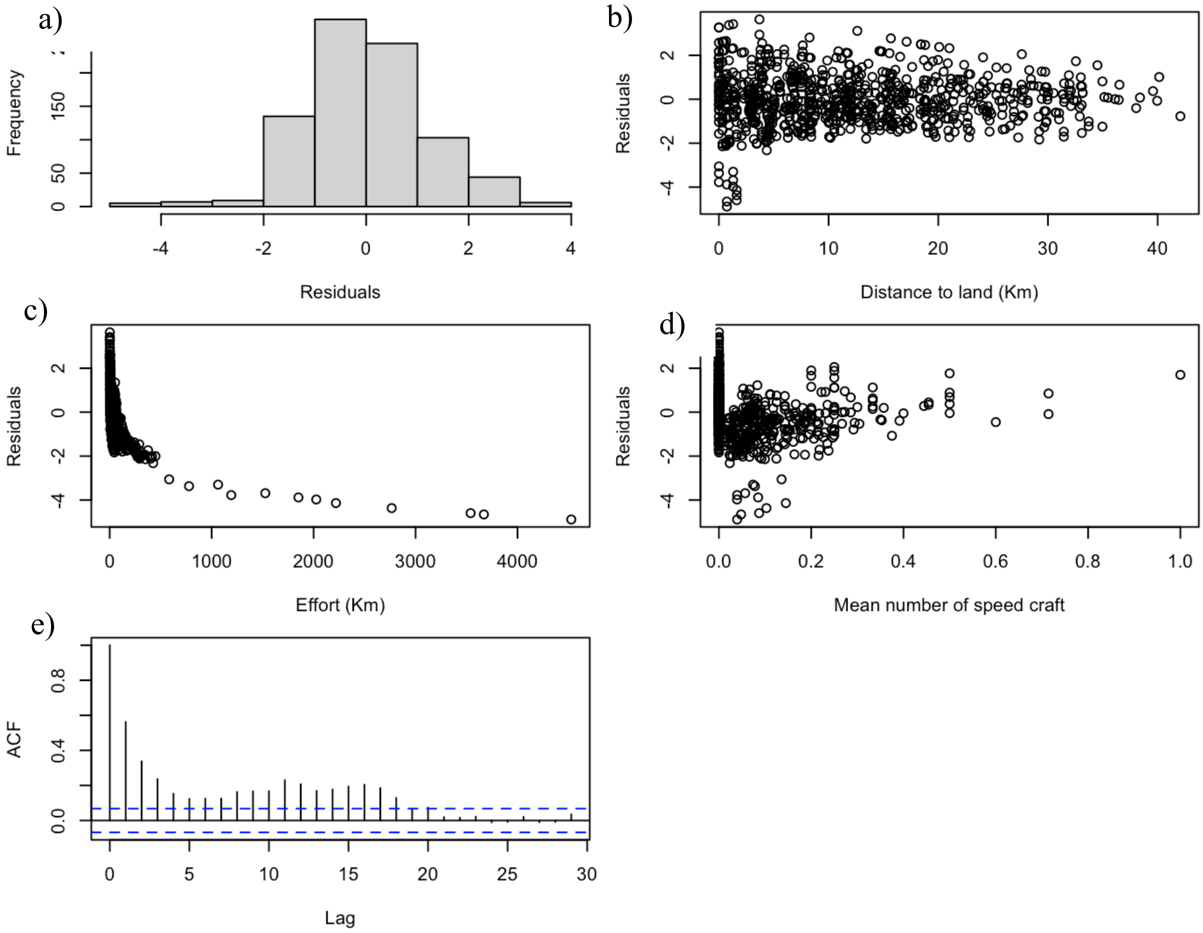


Figure S5 Model validation graphs. a) Histogram of the residuals (normality). b) Distance to land (Km) versus residuals. c) Effort (Km) versus residuals. d) Mean number of speed craft versus residuals. e) Correlation of model residuals as a function of time (sequence of surveys).

8.1.2 Chapter IV

8.1.2.1 Boat

- Distance boat-dolphin

M1<-glm(data$Dist_between_D_B.m.~data$LOCATION, family=quasipoisson)

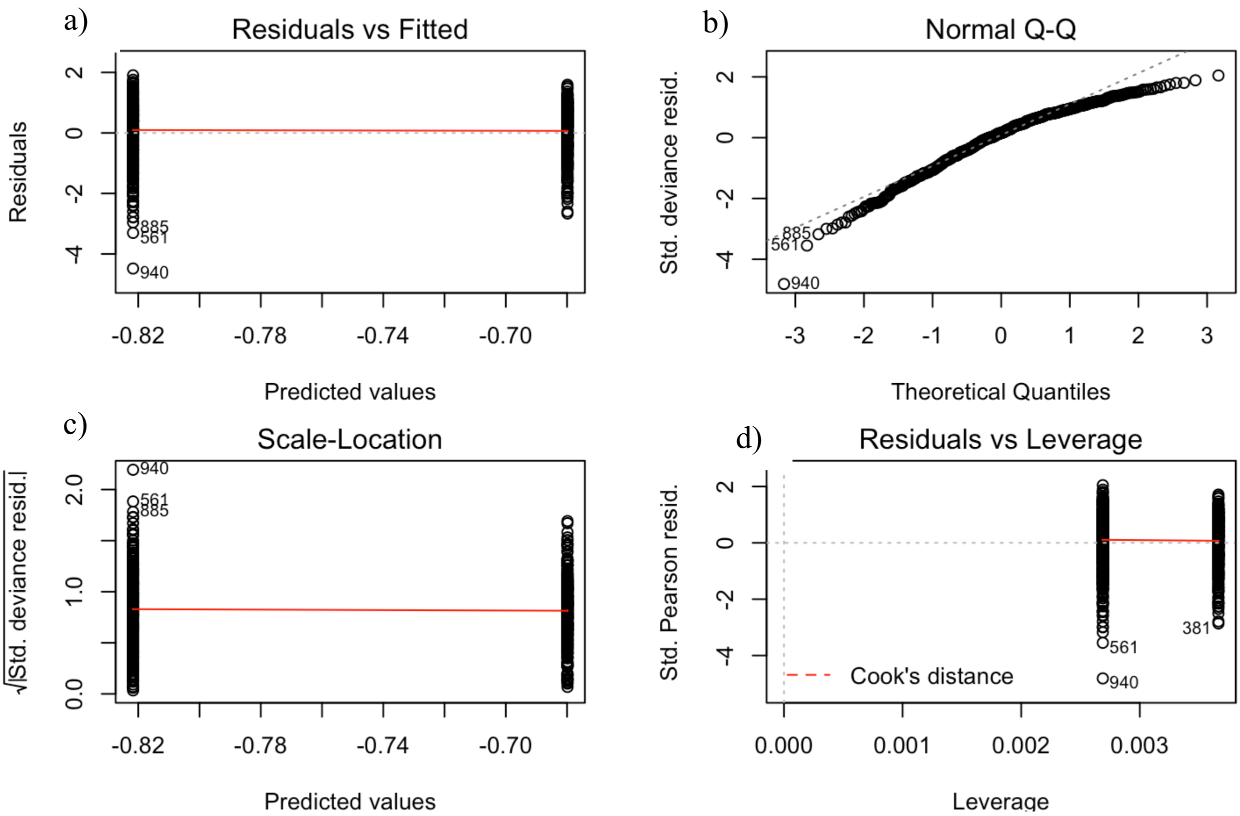


Figure S6 Model validation graphs. a,c) Fitted values versus residuals (homogeneity). b) QQ-plot (normality). d) Leverage versus standardised residuals and Cook statistic.

