Bottlenose Dolphin Monitoring in Cardigan Bay, 2014 – 2016
Appendix 2

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9. Appendix 2

9.1. History of dolphin research in Cardigan Bay

Cardigan Bay is renowned for its population of semi-resident bottlenose dolphins with sightings dating back at least to the 1920s and probably well beyond (Evans and Scanlan, 1989). The first photo-identification studies commenced in 1989, but intensive photo-ID surveys did not start until 2001 through a project funded jointly by the EU Interreg Programme and the Countryside Council for Wales (now Natural Resources Wales) (Baines *et al*., 2002).

Photo-identification effort was initially focused upon the area that was designated as the Cardigan Bay Special Area of Conservation in 2004, with dedicated surveys concentrating on this area in the 1990s until 2007 (Baines *et al*., 2002; Ugarte and Evans, 2006; Pesante *et al*., 2008b).

In 2007, *ad libitum* surveys were expanded to encompass the Pen Llŷn a'r Sarnau Special Area of Conservation (Pesante *et al*., 2008b). Additional information was contributed by a regular wildlife boat operator in this area, Alan Gray of *Shearwater Coastal Cruises* operating out of Pwllheli. In 2011, systematic line transect surveys were conducted for the first time throughout the Bay, including both the Cardigan Bay SAC and the Pen Llŷn a'r Sarnau SAC thus also providing photo-ID data for the entire bay (Veneruso and Evans, 2012a).

Since 2001, SWF has been regularly monitoring the bottlenose dolphin population within Cardigan Bay, incorporating abundance estimates, studies of ranging patterns, population structure, and life history characteristics from photo-ID (Baines *et al*., 2002; Ugarte and Evans, 2006; Pesante *et al*., 2008b; Feingold *et al*., 2011; Veneruso and Evans, 2012a, b; Feingold and Evans, 2014; Norrman *et al*., 2015).

9.2. Survey vessels

9.2.1. Vessel specification

Table 16: Vessels used for line transect surveys and dedicated non-line transect surveys (NLT) in Cardigan Bay in 2014 to 2016. *CB SAC = Cardigan Bay SAC, **NCB = Northern Cardigan Bay. *** only used for NLT surveys

Vessel name	Length (m)	Eye height (m)	Speed (kn)	Engine type	Area surveyed
Dunbar Castle II	9.7	3.5	5-6	120 hp diesel	CB SAC*
Ma Chipe Seabrin	10	4.5	10	Twin 220 hp diesel	NCB**
Pedryn	11.7	3.0	10-14	Twin 350 hp diesel	NCB**
Severn Guardian	18.3	5.5	10	Twin Volvo D9-MH	CB SAC*
Highlander	10	4	10	Twin 370 hp diesel	NCB**
*Bay Explorer****	10	2.5	Variable	Twin 200hp petrol	CB SAC*

Table 17: Vessels used for opportunistic observations in Cardigan Bay in 2014 to 2016. *CB SAC = Cardigan Bay SAC

Vessel name	Length (m)	Eye height (m)	Speed (kn)	Engine type	Area observed
Ermol V	11.5	2.5	6	Twin 128hp diesel	CB SAC*
Ermol VI	10.9	2.5	6	350 hp diesel	CB SAC*

9.3. Bottlenose dolphin abundance estimates: Supplementary information

9.3.1. Distance sampling estimates of bottlenose dolphins in Cardigan Bay SAC: Detection curves

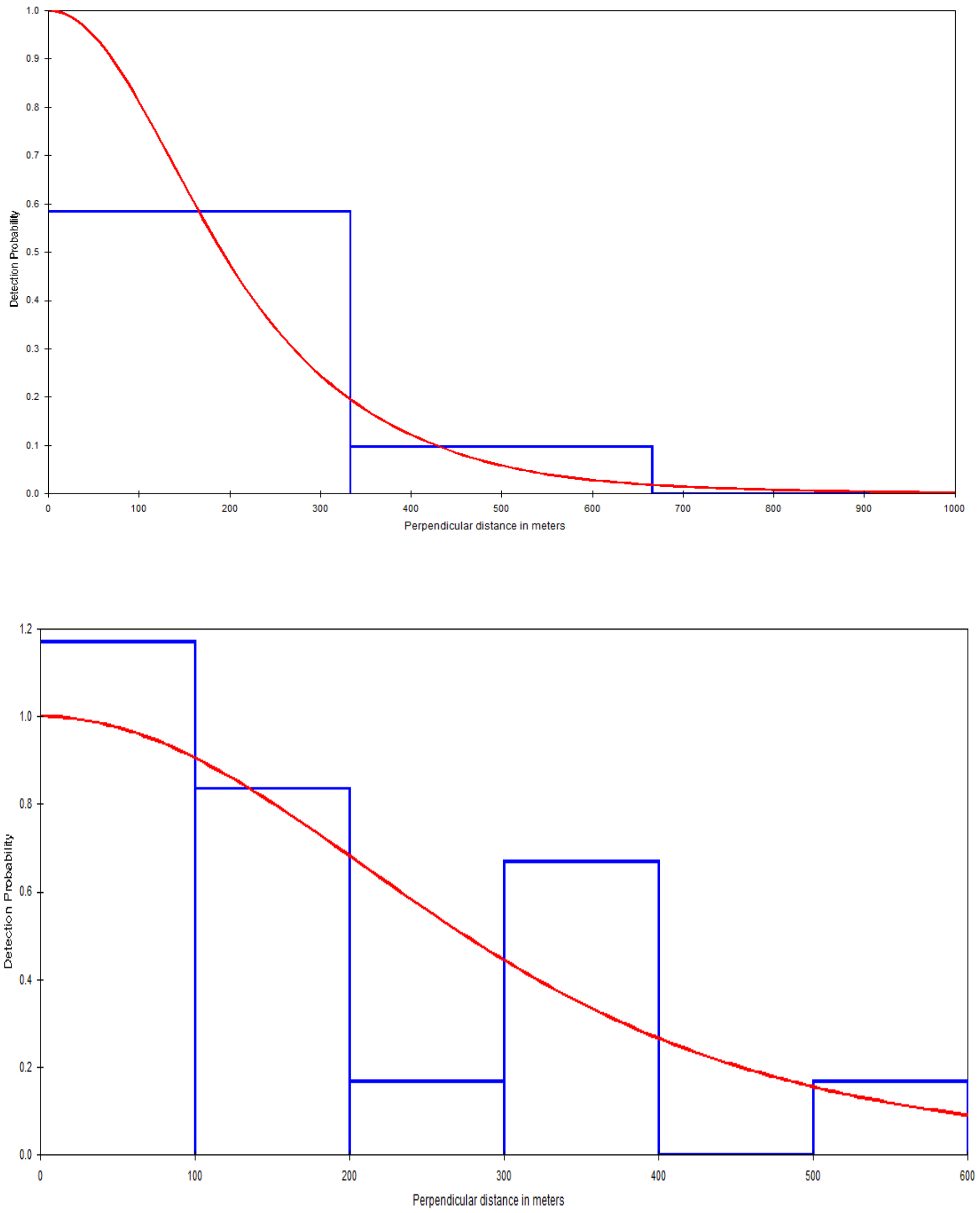
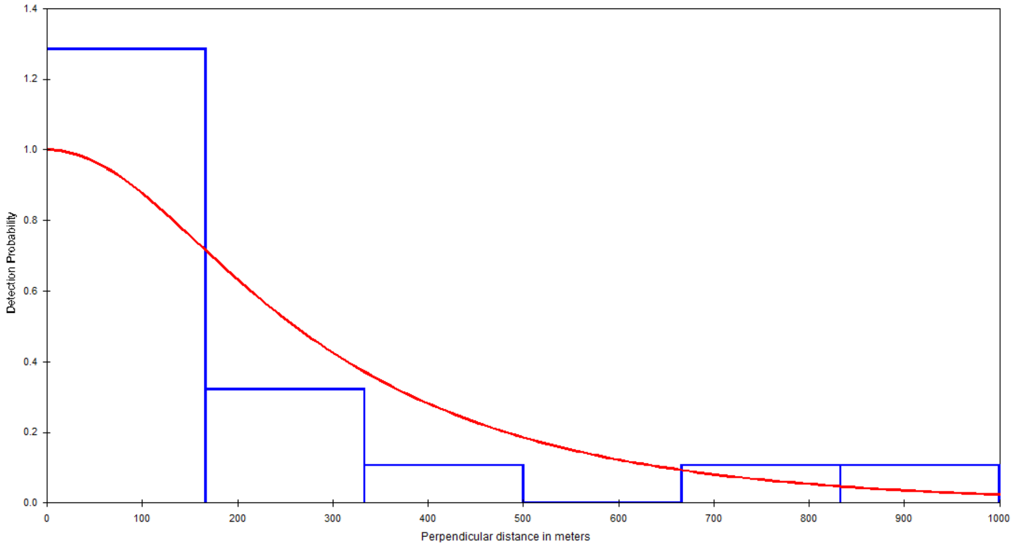


