Cardigan Bay bottlenose dolphin (*Tursiops truncatus*) connectivity within and beyond marine protected areas

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

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being currently submitted for any degree.

This dissertation is being submitted in partial fulfilment of the requirement of the M.Sc. in Marine Biology

The dissertation is the result of my own independent work / investigation, except where otherwise stated.

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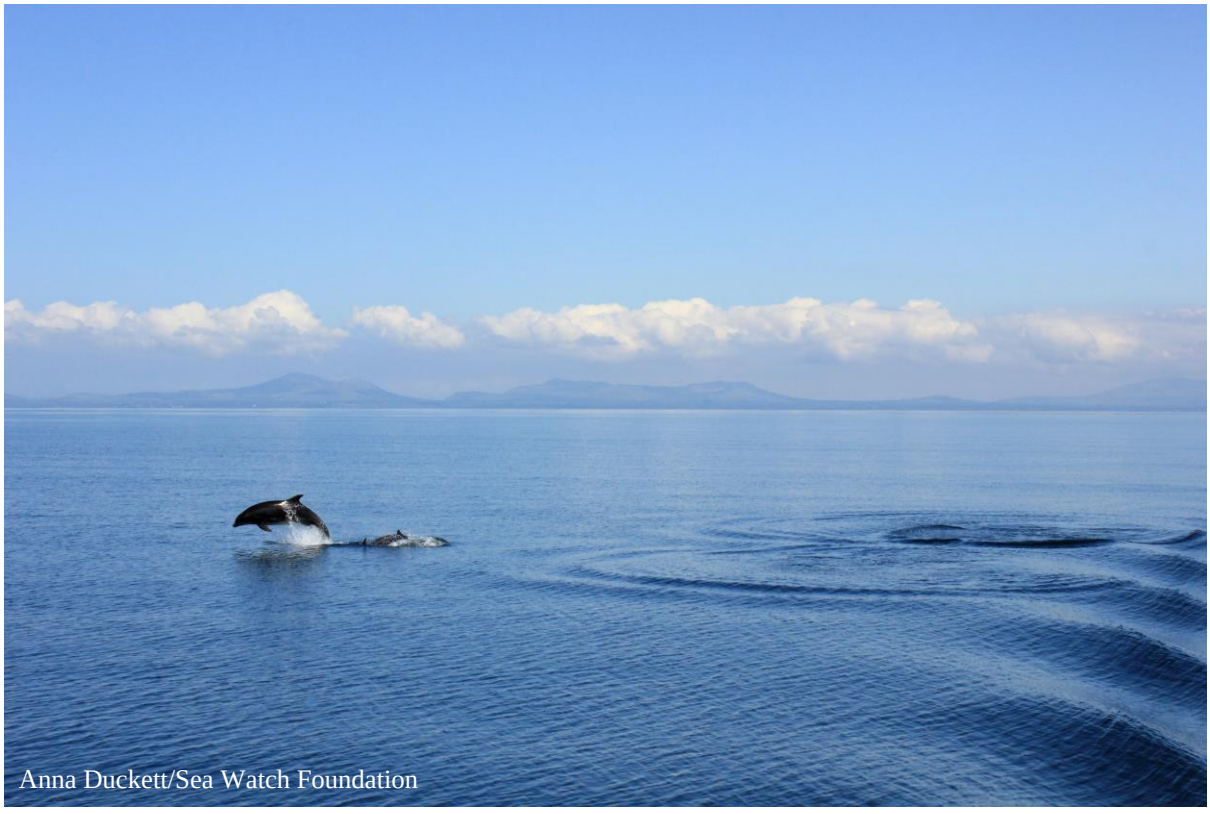

ABSTRACT

The EU Habitats Directive was put in place to conserve important species and habitats in the EU by creating Special Areas of Conservation (SAC). The bottlenose dolphin is listed under this directive and within the UK, the Welsh population has been protected with the creation of two SAC's within Cardigan Bay. However, recently it has been acknowledged that the population migrates to North Wales in the winter and this area is not protected. This study aimed to report on the status of individuals in North Wales and to compile information to advise policymakers on the potential creation of an additional SAC in North Wales. Using the Sea Watch Foundations database of bottlenose dolphin encounters and individual photo-ID records, results were compiled from 2006 to 2018 and was sorted in order to analyse gender and age class proportions between locations as well as group size, emigration rates, and the movement patterns of mothers with calves. There was a larger proportion of males sighted in Cardigan Bay compared to North Wales overall, however, there was no notable change in gender proportions between seasons for each area. This indicates that there is no gender bias occurring between sites. The majority of mothers (91%) chose to give birth in Cardigan Bay, however, only 69% chose to stay in the area after giving birth. This also supports the finding that there are nearly twice as many calves encountered in Cardigan Bay than in North Wales. Additionally, the group size in North Wales is five times larger than in Cardigan Bay and the rate of emigration to North Wales is declining. However, this is due to the lack of surveys recently. The results of this study illustrate the importance of the area to bottlenose dolphins and further study should be considered to fully protect this species.

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1.0 Introduction

1.1 Conservation and protected areas

Anthropogenic activities are directly causing a decline in marine biodiversity through activities such as habitat destruction, exploitation, and pollution as well as indirectly through climate change (Jackson et al., 2001; Pandolfi et al., 2003; Dulvy et al., 2003; Worm et al., 2005; Lotze et al., 2006). In a five-year timespan from 2010 to 2015, over 66% of the world's oceans have experienced an overall increase in 19 cumulative anthropogenic impacts that are threatening the health of the marine environment (Halpern et al., 2015). These impacts are having detrimental effects for marine life at population, species and functional group levels in regional ecosystems worldwide (Jackson et al., 2001; Pandolfi et al., 2003; Lotze et al., 2006). Reductions in biodiversity ultimately decrease the ability for an ecosystem to function properly and can cause irreversible damage (Holmund & Hammer, 1999; Worm et al., 2006). Thus, conservation efforts play a key role in protecting marine habitats and species that are vulnerable to anthropogenic activities.

One key tool that has helped the European Union to conserve species is the EU's Habitats Directive, which was established in 1992 to encourage all Member States to preserve local biodiversity and to restore or maintain key habitats to a Favourable Conservation Status (FCS). In order to practically achieve this goal, any habitat or species that are listed in Annexes I & II respectively under the Habitats Directive is protected through the creation of Special Areas of Conservation (SACs). Various levels of protection are given dependent on the level of importance and the status of the particular species or habitat. This directive, along with the Birds Directive, makes up the Natura 2000 network of protected areas in Europe, which is the cornerstone for Europe's conservation policy. Natura 2000 consists of a network of protected areas that are important for the breeding or feeding success of threatened and/or rare species in the EU. Nearly 18% of land and 6% of the marine environment in the EU is protected by this measure, and it has created the largest network of protected areas worldwide. These protected areas provide a potential future for Europe's most endangered and threatened species and a habitat to increase their populations.

The Natura 2000 network is unique as it underlines the importance of connectivity between protected areas in order to adequately protect the full extent of a habitat that a species requires in its lifespan. Connectivity is especially important in marine ecosystems as there are currently many unknown linkages between areas in the oceans, and these connections are difficult to protect as they are not fully understood (McLeod & Leslie, 2009). Due to the complexity of marine organisms' life-history patterns, conservation efforts in the marine environment have lagged behind terrestrial efforts. In the past, conservation efforts have focused solely on one stage of a species life, which does not provide the full range of habitat needed for the species to recover from habitat degradation and anthropogenic impacts (Kinney & Simpfendorfer, 2009). For example, in shark conservation, it was widely accepted that the most efficient way to protect the species was to protect inshore nursery areas that are used in early life stages as these are vital for population stability (Bonfil, 1997). However, it is important to protect not only nursery areas but other habitats that are used in various life stages. For example, special feeding and breeding areas that may only be used for a few days or months out of the year are equally as important as nursery areas for the overall species survival. Therefore, one should ensure that all key sites used by the species are protected (Kinney & Simpfendorfer, 2009). Many marine mammals, including bottlenose dolphins, use migratory routes and have multiple sites where they feed during the year. All of these areas are important to protect as by allowing a portion of these to become degraded may seriously affect the survival of the population (Kinney & Simpfendorfer, 2009).

1.2 Photo-Identification

The development of photo-identification techniques has allowed bottlenose dolphin research and conservation efforts to expand considerably (Wursig & Wursig, 1977; Wells et al., 1980). Photo-Identification or Photo-ID has allowed for a non-invasive and non-harmful method of tracking individuals of species that have recognisable markings. Bottlenose dolphins are recognised by individual markings on their dorsal fin, such as colouration, nicks, scars and unique fin shapes. Using photo-ID, a catalogue of individual dolphins within a population can be created which allows for mark-recapture techniques to be used to track social structure, movement patterns, habitat use, and health of individuals, and provides a method to compare the status of different populations (Irvine & Wells, 1972; Wells et al., 1980; Hohn et al., 1989). Not all individuals have identifiable features on their dorsal fin; however, an estimated 60% of dolphins have identifiable features within the UK (Wilson, 1995; Feingold & Evans, 2012).

1.3 The Bottlenose dolphin (*Tursiops truncatus)*

Bottlenose dolphins (*Tursiops* spp.) are one of the most well-known cetacean species worldwide. They belong to the order Cetacea and have commonly been described as one of the most recognisable charismatic marine megafauna worldwide (Leatherwood & Reeves, 1990; Reynolds et al., 2000; Wells & Scott, 2002). They have been studied extensively due to their wide distribution range and preference for easily accessible inshore areas (Smith et al., 2013). Two of the longest running studies of cetaceans have been on bottlenose dolphin populations in Sarasota Bay, Florida and in Shark Bay, Australia (Irvine and Wells, 1972; Connor and Smolker, 1985; Connor et al., 1999). Another key feature which allows bottlenose dolphins to be easily studied is their preference for site fidelity and semi-predictable annual home ranges (Rogers et al., 2004). However, there have been cases where dolphins have been found to undertake large-scale migrations, such as a study population in Argentina which were recorded 300 km from their usual study site (Würsig and Würsig, 1979; Defran & Weller, 1999). Other populations have been found to undertake seasonal migrations utilising a larger home range, such as the population of bottlenose dolphins found in the Moray Firth in Scotland, some individuals of which have been photographed on the west coast of Scotland for parts of the year, while they are usually based on the east coast of Scotland (Cheney et al., 2013). On the other hand, certain populations of bottlenose dolphins have only been recorded occupying a single site, with relatively little movements outside of an area (e.g. in the Sado Estuary, Portugal), and these are referred to as resident populations.

Bottlenose dolphins are social animals and usually form groups that may benefit by increased protection from predators, especially when calves are present (Connor et al., 1998). Cooperative feeding is another benefit of social living, as larger groups of individuals that work together can entrap larger groups of fish (Connor et al., 2000). Although dolphins use social groups to their advantage, they usually form fission-fusion groups, meaning they do not stay in the same group for their lifetime, rather they move between groups frequently, sometimes several times a day (Connor et al., 2000). Although group structure changes frequently, some associations such as a mother and calf and associations between two males, may last for years (Wells et al., 1987). Social structure varies between groups of bottlenose dolphins and it has been found to be partially determined by intrinsic and ecological factors, such as shared knowledge of prey availability, and behavioural traits (Lusseau et al., 2003; Daura-Jorge et al., 2012; Mann et al., 2012). Group size in bottlenose dolphins varies considerably even within a

single population, dependent on location and season (Lohrengel et al., 2017). Population size between independent populations can vary from the low tens of individuals (Wilson et al., 1999) up to 1,000 individuals, that primarily occur in offshore environments. Which is likely due to the greater difficulty to locate prey concentrations and possibly the need to avoid predators like killer whales (Boran et al., 2001; Read et al., 2003).

Bottlenose dolphin populations can also be categorised by their home ranges, with some being classed as transient, where they show no site fidelity (Defran & Weller, 1999). Other populations are migratory, moving between set locations usually dependent on season, while others are residential and show strict site fidelity within a single area, with no major changes in location throughout the year (Barco et al., 1999; Wilson et al., 1999). Bottlenose dolphins vary in size and morphology according to region, *Tursiops truncatus* is the largest species of bottlenose dolphin, and the UK populations are the largest in the world. Their diet is made up of a variety of prey, mostly consisting of fish and squid. However, diet varies regionally and by individual preference (Wells & Scott, 2002).

The common bottlenose dolphin (*Tursiops truncatus*) is the only species of bottlenose dolphin to occur in European waters and it is protected under the 1992 EU Habitats and Species Directive (94/43/EEC). It is listed in Annex II and Annex IV as a species requiring protection including the establishment of Special Areas of Conservation (SACs).

1.4 Distribution in the UK

There are several populations of bottlenose dolphins in the UK and Ireland, the most notable being the coastal populations inhabiting the Moray Firth, East Scotland and Cardigan Bay the West Wales, as well as a residential population in the Shannon Estuary, Western Ireland (ICES, 2016). Generally, the bottlenose dolphin population across the UK has remained somewhat stable, although there are variations between populations. The population in the Moray Firth appear to be genetically distinct from those on the west coast, and their home range is primarily the Moray Firth and the east coast of Scotland down to the English border (Evans et al., 2003; Wilson et al., 2004; Cheney et al., 2013; ICES, 2016). The most recent estimate of population size from 2014 gives an estimate of 170 individuals in this population. These numbers appear to be relatively stable, with no declines over 30% in any 10-year period of active monitoring (Cheney et al., 2014). The Cardigan Bay population is slightly larger, ranging up to around 300

animals although the most recent estimate was 174 individuals in 2016 (Lohrengel et al., 2017). The indication is of a decline since 2009 when there were an estimated 319 individuals (Lohrengel et al., 2017; Figure 1). Although no decline of 30% or more in any 10-year period, has taken place, these recent estimates have been some of the lowest recorded since 2001, which may signal the start of an overall population decline (ICES, 2016).

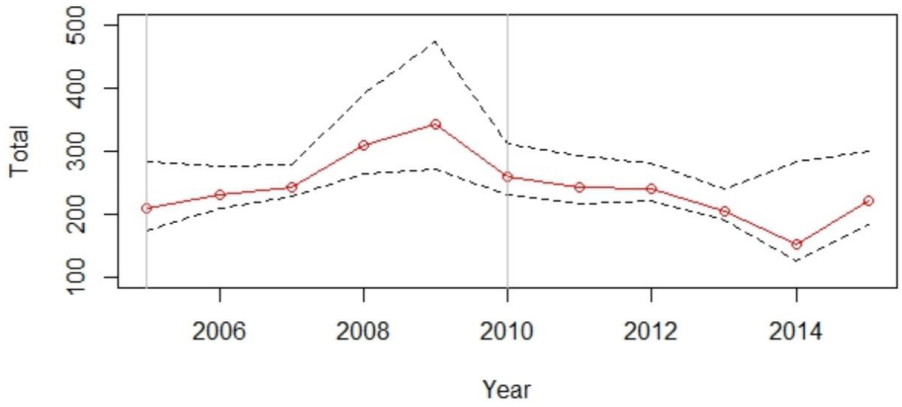

Figure 1. Estimates of *Tursiops truncatus* abundance measured in individuals in the wider Cardigan Bay region, Wales from 2001 to 2015. Dashed lines representing 95% confidence intervals (from ICES, 2016)

1.5 Special Areas of Conservation

As bottlenose dolphins are listed in the Habitats and Species Directive as Annex II species, the areas where the species regularly occur are candidates for the creation of a SAC under the Natura 2000 scheme. In Scotland, there is a SAC designated to protect a semi-resident population of bottlenose dolphins in the Moray Firth (Scottish Natural Heritage, 1995; Moray Firth Partnership, 2001). In Wales, there are currently two SACs that protect bottlenose dolphins: Cardigan Bay SAC, where bottlenose dolphins are a defining feature, and Pen Llyn a'r Sarnau SAC, which has bottlenose dolphins as an additional feature (CCW, 2008). These two SACs are both located in the wider Cardigan Bay area, which covers an area of 5,500 km^2 (Figure 2).

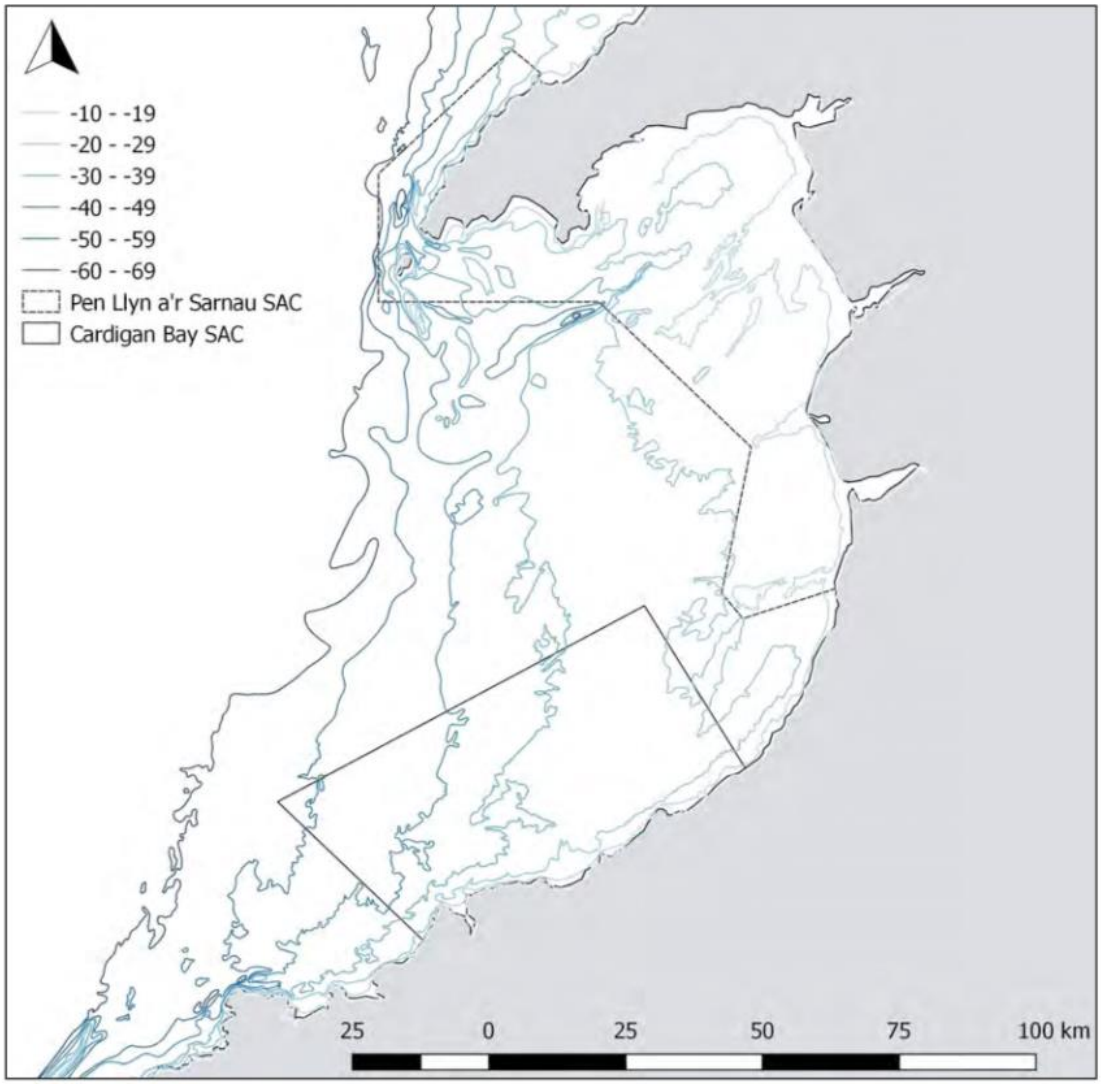

Figure 2. Locations of Cardigan Bay SAC (outlined by a continuous line) and Pen Llŷn a'r Sarnau SAC (outlined by a broken line) in Cardigan Bay, West Wales (From Lohrengel et al., 2017)

Cardigan Bay SAC was proposed for a SAC in 1996, due to the presence of a significant population of bottlenose dolphins. In 2001, the Cardigan Bay SAC Management Scheme was formally put into place. This SAC encompassed an area of 968 km^2 (CCW, 2008). As a key aspect of the management scheme, any activities that might impact bottlenose dolphins must have those impacts quantified and monitored. The aim of the management scheme is to maintain the favourable conservation status of Cardigan Bay by monitoring anthropogenic activities to ensure they do not disturb the habitat and species located in the Bay (CCW, 2008).