- Boat travel speed

M2<-glm(log(data$Speed_.m.sec._B)~data$LOCATION, family=gaussian)

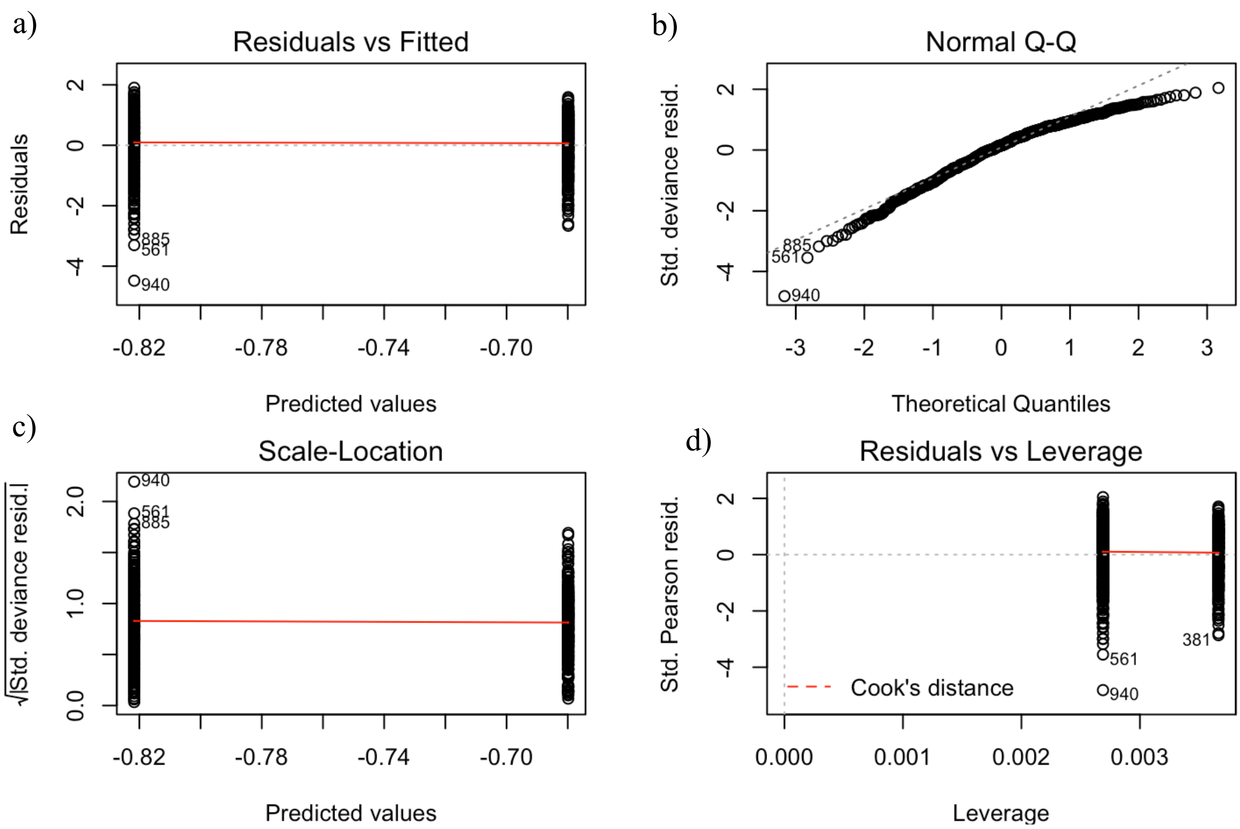


Figure S7 Model validation graphs. a,c) Fitted values versus residuals (homogeneity). b) QQ-plot (normality). d) Leverage versus standardised residuals and Cook statistic.

8.1.2.2 Dolphin

- Dolphin swim direction

```
M1 <- gam(DIRECTION_D_ii~Speed_.m.sec._B+DIRECTION_B_ii+s(ENC, bs="re"),
data=data, family=gaussian)
```

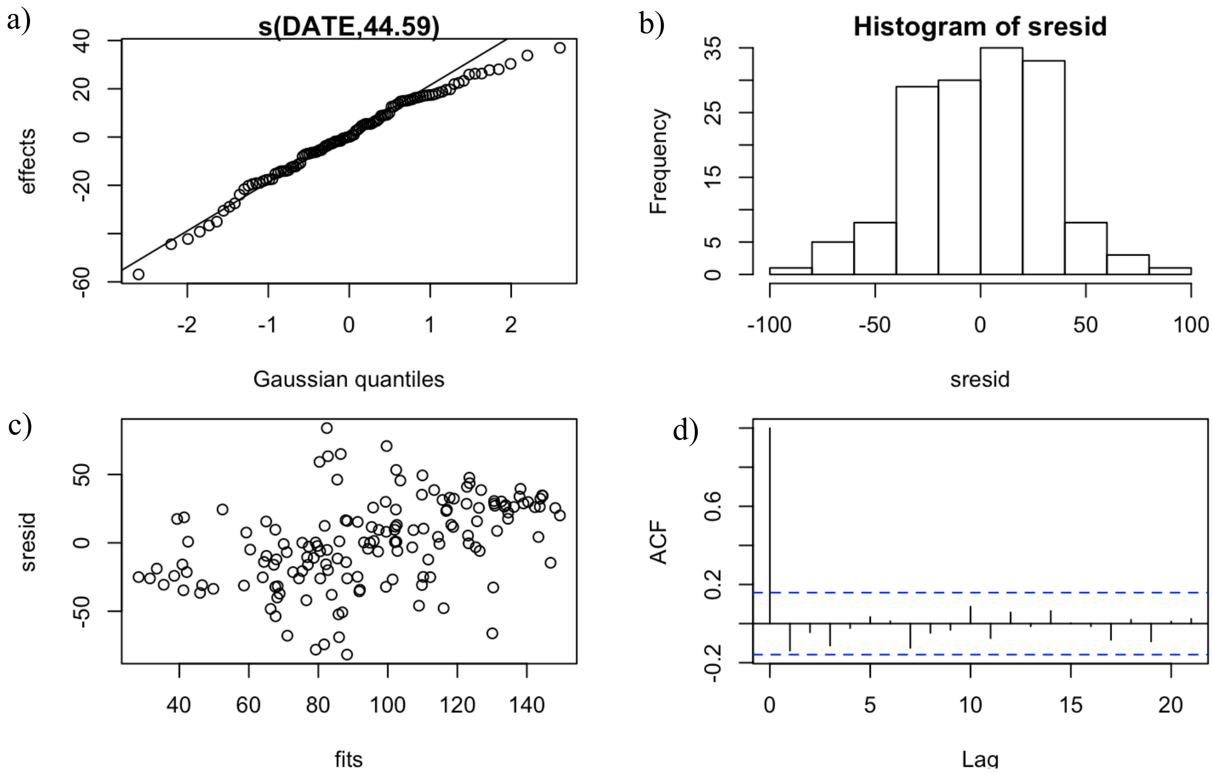


Figure S8 Model validation graphs. a) QQ-plot (normality). b) Histogram of the residuals (normality). c) Fitted values versus residuals (homogeneity). d) Correlation of model residuals as a function of time (sequence of surveys).

- Dolphin swim speed

```
M2 <- gam(Speed_.m.sec._D~Speed_.m.sec._B+DIRECTION_B_ii+
Dist_between_D_B.m.+s(ENC, bs="re"), family=gaussian, data=data)
```