Figure 44: Detection function of bottlenose dolphins in Cardigan Bay SAC in 2015 (top) and 2016 (bottom).

9.3.2. Distance sampling estimates of bottlenose dolphins in wider Cardigan Bay: Detection curves



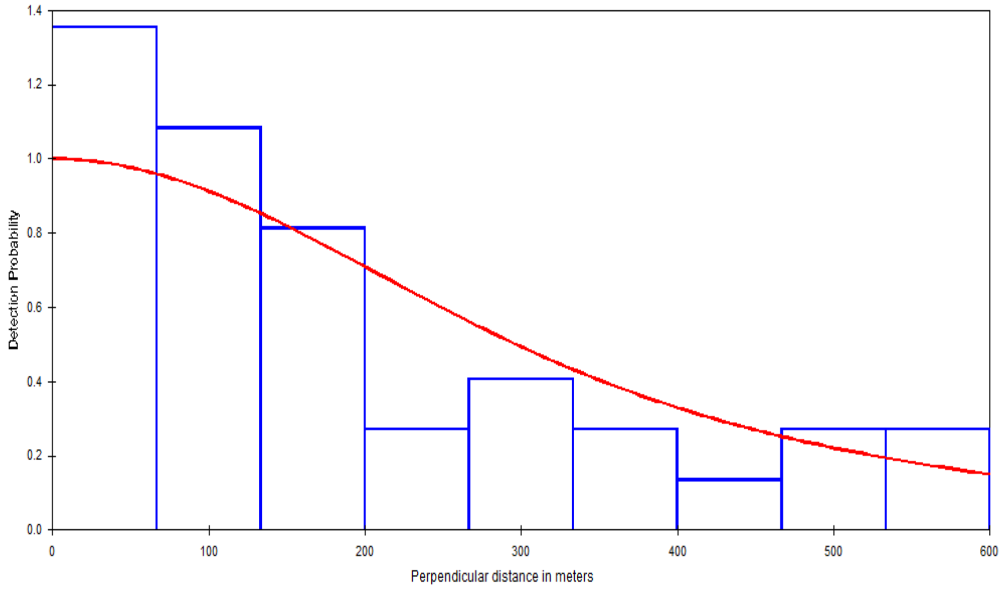


Figure 45: Detection functions of bottlenose dolphins in wider Cardigan Bay in 2015 (top) and 2016 (bottom)

Residency patterns of bottlenose dolphins in Cardigan Bay SAC and wider Cardigan Bay derived from a robust CMR model: Table of Standard Errors

Table 18: Standard Errors for bottlenose dolphin residency patterns in Cardigan Bay SAC using a robust population model

Period	Gamma''	Standard Error	Gamma'	Standard Error
2001-02	0.62	0.06		
2002-03	0.13	0.06	0.28	0.08
2003-04	0.17	0.04	0.70	0.13
2004-05	0.38	0.06	0.64	0.10
2005-06	0.28	0.06	0.43	0.08
2006-07	0.23	0.05	0.51	0.09
2007-08	0.34	0.05	0.58	0.09
2008-09	0.38	0.06	0.44	0.08
2009-10	0.12	0.04	0.52	0.08
2010-11	0.27	0.05	0.45	0.10
2011-12	0.19	0.05	0.36	0.10
2012-13	0.36	0.06	0.75	0.07
2013-14	0.44	0.07	0.78	0.07
2014-15	0.24	0.07	0.52	0.07
2015-16	0.25	0.06	0.47	0.11

Table 19: Standard Errors for bottlenose dolphin residency patterns in wider Cardigan Bay using a robust population model

Period	Gamma''	Standard Error	Gamma'	Standard Error
2005-6	0.214	0.046		
2006-7	0.131	0.034	0.459	0.088
2007-8	0.217	0.038	0.534	0.097
2008-9	0.051	0.030	0.396	0.085
2009-10	0.213	0.037	1	6.48E-05
2010-11	0.148	0.037	0.470	0.085
2011-12	0.114	0.033	0.45	0.084
2012-13	0.157	0.037	0.757	0.082
2013-14	0.368	0.051	0.786	0.069
2014-15	0.215	0.055	0.449	0.074
2015-16	0.294	0.054	0.463	0.105

9.4. Behavioural data: activity budgets

9.4.1. Behavioural budgets: results

Behavioural data were collected during every bottlenose dolphin encounter whilst on line transect surveys. Additional data were obtained during dedicated and ad libitum surveys. However, this was generally not included in the overall behavioural budget as marked differences were observed between activity budgets derived from line transect and ad libitum data, particularly in 2016.