The Pen Llyn a'r Sanau SAC is located in the northern part of Cardigan Bay and covers an area of 1,460 km^2 (Figure 3). This area was put forward as a candidate for a SAC in 2004 due to the presence of reefs and estuaries, although bottlenose dolphins were also listed as a conservation feature under the Habitats and Species Directive (CCW, 2008).

Coastal bottlenose dolphins display a wide range of behaviours and movements worldwide, with each population having unique movement patterns and interactions. Different populations of bottlenose dolphins across the world have shown seasonal migrations, long-term site fidelity as well as long-term movements without establishing residency (Wells & Scott, 1999). These variations between populations make it difficult to establish a conservation plan without monitoring the population first, as each population needs to be observed to consider their social dynamics and behaviour. Currently, the majority of studies on bottlenose dolphins focus on populations with strong site fidelity as these are the easiest to monitor through long-term mark-recapture programmes. Until recently, it was thought that the population in Cardigan Bay had also established a long-term residency in the Bay (Pesante et al., 2008). However, it is now known that only a portion of the population is resident while most of the population move between Cardigan Bay and North Wales (and beyond) dependent on the season (Pesante et al., 2008; Feingold & Evans, 2012; Lohrengel et al., 2017). As more is known about the movement patterns of this population in Wales, an updated conservation plan can be created with new information on their movements and the amount of time spent in each area.

1.3. Cardigan Bay

Within Cardigan Bay, bottlenose dolphins are usually sighted in smaller groups of approximately five individuals, although they have been sighted in groups with up to 20 individuals, particularly in late summer and autumn (Lohrengel et al., 2017). The Bay is primarily used by bottlenose dolphins for feeding, breeding, socialising and raising calves (CCW, 2008). Overall, high productivity areas that are nutrient rich are often favoured by bottlenose dolphins as these types of areas are generally higher in prey abundance (Genin, 2004; Dinis et al., 2016). The highest abundance of dolphins within the Bay is recorded in the summer months from April to August, after which it gradually decreases from October into the winter months (Feingold & Evans, 2014a). One potential reason for this decline may be due to an increase in prey availability in this area during the summer, which then naturally declines in the winter (Lopes, 2017). However, this is difficult to determine as measuring prey

availability is challenging (Torres et al., 2008). Certain abiotic factors such as salinity, temperature, current velocity, depth, thermoclines or bottom topography may also influence the distributions of marine mammals and of their prey (Jaquet & Whitehead, 1996; Fiedler et al., 1998; Bräger et al., 2003).

The population of bottlenose dolphins in Cardigan Bay, Wales is the largest semi-resident population of coastal bottlenose dolphins in the UK (Pesante et al., 2008). When long-term monitoring of Cardigan Bay SAC began in 2001, there was a total of 149 individuals in the population, this grew to 239 individuals in 2008, before gradually declining to the current count of 147 individuals within the Cardigan Bay SAC (Lohrengel et al., 2017). In 2005, the monitoring of the Bay expanded to the entire Bay including the Pen Llyn a'r Sarnau SAC. Within the wider Cardigan Bay area, the initial estimates were of 195 individuals in 2005, which rose to 319 in 2009 and declined since then to the latest estimate of 174 individuals from 2017, in a similar pattern to the Cardigan Bay SAC (Lohrengel et al., 2017). It was initially thought that the bottlenose dolphins in Cardigan Bay had strong site fidelity and small home ranges within the Bay (Morris, 1991; Bristow & Rees, 2001). However, this population is now considered a mix of residents, occasional visitors and transients (Lohrengel et al., 2017), and only 7% of individuals show strict site fidelity within the Cardigan Bay SAC (Feingold & Evans, 2014b).

Although it is known that the Cardigan Bay population of bottlenose dolphins moves outside of the Bay and it is not a strictly resident population, the full range of movement of this population is not currently known. There is more evidence showing that a large portion of the population spends the winter months north of the Bay in North Wales, to at least as far as around the Isle of Man (Feingold & Evans, 2014b; Norrman et al., 2015). In addition to the individuals that have been sighted in the winter in North Wales, there are some individuals that are believed to have emigrated to North Wales after having not been sighted in Cardigan Bay for several years (Lohrengel et al., 2017).

1.6 Bottlenose dolphins in North Wales (Connectivity)

Nearshore coastal bottlenose dolphin populations commonly undertake seasonal migrations as temperature and prey availability fluctuate over the year (Shane et al., 1986). While small seasonal shifts in habitat are common, some populations undertake larger seasonal migrations,

as in Florida, where individuals travel up to 400 km during their migrations (Wells et al., 2002). Studies show that within a population there can be variation between migration patterns and the extent of those migrations based on gender, with females usually utilising a smaller range, and males being more likely to travel further and have more social interactions (Bearzi et al., 1997). Individual foraging preference may also influence seasonal habitat changes as different individuals can prefer different prey types (Hastie et al., 2004; Mellink et al., 2006). Abiotic factors may also be a driver for changes in habitat. A study in Australia on bottlenose dolphin movement showed a link between dolphins seeking shelter in bays from rough water (Lear & Bryden, 1980). This study also found that dolphins foraged in response to tidal patterns to gain an advantage over their prey (Lear & Bryden, 1980).

Although it has been known for several years that the dolphins in Cardigan Bay also visit North Wales, there have been few studies on the status of the individuals that use the area, and how group composition differs in and out of an SAC. The first report that focused on the connectivity of bottlenose dolphins in Wales found that 91% of individuals that were identified in North Wales between 2007 and 2008 could be matched to the Cardigan Bay catalogue through photo-identification (Pesante et al., 2008). This meant that the Cardigan Bay population had a much larger home range that included North Wales, and they were not resident within the boundaries of the SAC's in Cardigan Bay. Bottlenose dolphin sightings were much more frequent around North Wales in the winter months, and so photo-ID surveys concentrated on this period (Pesante et al., 2008). There was a lack of surveys in North Wales in summer, as most of the identifiable individuals are seen in Cardigan Bay in summer, indicating that the majority of this population spend the summer in Cardigan Bay (Pesante et al., 2008).

Between April 2011 and February 2012, a total of seven sightings were recorded off the coast of Anglesey that resulted in a photo-ID session. The group sizes varied between 13 and 100 individuals in a single pod (Veneruso & Evans, 2012). A second study on connectivity was published in 2012 and analysed a total of 221 individuals that were sighted in North Wales from 2007 to 2012. This study found that 95% of individuals seen in North Wales could be matched to the catalogue of dolphins in Cardigan Bay (Veneruso & Evans, 2012; Figure 3). However, with the addition of surveys in summer months, it was found that in summer, only 38-62% of dolphins seen in North Wales matched to the Cardigan Bay catalogue (Veneruso & Evans, 2012). This study provided further evidence that out of the Cardigan Bay population, the majority of individuals spent summer months in Cardigan Bay exclusively and were then

seen in North Wales during the winter, which would strongly indicate that there is regular seasonal migration between these locations (Veneruso & Evans, 2012).

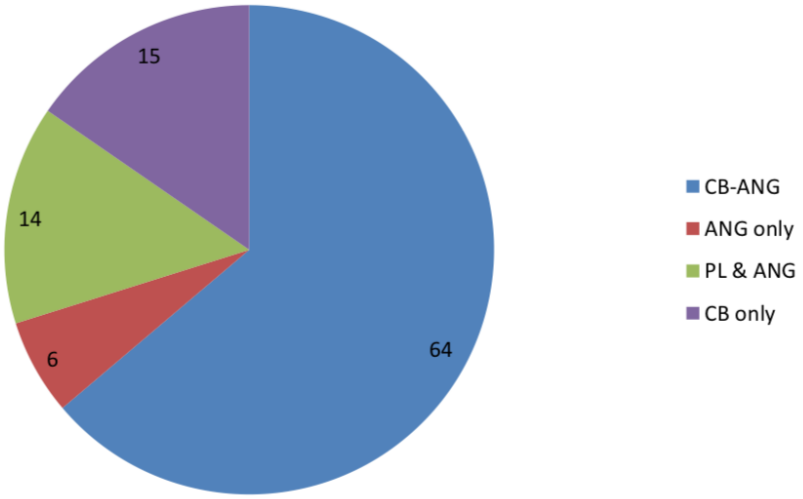

Figure 3. Sightings of bottlenose dolphins between 2007-2012 (CB-ANG= individuals sighted in Cardigan Bay SAC and Anglesey; ANG= only sighted around Anglesey; PL & ANG= dolphins sighted in the Pen Llyn a'r Sarnau SAC and Anglesey; CB= individuals only sighted in the Cardigan Bay SAC) (From Veneruso & Evans, 2012)

Between 2007 and 2013, a total of 211 individuals were sighted in North Wales, with 66% sighted both in Cardigan Bay and North Wales (Figure 4). Compared with the results from a similar analysis two years previously by Veneruso & Evans (2012), the proportion of individuals that were exclusive to Cardigan Bay had declined by 50% (Figure 4). A comparison of group size showed that the average group size in North Wales (26.4 individuals) was six times larger than in Cardigan Bay (4.23 individuals) (Feingold & Evans, 2014b).

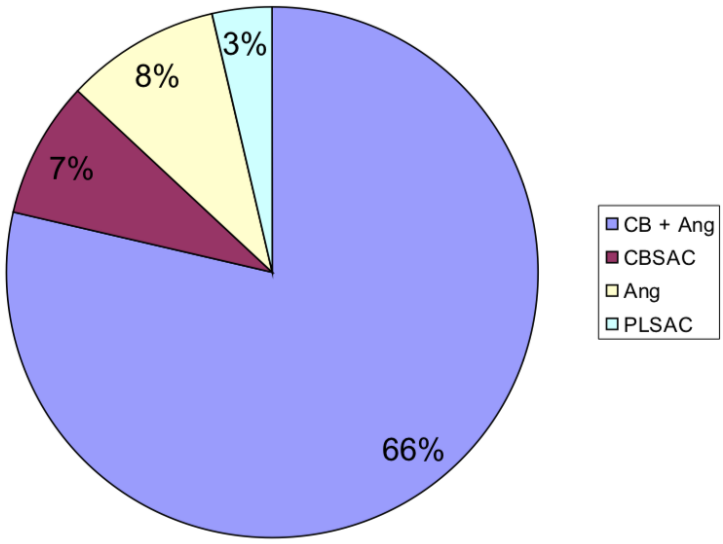

Figure 4. Photo-ID sightings of bottlenose dolphins between 2007-2013 (CB-ANG= individuals sighted in Cardigan Bay SAC and Anglesey; ANG= only sighted around Anglesey; PL & ANG= dolphins sighted in the Pen Llyn a'r Sarnau SAC and Anglesey; CB= individuals only sighted in the Cardigan Bay SAC) (From Feingold & Evans, 2014b)

The most recent study of bottlenose dolphin connectivity within the Welsh population was published in 2017. From 2001 to 2016, 77% of dolphins recorded in Cardigan Bay have been sighted in North Wales, and 20% were sighted around the Isle of Man (Lohrengel et al., 2017). The number of individuals that are classed as residents in the Cardigan Bay SAC has decreased in recent years. From 2001-2017, 58% of recognisable individuals were only seen in the Cardigan Bay; however, from 2001-2016, this decreased to 42% of individuals (Lohrengel et al., 2017). The number of sightings of bottlenose dolphins in North Wales has increased in the summer months although the number of photo-ID sessions has also increased in recent years (Lohrengel et al., 2014; SWF, unpublished data). From the summer photo-ID sessions in North Wales, most of the individuals had never been sighted in the Cardigan Bay SAC and have only been observed in North Wales or in the Pen Llyn a'r Sarnau SAC. The increase in surveys in North Wales has shown that the Cardigan Bay population actually uses a much larger area and splits its time between the two areas (Lohrengel et al., 2017). This would mean that only half of their home range is protected through the creation of SACs, which could impact their overall conservation, as the populations numbers are currently decreasing (Lohrengel et al., 2017).

1.7 Conservation Importance and Implications

The main threats that impact coastal populations of bottlenose dolphins are predominantly anthropogenic, including exposure to pollutants, boat traffic disturbance, entanglement in fishing gear, and noise pollution from offshore construction and large vessel activity (Morris et al., 1989; Borrel, 1993; Vidal, 1993; Janik & Thompson, 1996; Wells & Scott, 1997; Allen & Read, 2000). The creation of the Cardigan Bay SAC and the Pen Llyn a'r Sarnau SAC in Cardigan Bay has provided the Welsh population with some regulation of boat traffic and disturbances that occur there. In Cardigan Bay the main threats facing bottlenose dolphins are summertime recreational boating, which includes wildlife sight-seeing tours, and potential habitat destruction from scallop dredging in the winter months; both of these have increased in recent years (Feingold & Evans, 2014a, b; Norrman et al., 2015; Lohrenegel et al., 2017). Due to the presence of the Cardigan Bay SAC, regulations are placed on recreational boats interacting with bottlenose dolphins. These types of protection afforded by SAC's can be invaluable for the continued survival of the population.

However, many populations of bottlenose dolphins migrate seasonally or have an extended home range, utilising a large area dependent on food availability, season and abiotic factors (Wilson et al., 1997). When these populations become more migratory and extend their home range, their protection decreases as they travel outside of the bounds of an established SAC, and their likelihood of contact with human activities increases. This is the problem that is currently facing the Welsh population, as the SAC that was created to protect them is only one particular area in which they spend time. Currently, bottlenose dolphins are frequently sighted in North Wales, around Anglesey to Liverpool Bay, and even further north around the Isle of Man (Lohrengel et al., 2017). However, no research has been undertaken to establish the potential reasons behind the migrations to North Wales from Cardigan Bay, which could be used to determine if another SAC should be established in North Wales to increase protection under Natura 2000.

The coastal area around North Wales also has recreational activity in particular locations as well as pile driving activity with the construction of Gwynt y Mor and Rhyl Flats wind farms, with plans for other wind farms in the area underway which may disturb any marine mammals in the area. In addition, Liverpool Bay is considered as one of the most heavily polluted areas of inshore sea in Europe, because of the chemical-based industry that occurs in that area

(Doody, 1996; Crumpton et al., 1996; Vane et al., 2007). There have been several reports of marine mammals with high levels of hydrocarbons such as PCBs and heavy metals like mercury which can have damaging, and even lethal effects on animals (Morris et al., 1989; Law et al., 1991, 1995).

Increased concentrations of organochlorines in small cetaceans can affect the immune system and may decrease reproductive success which causes serious consequences for the overall health of the population (Morris et al., 1989; Jepson et al., 2016). A study on a population of grey seals (*Halichoerus grypus*) in Liverpool Bay has found that seals there had much higher concentrations of PCBs than seals from other areas of the UK (Law et al., 1989). In addition to this, female seals with high levels of DDT and PCBs were found to have abnormal reproductive tracts which, overall, reduced their reproductive success (Reijnders, 1980). Discharged PCBs in large volumes are a growing problem due to the damage they cause in the local environment and the effects for species in the area. This is especially damaging for larger marine mammals as these chemicals can bioaccumulate through the food chain (Johnson et al., 1991).

The Welsh bottlenose dolphin population has shown high levels of contaminants which may be due to their seasonal migrations into the heavily polluted areas of North-east Wales and Liverpool Bay, and from feeding in these areas. These cases of high contamination have come from dead individuals that been autopsied. In 1988, a bottlenose dolphin calf was found in Cardigan Bay with one of the highest levels of PCBs (290ppm), dieldrin (74 ppm) and DDT (150 ppm) that had ever been recorded in the UK at the time (Morris et al., 1989). In addition, a four-year-old was recorded in 1989 with similar levels of contaminants as well as a 23-year old in 1991 (Law et al., 1995). These reports of individuals with high levels of contamination may indicate that the dolphins in the Welsh population were already making seasonal movements between Cardigan Bay and North Wales long before monitoring began. This could be possible due to the lack of surveys in North Wales in earlier years. As it is becoming apparent that bottlenose dolphins are spending an increased amount of time in North Wales, further protection is needed in this area to mitigate the effects of pollutants and contaminants from industrial activity.

In order to better advise policymakers on the protection of this species, information on the movements of bottlenose dolphins and movement patterns are crucial in determining which areas are important sites and how they are being used. This information is also important in

determining casework enquiries and in order to accurately undertake strategic environmental assessments (SEAs) (Pesante et al., 2008). These types of assessments are used to inform developers and local authorities on environmental impacts associated with any development project, such as wind farms, tidal energy installations and other offshore infrastructure development (Pesante et al., 2008). As the bottlenose dolphin is protected under the EU Habitats and Species Directive and its Natura 2000 network, it is necessary to establish what proportion of Welsh bottlenose dolphins is spending a significant amount of time in North Wales (Feingold & Evans, 1014a), and to recognise that individuals may travel regularly between North Wales and Cardigan Bay, and spend a significant portion of the year outside protected areas (Feingold & Evans, 2014b). Further studies on the movements of this population in North Wales, and additional surveys in the area, will increase the knowledge needed to inform decisions on increasing protection of this population through the possible creation of an SAC to fully protect this species.

1.8 Aims and Objectives

The overall aim of this study is to assist in reporting on the status and range of individual bottlenose dolphins that are located in Welsh waters and to determine why these individuals move between North Wales and Cardigan Bay, using photo-identification techniques and unique sightings histories. Photographic matching of individuals found in North Wales and tracking of their movements would inform policymakers of the range and usage linkages between locations in Wales. The status of individuals that use North Wales regularly and where these individuals breed and give birth as well as any seasonal variations would help to uncover the life-history patterns of the Welsh population and could be used to potentially increase the protection for bottlenose dolphins into areas hitherto relatively unprotected.

The specific objectives of this study are:

- To compare photographic identification images from outside of Cardigan Bay with established catalogues of Cardigan Bay to identify and find patterns in dolphin movements between sites.
- To determine the characteristics of individuals that have been recorded moving either seasonally or more permanently between Cardigan Bay and North Wales (e.g. male or female, juvenile or adult, giving birth I that year), and why they may be moving between habitats.

- To determine the composition of individuals that make up groups outside of the Cardigan Bay area.
- To determine if bottlenose dolphins are sufficiently protected in Welsh waters or if additional protection/management is needed.

Hypotheses:

1. There will be a difference in gender proportions between individuals seen in North Wales and those seen only in Cardigan Bay.
2. There will be evidence that females move between North Wales and Cardigan Bay before or after giving birth, and there is a preferred location in which to give birth.
3. There will be a difference in the proportions of age classes (Adults, juveniles, calves and new-borns) between North Wales and Cardigan Bay.
4. There will be an increase in the number of individuals that have emigrated to North Wales from Cardigan Bay since 2004.