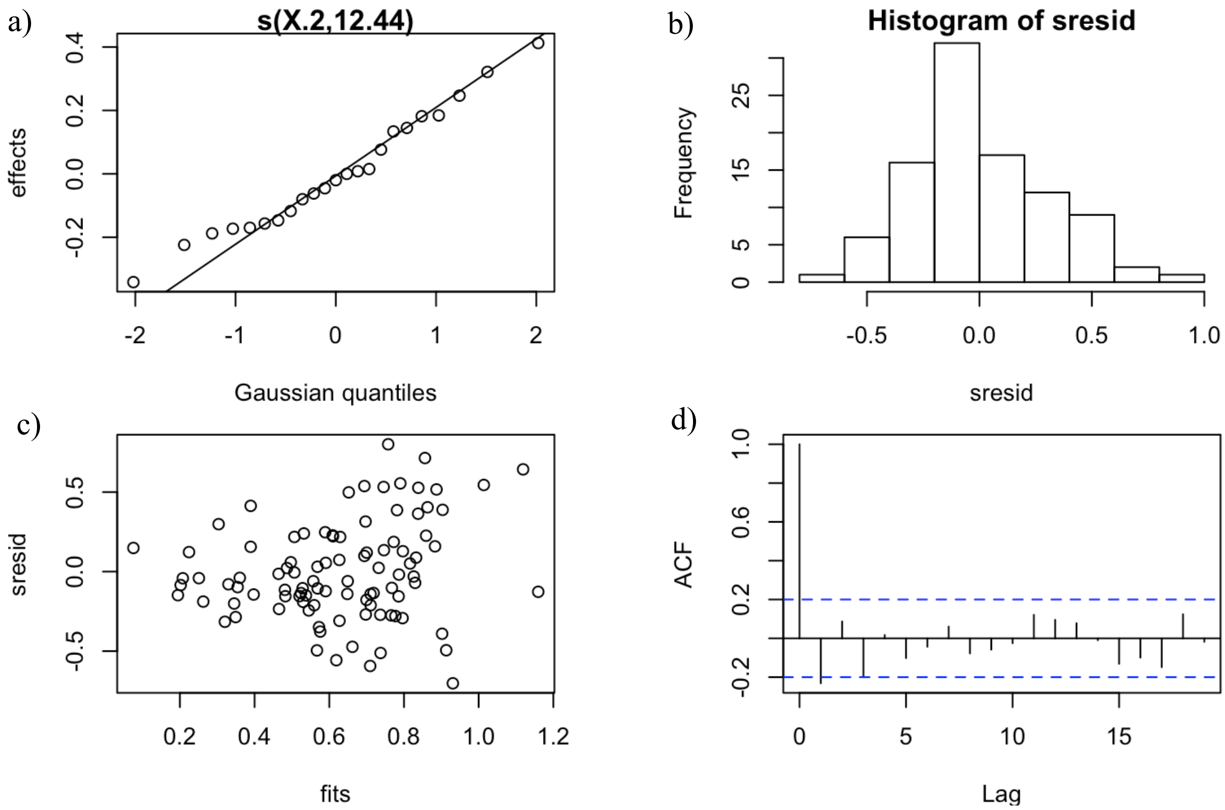


Figure S9 Model validation graphs. a) QQ-plot (normality). b) Histogram of the residuals (normality). c) Fitted values versus residuals (homogeneity). d) Correlation of model residuals as a function of time (sequence of surveys).

- Dolphin abundance

M3<-gam(DOLPHINS_.n.~Speed_.m.sec._B+B_DIR_i+BOAT_CAT+LOCATION+NUMBER_BOATS+s(ENC, bs="re"), data=data, family=gaussian)

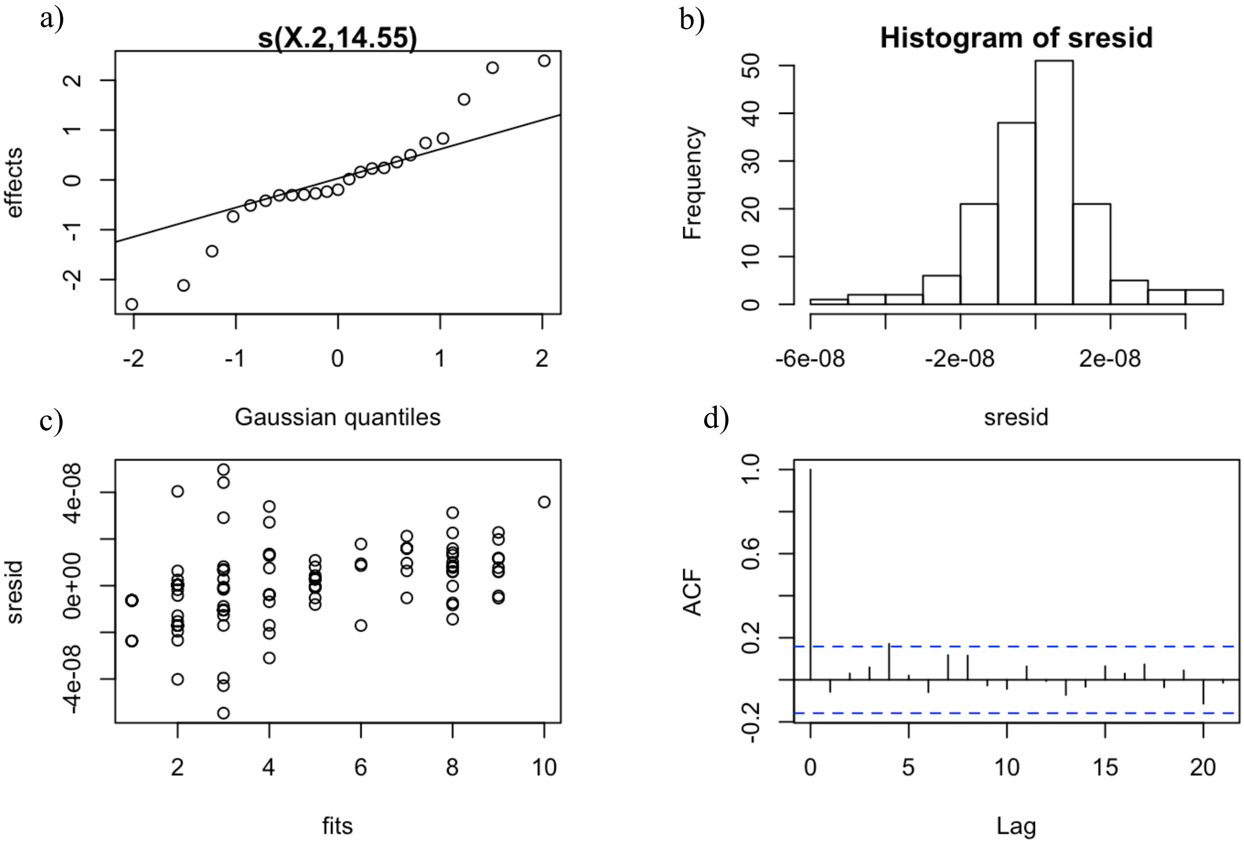


Figure S10 Model validation graphs. a) QQ-plot (normality). b) Histogram of the residuals (normality). c) Fitted values versus residuals (homogeneity). d) Correlation of model residuals as a function of time (sequence of surveys).

8.1.3 Chapter V

8.1.3.1 Dolphin clicks

- M1<- glm(Click ~ Site *Bt, data=data, family=binomial)