The predominant behaviour which bottlenose dolphins were observed engaged in was travel followed by foraging or feeding, while the least commonly observed behaviours were socialising and resting. Behavioural budgets were similar for all three years although there was some variation, particularly with regards to proportion of travel versus feeding/foraging. The year 2014 had the lowest levels of feeding/foraging behaviour (16.4%) and the highest proportion of travel (83.6%) (Figure 45) recorded of all three years. The year 2015 had the highest proportion of forage/feeding behaviour (29.7%) (Figure 47).

The year 2016 saw a decrease in observed feeding and foraging behaviour, calculated at 29.7% and 20.9% in 2015 and 2016 respectively, while socialising (up by 4.3%), travelling (up by 2.7%) and resting (up 0.6%) were observed more frequently (Figure 46-48).

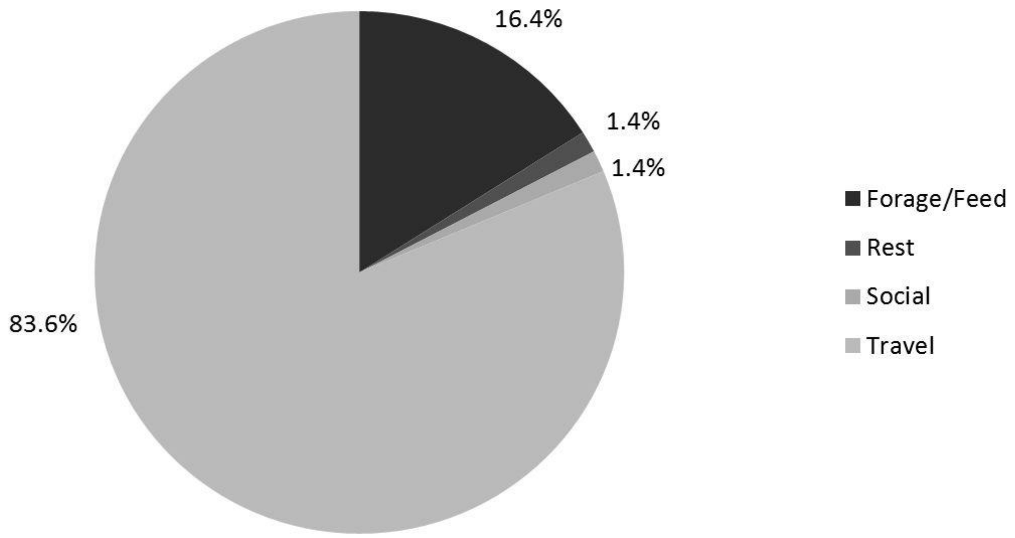


Figure 46: Behavioural budget for bottlenose dolphins in wider Cardigan Bay in 2014

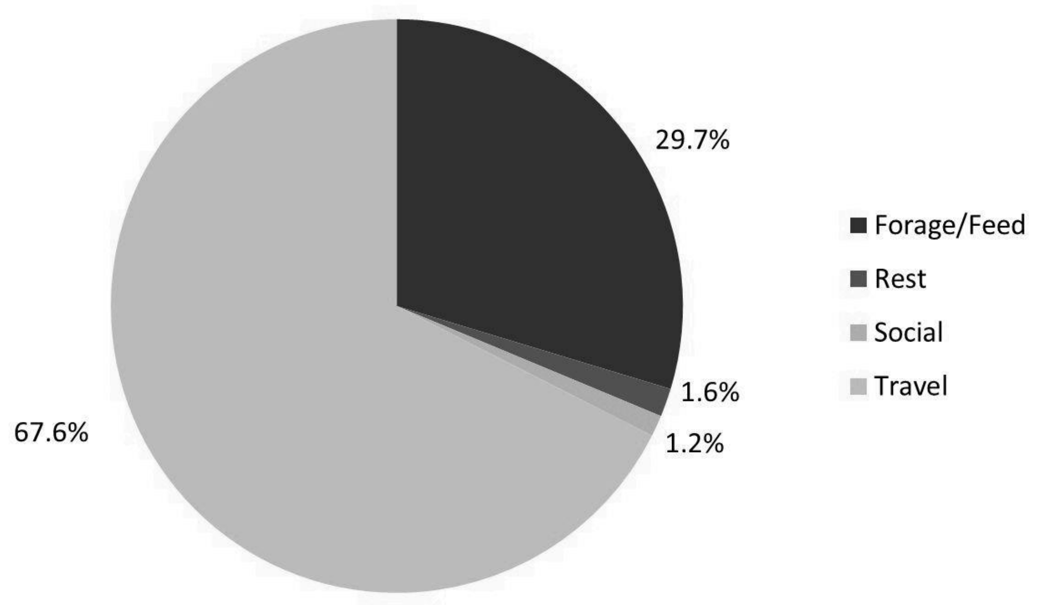


Figure 47: Behaviour budget for bottlenose dolphins in wider Cardigan Bay in 2015