3.0 Methods

3.1. Study sites

3.1.1. North Wales and Anglesey

For the purpose of this study, North Wales is considered to be the marine environment that encompasses the area north of the westernmost point of the Llyn Peninsula (52° 47’ 45’’ N, 004° 46’ 00’’ W). This area includes the Isle of Anglesey to Liverpool Bay and the waters around the Isle of Man (Figure 5). North Wales makes up part of the Irish Sea and is located east of the northern Celtic Sea Trough (Baines & Evans, 2012).

Figure 5. Map of North Wales with the boundary of the tip of the Llÿn Peninsula shown by solid red line.

The marine environment of North Wales is made up of a variety of habitats, with varied sediment types from soft muddy sediments to rocky and pebble sediments (Barne et al., 1996). The main bathymetric feature in Wales is a wide trough that is more than 100 m deep, which occurs between Ireland and Wales. Water depth reaches a maximum of 20 m a few kilometres offshore from the north coast of Anglesey, and the isobath continues to the Great Orme near Llandudno while shallower waters are found near Conwy Bay (Barne et al., 1996).

3.1.2. Cardigan Bay

Cardigan Bay encompasses an area of 5,500 km^2, making it the largest bay in the UK (Baines et al., 1995). Cardigan Bay is located off the western coast of Wales and extends over 100 km from the westernmost point of the Llyn Peninsula (52° 47’ 45’’ N, 004° 46’ 00’’ W) down to the southernmost point in Saint David’s Head (51° 54’ 10’’ N, 005° 18’ 54’’ W) (Lohrengel et

al., 2017). Cardigan Bay includes the Cardigan Bay SAC area as well as Pen Llyn a'r Sarnau SAC (Figure 6).

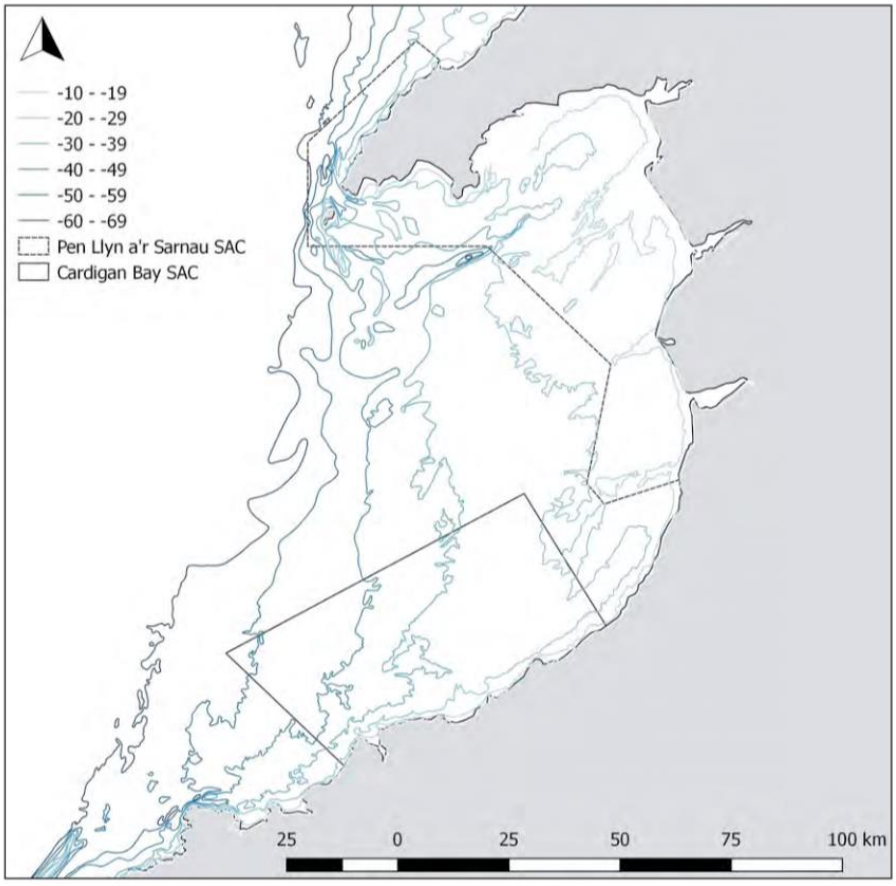

Figure 6. The study area of Cardigan Bay, West Wales. Depth contours are shown as well as the outlines of the Cardigan Bay SAC (solid line) and the Pen Llyn a'r Sarnau SAC (dashed line) (Lohrengel et al., 2017).

Cardigan Bay is classed as a shallow bay that has a gentle slope to a depth of 60 metres becoming progressively deeper from east to west (Figure 7). The bay has weak tidal currents, with the strongest currents located near estuaries and headlands, while weaker currents primarily occur in the north-easternmost part of the bay (Evans, 1995). The sea surface temperature can vary during the year due to seasonality, the shallow nature of the bay and the input of freshwater from the land. February and March have the lowest reported sea surface temperatures at between 5°C and 8.5°C, while during the summer, between August and September they reach a peak of 14°C to 16°C offshore and up to 20°C inshore (Evans, 1995; Baines et al., 2000).

Biological characteristics of Cardigan Bay include a wide variety of marine flora and fauna (marine mammals, seabirds, invertebrates, and fish) due to the variety of habitat types. Bottlenose dolphins were first documented in the bay in the 1920's (Evans and Scanlan, 1988) but probably occurred here long before that time.

3.2. Photo-Identification process

All photos taken for photo identification followed the guidelines that are outlined in the photo-identification licence that was granted to the Sea Watch Foundation by Natural Resources Wales (NRW) (previously known as Countryside Council for Wales (CCW)). All encounters also followed the protocol outlined by Würsig & Jefferson (1990), which is a widely used method of identifying and capturing adequate photos that can be used to match individual cetaceans. The primary equipment used to photograph the dolphins was a Canon EOS digital SLR camera with one of four lenses (17-85mm, 18-200mm, 70-200mm or a 75-300mm zoom lens). Dolphins were approached at a distance of 20-50 metres and the photo-ID session lasted until a) clear photos of each dolphin's dorsal fin had been taken on both the left and right side, b) until the dolphins moved away or showed signs of distress, c) the group was lost to view, d) weather deteriorated making photo-ID unfeasible, or e) the time allowance of 40 minutes for photo-ID sessions under the licence from the NRW was reached.

After a photo-identification session had stopped, the encounter was given a unique number. A group of dolphins was classed as individuals within 100 metres of each other that exhibit the same behaviour or are travelling in the same direction (Wells et al., 1987; McHugh et al., 2011). The number of individuals in each encounter was established through counting and was confirmed using photos at a later date. In North Wales, dolphins occur in large groups of up to 100 individuals that form sub-groups that are spread over a wide area. These sub-groups may be seen coming together to form one large group at some point and then separating into smaller groups, but most were scattered over a wide area as sub-groups. These types of encounters were counted as a single group and a single encounter.

When dolphins were encountered, each was aged using four age categories (adults, juvenile, calf and new-born) (Bearzi et al., 1997; Feingold & Evans, 2012). Individuals that were between 2.5 and 4 metres in length and that had nicks or marks on their dorsal fin were classified as adults. Individuals that were two-thirds the length of an adult and seen swimming

independently were classified as juveniles. Individuals one-third to one-half the size of an adult and were seen swimming in close association with one adult were classified as calves. Lastly, individuals one-third of the size of an adult, with foetal folds present along the length of the body and a small darker dorsal fin, were identified as new-borns. New-borns were also always seen swimming in very close association to an adult.

The matching of photographs to the pre-existing catalogue of dolphins was done using Adobe Photoshop 7.0 and/or ACDSee Pro. This process followed the techniques described by Würsig & Jefferson (1990) and Defran et al. (1990). Only photos that could clearly be identified and were of high-quality were used to identify individual dolphins in order to avoid the chance of getting a false positive/negative identification. Matches were also confirmed by a second person (Hammond, 1986; Scott et al., 1990; Stevick et al., 2001).

3.3. Data collection

The bottlenose dolphin population in Wales has been studied since the late 1980's. The Sea Watch Foundation has been studying the Cardigan Bay population using photographic mark-recapture techniques since that time, but most intensively from 2001 onwards. The organisation maintains a photo-identification catalogue of more than 250 recognisable bottlenose dolphins. Surveys in 2001 began in the southern Cardigan Bay. However, in 2005, this expanded to include the northern Cardigan Bay and more recently expanded even further into North Wales around the coast of Anglesey. Several interns and volunteers have assisted in collecting the relevant data after receiving training in the data collection protocols that Sea Watch has developed. All effort and sightings data that are collected are entered into a database that is available from the Sea Watch Foundation office located in New Quay, Wales.

3.3.1. Boat-based surveys

During boat surveys, sightings and effort data have been collected by a minimum of four people at any one time. This consists of two primary observers, at least one independent observer, and a person collecting effort data.

The primary observers were seated on the roof or highest point of the vessel and searched for any cetacean or pinniped from a 90-degree angle to 10 degrees on the opposite side of the boat.

Scanning of the sea was done with the naked eye, with binoculars used to confirm a potential sighting or to ID the species sighted. Once an animal was sighted, one of the primary observers would record it on the sightings form (Appendix 1). Data recorded included the time, location (latitude and longitude), estimated distance from boat, boat course and speed, species, group size and composition, behaviours, cue used to identify the species, and the reaction of the animals to the boat. One primary observer was also responsible for recording behavioural data on a separate behaviour form (Appendix 2) when bottlenose dolphins were 100 metres or less from the boat. Behavioural data were taken every 3 minutes during an encounter. Data recorded included time, location (latitude and longitude), interactions with other species including birds, reactions to the vessel, number of individuals, group formation and composition, surfacing mode and direction of travel. The behavioural modes recorded were split into the categories of normal swim, fast swim, slow swim, suspected feeding, observed feeding (when prey was seen), leaping, resting, socialising, bow riding, or unknown behaviour.

At least one independent observer participated in most line transects, and usually there were two (depending on the vessel used for the survey). Independent observers were generally situated away from the primary observers and would scan the sea using binoculars. They were not allowed to have any direct contact with the primary observers during watches. All sightings by the independent observers were recorded on an independent observer form (Appendix 3). If bottlenose dolphins were sighted, independent observers would only reveal the sighting to the rest of the team when the individual or group was 90 degrees to the vessel, so the primary observers have the chance to sight and record the sighting as well.

When bottlenose dolphins were spotted while on transect, the vessel would deviate from the transect line in order to conduct photo-identification. After sufficient images were taken, the vessel would then resume the transect at the point where the line was left.

The person responsible for collecting effort data recorded the effort and environmental factors on an effort form (Appendix 4) every 15 minutes or every time the environmental conditions changed markedly, or when the vessel had a noticeable change in course or speed. When a photo-ID session was conducted, effort data were recorded every 3 minutes for the duration of the encounter. Effort data included time, location (latitude and longitude), the number and type of boats that could be seen, the vessel speed and course, glare intensity, precipitation type, visibility and sea state. The type of effort was also recorded, split into four categories: line

transect on a pre-defined transect, dedicated search when not on line transects but observers were on duty, casual watch, usually when weather conditions were unfavourable or when on a visitor passenger boat from New Quay, and photo-identification when dolphins were approached in order to take photos.

3.3.2. Cardigan Bay

The data obtained from Cardigan Bay were collected from 2001-2018, over a period of 18 years. Boat-based surveys in southern Cardigan Bay began in 2001, while surveys of northern Cardigan Bay that include the Pen Llyn a'r Sarnau SAC began in 2005. For the purpose of this study, Cardigan Bay represents the entirety of the Bay, including the Cardigan Bay SAC as well as that part of Pen Llyn a'r Sarnau SAC south of the Llyn Peninsula, and the rest of the Bay (Figure 7). For this project, the main focus of the data collection was the Photo-ID aspect; this was collected primarily through distance-sampling line-transects as well as non-line transect surveys and dedicated searches while not on transect (Lohrengel et al., 2017).

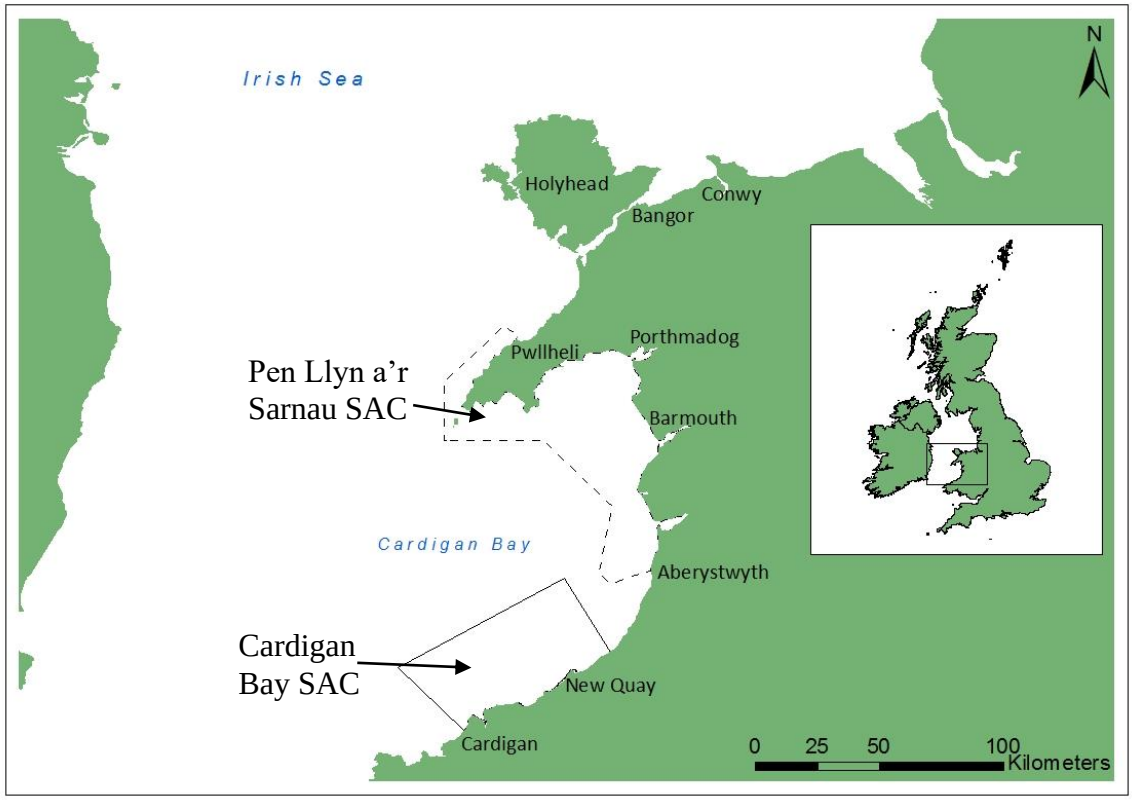

Figure 7. A Map of West Wales within the UK. Cardigan Bay SAC is shown by the solid line while the Pen Llyn a'r Sarnau SAC is shown within the dotted lines (Baylis, 2013)

3.3.2.1. Line-transect surveys

Data collected in Cardigan Bay were partially collected using line-transect surveys, which is a distance sampling method that is commonly used to survey cetacean abundance. In Cardigan Bay SAC, these transect lines are split into inshore transects, up to 11 kilometres from the coast and offshore ones, which were up to 23 kilometres from the coast (Figure 8). In northern Cardigan Bay, a much wider area of sea was covered by line transects (Figure 9). Each transect is divided into legs, each with a specific start and end point. In order to randomly survey Cardigan Bay, a transect line is randomly chosen on the day of the survey. Boat surveys were only conducted when the sea state was three or less on the Beaufort scale. When the sea state was higher than a three, the survey was cancelled as a rough sea state can reduce detection rates.

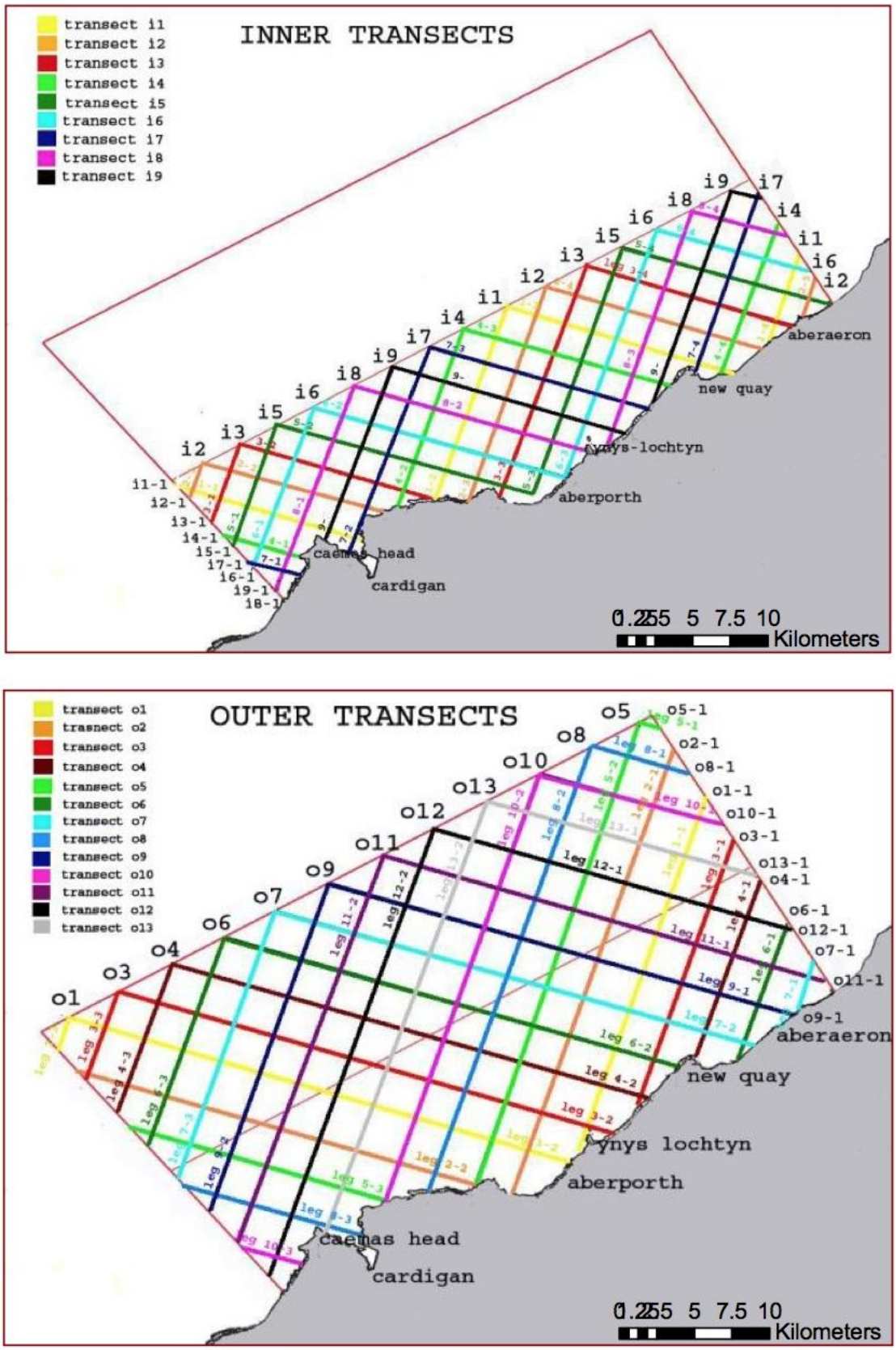

Figure 8. Inner and outer line transects for southern Cardigan Bay including the Cardigan Bay SAC (From Feingold & Evans, 2013)