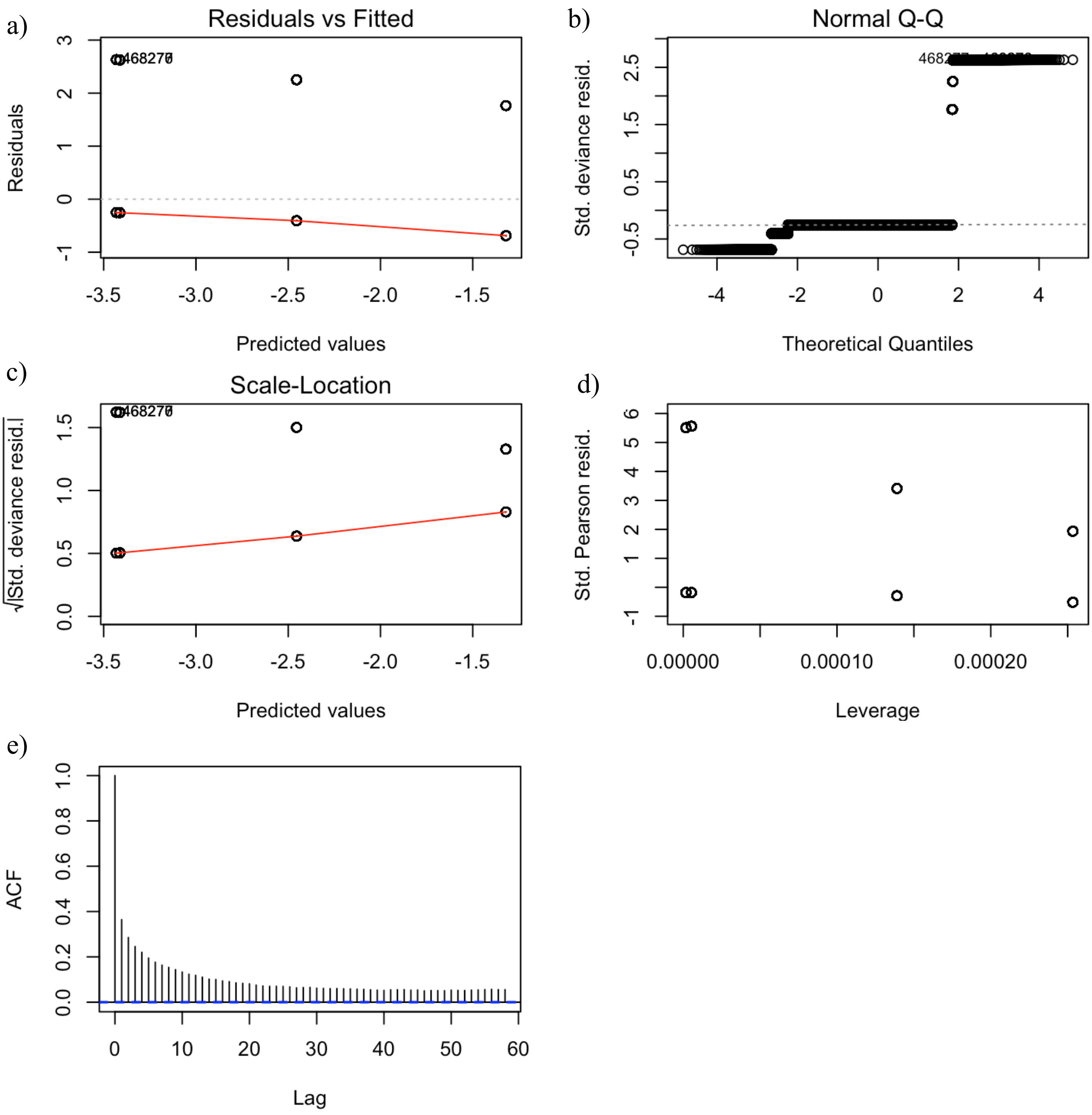


Figure S11 Model validation graphs. a,c) Fitted values versus residuals (homogeneity). b) QQ-plot (normality). d) Leverage versus standardised residuals and Cook statistic. e) Correlation of model residuals as a function of time (sequence of surveys).

- M2<- glm(Click ~ Site *BtTP, data=data, family=binomial)

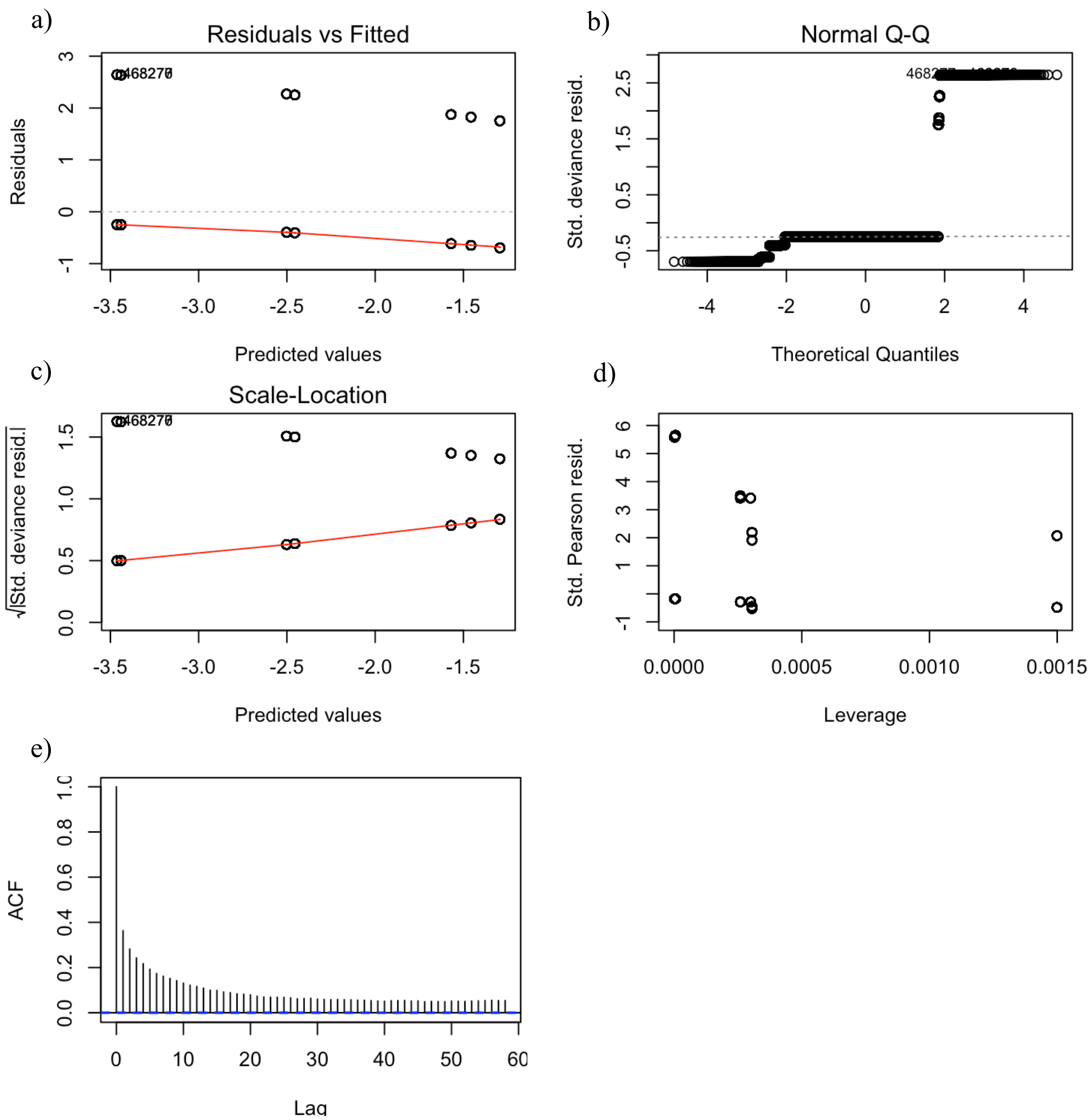


Figure S12 Model validation graphs. a,c) Fitted values versus residuals (homogeneity). b) QQ-plot (normality). d) Leverage versus standardised residuals and Cook statistic. e) Correlation of model residuals as a function of time (sequence of surveys).

8.1.3.2 Dolphin buzzes

- M1<- glm(Buzz ~ Site +Bt, data=data, family=binomial)