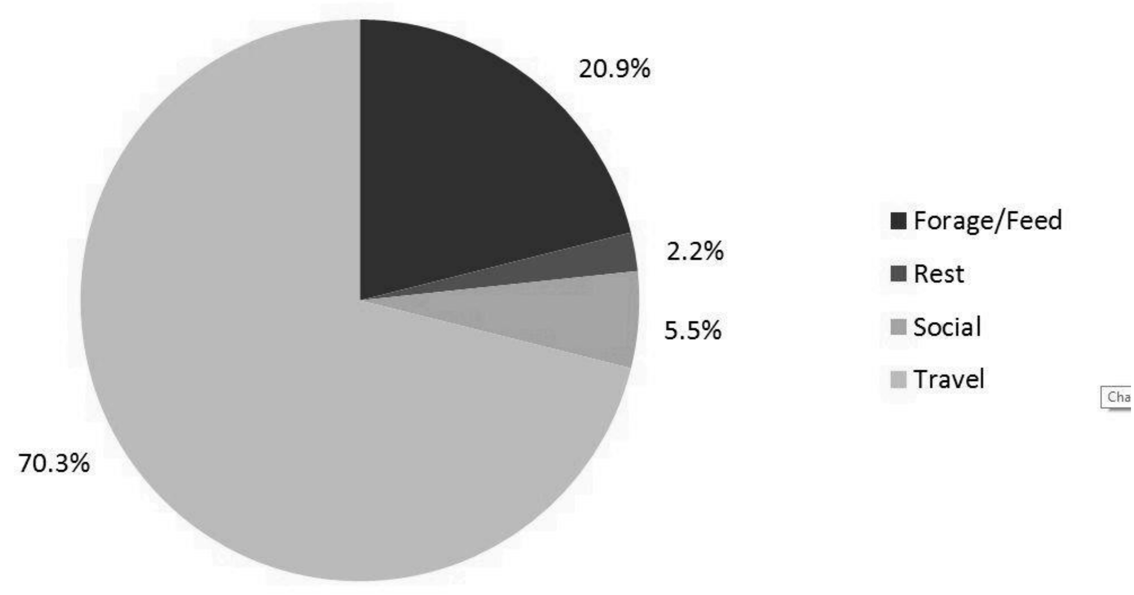


Figure 48: Behaviour budget of bottlenose dolphins from dedicated line transect surveys in wider Cardigan Bay in 2016 (n=91)

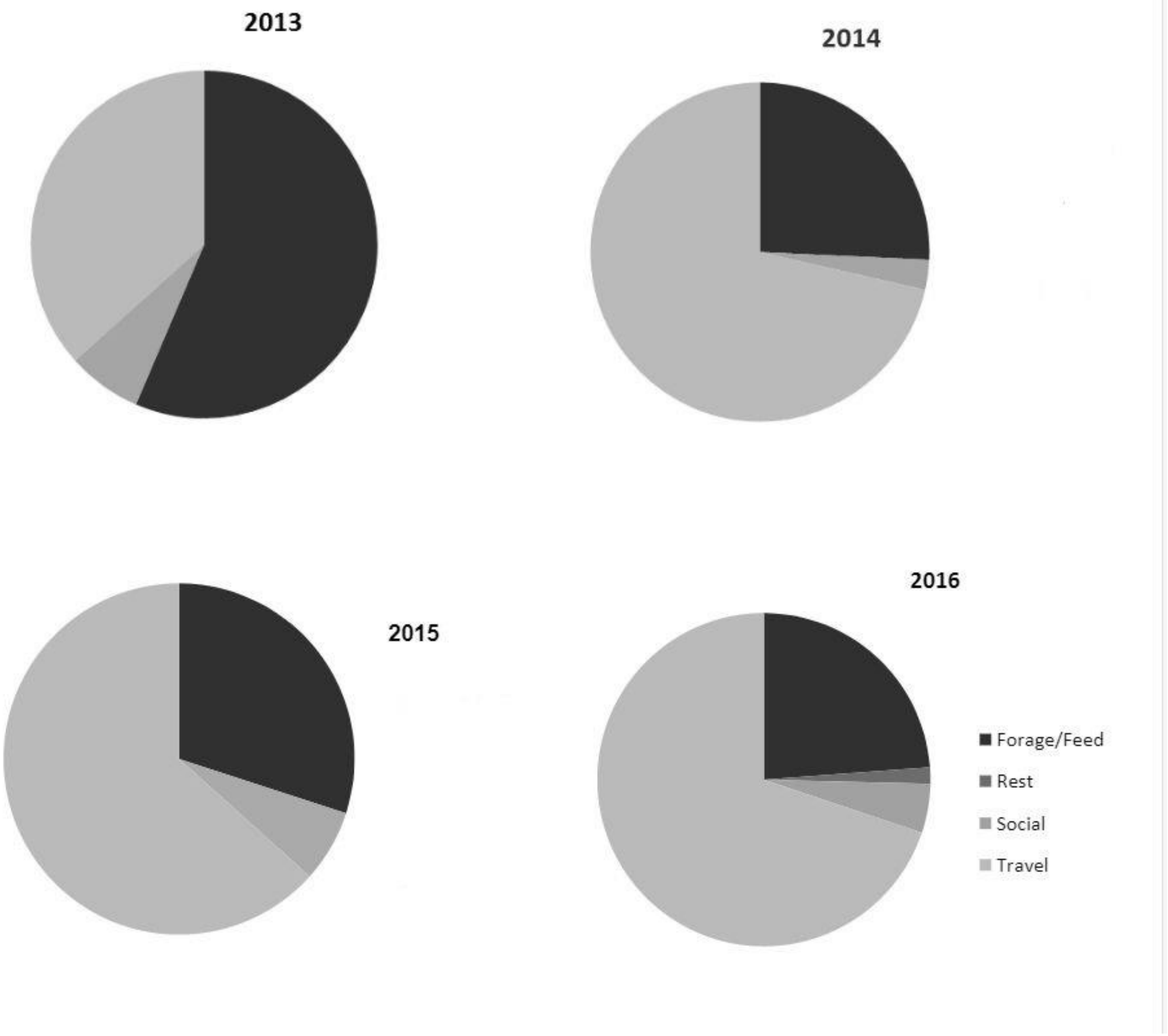


Figure 49: Behavioural budget of bottlenose dolphins recorded from line transect surveys in Cardigan Bay SAC in 2013, 2014, 2015 and 2016 respectively (n=101, 70, 42 and 63)

Activity budgets for Cardigan Bay SAC from 2014 to 2016 (Figure 49) show similar trends, the dominant behaviour in all three years being travel, followed by foraging and feeding, and the least observed behaviours being resting and socialising. The year 2013 represents the outlier from the past four years, the predominant observed behaviour being feeding not travelling, and a comparatively large proportion of socialising observed. The activity budget for Cardigan Bay SAC in 2016 closely resembles the overall activity budget for the whole of Cardigan Bay; travel remains the dominant behaviour observed (69.8%), followed by feeding and foraging (23.8%), socialising (4.8%), and resting (1.6%). Data collected from dedicated and opportunistic ad libitum surveys in Cardigan Bay, however, differ from data collected on line transect surveys (Figure 50).