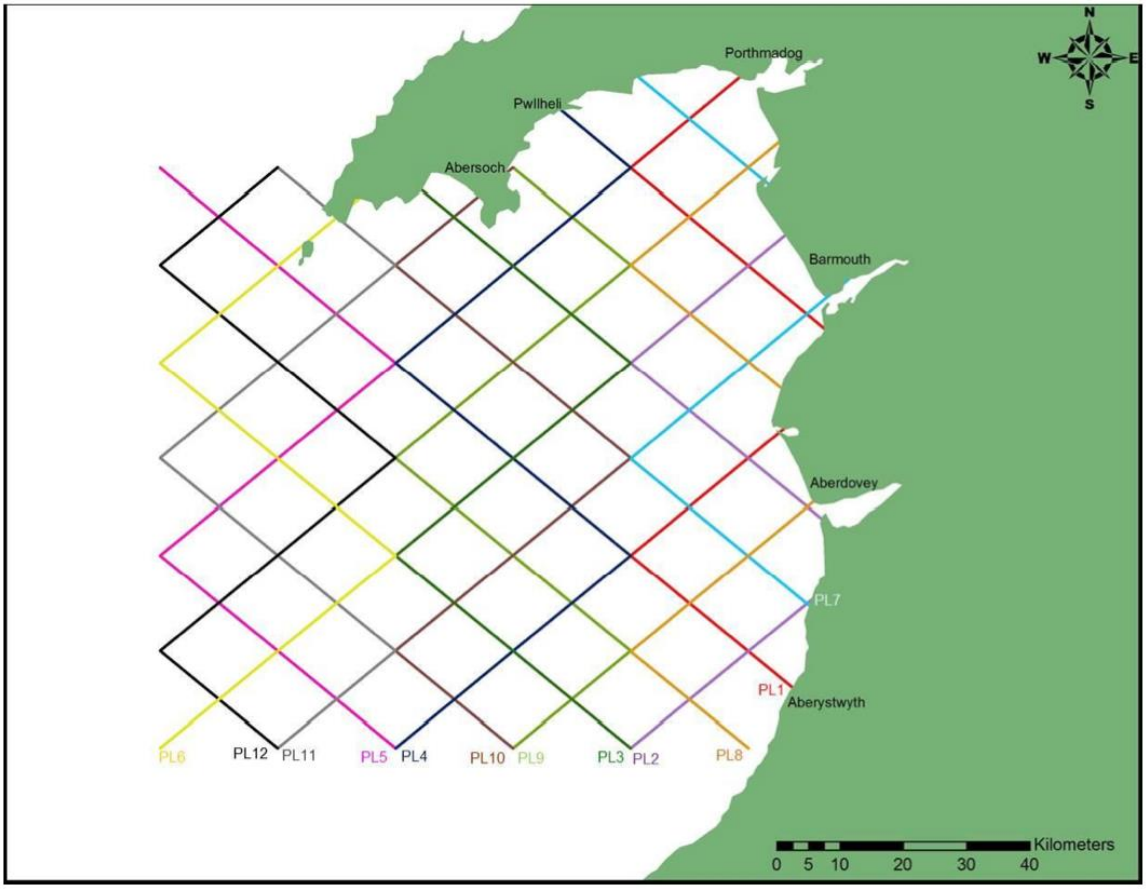

Figure 9. Line transects for Northern Cardigan Bay including the Pen Llyn a'r Sarnau SAC (From Feingold & Evans, 2013)

3.3.2.2. Non-line transect surveys

Ad libitum surveys were conducted in addition to line transects. These were survey trips that did not follow an exact route. These surveys included "dedicated search" and "casual watching". Dedicated searches were conducted while a vessel was travelling to or from a transect line. During this time, only primary observers were actively looking for cetaceans. If bottlenose dolphins were sighted during dedicated searches, this would result in a photo-ID session. Casual watches took place when the conditions were unfavourable for dedicated searches and systematic surveys. Casual watches also included the one- and two-hour commercial boat trips that were conducted by the wildlife tour operator that travelled down the coast from New Quay. Due to the commercial nature of the boat trips, these boats were not allowed to approach the dolphins within 100m. Photo-ID was taken if the dolphins were in range; however, they were not approached on these surveys. Effort and sightings data were recorded by the SWF intern or volunteer on-board using the relevant forms.

3.3.3. North Wales

Surveys from North Wales were conducted on boat surveys mainly from Amlwch harbour but occasionally out of Menai Bridge or Beaumaris, all located on the Isle of Anglesey. Surveys have mostly aimed at getting sufficient photo-ID images of groups of dolphins off the coast of Anglesey, thus vessels seldom covered a very large area. However, some surveys were conducted over a wide area focused on the coastal zone from around Anglesey to the Great Orme headland on the mainland coast of Wales.

Most surveys in North Wales involved dedicated search rather than line transects, and involved one or more primary observers with effort forms, sightings forms, photo-ID and behavioural forms filled out on the duration of the surveys. In some cases, local fishermen would alert Sea Watch when they sighted dolphins in the area, and, weather permitting, a photo-ID survey would be undertaken using the motor catamaran *Seekat C.* In the earlier years, Dave Powell was a main sources of reporting cetacean sightings around North Wales, as he would regularly watch for cetaceans from Point Lynas, whereas phone contacts with fishermen were established through the *Seekat*'s skipper, Jon Shaw. All data collected were validated before being added to the main database. Most photo-ID sessions in North Wales were undertaken by Sea Watch's Director, Dr Peter Evans.

3.3.4. Additional data

Additional data were also collected by relevant parties and sent to the Sea Watch Foundation. These came mostly in the form of photographs that could be used for photo-ID, along with basic environmental data and the time and location of the individuals photographed. The Manx Whale and Dolphin Watch, for example, kindly sent photos of bottlenose dolphins that were sighted near the Isle of Man. In Liverpool Bay, England, a local Sea Watch group undertook some opportunistic surveys that resulted in photo-ID sessions, and these photos were then matched to individuals in the SWF catalogue. Photos were also given to the SWF by wildlife tour operators and casual observers and used for individual identification when they were of sufficient quality.

3.4 Data Analysis

3.4.1 Hypothesis 1: Gender bias and composition

To determine whether is a gender bias occurs in the individuals seen in North Wales compared with those seen in Cardigan Bay, a full table of each individual, their gender and where the individual was seen in winter and summer each year was created. Data for this analysis were taken from the Sea Watch Foundation database. A query was used to separate data from North Wales and Cardigan Bay using the latitude where the encounter occurred. Data were taken from 2006 to 2017 as this was the time period when data from North Wales had been obtained, so data from Cardigan Bay was extracted only from those years in order to be able to make a direct comparison. To compare seasonal variations, each year was split into summer (May to October) and winter (November to April). Each individual that was seen in a particular area in a season was identified and the numbers for each gender were calculated for the two locations by season and by year. In some cases, when individuals were sighted in both locations in the same season, those were then recorded in both locations and counted towards the proportions in each area.

Within the database, each individual is listed as either female, possible female, male, possible male, or unknown gender. For the purpose of this analysis to increase the sample size, the females and possible females were combined, as where males and possible males.

A one-way Analysis of Variance (ANOVA) was performed in order to determine if there were significant differences between the proportion of each gender (female, male and unknown) between North Wales and Cardigan Bay. An ANOVA was also run in order to determine if there was a significant difference in the proportion of each gender between seasons in North Wales. If the assumptions of an ANOVA were not met, a square root transformation was applied to the proportions. An ANOVA was also performed on the number of overall individuals sighted in North Wales and Cardigan Bay, along with a separate ANOVA on the number of females, males and unknown gender individuals sighted between each area. ANOVA's were also performed on the number of individuals that were sighted in each location in summer and winter respectively. If the assumptions of homogeneity of variance continued to be not met, a non-parametric Kruskal-Wallis analysis was performed. Proportions were used as sample sizes vary significantly for each year and location, so in order to give an overall view, regardless of how many individuals visit a particular area's proportions were used.

3.4.2 Hypothesis 2: Mothers: movement patterns and birthing location

The sightings histories of female bottlenose dolphins were analysed to determine if they had been seen with a new-born calf and where they had been seen before and after giving birth. Females that were seen with a new-born or small calf within a one-month timespan were used in the analysis. This was done to ensure that the analysis of the location of births could be estimated accurately enough to determine the movements of each mother before and after giving birth. Birth dates were estimated based on the last sighting of the mother and the first sighting with a new-born or calf within a short time span. This was also used to determine the season in which each calf was born and if they had been born inside or outside Cardigan Bay.

There were 111 births that had sufficient sightings of each calf with the mother. Some of these involved the same mother, but a different calf over her lifetime. Of these 111 births, 13 had insufficient data, with no sightings recorded either two years before or two years after giving birth, insufficient to be able to analyse the movements and location preferences before and after giving birth. They were therefore excluded from further analysis. For each individual, the sightings history was taken from the two years before and after giving birth, so this also included the season in which the individual had given birth in and the location. There were adequate data for 96 individual births in total.

These data were analysed in order to investigate why these individual dolphins move between North Wales and Cardigan Bay, and whether there is any link to breeding and calving grounds. Individuals that were recorded using North Wales as a calving location or relied heavily upon North Wales before or after birth were analysed separately to determine what percentage of those mothers then use Cardigan Bay as a nursery ground, and to attempt to discern patterns in habitat usage.

3.4.3 Hypothesis 3: Group size and gender composition

In order to determine if there was a significant difference between group sizes in North Wales and group sizes in Cardigan Bay, a Chi-squared test was performed using SPSS. The mean group sizes were calculated for the overall mean from 2007 to 2015, when data from both areas were available. Standard error was calculated overall and for each year independently. Group

size was estimated by volunteers on vessels during the encounter and was double-checked using photographs after the encounter had ended.

The overall age composition of groups in Cardigan Bay and groups in North Wales was extracted. Individuals were either identified as an adult, juvenile, calf or new-born (Table 1). The mean number of adults, juveniles, calves and new-borns in each encounter was calculated for each year between 2007- 2015 for North Wales and Cardigan Bay independently and as a total for each location.

Table 1. Description of the criteria for age classification that is used by the Sea Watch Foundation based on size and physical description.

	Descriptive criteria	Size criteria
Adult	Nicks, marks and/or scars apparent on dorsal fin	2.5 to 4 meters in length
Juvenile	Swimming independently of adult	2/3rd the size of adult
Calf	Swimming in close association with adult	1/3rd to ½ the size of adult
New-born	Presence of foetal folds along the length of the body and a small darker dorsal fin. Swimming in close association with adult	1/3rd the size of adult

A one-way ANOVA was conducted to explore the variation in the number of adults/juveniles/calves/new-borns that were seen between the years 2007 and 2015 in North Wales. Before the ANOVA tests were conducted, Levene's test was used to determine if the data fit the assumptions of a parametric ANOVA test. If the data did not fit the assumptions, a square root transformation was applied to the data, if the assumptions were continued to not be met, a non-parametric Kruskal-Wallis test was performed in its place.

3.4.4. Hypothesis 4: Emigration

The number of individuals that have emigrated from Cardigan Bay to North Wales from 2004 to 2015 was analysed to determine if the emigration rates were unchanged, increasing or decreasing. The sighting histories of a total of 259 individuals were analysed to determine their movement and location for each year. Individuals can have very high site fidelity in some cases, while others may have a very large home range that can include both Cardigan Bay and North

Wales. Several individuals move between these areas depending on the season, with more individuals seen in North Wales in winter months and in Cardigan Bay in summer. Due to this, an individual was only considered to have emigrated if they had not been seen in Cardigan Bay for three years or more, and in that time period, they had been sighted in North Wales. This emigration also had to be their most recent move to North Wales from Cardigan Bay. In cases where individuals had a history of moving between areas for long periods of time or were considered "missing" or had not been sighted for several years to reappear a few years later, these were not considered as emigrated, as the move was not permanent.

In order to determine if there was a correlation between the number of individuals that have emigrated over time, a Spearman's correlation was performed. Additionally, to determine when individuals started to first appear in North Wales, a Spearman's correlation was performed comparing the relationship between the number of individuals that were first sighted in North Wales per year over time. To correct the number of new sightings per year for effort, the number of individuals that were sighted in North Wales for the first time per encounter was used.

4.0 Results:

4.1 Hypothesis 1: Gender bias and composition

There was no significant difference in the number of individuals that were sighted in Cardigan Bay and North Wales (Kruskal Wallis; χ^2= 1.26, df=1, p=0.26). Females made up the highest percentage in both locations, with a slightly higher percentage in North Wales as there were fewer males in this area overall (Figure 10). There was a significant increase in the proportion of males that were seen in Cardigan Bay compared to North Wales (Kruskal-Wallis; χ^2=11.79, df=1, p=0.001). However, there was no significant difference in the proportion of females sighted in Cardigan Bay and North Wales (ANOVA; $F_{(1,46)}$ =0.36, p=0.55). There was also no significant difference in the proportion of unknown gender individuals between North Wales and Cardigan Bay (ANOVA; $F_{(1,46)}$ =0.36, p=0.55).

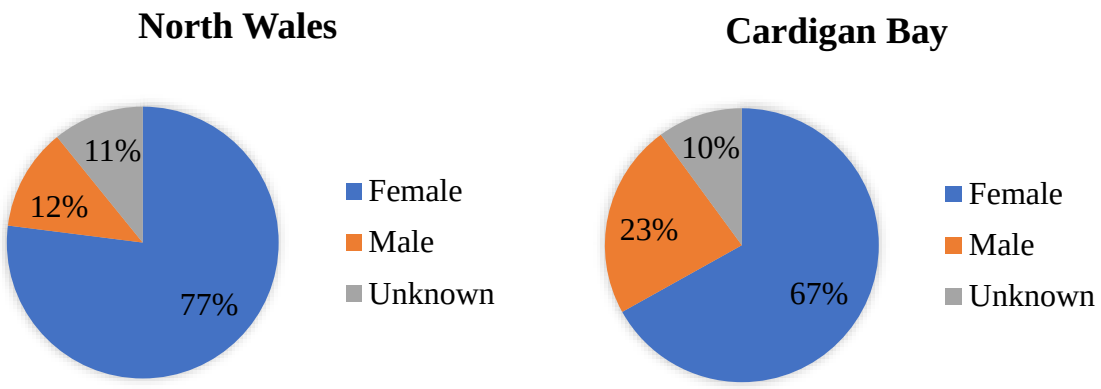

Figure 10. Gender proportions in North Wales and Cardigan Bay by individuals seen every season for each year

There were more individuals overall that were seen in the winter in North Wales and more in the summer in Cardigan Bay (Figure 11). However, this was biased by the number of surveys conducted in each area for each season. Generally, more surveys were undertaken in the summer months in Cardigan Bay and more surveys in the winter months in North Wales, although the number of surveys in the summer months is increasing in North Wales.

In North Wales, there was an overall trend of more individuals being encountered in winter when compared to summer months. There was no significant difference in the number of individuals that were encountered in North Wales between summer and winter (ANOVA; $F_{(1,22)}$= 3.26, p=0.08). There was also no significant difference in the number of female bottlenose dolphins that were encountered in North Wales between summer and winter (ANOVA; $F_{(1,22)}$=3.00, p=0.97). Although, there is a general increase in the number of all individuals in the winter than in the summer. Additionally, there is no significant difference in the number of males (ANOVA; $F_{(1,22)}$=2.22, p=0.15) and the number of individuals of an unknown gender (ANOVA; $F_{(1,22)}$=2.55, p=0.13) in North Wales between summer and winter.

In Cardigan Bay, there was a significant increase in the overall number of individuals that were encountered and identified in the summer months when compared to the winter (ANOVA-SQRT; $F_{(1,22)}$=75.88, p<0.00). There was a significant increase in the number of female bottlenose dolphins that were encountered in Cardigan Bay in the summer months compared to the winter (ANOVA; $F_{(1,22)}$=34.06, p<0.00). There was a significant increase in the number

of males that were sighted in Cardigan Bay in the summer compared to the winter (ANOVA-SQRT; $F_{(1,22)}$=41.48, p<0.00). There was also a significant increase in the number of unknown individuals that were sighted in Cardigan Bay in the summer when compared to the winter (ANOVA-SQRT; $F_{(1,22)}$=60.87, p<0.00).

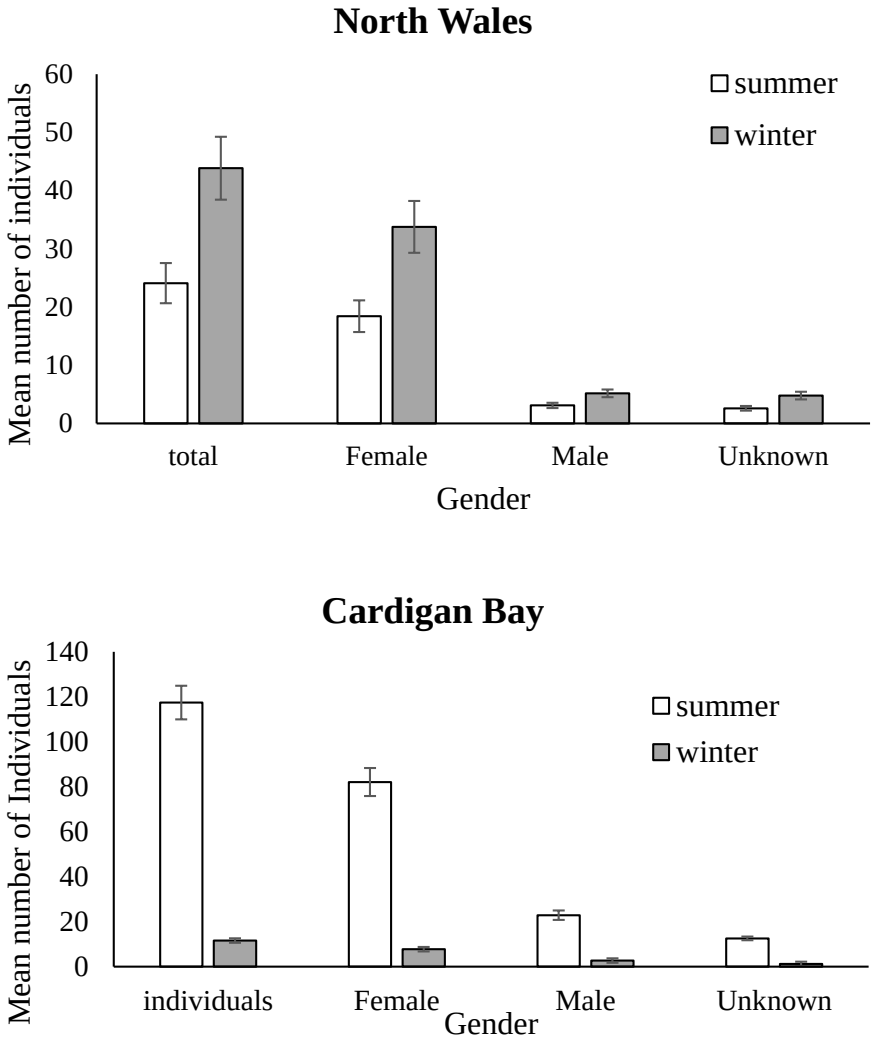

Figure 11. The mean number of individuals (+/- SE) that were seen in (Top) North Wales and (Bottom) Cardigan Bay in both summer and winter from 2006 to 2017, divided by gender

The gender composition did not vary notably between summer and winter for either location. In North Wales, there was no significant difference in the proportion of females that were seen between summer and winter (Kruskal-Wallis; χ^2=0.44, df=1, p=0.51). Additionally, there was no difference in the proportion of males that were seen between summer and winter (ANOVA; $F_{(1,22)}$=0.7, p=0.79). There was also no significant difference in the proportion of individuals whose gender is unknown between summer and winter in North Wales (ANOVA; $F_{(1,22)}$=1.57, p=0.22). There were very few differences in gender proportions between summer and winter in North Wales (Figure 12).