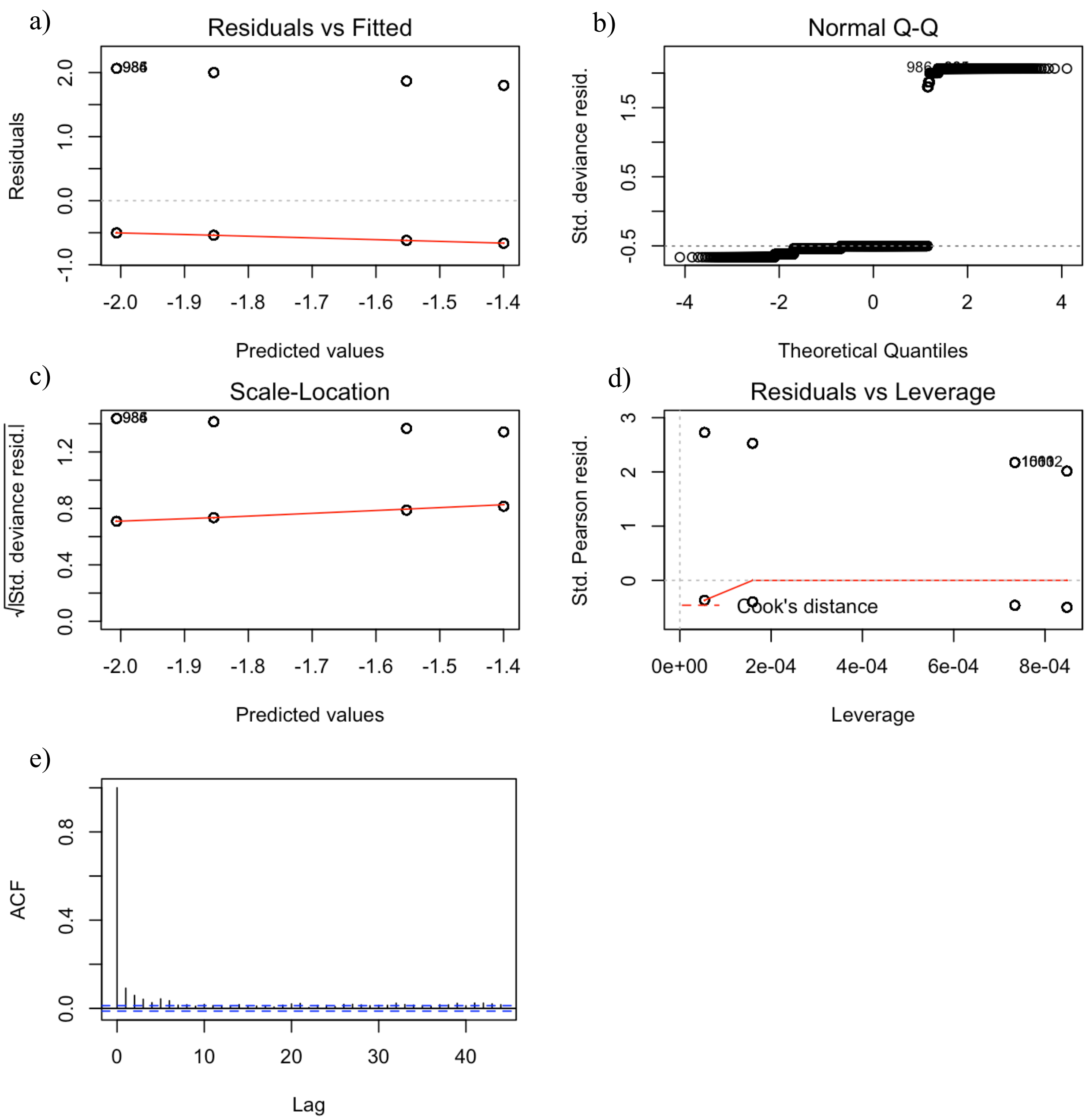


Figure S13 Model validation graphs. a,c) Fitted values versus residuals (homogeneity). b) QQ-plot (normality). d) Leverage versus standardised residuals and Cook statistic. e) Correlation of model residuals as a function of time (sequence of surveys).

- M2<- glm(Buzz ~ Site+BtTP, data=data, family=binomial)

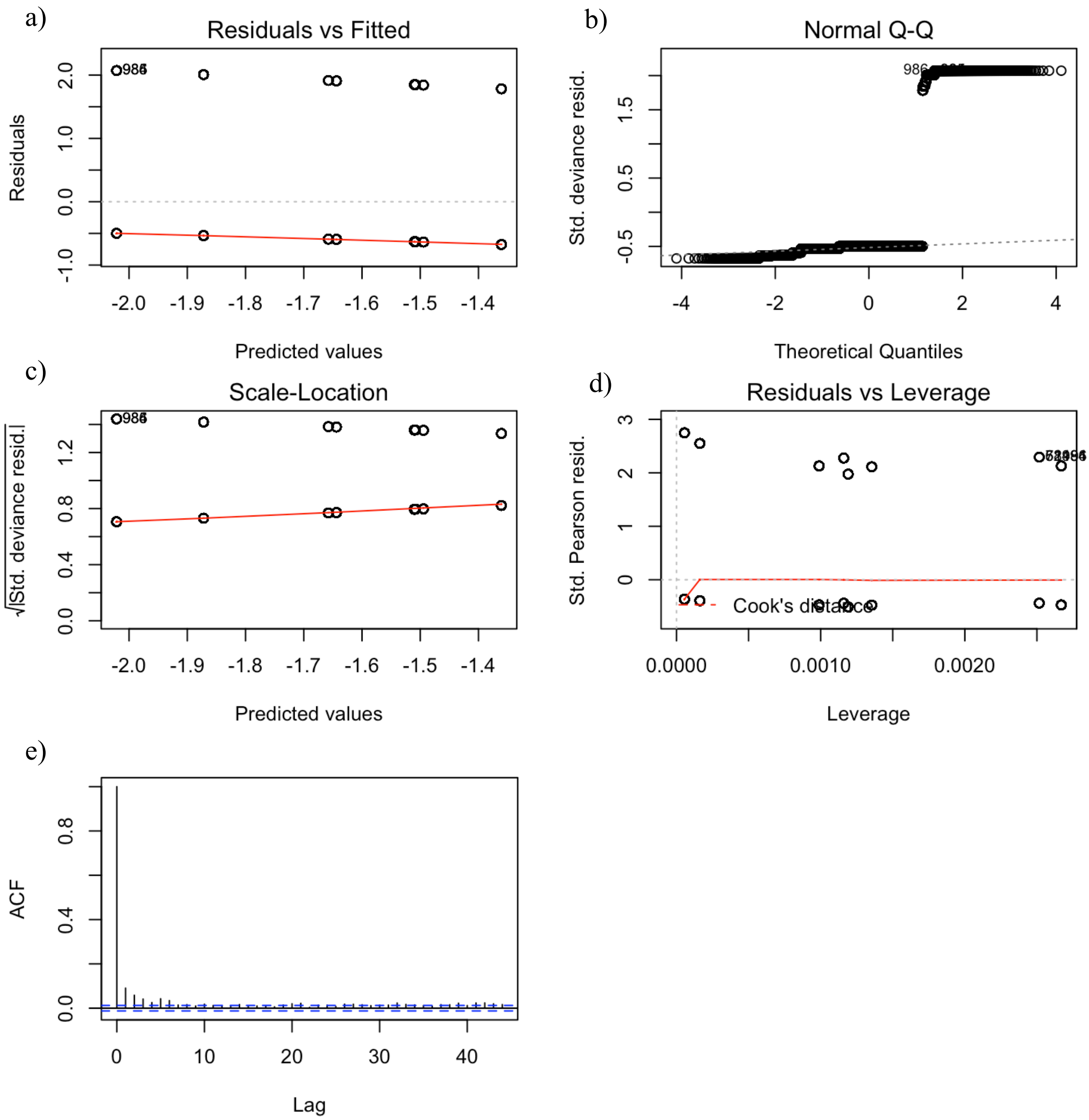


Figure S14 Model validation graphs. a,c) Fitted values versus residuals (homogeneity). b) QQ-plot (normality). d) Leverage versus standardised residuals and Cook statistic. e) Correlation of model residuals as a function of time (sequence of surveys).

8.2 Recreational user questionnaire

QUESTIONNAIRE TO RECREATIONAL USERS

To recreational user

My name is Alejandra Vergara-Peña. I am researcher at Bangor University in collaboration with Sea Watch Foundation. The purpose of this study is to evaluate and to describe the recreational use of Cardigan Bay in West Wales, to establish user needs and behaviour, to integrate them into bottlenose dolphin conservation. You are invited to participate in this research project because you visit Cardigan Bay and may have encountered bottlenose dolphins in the area.

Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this survey, you can withdraw at any time. The survey contains 23 questions, which will take a short time to complete. Your responses are anonymous and confidential. Results from the survey will be collated at Bangor University. If you have any questions about the research study, please contact Alejandra Vergara-Peña (elp2ae@bangor.ac.uk, 01248388501).