Data collected on the primarily coastal NLT surveys and opportunistic surveys in Cardigan Bay SAC show a much higher proportion of sightings with animals engaged in foraging or feeding behaviour, 42% compared to 23.8%. Travel remains the most commonly observed behaviour but is greatly reduced, from 70% to 53%. The difference in behavioural budgets suggests a difference in habitat use of the inshore and offshore sectors, feeding occurring preferentially in the shallow, coastal area.

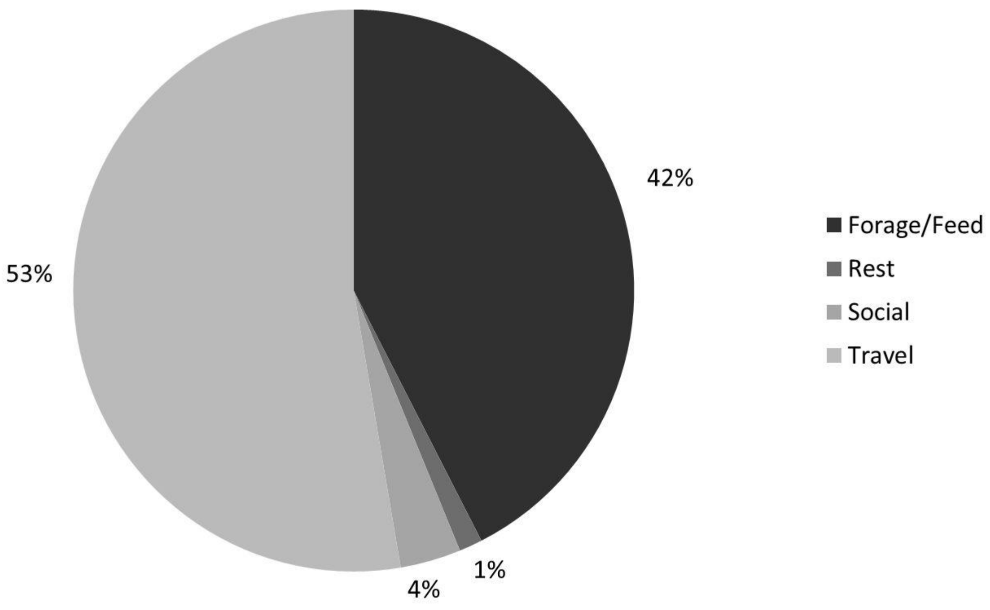


Figure 50: Behavioural budget of bottlenose dolphins in the Cardigan Bay SAC derived from dedicated NLT surveys and observations from opportunistic observations (n=360)

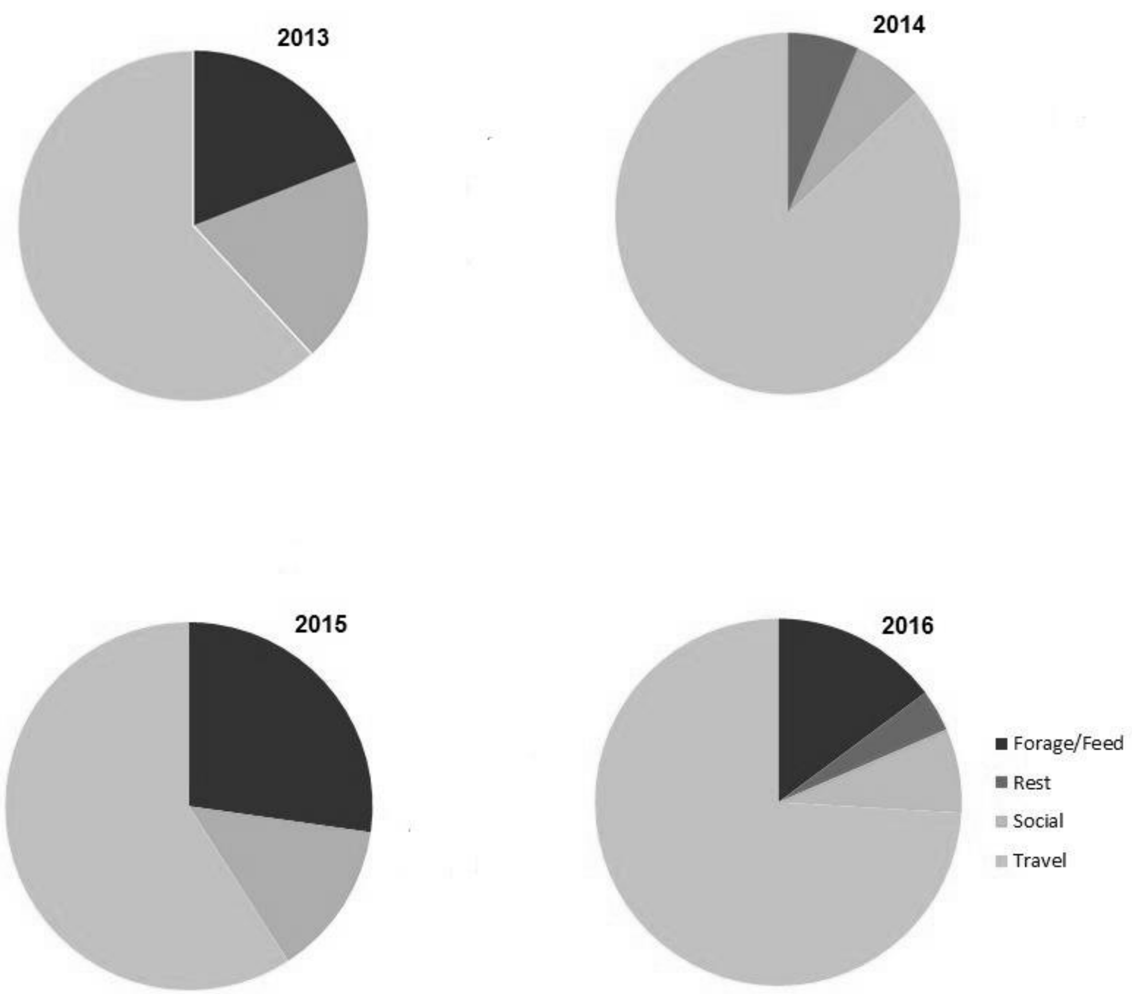


Figure 51: Behavioural budgets of bottlenose dolphins recorded on line transect surveys in northern Cardigan Bay in 2013, 2014, 2015 and 2016 respectively (n=42, 15, 22 and 27)