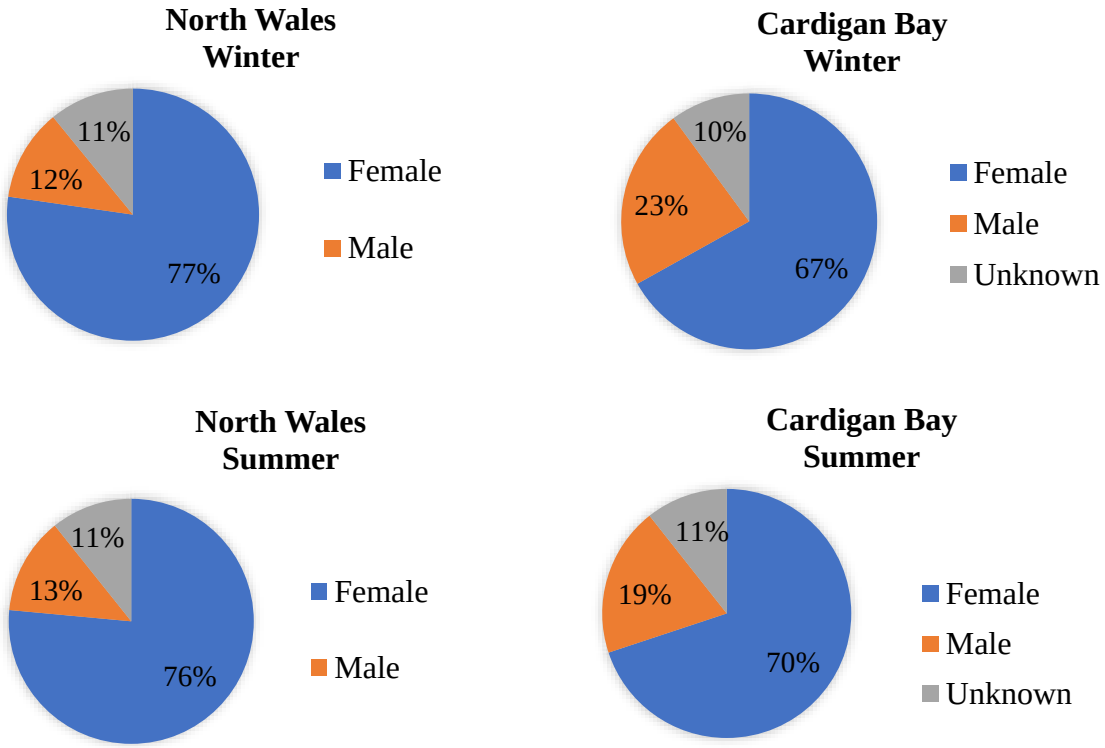

Figure 12. Gender composition of individuals seen in North Wales for summer and winter and in Cardigan Bay in summer and winter

In Cardigan Bay, the gender proportions change over time especially in winter when there are fewer encounters than in the summer months due to the lack of surveys in winter. There were no encounters in 2009 and very few in 2008, 2010, 2013, 2014 and 2017. In these years the gender proportions are more skewed due to the small sample size. In contrast, 2007, 2011 and 2012 had the most individuals sighted in the area, which gives a more representative gender proportion as there were over 20 individuals encountered during those years. In the majority of

years, there was a high proportion of females compared to males (Figure 13). However, in 2011, when the greatest number of individuals were sighted in the winter in this area, there was a much more even split between female and males (Figure 13).

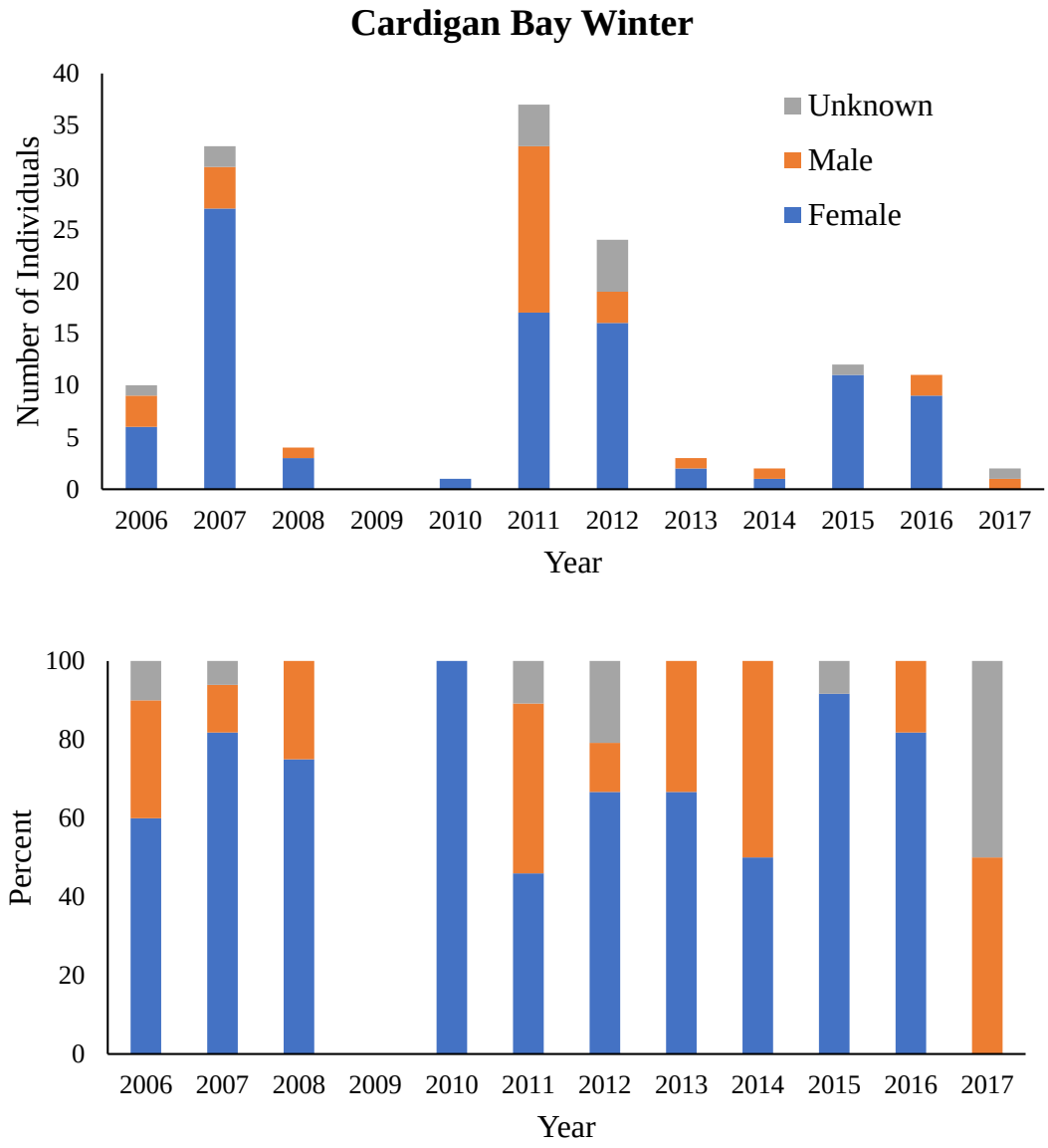

Figure 13. Cardigan Bay gender ratio in winter by individuals seen every year (Top) and by female, male, and unknown gender proportions (Bottom) per year from 2006 to 2017

In Cardigan Bay, the gender proportions in summer were more consistent than the gender proportions for winter as there were more surveys in these months, and therefore, more sightings. Similar to the winter, 2010 was the year where the most individuals were sighted in the summer. However, for the majority of years from 2006 to 2017, there were over 100 individuals sighted within the six month period of summer. Overall, there is little variation in

the proportions of males to females and unknown individuals from 2006 to 2017, with a slight increase in the proportions of males in 2011 and 2013 (Figure 14).

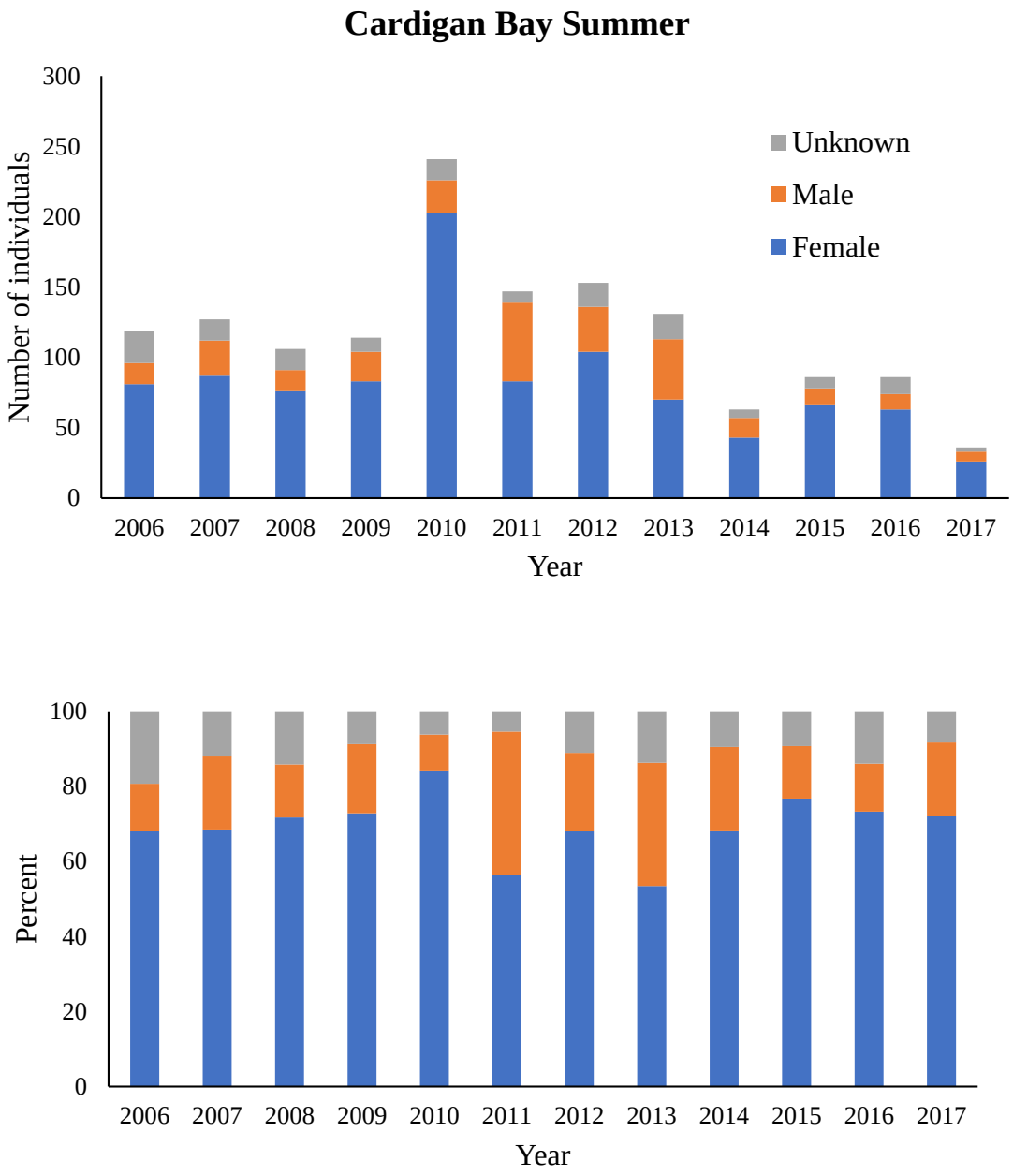

Figure 14. (Top) The number of females, males and unknown gender individuals that were sighted in Cardigan Bay summer and (Bottom) the percentage of each gender per year from 2006 to 2017

The gender proportions in North Wales during the summer were fairly consistent from 2007 to 2017, with the majority of individuals being female (Figure 15). There were no sightings from summer in 2015 due to a lack of surveys.

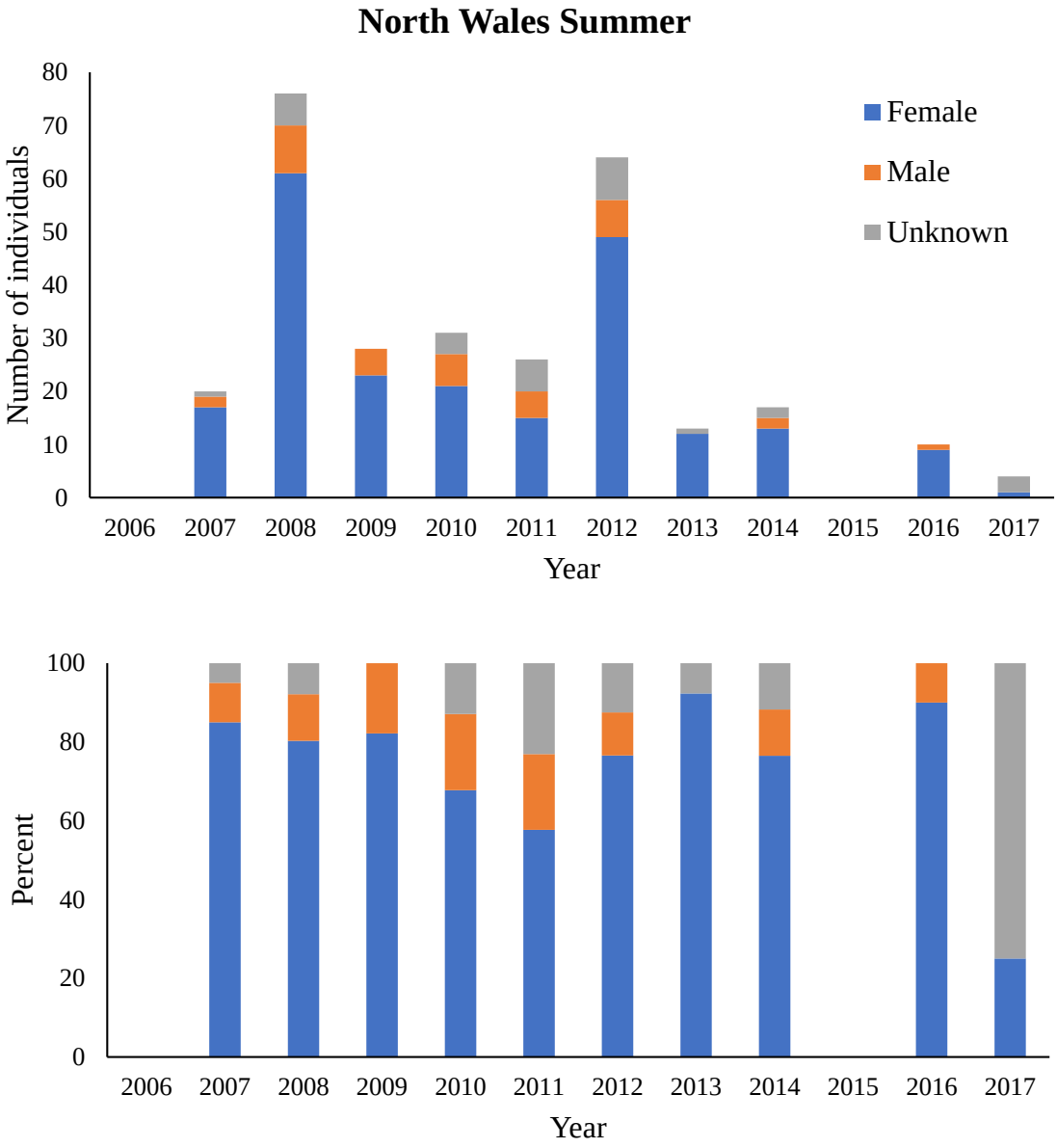

Figure 15. The number of females, males and unknown gender individuals that were sighted in North Wales in summer (Top) and the percentage of females, males and unknown gender individuals every year (Bottom) from 2006 to 2017

Gender proportions in North Wales in the winter were also consistent from 2006 to 2017. In years where sightings were very low, such as 2006 and 2017, gender proportions were skewed as there were not enough individuals to accurately assess gender proportions (Figure 16). The number of individuals that were recorded in North Wales in winter increased from 2006 to

2012 where it peaked at 125 individuals, after that there was a decrease until 2017, mainly due to the lack of surveys in the area.

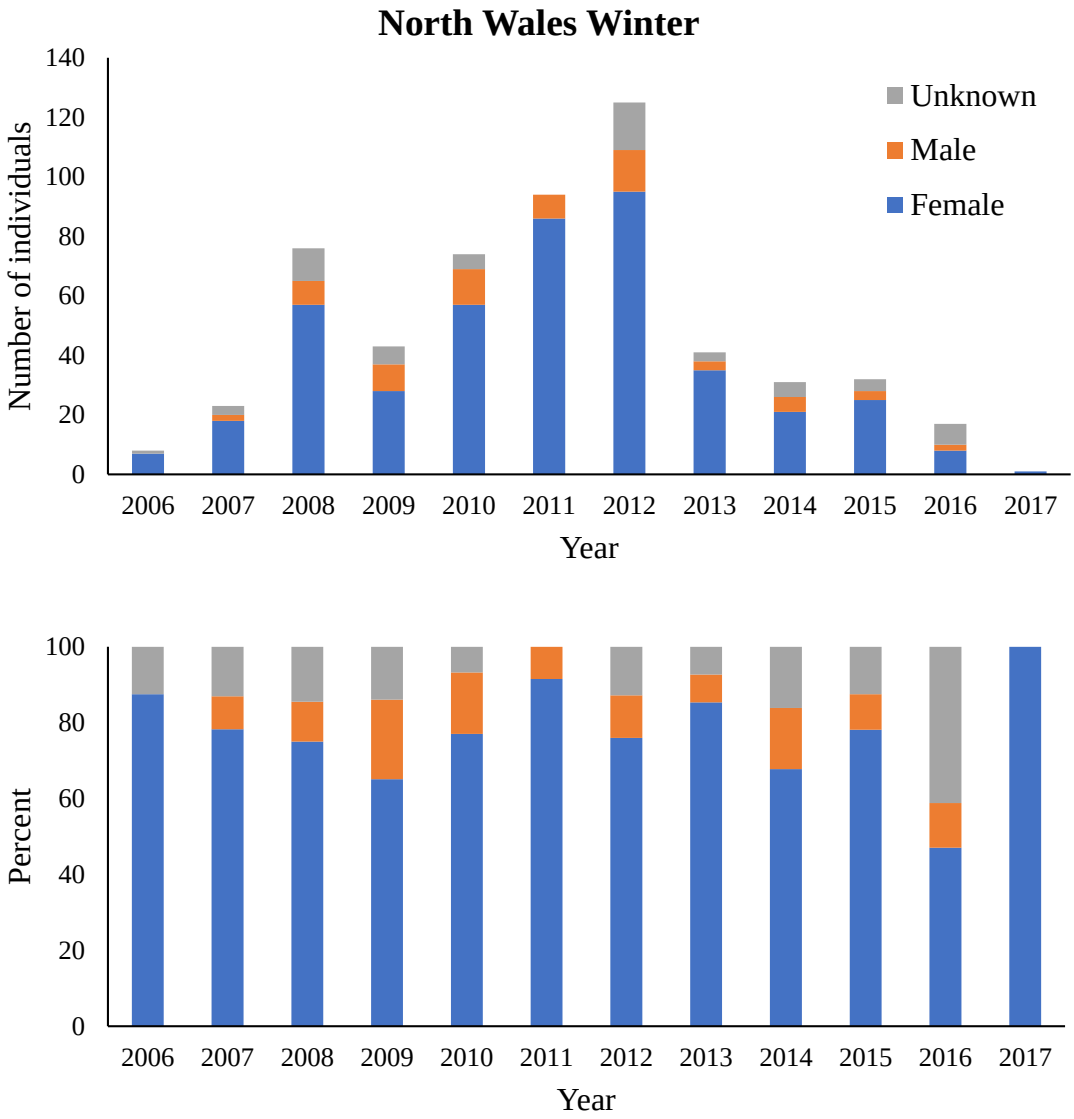

Figure 16. The number of females, males and unknown gender individuals that were sighted in North Wales in winter (Top) and the percentage of females, males and unknown gender individuals every year (Bottom) from 2006 to 2017

Overall, there was only a significant difference in proportions of males between North Wales and Cardigan Bay, with a higher proportion of males in Cardigan Bay. Females and unknown gender individuals had no significant differences between the locations. However, there was a slightly higher proportion of females in North Wales due to the changes in the proportion of males. There were no significant differences in the number of individuals seen in North Wales between summer and winter and there were no significant differences between the number of

each gender between seasons. However, there was a significant difference in the number of individuals seen in Cardigan Bay between summer and winter. This is most likely due to the larger sample size in Cardigan Bay.