Thank you for helping me with my PhD research,

Alejandra Vergara-Peña
PhD student
Bangor University
https://www.bangor.ac.uk/oceansciences/staff/phd-students/alejandra-vergara-pena

Supervisors' details:

Line Cordes,
+44 (0)1248 383503
l.cordes@bangor.ac.uk

John Turner
+44 (0)1248 382881
j.turner@bangor.ac.uk

Peter Evans

peter.evans@bangor.ac.uk

Questionnaire location and date:

1. What type(s) of vessel(s) do you use in Cardigan Bay?

○ Speed boat ○ Sailboat ○ Paddle craft ○ Other ________

○ RIB ○ Fishing boat ○ Jet ski

2. How many years have you been visiting Cardigan Bay to use your recreational craft?

3. Last year, how many days a month did you visit Cardigan Bay to use a recreational vessel?

___ January ___ April ___ July ___ October
___ February ___ May ___ August ___ November
___ March ___ June ___ September ___ December

4. Over the past 6 years, approximately how many days per year did you spend on a vessel in Cardigan Bay?

___ 2016: ___ 2014: ___ 2012:
___ 2015: ___ 2013: ___ 2011:

5. Do you generally visit Cardigan Bay during weekends, weekdays or holidays?

○ Weekends ○ Weekdays ○ School holidays ○ Bank holidays

6. From where do you typically launch?

7. Where in Cardigan Bay do you go on your recreational vessel? In the map given, please specify in each grid the area usage on a scale from 1 to 3 (with 1 being rare visited and 3 visited a lot)

8. Please rate/tick the importance of the following for you when using a recreational craft in Cardigan Bay?

	Not important	Slightly important	Moderately important	Important	Very important
Scenery					
Taking photographs/video					
Fishing					
Seeing seabirds					
Seeing dolphins					
Seeing seals					
Other?					

9. Last year, on what percentage of trips did you encounter bottlenose dolphins?

○ 0% ○ 30% ○ 60% ○ 90%

○ 10% ○ 40% ○ 70% ○ 100%

○ 20% ○ 50% ○ 80%

10. Where in Cardigan Bay do you encounter bottlenose dolphins? In the map given, please specify in each grid the sightings on a scale from 1 to 3 (with 1 being rare sightings and 3 many sightings)

11. Do you report bottlenose dolphin sightings to anyone or anywhere?

○ YES ○ NO

If yes, where do you report them?

12. Once encountering bottlenose dolphins, what is your procedure? (select one from each column)

○ Slow down ○ Stop ○ Move towards

○ Speed up ○ Move away ○ Continue your course

13. During an encounter with bottlenose dolphins, on average how long do you spend with them?

- ○ 0-5 minutes
- ○ 16-30 minutes
- ○ >60 minutes
- ○ 6-15 minutes
- ○ 31-60 minutes

14. When approaching bottlenose dolphins, generally how close do you get?

- ○ 0-20 metres
- ○ 51-100 metres
- ○ >200 metres
- ○ 21-50 metres
- ○ 101-200 metres

15. Are you part of the Ceredigion and Gwynedd registration scheme?

- ○ Yes
- ○ No
- ○ Don't know

16. During your trips, do you experience interference from other vessels?

- ○ YES
- ○ NO

If yes:

- Last year, on what percentage of trips were dolphin encounters impacted by interference from commercial boats (fishing boats, wildlife trip boats)?

___ January	___ April	___ July	___ October
___ February	___ May	___ August	___ November
___ March	___ June	___ September	___ December

- Last year, on what percentage of trips were dolphin encounters impacted by interference from other recreational crafts?

___ January	___ April	___ July	___ October
___ February	___ May	___ August	___ November
___ March	___ June	___ September	___ December

17. Since your first visit to Cardigan Bay, have you noticed any change in the number of bottlenose dolphin encounters during your trips in Cardigan Bay?

- ○ Yes
- ○ No
- ○ Don't know

If yes: has the number ○ Decreased ○ Increased

- Do you have any suggestions why? ______________________________

18. Do you know of any guideline that protects bottlenose dolphins in Cardigan Bay?

- ○ YES
- ○ NO

If yes, what is it?

19. Gender

- ○ Female
- ○ Male

20. Do you own a property in Cardigan Bay?

- ○ Yes
- ○ No

21. Age

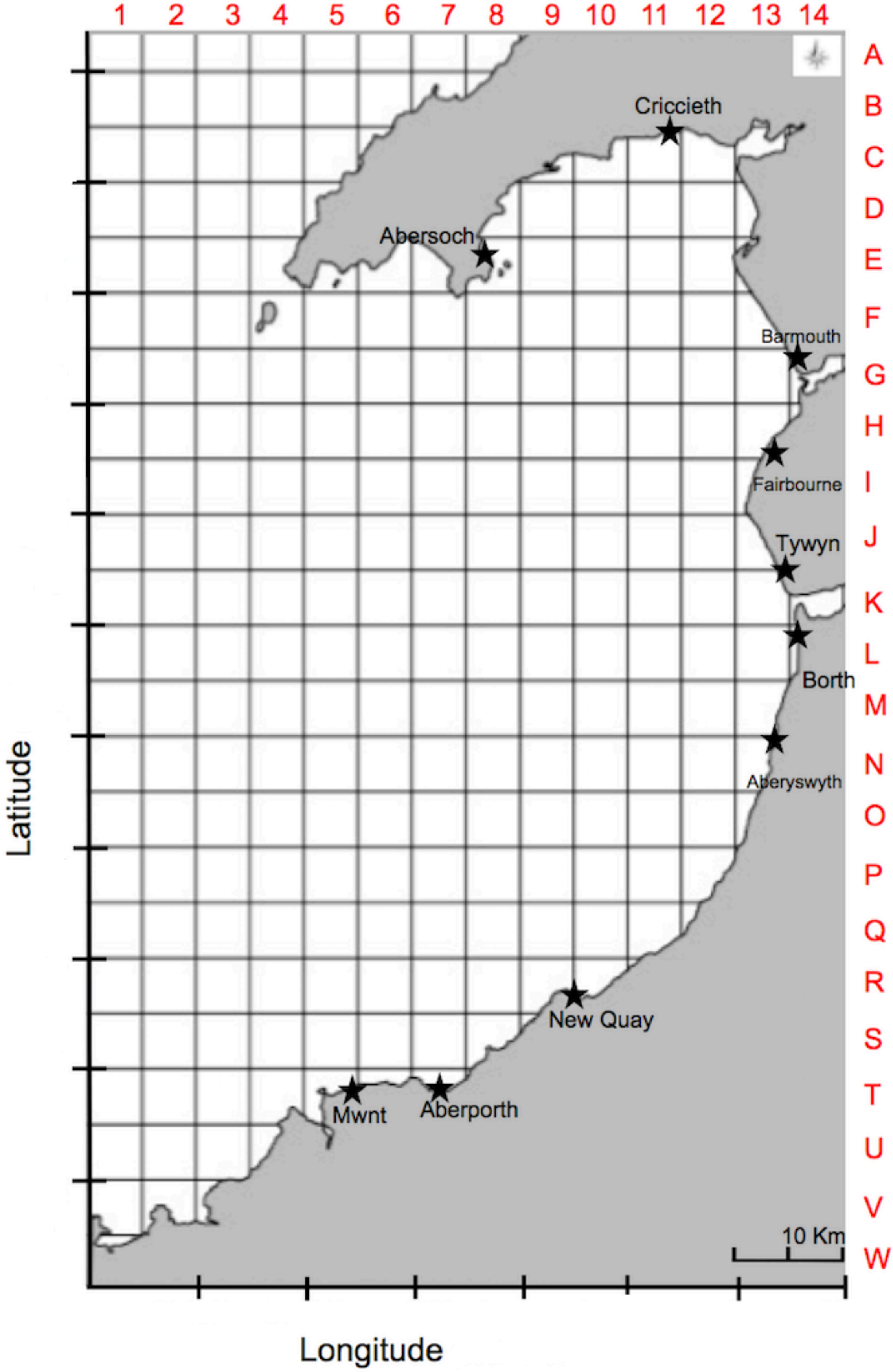
- ○ Under 25 years
- ○ 36-45 years
- ○ 56-65 years
- ○ 26-35 years
- ○ 46-55 years
- ○ >65 years