Data collected from bottlenose dolphin sightings in northern Cardigan Bay followed patterns similar to those in the Cardigan Bay SAC, overall. In 2016, the most frequently observed behaviour was travel (71.4%), followed by foraging/feeding (17.9%), socialising (7.1%), and resting (3.6%) (Figure 51). The frequency of foraging/feeding behaviour was lower than in Cardigan Bay SAC, whereas social behaviour was observed more frequently. The behavioural budget for northern Cardigan Bay broadly resembles previous years, particularly 2013 and 2015, with travel being the most dominant behaviour, followed by feeding/foraging and social behaviour. In 2016, however, travel was observed more frequently and social behaviour less frequently than in previous years, the percentage of social behaviour observed nearly halving from 2015 to 2016 (13% to 7.1%) and forage/feeding being reduced from 27% to 17.9%.

It is possible that, as with Cardigan Bay SAC, feeding might have been taking place preferentially in the coastal areas and was therefore not observed as frequently.

In 2016, behavioural budgets in Cardigan Bay varied through the season (Figure 52). Throughout May, June, August, September and October, travel was the dominant observed behaviour, followed by feeding and foraging, socialising, and resting. April and July deviated from this pattern. In April, dolphins were primarily observed resting (63%), followed by travelling (38%); no feeding or social behaviour was recorded. However, sample size was small for that month (n=8) so this might not be representative. In July, foraging was the predominant behaviour observed (56%), and not travel (33%), and there was also a comparatively high proportion of confirmed feeding activity (9%).

Since 2006, there seems to have been a steady increase in foraging behaviour up to 2013, before a sharp drop in 2014 to the lowest level recorded since 2006 (7%) (Figures 52 & 53). This rose to 20% and 19% in 2015 and 2016 respectively, whilst confirmed feeding behaviour declined from 2014 to 2016, from 13% in 2014, to 10% in 2015 and finally only 1% in 2016, the lowest it has been since 2006. When combining data from past years (2011 to 2016), there is a general decline in confirmed feeding activity through April to August, with a concurrent rise in food searching (foraging) behaviour (Figure 54), before rising again in September and October, with a concurrent drop in foraging behaviour. Although 2016 did have slightly higher rates of confirmed feeding in September and October (3% each) than in August (2%), the highest rate of confirmed feeding was recorded in July (9%) with no confirmed feeding activity recorded in April, May and June.

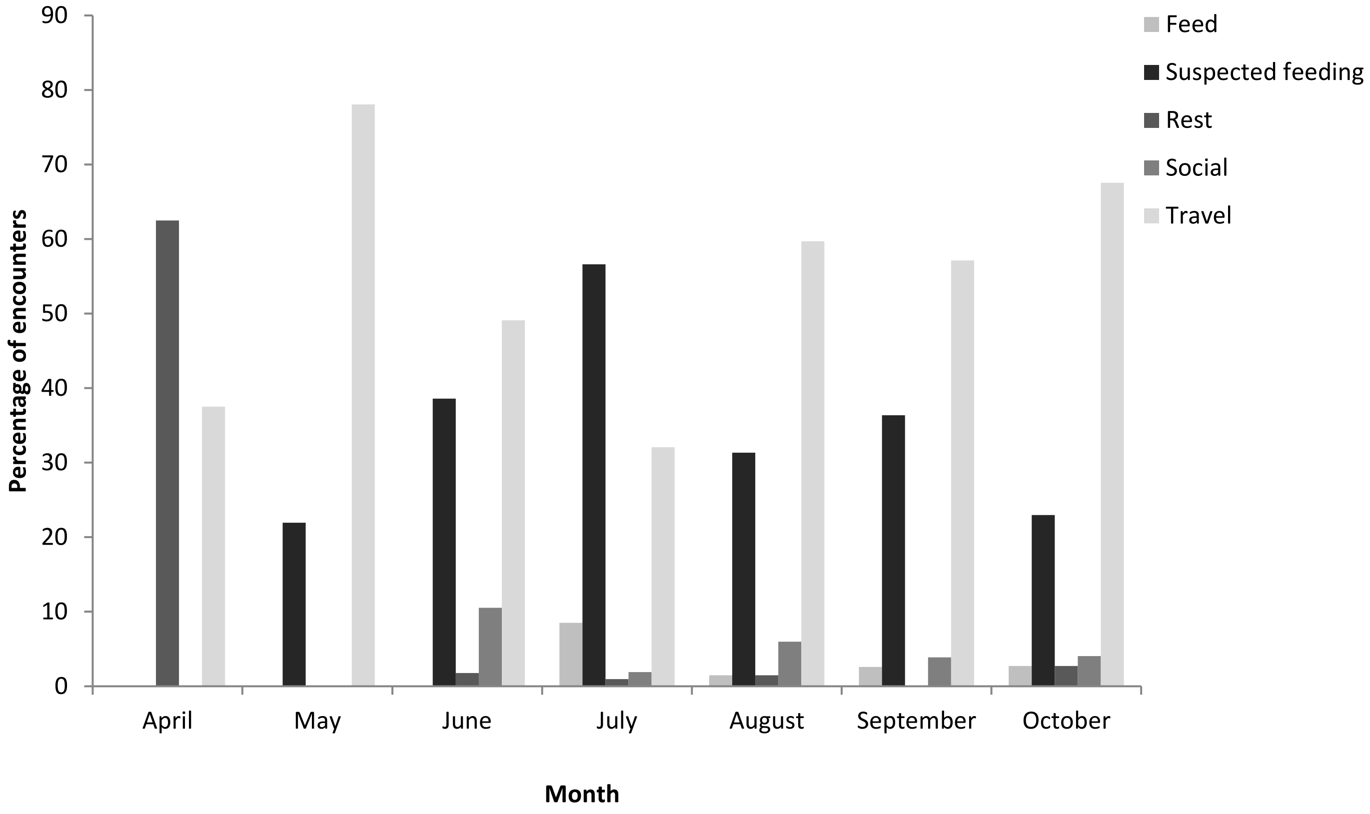


Figure 52: Behavioural budgets of bottlenose dolphins recorded from line transect and ad libitum surveys in Cardigan Bay SAC in 2016 (n=8, 41, 57, 106, 67, 77 and 74)