4.2 Hypothesis 2: Mothers: movement patterns and birthing location

Out of the 249 individuals that were identified in North Wales, 64 of those were identified as female, while an additional 138 individuals were identified as possible females. There were 72 individuals out of those that had been seen with a new-born or small calf within a timespan that the birth could be estimated within a three-month period. There were 96 individual births that had sufficient sightings data from the mothers to be included in an analysis. The breakdown of their movements before and after giving birth is shown in Figure 17 along with where they gave birth. The majority of individuals were seen exclusively in Cardigan Bay before giving birth (65%), while the remaining 35% were seen in North Wales two years before giving birth. 91% of calves were born in Cardigan Bay, and a total of 69% of mothers stayed in Cardigan Bay for at least two years after birth (Figure 17).

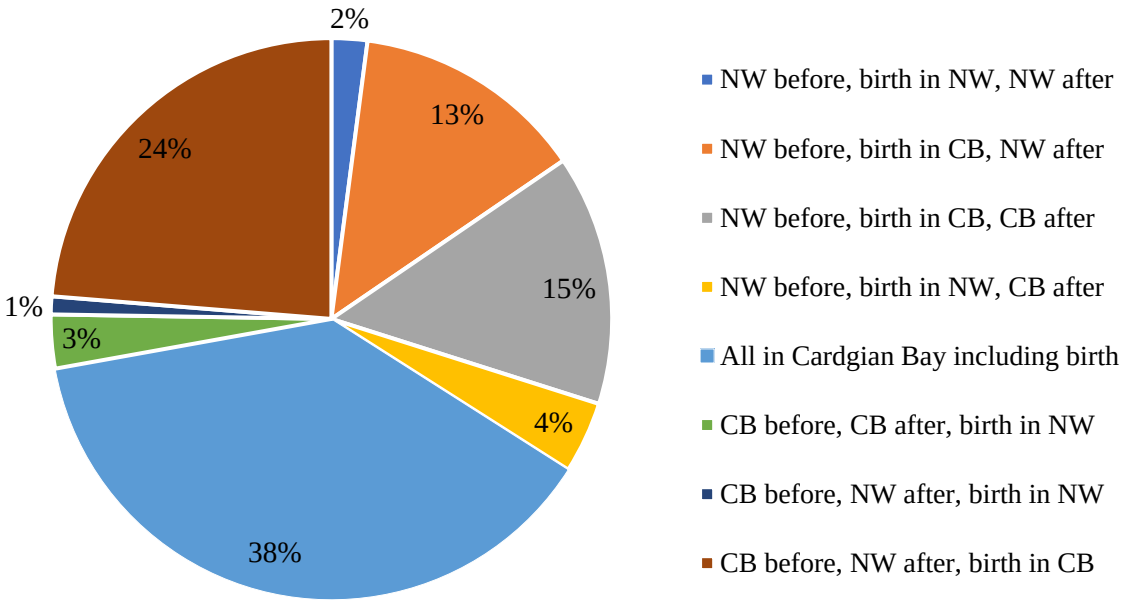

Figure 17. Various patterns of mother's movements before and after giving birth. NW= North Wales, CB= Cardigan Bay

Of those individuals that had been sighted in North Wales up to two years before giving birth, the majority (43%) migrated to Cardigan Bay to give birth and remained there for at least two years after giving birth (Figure 18). Only two individuals (6%) were only sighted in North Wales for two years before and after giving birth and then gave birth in North Wales. However, 39% of individuals stayed in North Wales before and after giving birth but travelled to Cardigan Bay to have the calf, returning to North Wales within one year of giving birth. 12% of individuals that were sighted in North Wales before giving birth stayed in the area to give birth and within a six-month period after birth they were seen in Cardigan Bay, indicating that they travelled down to the bay shortly after giving birth. Overall, 82% of individuals that had been previously sighted in North Wales travelled to Cardigan Bay to give birth, while the other 18% stayed in North Wales to have their calf. This provides strong evidence that individuals that reside in North Wales for all, or part of the year, may move to Cardigan Bay to give birth and the majority of these individuals stay in Cardigan Bay with their calf for at least two years.

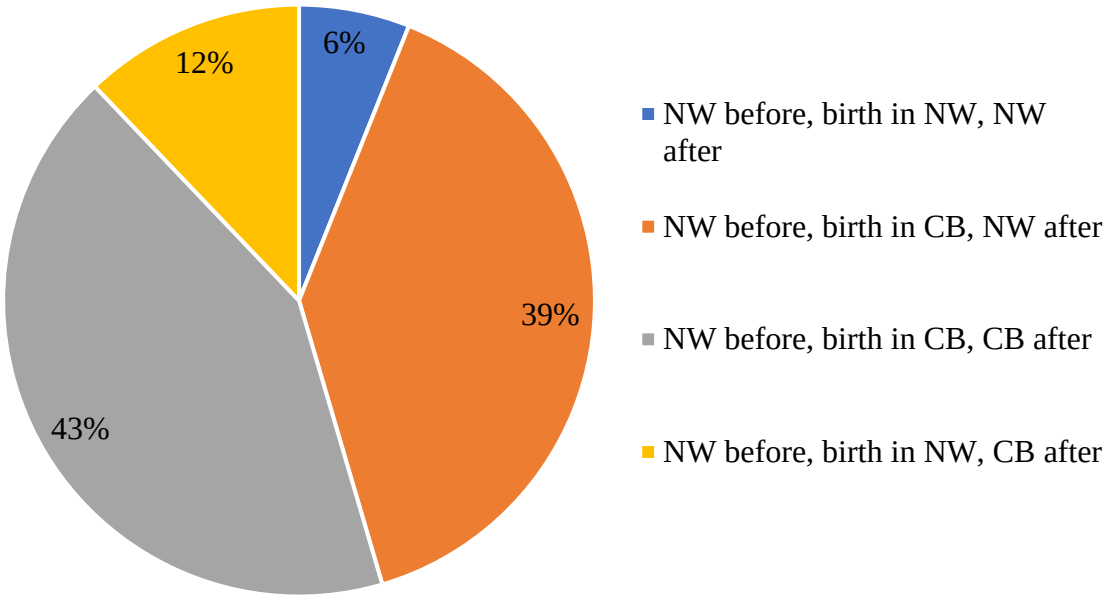

Figure 18. Percentage of individuals that have been sighted in North Wales two years before giving birth and their movements after birth, and location of birth

Of the 63 times when an individual was seen only in Cardigan Bay before giving birth, the majority of the time, (59%) the individual would remain in Cardigan Bay to give birth and for at least two years after giving birth (Figure 19). The other common pattern that occurred 36% of the time was that individuals that were seen in Cardigan Bay before giving birth had their

calf there but were sighted in North Wales within two years of giving birth. Although this was not the most common pattern of movement it represents the movements of 23 individual mothers. Individuals that were only seen previously in Cardigan Bay seldom travelled to North Wales to give birth; this was only recorded in a total of four times; three of the mothers that displayed this movement were recorded back in Cardigan Bay the season after giving birth, while one mother remained in North Wales with her calf.

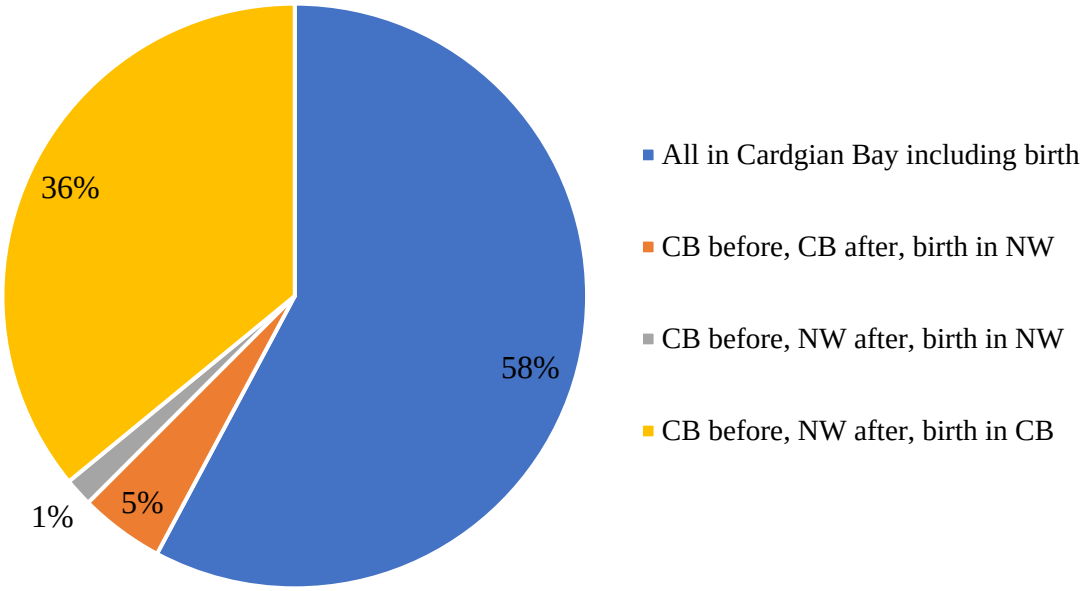

Figure 19. Percentage of individuals that were seen only in Cardigan Bay before giving birth and their patterns of movements after giving birth

Overall, approximately two-thirds of individuals were only seen in Cardigan Bay two years before giving birth, while the remaining one-third was seen in North Wales. Of the individuals that were seen in Cardigan Bay before, nearly 60% stayed in Cardigan Bay before, after and during birth. A smaller proportion gave birth in Cardigan Bay but travelled to North Wales with their calf in the two years after giving birth. Of the 34% of total individuals that were seen in North Wales before giving birth, most would use Cardigan Bay as a place in which to give birth, however, half of those mothers would stay in Cardigan Bay, while the other half would move to North Wales after giving birth. This does indicate that most females that have given birth choose to give birth in Cardigan Bay, however, where those individuals go before and after giving birth is split between North Wales and Cardigan Bay with no strong indication of a preferred location. More interestingly, of the individuals that were seen in North Wales before

giving birth, 18% stayed in North Wales to give birth, and of the individuals that gave birth in Cardigan Bay, half stayed in Cardigan Bay for a full two-years, while half travelled back to North Wales.

4.3 Hypothesis 3: Group size and gender composition

The mean group size in North Wales was significantly larger than the mean group size in Cardigan Bay (Kruskal-Wallis; χ^2=126.61, df=1, p<0.00). The mean group size of vessel-based sightings in North Wales from 2007 to 2015 was 30.13 individuals, which is five times larger than the group size in Cardigan Bay (Figure 20). There has been no significant difference in overall group size in North Wales at the p=0.5 level in group size between years (ANOVA; $F_{(9,59)}$= 1.16, p= 0.34; Figure 20). Although, there has been a significant change in group size between years within Cardigan Bay (Kruskal Wallis; χ^2=62.7, df=8, p<0.00; Figure 20). However, this could be due to the greater amount of surveys in this area resulting in smaller variation between sightings and therefore a greater likelihood of having a significant difference.

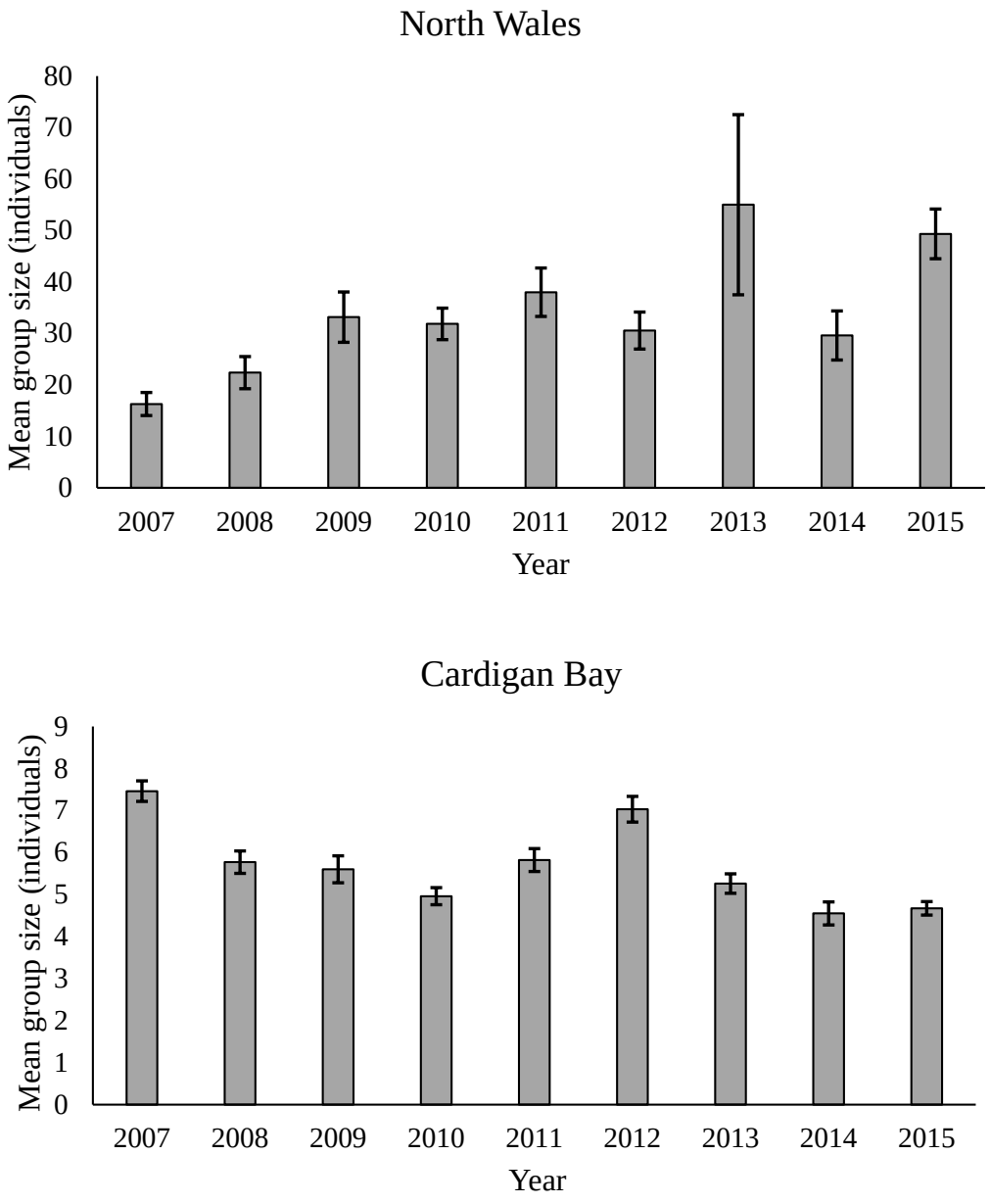

Figure 20. Bottlenose dolphin mean group size (+/- SE) from 2007 to 2015 from vessel-based surveys in (top) North Wales and (bottom) Cardigan Bay

Overall, adult bottlenose dolphins made up the majority of individuals that were sighted in North Wales (Figure 21), this was significantly higher than the proportions of adults in Cardigan Bay (Kruskal-Wallis; χ^2=7.41, df=1, p=0.006). However, there were no significant differences in the number of adult bottlenose dolphins that were encountered in North Wales between 2007 to 2015 (ANOVA; $F_{(9,59)}$=1.29, p=0.26).

There was a significantly higher proportion of juveniles in Cardigan Bay than in North Wales (Kruskal-Wallis; χ^2 =10.98, df=1, p=0.001). There was also no significant difference in the number of juveniles encountered in North Wales between years (ANOVA; $F_{(9,59)}$=0.74, p=0.67).

Calves made up an average of 13.52% (SD=17.42, SE=0.42, n=1,741) of individuals encountered in Cardigan Bay, while they only made up 7.64% in North Wales (SD=7.22, SE=0.88, n=68). Although calves made up a higher proportion of individuals in Cardigan Bay than in North Wales, there was no significant difference between the locations (Kruskal-Wallis; χ^2=0.08, df=1, p=0.78). Additionally, there was no significant difference in the number of calves encountered between years in North Wales (ANOVA; $F_{(9,59)}$=1.05, p=0.41).

In both Cardigan Bay and North Wales, new-borns made up a very small percentage of the individuals that were encountered. In North Wales new-borns only made up 0.2% (SD=0.72, SE=0.09, n=68) of all individuals encountered, while in Cardigan Bay, new-borns accounted for 2.12% of all individuals (SD=7.94, SE=0.19, n=1,741). However, there was not a significant difference in the proportion that new-borns between North Wales and Cardigan Bay (Kruskal-Wallis; χ^2=0.53, df=1, p=0.47). Additionally, there was no significant difference in the number of new-born bottlenose dolphins encountered in North Wales between 2007 to 2015 (Kruskal-Wallis; χ^2= 7.07, df= 8, p= 0.529).