22. In what town and county do you live?

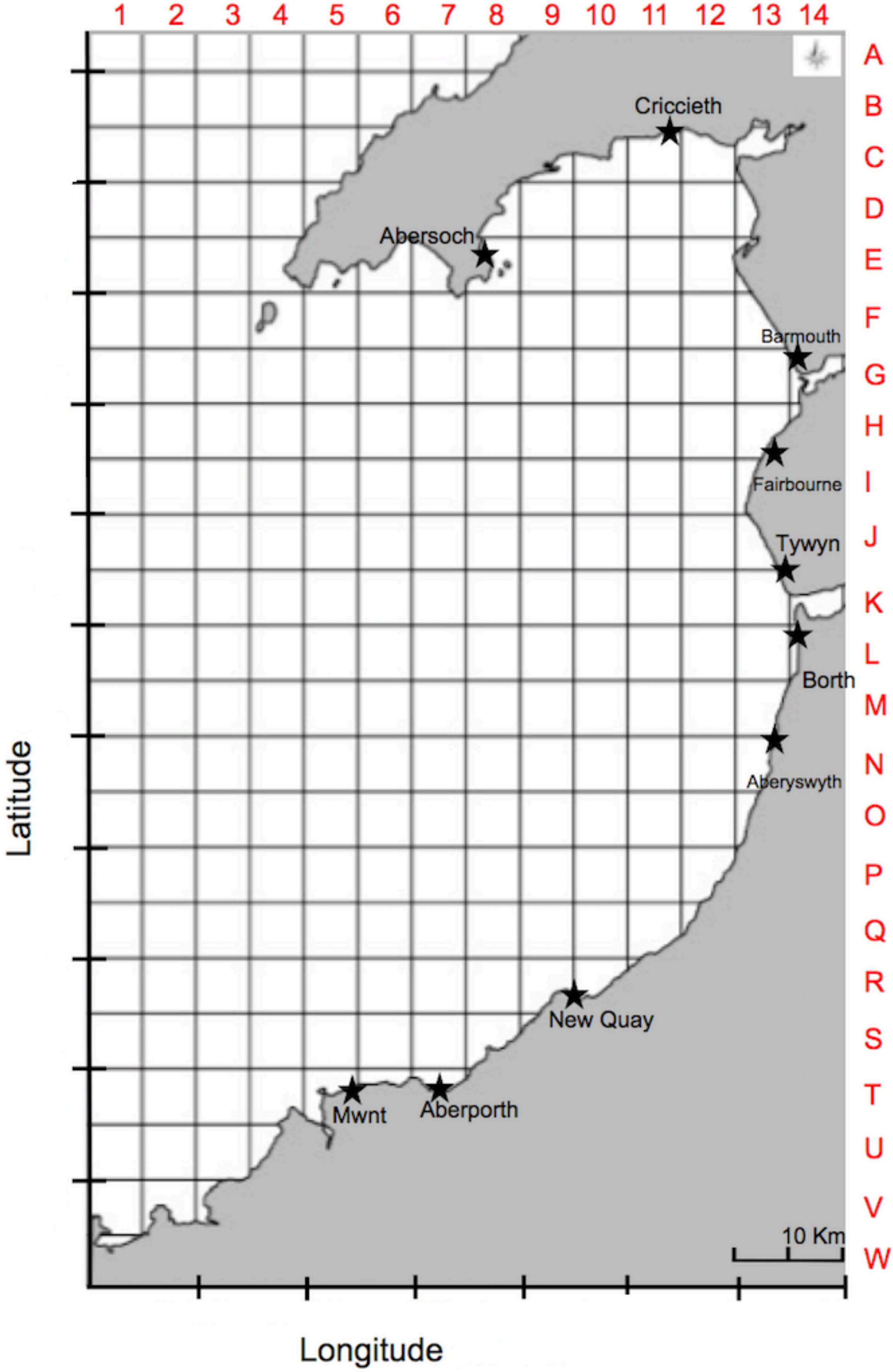
23. Are you a member of an environmental group (e.g. Marine Conservation Society, Wildlife Trust, RSPB)

- ○ Yes
- ○ No
- ○ Don't know

7:


1 2 3 4 5 6 7 8 9 10 11 12 13 14
A B C D E F G H I J K L M N O P Q R S T U V W
Criccieth
Abersoch
Barmouth
Fairbourne
Tywyn
Borth
Aberyswyth
New Quay
Mwnt
Aberporth
10 Km
Latitude
Longitude

10:



1
2
3
4
5
6
7
8
9
10
11
12
13
14
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
Criccieth
Abersoch
Barmouth
Fairbourne
Tywyn
Borth
Aberyswyth
New Quay
Mwnt
Aberporth
10 Km
Latitude
Longitude

8.3 Interview to wildlife operators

PRIFYSGOL BANGOR UNIVERSITY

INTERVIEW TO WILDLIFE OPERATORS

READ TO INTERVIEWEE

Good morning/afternoon. My name is Alejandra Vergara-Peña. I am researcher with Bangor University in collaboration with Sea Watch Foundation. The purpose of this study is to describe the commercial tourism industry in Cardigan Bay. You are invited to participate in this research project because you operate in Cardigan Bay and you are likely to encounter bottlenose dolphins regularly in the area. Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research interview, you can withdraw at any time. The interview contains 21 questions, which will take a short time to complete. Your responses are confidential.

Date:

Name of interviewee:

Position in company:

Year of birth of interviewee:

Location of interview:

Company:

Gender of interviewee:

Comments:

SPATIAL AND TEMPORAL FOOTPRINT OF INDUSTRY

Note: Since the wildlife tour operators are going to be contacted prior to the interview and most of them have websites that provide information about their boats and tours, some data can be filled before the interview, avoiding asking them more than needed.

1. How many vessel(s) do you have in commercial operation?

What vessel type do you use? (note to self: if more than one, specify below, if one vessel go to next question)	What is the name of the vessel?	What is its length?	What is its engine size?	What is its cruising speed?	What is its maximum speed?	What is its passenger capacity?
What vessel type do you use?	What is the name of the vessel?	What is its length?	What is its engine size?	What is its cruising speed?	What is its maximum speed?	What is its passenger capacity?
What vessel type do you use?	What is the name of the vessel?	What is its length?	What is its engine size?	What is its cruising speed?	What is its maximum speed?	What is its passenger capacity?

What vessel type do you use?	What is the name of the vessel?	What is its length?	What is its engine size?	What is its cruising speed?	What is its maximum speed?	What is its passenger capacity?
What vessel type do you use?	What is the name of the vessel?	What is its length?	What is its engine size?	What is its cruising speed?	What is its maximum speed?	What is its passenger capacity?

2. How many years have you been operating commercially in Cardigan Bay?

3. Where in Cardigan Bay do you operate? Please specify the area usage on a scale from 1 to 3 (with 1 being rare visited and 3 visited a lot) (note to self: give them map with grid and town names)

IMPORTANCE OF BND TO THE TOURISM INDUSTRY

Note: Since the wildlife tour operators are going to be contacted prior to the interview and most of them have websites that provide information about their boats and tours, some data can be filled before the interview, avoiding asking them more than needed.

4. Last year, how many commercial trips did you run per month?

	1 Hour	2 Hour	__ Hour		1 Hour	2 Hour	__ Hour
January				July			
February				August			
March				September			
April				October			
May				November			
June				December			

If information about the length of their trips is not in their website:
What is the typical length of time of one of your commercial trips?

5. Over the past 6 years, approximately how many commercial trips did you run per year?

2016: 2013:
2015: 2012:
2014: 2011:

6. Over the past 6 years, approximately how many Adult/Children tickets did you sell per month per year?

	2016		2015		2014		2013		2012		2011	
	A	C	A	C	A	C	A	C	A	C	A	C
January												
February												
March												
April												
May												
June												
July												
August												
September												
October												
November												
December												
Annual												

If operator does not keep a detailed log:
Last year, how many tourists did you take on a commercial trip per month?

January	July
February	August
March	September
April	October
May	November
June	December

If operator does not have a monthly data, I need to make sure to ask information about their season:
Over the last 6 years, during which months did you operate commercially?