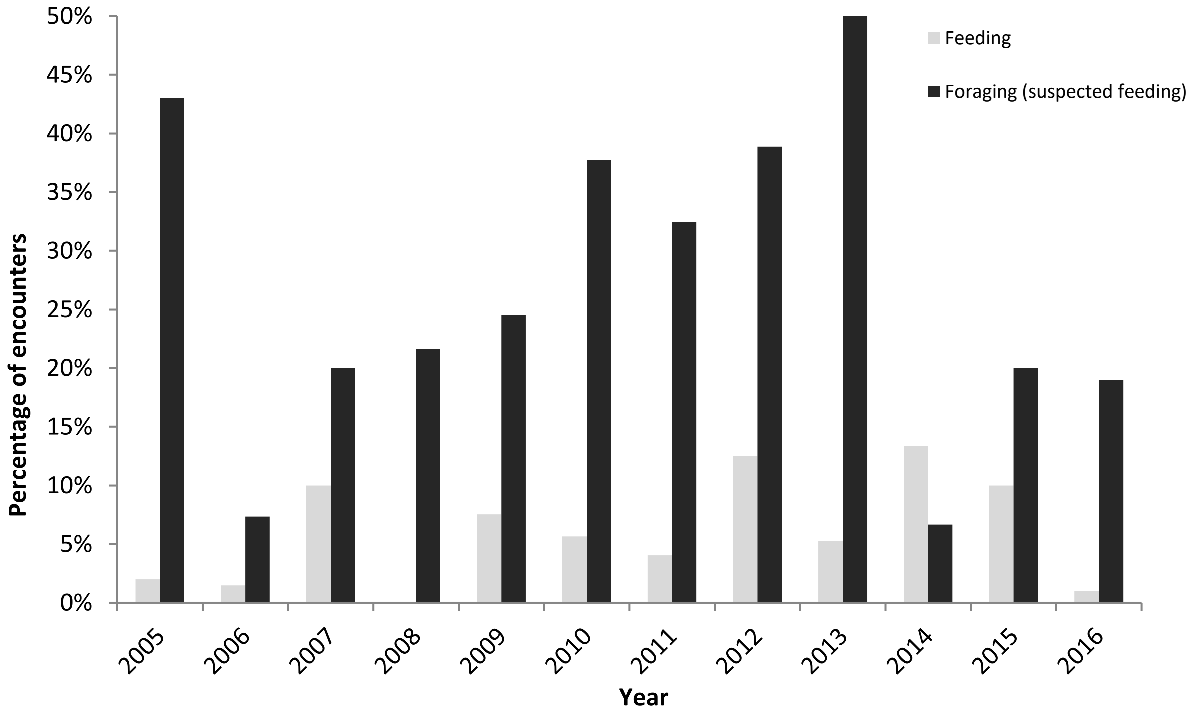


Figure 53: Yearly comparison of behavioural budgets of bottlenose dolphins recorded from line transect and *ad libitum* observations in Cardigan Bay SAC 2011- 2015 (feeding and suspected feeding only) (n= 87, 77, 88, 39, 59, 56, 83, 99, 101, 70, 42 and 157 respectively)

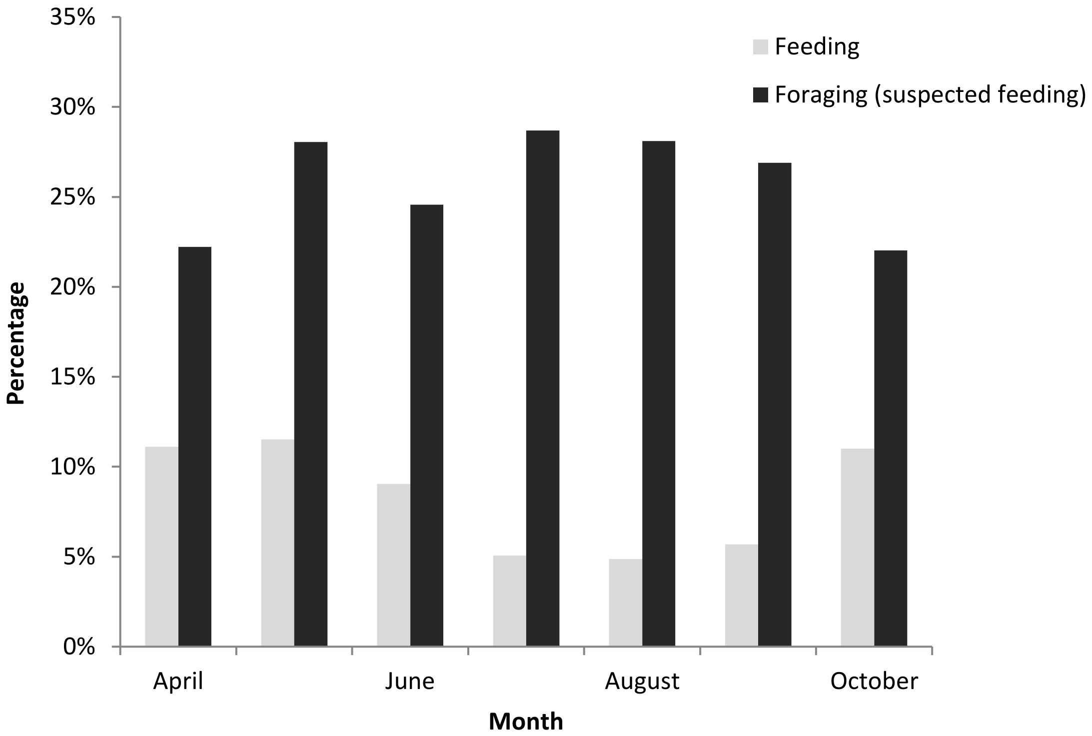


Figure 54: Seasonal comparison of behavioural budgets of bottlenose dolphins recorded from line transect and dedicated ad libitum surveys in Cardigan Bay SAC 2011-2016 (n=36, 139, 232, 237, 185, 264, 109)