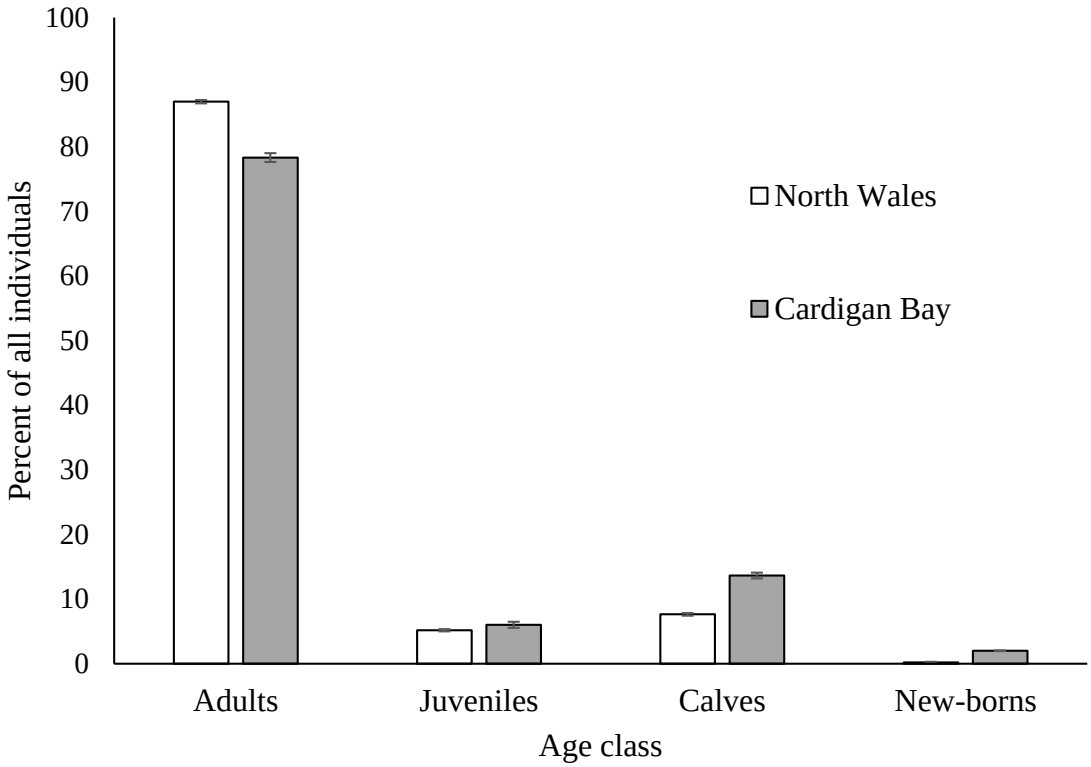

Figure 21. The mean percentage (+/- SE) of each age class that was encountered between 2007 to 2015 in North Wales (grey) and Cardigan Bay (white)

The mean group size in North Wales was significantly larger than the mean group size in Cardigan Bay, however, there were no significant differences between years in North Wales, most likely due to the small sample size. There was a significant difference between years in Cardigan Bay. The group composition varied between Cardigan Bay and North Wales, with North Wales having a significantly higher proportion of adults than Cardigan Bay. Besides adults, there a significant difference in juveniles, with a higher proportion in Cardigan Bay then North Wales, by just over 1%. There were no significant differences in the proportion of calves and new-borns between North Wales and Cardigan Bay.

4.4 Hypothesis 4: Emigration

From 2004 to 2015 there has been a weak neutral correlation between time and the number of emigrated individuals (r=-0.047, n=1809, p=0.048). The year with the highest emigration rate was in 2010 when nine individuals emigrated from Cardigan Bay to North Wales. Before 2010, the number of individuals emigrating had been rising since 2004 (Figure 22). However, after 2010, fewer individuals were seen emigrating from the area. This could be due to a decrease in

survey effort in North Wales in recent years, as individuals may have left Cardigan Bay but not been seen after that. There were no recorded emigrations in 2013 and 2014. As there is a three-year cut-off, these individuals would have had to be seen in North Wales in 2016 and 2017. However, during these years, there was a combined total of just five encounters, with only 30 individuals identifiable by photo-ID.

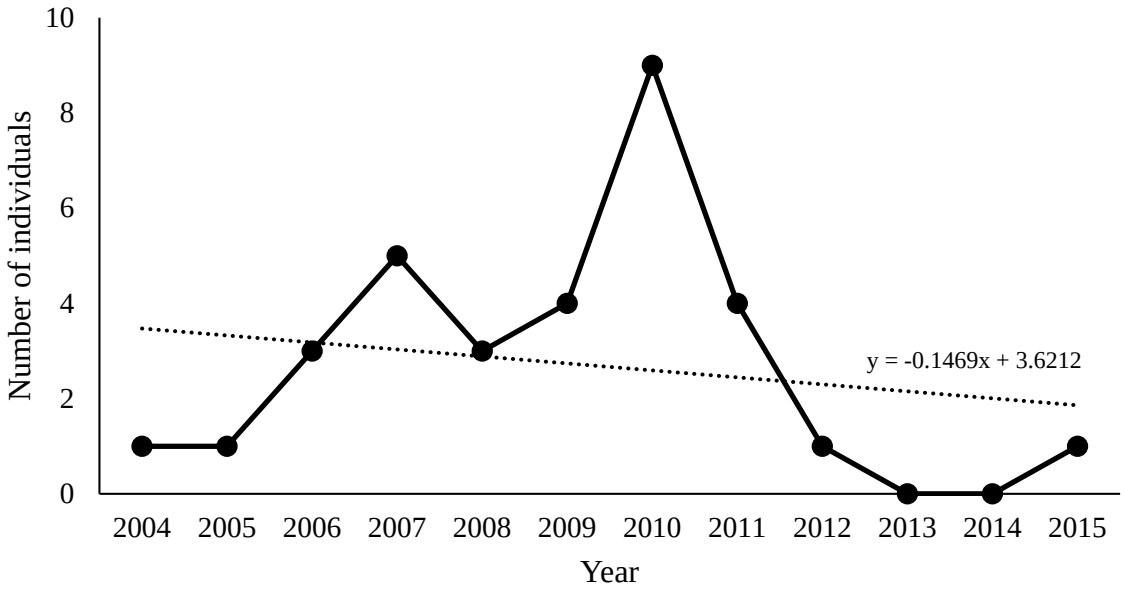

Figure 22. Number of individuals that have emigrated from Cardigan Bay to North Wales every year from 2004 to 2015 with the line of best fit

In order to determine if more individuals of a specific gender are emigrating, a comparison of females, males and individuals whose gender is unknown, was constructed per year. Overall, the majority of individuals (77%) that emigrate are female, while there have only been four males that have emigrated, making up 13% of the emigrated individuals. The remaining three individuals' gender is unknown (Figure 23). The majority of females emigrated during the same time period, from 2007 to 2010, with very little emigration outside of those years, while males were more evenly spread over the 12 years.

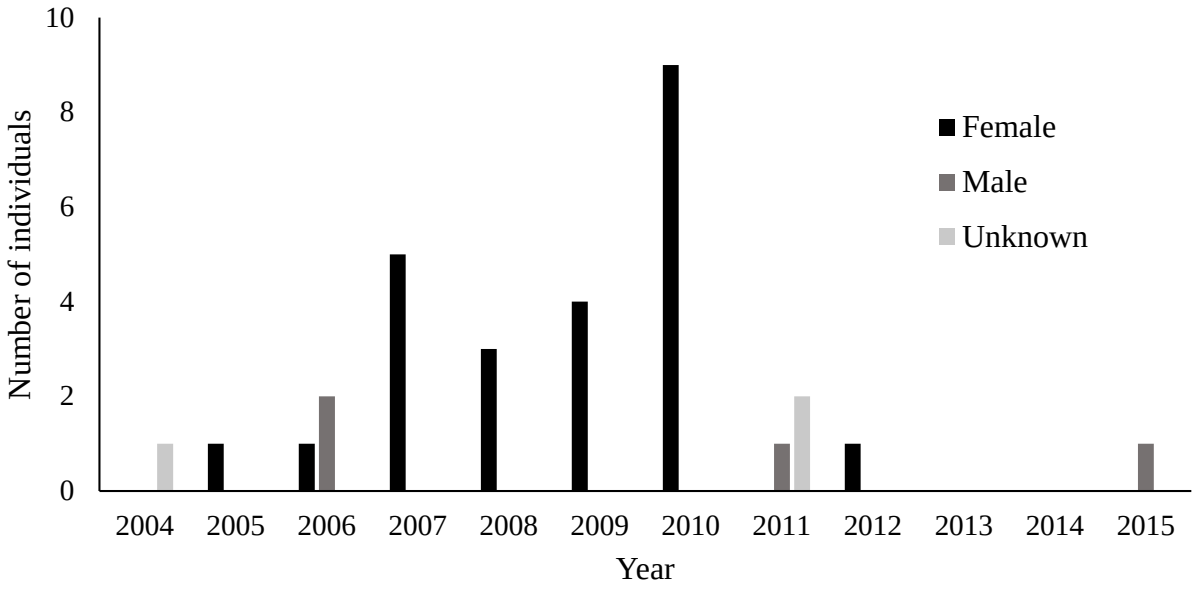

Figure 23. Number of female, male and unknown gender individuals that have emigrated from Cardigan Bay to North Wales from 2004 to 2015

In order to determine the number of individuals that were first being sighted in North Wales, a Spearman's correlation was performed. In order to account for effort, the number of new individuals sighted in North Wales was calculated per encounter. There was an overall strong negative correlation between 2004 to 2014 and the number of new individuals seen in North Wales per encounter ($r=-0.93$, $n=9$, $p<0.00$). There was a gradual decline overall, with a peak in 2008 and in 2011 (Figure 24). This would indicate that most individuals in the Cardigan Bay population have already been sighted in North Wales, as the encounters in recent years have been showing fewer individuals first recorded in that region.

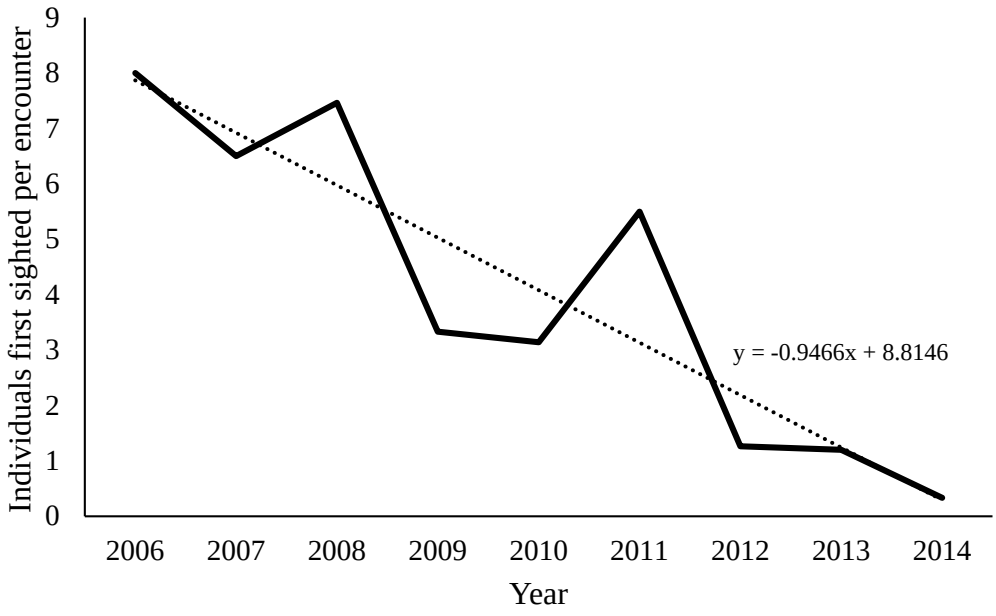

Figure 24. The number of individuals that were sighted for the first time in North Wales per encounter from 2006 to 2014, with a line of best fit

There has been an overall decrease in the number of individuals that have emigrated from Cardigan Bay to North Wales from 2004 to 2015. 2010 had the greatest number of individuals that emigrated from Cardigan Bay. However, there was no emigration in 2013 and 2014, this may be due to the lack of surveys in 2016 and 2017 in North Wales to confirm the emigration. The majority of individuals that emigrated were female. There was a very strong negative correlation between the number of individuals sighted for the first time in North Wales over time. This indicates that there are fewer individuals visiting North Wales for the first time and more reoccurring visits from individuals over time.

5.0 Discussion

5.1 Bottlenose dolphin connectivity within and beyond SACs

Members of the bottlenose dolphin population in Cardigan Bay regularly travel outside of the SAC's that were established to protect them. A large majority of the population has been sighted in North Wales. However, this poses a threat to the wellbeing of the population as this area is not protected for the species and human activities there pose additional threats. In order to adequately protect this species under the EU Habitats and Species Directive, it is important to understand the status of individuals that frequently use this area in North Wales.

Additionally, it is important to know why certain individuals may be using this area. If information indicates that this area is an important habitat for the species, it can be used to inform policymakers in regard to the possibility of expanding the network of protected areas available to this species under the Natura 2000 scheme.

This study set out to determine the status of individuals that are frequenting North Wales and to establish how many individuals are emigrating to North Wales to determine the importance of the area for the population. The findings presented here have identified that the majority of individuals in the Welsh population use North Wales in some capacity and that this is not confined to a specific gender or age category. For instance, although there is no gender bias in North Wales, there are fewer calves in this area, which suggests that Cardigan Bay is the preferred calving area. This is supported by the movement patterns of pregnant females, before and after giving birth, as the majority preferred to give birth in Cardigan Bay. However, after giving birth, a large percentage of individuals travelled to North Wales with their calf within 2 years of giving birth. Overall, the emigration rates to North Wales have been declining over time, although this may be due to the lack of recent surveys. A study by Barco et al. (1999) investigated seasonal migrations in a population of bottlenose dolphins off the coast of Florida, USA. They found that there was a clear seasonal migration of individuals coming into the bay area during the summer and returning to a larger offshore population during the winter, which is the general pattern of movement exhibited by the Welsh population. They concluded that there was most likely a mix of thermal tolerance and prey availability that drove the seasonal migrations in Florida. They also acknowledged that calf rearing and reproduction play an important role in distribution and that a combination of all these conditions was the most likely drivers in distribution (Lockyer & Brown, 1981; Gaskin, 1982; Barco et al., 1999). It appears that North Wales is not used for a specific purpose for this population. However, it is used year-round by an increasing number of individuals and seasonally by other individuals. It is not uncommon for populations to utilise two areas especially seasonally as productivity and prey availability may change considerably over the course of the year (Wilson et al., 1997; Barco et al., 1999; Zolman, 2002). Additionally, there may be an increased benefit of inhabiting North Wales, as there has been an increase in sightings in this location, and it appears that several individuals have left Cardigan Bay entirely in order to remain in North Wales.

5.2 Gender bias and composition

According to the results of this study, there is no significant difference in gender proportions of individuals encountered between North Wales and Cardigan Bay. However, there was a difference, although not significant, in the proportion of males between the areas. Cardigan Bay had nearly twice the proportion of males as North Wales did, which may indicate that males are more likely to stay in Cardigan Bay, while females utilise a larger area on a regular basis. This differs from other studies, as in most study populations females have a smaller home range compared to males, which tended to range further and would regularly be reported to leave the area for extended periods of time before returning (Wells et al., 1996; Connor et al., 2000).

The comparison of gender composition between summer and winter in North Wales showed no significant difference. One possible reason for the low variability is the uneven sample sizes, as there are very few surveys in summer in North Wales. There was a clear increase in the number of individuals that were identified in North Wales during the winter when compared to the summer. This may be due to the lack of effort in this area at the time, or, it could also be due to the actual decrease of individuals found in the summer in this area. Year-round effort-related observations from Anglesey suggest there is a real increase in winter, although bottlenose dolphins can be seen in the region in any month of the year (Evans et al., 2015). Past studies on connectivity of bottlenose dolphins in this region have concluded that this population has a strong site fidelity in Cardigan Bay during the summer months (Pesante et al., 2008; Feingold & Evans, 2014b; Lohrengel et al., 2017). This study supports that theory, although the amount of effort has to be considered as well, as there are almost no surveys in Cardigan Bay in the winter, and there are fewer surveys in North Wales in the summer months (although this has been increasing in recent years) (Feingold & Evans, 2014b). Acoustic monitoring in Cardigan Bay SAC supports the indication that numbers of bottlenose dolphins in the area decline during winter months (Simon et al., 2010; Nuuttiila et al., 2017). The fact that there is no change in gender composition between the two areas is important, as this indicates that North Wales is not an area that only males or only females use. As the majority of the population, regardless of gender, has been seen in North Wales, it can be concluded that this is an important area for the population generally, as they have been documented here for over ten years in large numbers (with 100 animals or more seen on occasions at any one time), and additional individuals have been sighted in the area for the first time every year.

5.3 Mothers: movement patterns and birthing location

According to this study, females that were recorded before and after giving birth exhibited several variations in their patterns of movement and where they gave birth. However, there were some patterns that were more common. The majority of individuals gave birth in Cardigan Bay and they were also more commonly seen before and after giving birth within the Bay. This may be due to the physical attributes of Cardigan Bay. Shallow water habitats are more suitable for raising calves and have been linked to higher levels of calf survivorship (Mann, 1997). Additionally, the mother's own maternal experience and age may play a role in calf survivorship, in addition to ecological factors such as prey abundance (Connor et al., 2000). As Cardigan Bay is an important area for the dolphins, individuals may return to give birth as they are most confident within the Bay. A study by Urian et al. (1996) found a correlation between the origin of the population and the seasonality and location of reproduction in future generations. They suggested that the adaptations of individuals to the local environmental conditions have a strong influence on the reproductive success in bottlenose dolphin populations (Urian et al., 1996).

Thirty-five percent of identified individuals were seen in North Wales before giving birth, which is a significant portion of the population, and those individuals showed an interesting combination of patterns of movement. Sixty-five percent of the females that were sighted in North Wales before giving birth migrated down to Cardigan Bay to give birth, and half of those remained in Cardigan Bay after giving birth, while the other half returned to North Wales. There are several reasons why there may be more births in Cardigan Bay and why mother and calf pairs tend to stay in the area after. One possible explanation is that the physical characteristics of the bay allow for easier prey catchability, as dolphins learn hunting skills from their mothers and may be more comfortable providing for their young in an environment that is more familiar (Norris & Prescott, 1961). Cardigan Bay has a favourable physical environment for calves as it is a mixed substrate of reefs, sandy areas and rocky areas which provides a variety of habitats for benthic and demersal fish, which in turn provides a reliable source of prey for the dolphins (Evans et al., 2001). Additionally, the shallow nature of the bay allows mothers to feed on the bottom without leaving their calf at the surface unattended for a long period of time. The shallow water also provides a better opportunity for calves to learn how to forage for themselves.

Another factor that can affect the location of birth is seasonal variation in habitat use. The bulk of the Welsh population of bottlenose dolphins has been known to spend summer in Cardigan Bay and winter in North Wales (Pesante et al., 2008; Veneruso & Evans, 2012; Feingold & Evans, 2014b). Within the population, 96% of births have occurred in the summer months (Lohrengel et al., 2017), when most individuals are already in Cardigan Bay. This may influence the proportion of females that give birth in Cardigan Bay as they would normally be within the bay during that season. To conclude, although Cardigan Bay appears to be the most common place to give birth and raise a calf, there is a significant proportion of the population that spends the time before and after giving birth in North Wales. This illustrates that Cardigan Bay is not the exclusive calving area for this population, and as more individuals are travelling and emigrating from the area and therefore becoming more familiar and comfortable in North Wales, more calves may be born there in future years.