2016:	2013:
2015:	2012:
2014:	2011:

7. Could you please rate the relative importance to your commercial operation of the following?

	Not important	Slightly important	Moderately important	Important	Very important
Scenery					
Enjoying being on a boat on the sea					
Good photo opportunities					
Seabirds					
Fishing					
Bottlenose dolphin					
Harbour porpoise					
Seal					
Any other?					

If more than one option is “Very important”, please rank the important and very important ones using the cards provided

8. Last year, on what percentage of trips did you encounter bottlenose dolphins?

January	July
February	August
March	September
April	October
May	November
June	December

9. Where in Cardigan Bay do you encounter bottlenose dolphins? Please specify the sighting area on a scale from 1 to 3 (with 1 being rare sightings and 3 many sightings) (note to self: give them map with grid and town names)

10. On a scale from 1 to 5 (with 1 being not important and 5 being very important), how important is a healthy bottlenose dolphin population in Cardigan Bay to your business?

ADHERENCE AND ENGAGEMENT IN REGULATIONS AND CONSERVATION OF BND

11. Could you please rate, how much do you tell the passengers about the following?

	None	Very little	Some	Quite a bit	Very much
Local history					
Special Are of Conservation/Conservation					
Research in the area					
Sea birds					
Seals					
Bottlenose dolphin					

12. Do you report bottlenose dolphin sightings to anyone or anywhere? If yes, where do you report them?

Please think about another wildlife tour operator in Cardigan Bay and answer questions 13, 14 and 15 based on its actions whilst keeping their anonymity

13. Once encountering bottlenose dolphins, what is their procedure? (note to self: approach, stop, get away, neutral)

14. During an encounter with bottlenose dolphins, on average how long do they spend with them?

15. When approaching bottlenose dolphins, generally how close do they get?

16. Have you or any of your staff attended a WiSe course? If yes, when did you/they attend it?

17. For dedicated operators: What regulation protects bottlenose dolphins in Cardigan Bay?

For opportunistic operators: Do you know of any restriction or regulation that protects bottlenose dolphins in Cardigan Bay? YES/NO
If yes, what is it?

PERCEPTION OF BND STATUS AND THE IMPACT OF WILDLIFE TOURISM

18. During your trips, do you experience interference from other vessels? YES/NO
If yes:

- Last year, on what percentage of trips were dolphin encounters impacted by interference from other commercial boats?

January	July
February	August
March	September
April	October
May	November
June	December

- Last year, on what percentage of trips were dolphin encounters impacted by interference from recreational crafts?

January	July
February	August
March	September
April	October
May	November
June	December

19. In the last 5-10 years, have you noticed any change in the total number of people going on wildlife boat tours in Cardigan Bay?
Yes No Don't know

If yes: has the number Decreased Increased
: Do you have any suggestions why?

20. In the last 5-10 years, have you noticed any change in the number of bottlenose dolphin encounters during commercial trips in Cardigan Bay?
    Yes No Don't know

    If yes: has the number Decreased Increased
    : Do you have any suggestions why?

21. Do you consider that current regulations provide a good way to get the right balance between conservation and wildlife tourism activities? YES/NO

Thank you very much for your time and cooperation

8.4 Dolphin-watching client questionnaire

PRIFYSGOL BANGOR UNIVERSITY

QUESTIONNAIRE TO WILDLIFE TOUR CLIENTS

To client

My name is Alejandra Vergara-Peña. I am researcher at Bangor University in collaboration with Sea Watch Foundation. The purpose of this study is to assess the commercial tourism industry in Cardigan Bay. You are invited to participate in this research project because you visit Cardigan Bay and may have watched bottlenose dolphins in the area.

Your participation in this research study is voluntary. You may choose not to participate. If you decide to participate in this research questionnaire, you can withdraw at any time. The questionnaire contains 22 questions, which will take a short time to complete. Your responses are anonymous and confidential. Results from the questionnaire will be collated at Bangor University. If you have any questions about the research study, please contact Alejandra Vergara-Peña (elp2ae@bangor.ac.uk, 01248388501).

Thank you for helping me with my PhD research,

Alejandra Vergara-Peña
PhD student
Bangor University
https://www.bangor.ac.uk/oceansciences/staff/phd-students/alejandra-vergara-pena

Supervisors' details:

Line Cordes,
+44 (0)1248 383503
l.cordes@bangor.ac.uk

John Turner
+44 (0)1248 382881
j.turner@bangor.ac.uk

Peter Evans

peter.evans@bangor.ac.uk

Questionnaire location and date: Company provider of the tour:

1. What was the duration of your trip? (Hours) _______________

2. Is this your first wildlife trip experience in Cardigan Bay? YES NO
   If no, for how many years have you been coming on wildlife trips in Cardigan Bay? ______________

3. Last year, how many times did you go on a wildlife trip each month?

____ January	____ April	____ July	____ October
____ February	____ May	____ August	____ November
____ March	____ June	____ September	____ December

4. a) Why did you go on a wildlife trip

   ○ Spur of the moment ○ Main reason for visiting

   b) What were the main reasons for you to go on this trip?

	Not important	Slightly important	Moderately important	Important	Very important
Scenery					
Being outside					
Taking photographs/video					
Seeing seabirds					
Fishing					
Seeing dolphins					
Seeing seals					
Other?					

5. Did you see any dolphins on your trip? YES NO If yes, how many?_____________

6. How much were you told about the following?

	None	Very little	Some	Quite a bit	Very much
Local history					
Conservation					
Research in the area					
Seabirds					
Seals					
Bottlenose dolphin					
Do’s and don’t during a dolphin watching trip					

7. Once encountering bottlenose dolphins, what was the operator’s procedure? (select one from each column)

   ○ Slow down ○ Stop ○ Continue its course

   ○ Speed up ○ Move away ○ Move towards them

8. On average, how long did the operator spend with the dolphins during an encounter with them?

   ○ 0-5 minutes ○ 16-30 minutes ○ >60 minutes

   ○ 6-15 minutes ○ 31-60 minutes

9. Did the dolphins follow the boat for a time, and if so, for how long? (Minutes) _____________

10. Generally how close did the operator approach the dolphins?

   ○ 0-20 metres ○ 51-100 metres ○ >200 metres

   ○ 21-50 metres ○ 101-200 metres

11. Do you know if there are any restrictions or regulations which affect the bottlenose dolphin in the area?

○ Yes ○ No

12. During your dolphin encounter, did you experience interference from other vessels? YES NO
If yes which of the following:

○ Speed boat ○ RIB ○ Paddle craft
○ Fishing boat ○ Sailboat ○ Other wildlife watching boat

13. Compared to your expectations, how would you rate your current dolphin watching experience?

Much worse	Somewhat worse	About the same	Somewhat better	Much better

14. In your opinion, wildlife trips in Cardigan Bay apply to which of the following potential benefits and negative impacts?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Economic opportunities for local communities					
Education of participants, which helps to protect dolphins					
Negative impact on the marine environment					
Negative impact on dolphins					
Raise of awareness of participants for marine conservation issues in general					
Other					

15. Overall, how do you evaluate the impact on dolphins of dolphin watching:

Very negative	Somewhat negative	Neutral	Somewhat positive	Very positive	Not sure

16. Are you
○ Female ○ Male

17. Do you own a property in Cardigan Bay?
○ Yes ○ No

18. In what town and county do you live?
____

19. Age

○ Under 25 years ○ 36-45 years ○ 56-65 years
○ 26-35 years ○ 46-55 years ○ Over 65 years

20. After your experience, would you return to Cardigan Bay specifically for dolphin watching?

○ Yes ○ No ○ Don't know

21. Are you a member of a conservation group or similar organisation (e.g. Marine Conservation Society, Wildlife Trust, RSPB, WWF)?

○ Yes ○ No ○ Don't know

22. Approximately how much money will you spend during your time in the area?

________________£ Dolphin watching

________________£ Transportation and accommodation costs

________________£ Other trip expenses (food, entertainment, etc)

23. Could you please tell me what it is the distance from here to … (use a reference/known point)