5.4 Group size and gender composition

North Wales had significantly larger group sizes than in Cardigan Bay, at almost five times the size of groups. This difference in group size has been reported in past studies on this population, although based on the same data. Feingold and Evans (2014b) found that group sizes in North Wales were six times larger than that in Cardigan Bay. Additionally, the average group size in southern Cardigan Bay has been historically smaller than in the northern Cardigan Bay (Feingold & Evans, 2014b). The most likely reason that the group size is larger in North Wales is the type of prey in the area. As North Wales has deeper water than Cardigan Bay, the main prey species that are in the area are shoals of pelagic species which need a large group of dolphins cooperating in order to catch enough prey. Smaller groups are more likely to be feeding upon demersal or benthic species in shallow areas as these are easier for individuals to catch. When mothers are with their calf, they are more likely to favour being in small groups with other females present, however, in North Wales, where there is deeper water, dolphins are more inclined to forage offshore in larger groups. One factor that is unlikely to be the cause for determining group size in this population is the presence of predators, as the main predators for this species are large sharks and killer whales, both of which are very uncommon in North Wales and Cardigan Bay (Wilson et al., 1997; Pesante et al., 2008). Large aggregations of dolphins have been sighted in North Wales and around Anglesey with groups of 50-100 individuals (Feingold & Evans, 2014a). This combined with the large average group size indicates that there is some factor in North Wales that promotes larger group sizes.

The age composition of individuals sighted in North Wales and those sighted in Cardigan Bay were similar but with some key differences. North Wales had a higher percentage of adults, while Cardigan Bay had nearly double the proportion of calves as North Wales and had more new-borns as well. This may be due to Cardigan Bay being the preferred area for giving birth, which would result in more new-borns and calves being sighted in that area. This is notable as Cardigan Bay continues to be an important area for the Welsh population with more calves and new-borns sighted in this area compared to North Wales. However, calves are also sighted in North Wales. Although they make up a small percentage of the overall total, it is still recognised that North Wales is an area that some females choose to travel to with their calves, which should be considered when addressing the need for additional protection for the population of bottlenose dolphins in North Wales.

Overall, North Wales has significantly larger average group sizes and these are made up primarily of adults, with relatively few calves seen in the area. These larger groups could be the result of increased threats in North Wales, including noise disturbances by increased large vessel traffic in the area (Lusseau, 2005). It could also be due to adaptations in hunting strategies caused by variation in substrate and prey type which can cause dolphins to change hunting patterns (Norris & Dohl, 1980; Wells et al.,1980). In winter the northeast Irish Sea is a major spawning ground for whiting, a semi-pelagic species, and pelagic species such as herring are also common in this region (Evans et al., 2001). These pelagic species require larger group sizes for bottlenose dolphins to hunt them, while in Cardigan Bay, small groups are most often located in shallow coastal water where they feed upon demersal species that are more easily captured in small groups. Within Cardigan Bay, there are some larger groups that are most often located in deeper water offshore, this group size facilitates locating a patchy food source and may also assist in food capture by corralling shoals of fish (Evans et al., 2001).

These results could also indicate that North Wales is a more challenging environment for bottlenose dolphin calves, as the water is deeper in this area and calves will have more difficulty capturing pelagic prey compared to prey that is close to the seabed in shallow waters (Norris & Dohl, 1980). The larger group size also may be due to the pelagic environment, as pelagic shoaling species of prey is much harder to catch in small groups, therefore, larger groups of dolphins work together to be able to catch larger groups of prey as this would not be possible for individuals alone.

5.5 Emigration

There has been an overall decrease in the number of individuals that have emigrated to North Wales between 2004 and 2015. However, there was a sharp increase from 2004 to 2010, followed by a dramatic decline from 2010 onwards, which was due to the lack of photo-ID effort in recent years as there has been no funding. There were only two known individuals that emigrated to North Wales from 2012 to 2015. This may be due to the lack of encounters in North Wales in recent years, as the threshold for emigration is three years. This means that if an individual was said to have left Cardigan Bay in 2013, they would have to be seen in North Wales from 2016 onwards.

Females made up the majority of individuals (77%) that emigrated to North Wales in this time period, which is consistent with the overall composition of male and females in the population, as females make up roughly three-quarters of the total identifiable population. There was no pattern of emigration in males, as the four males that emigrated were fairly spread out over the 11-year period. However, females tended to emigrate in larger groups in a single year. Between 2007 and 2010, a high majority of females emigrated, with up to nine individuals leaving Cardigan Bay in a single year. One possible reason for this is that females have a larger habitat range that is strongly dependent on the quality of their habitat (Lin & Batzli, 2004; Natoli et al., 2005). This period of higher emigration may be related to a change in habitat, either the altering of the physical habitat or an increase in human activities in the area. A higher rate of female emigration compared with male emigration is also seen in Scotland (Wilson et al., 1997), as populations of bottlenose dolphins in the UK are at their uppermost range limits for the species, the temperature change is not extreme between sites (Natoli et al., 2005).

Studies on several populations of bottlenose dolphins have found that their patterns of movement are defined by habitat dependency (Hastie et al., 2004; Natoli et al., 2005). Local populations can favour specific habitats and there is potentially social facilitation of foraging strategies within those local populations, where male and female individuals tend to return to their natal site where they were shown how to hunt by their mothers, as well as transferring knowledge as subadults and aiding group coordination (Hoese, 1971; Mann & Smuts, 1999; Janik, 2000; Natoli et al., 2005). These patterns of movement based not only on habitat quality but also on the socially learned skills for foraging strategies and habitat use (Hastie et al., 2004), may drive emigration to North Wales. As more females have emigrated to the area, more

individuals have been sighted in North Wales, which possibly explains that these individuals are using social learning to pass on information over generations, especially as a large portion of mothers have been seen with small calves in North Wales, as these calves may be learning to hunt in this area instead of Cardigan Bay.

There is a strong negative correlation in the number of individuals that have first been sighted in North Wales per encounter over time. This most likely indicates that the majority of individuals in the Cardigan Bay population use North Wales on a regular basis. As the number of new individuals in North Wales is declining, there are few dolphins that have exclusively been sighted in Cardigan Bay. A study by Feingold and Evans (2014b) showed that only 10% of the population is exclusive to the area of Cardigan Bay SAC. The large majority of individuals now travel between North Wales and Cardigan Bay, even though the emigration rates show a decline over years. This is only due to the very low survey effort in the area, and in fact, it is likely that more individuals have been emigrating in recent years.

5.6 Limitations and recommendations

The limitations of this study involved among others, those limitations in using photo-ID to track mobile cetaceans. Photo-ID relies heavily on the number of surveys that take place and a complete coverage of the area that is being surveyed, as well as the quality and skill of the photographer taking the photographs. As regular surveys were much more prevalent within Cardigan Bay, there is a much higher volume of data for this region, and the chances that an individual will not be seen during the summer are much less than in North Wales where survey effort has much reduced in recent years as well as being variables between seasons and biased in the area being surveyed. As well as variation in survey effort, which was accounted for in some analyses, there is the dependency on individuals having recognisable markings on their dorsal fins. As only approximately 60% of bottlenose dolphin individuals in the UK have recognisable markings, another 40% including young individuals are not marked, which prevents photo-ID being used on this portion of the population. This is difficult to mitigate as it is an inherent limitation of using photo-ID to monitor individuals within a population.

When comparing group composition between seasons in locations, the disproportionate number of surveys in one season compared to the other made it difficult to accurately compare between seasons. In Cardigan Bay, there were many more surveys in summer, with better

weather, more boat availability, and more volunteers and interns to collect data on regular surveys in this area. The number of surveys in winter decreases considerably as the weather becomes worse and this limits the number of surveys that can occur. In addition to the usual decrease in weather conditions, Sea Watch does not run winter internship programmes so the number of people available to collect data is limited. It would be useful to have the resources to collect more data in the winter to confirm that the majority of individuals in the population migrate to North Wales in the winter.

The surveys that occurred in North Wales were clustered around the northern coast of Anglesey across to the Great Orme on the mainland coast of North Wales. Survey effort has been much less elsewhere in North Wales. In addition to this, a large portion of encounters were recorded and photographed by the Sea Watch Director Dr Peter Evans, who has ready access to a vessel that will seek out dolphins when they are reported in the area. This results in greater coverage of the north coast of Anglesey than elsewhere which means that the focus of photo-ID effort will be in this study area rather than other areas of North Wales. Although photo-ID effort is focused off of north Anglesey, there is a sightings network with observers covering the coast of Anglesey to report sightings and estimates of group size, although they do not undertake photo-ID, so the identity of individuals is unknown. The addition of regular surveys throughout North Wales covering a larger portion of the region would reduce this bias and give a more representative overview of the distribution of the species in this area. The regular increased coverage of this area would also allow further studies to be conducted on site usage in North Wales to better determine “hot spots” for individual dolphins, where they are seen more commonly or in greater numbers. This information would be especially helpful in the potential creation of an SAC, as the focus could be placed on areas that are more frequented by dolphins.

In order to accurately assess the need for a Special Area of Conservation in North Wales for bottlenose dolphins, a quantification of the anthropogenic impacts in North Wales should be conducted in conjunction with the areas that are most used by the dolphins. A greater understanding of the areas that the dolphins utilise and the behaviour exhibited in those areas are key to understanding how these individuals use them and how to best protect the animals. Thus, future studies should focus on increasing the number of surveys in the area and increasing the area that they cover in order to obtain the best understanding of how this species uses this habitat.

6.0 Conclusion

The Welsh bottlenose dolphin population utilises a large habitat range from the Isle of Man to the southern part of Cardigan Bay. This population has been afforded protection within Cardigan Bay with the creation of two SAC's, however, with their presence in North Wales increasing, additional protection may be needed in order for the population to remain stable. This study set out to investigate the status of individuals that use North Wales to greater understand the movements of this population.

The findings of this study suggest that the majority of individuals migrate to North Wales either seasonally or more frequently. Additionally, the identified individuals that migrate seasonally to North Wales are not confined to a specific gender, although in both locations there are more females than males. The proportion of males and females sighted between seasons in each area had little variation except for in Cardigan Bay, where there was an increase in the proportion of males present in the winter, which suggests more males stay within Cardigan Bay during winter instead of migrating to North Wales. The group size was over five times larger in North Wales than in Cardigan Bay. This is most likely due to the variation in hunting strategies and prey types in the area, as pelagic shoaling fish species require more individuals to work together to prey upon them.

Although emigration rates have declined over the last 10 years, this is largely due to the lack of surveys in North Wales in recent years as there has been no funding. If survey effort in North Wales increased, an accurate level of emigration could be calculated. Emigration rates did rise until 2010 and this could be a continued trend, as emigration requires three years of absence from Cardigan Bay, and a lack of surveys in North Wales to confirm the emigration is halting results.

One of the most interesting results of this study was the patterns of movements of females before and after giving birth. The majority of individuals chose to give birth and stay in Cardigan Bay after giving birth, most likely due to the shallow topography that allows mothers to feed without leaving their calves for long periods of time. Additionally, there was significantly more calves in Cardigan Bay than in North Wales, which supports the results of mother and calf movements as more calves are born and remain in Cardigan Bay for the first

few years as this environment is easier to learn how to forage for food. There were however, several mothers that chose to give birth in North Wales or move there with their calves after giving birth. This may indicate that North Wales is an important area for calves even though it is not the most popular location. The small percentage of calves that were sighted in North Wales areas still important to consider when advising the protection of the area for the species.

Overall, the Welsh bottlenose dolphin population has shown a strong affiliation to North Wales and over ninety percent of individuals have been sighted either only in North Wales or both in Cardigan Bay and North Wales. The seasonal migrations of these individuals from Cardigan Bay in the summer and North Wales in the winter illustrates a clear pattern of movement. North Wales is most likely an important feeding site for this population, as pelagic shoaling species of fish spawn there in winter. North Wales does not appear to be the most popular calving site, as a higher percentage of calves are seen in Cardigan Bay. However, from the results of this study, North Wales appears to be an important area for the survival of this population and the creation of an SAC should be considered in order to fully protect the range of this species in UK waters under the Natura 2000 scheme. However, further study of specific sites that are of importance to the species should be undertaken to continue to advise policymakers on this issue.

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APPENDICIES

SIGHTING FORM
Date:________________ Type of trip: LT □ NLT □ Page:___of___ Entered into PC □ Checked by ____________
GMT or BST

Sight #	Time (hh.mm)	Lat (min.sec)	Long (min.sec)	Effort type	An. Ang (deg)	Boat course (deg)	Dist (m)	Species		Tot num	A	J	C	NB	Cue	Beh	Reac. to Boat		Seen by
																Dir			
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	
		N52°	W004°					BND	HP								A	T	
								GS									U	N	

Type of trip LT = line transect surveys, NLT = other than line transect surveys GMT=Greenwich Mean Time, BST=British Summer Time Effort type LT, DS, CW, ID Species BND=bottlenose dolphin, HP=harbour porpoise, GS=grey seal A=adult, J=juvenile, C=calf, NB=newborn Cue HE=head, F=fin/fluke, L=leaping, S=splash, B=blow, BA=back, BI=bird, R=reflection, O=other, U=unknown. Behaviour For BND and HP SS=slow swim, NS=normal swim, FS=fast swim, SF=suspected feeding, FF=feeding (fish seen), L=leaping, B=bowriding, R=resting/milling, S=socializing, O=other, U=unknown, N=not recorded. For GRS H=hauled out, W=in the water Reaction to boat A=swimming away, T=swimming toward us, U=unknown, N=none.

Figure 2. 5 Sighting form

Appendix 1. Sightings form from the Sea Watch Foundation

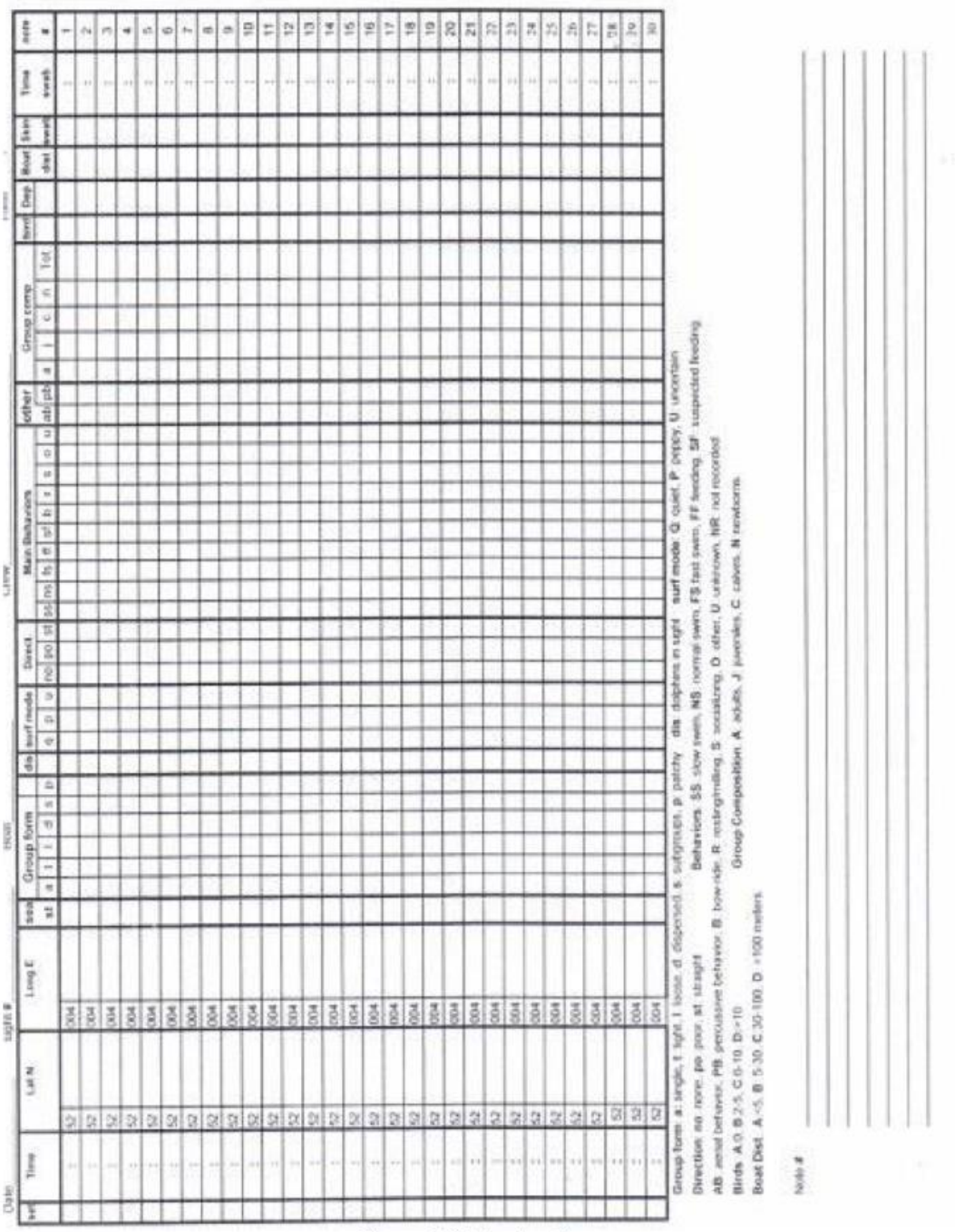

Figure 2. 8 Behaviour form

Appendix 2. Behaviour form from the Sea Watch Foundation

INDEPENDENT OBSERVER FORM
Date:______________ Type of trip: LT □ NLT □ Page:___of___ GMT or BST
Entered into PC □ Checked by ___________

IO #	Time (hh.mm)	Lat (min.sec)	Long (min.sec)	An. Ang. (deg)	Boat course (deg)	Dist (m)	Species		Ind. #	Cue	Effort type		Seen by prim.platform?		If yes, sighting #	Seen by	Comments
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			
		N52°	W004°				BND GS	HP			LT	DS	Y	N			

Type of trip LT = line transect surveys, NLT = other than line transect surveys; GMT=Greenwich Mean Time, BST=British Summer Time; Species BND=bottlenose dolphin, HP=harbour porpoise, GS=grey seal Cue F=fin/fluke, L=leaping (body out of water), S=splash, B=blow, BA=back, BI=bird, R=reflection, O= other, U=unknown. Effort type LT=line transect, DS=dedicated search.

Appendix 3. Independent observer form from the Sea Watch Foundation

EFFORT FORM

Boat: ____________ Person responsible for data ______________ Crew: ________________________________ Page ___of___

Date: ________________ Time start ___________ Time end ___________ GMT or BST Type of trip: LT ☐ NLT ☐

Time hh.mm	Lat. (min.sec)	Long. (min.sec)	Transect	Leg num.	Tran. point	Boat act.	Speed knots	Course Deg.	Glare degrees	Effort type	Precipitation Type	Precipitation Int.	Visibility (km)	Sea state B	Sea state S	Sigh. ref.	Comments
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				
	N52°	W004°		S C E					0 1 2 3	CW DS LT ID	N R F	I L M C H	<1 1-5 6-10 >10				

Type of trip LT = line transect surveys, NLT = other than line transect surveys; Leg S=start, C=continuation, E=end; Boat activity NB=none, YA=yatch or sailing, RB=kayak, JS=jet ski, SB=speed boat, MB=motorboat, FI=fishing boat, Fe=ferry, LS=>30m; Glare 0=no glare, 1=mild, minimal impact on sightability, 2=moderate, 3=severe Effort type CW=casual watch, DS=dedicated search, LT=line transect, ID=photoid; Precipitation type N=none, R=rain, F=fog, I=intermittent, C=continuous, L=light, M=moderate, H=heavy; Sea state B=sea state in Beaufort scale, S=swell presence and height (L= <1m, M= ≥1 and <2, H ≥ 2m). Entered into PC by _____________Checked by_____________________

Appendix 4. Effort form from the Sea Watch Foundation