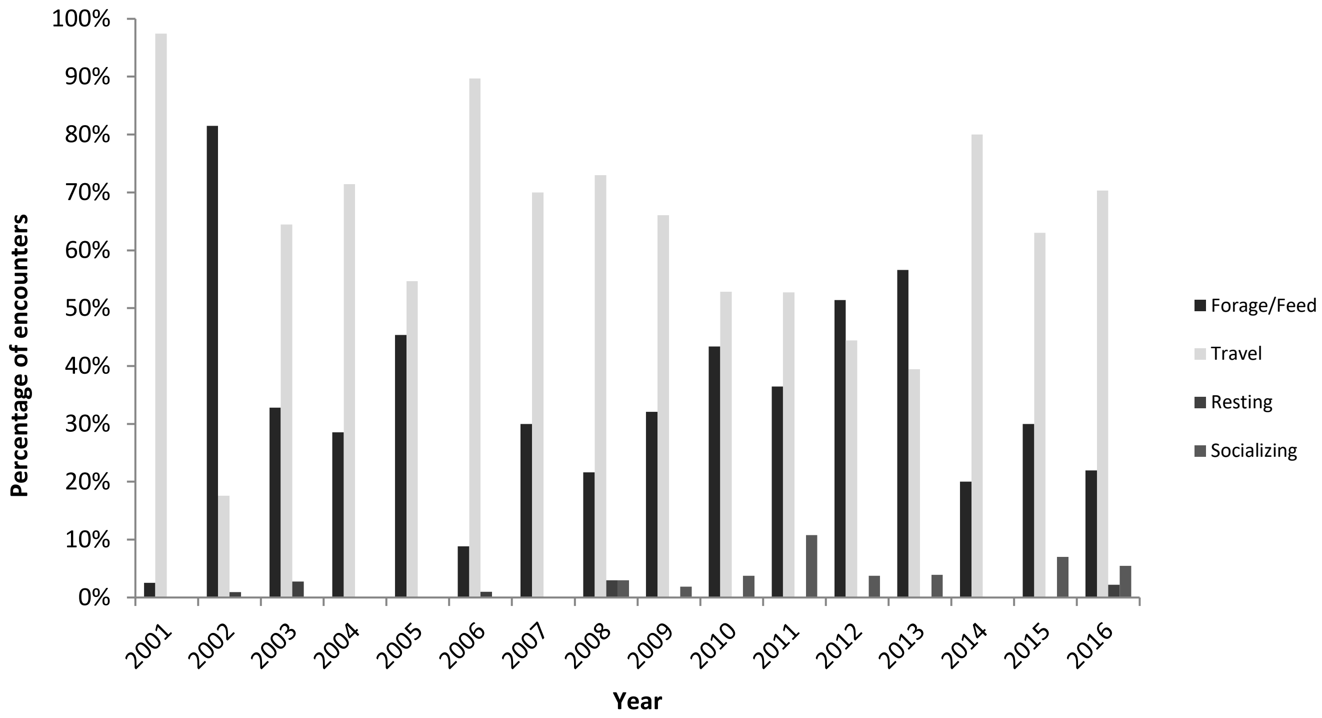


Figure 55: Behavioural budgets of bottlenose dolphins based on line transect surveys and dedicated *ad libitum* surveys in Cardigan Bay 2001-2016

Generally, high proportions of feeding/foraging behaviour correlate negatively with proportion of travel observed, whether viewed on a monthly or an annual basis (Figures 52 & 55). In the last three years, travel has been at its highest and feeding/foraging at their lowest observed levels since 2009.

9.4.2. Behavioural data: discussion

9.4.2.1. Behavioural budgets

As in previous years, the dominant behaviours observed throughout Cardigan Bay from 2014 to 2016 were travelling and feeding/foraging (Pesante *et al*. 2008; Feingold and Evans, 2014a). Looking at Cardigan Bay as a whole, travel was the most commonly observed behaviour (83.6%, 67.6% and 70.3% for 2014, 2015 and 2016 respectively), followed by feeding and foraging (16.4%, 29.7% and 20.9% for 2014, 2015 and 2016 respectively). Social behaviour and resting were the least commonly observed behaviours. Although travel and foraging/feeding have been the two dominant behaviours observed in Cardigan Bay since 2001, the proportion of travel to feeding and foraging has changed over the last three years. The proportion of travel recorded has increased considerably since 2013 and is at its highest since 2009 when it was 66%. The period 2010 to 2013 saw much lower rates of travel (39-53%) and corresponding higher rates of foraging and feeding behaviour (32-57%). It is likely that a large proportion of behaviour recorded as travel would be more accurately described as 'forage-travel', when animals are travelling in search of prey (Feingold and Evans, 2014a) and the increase of travelling behaviour in recent years could be an indication that food availability has been low, resulting in a larger amount of time spent travelling in search of food.

The change is particularly apparent in Cardigan Bay SAC, where in 2012 and 2013, 64% and 54% of behaviours recorded respectively were related to feeding and foraging, compared with only 26% in 2014, 30% for 2015 and 24% for 2016. In all three years, the proportion of foraging/feeding behaviour was higher in Cardigan Bay SAC than for the wider Cardigan Bay or northern Cardigan Bay, with 0%, 27% and 18% respectively for years 2014, 2015 and 2016. This suggests that Cardigan Bay SAC is an important feeding ground for bottlenose dolphins. Previous reports detailing behavioural budgets as well as acoustic T-POD recordings indicate that bottlenose dolphins feed preferentially in areas along the Cardigan Bay SAC coast such as New Quay Head, Ynys Lochtyn, Aberporth and Mwnt (Nuuttilla *et al*., 2013; Feingold and Evans, 2014a; Nuuttila *et al*., 2017). It is likely that the environmental conditions there, shallow waters, gentle slopes and a mixture of substrate types are particularly rich in prey species such as bottom dwelling fish and crustaceans that bottlenose dolphins target in these areas (Evans *et al*., 2000; Pesante *et al*., 2008b; CCW, 2008). Salmonids, such as sewin, the marine form of brown trout (*Salmo trutta)*, that occurs in the river Teifi in southern Cardigan Bay, and pelagic species such as herring (*Clupea harengus*) are also thought to be an important part of bottlenose dolphin diet (Baines *et al*., 2000). In 2016, a comparison between behavioural budgets based on dedicated surveys and on observations from tourist boats, differed greatly. Behavioural budgets based on *ad libitum* observations showed a much higher proportion of feeding and foraging behaviour: 42% based on opportunistic observations compared with only 24% from line transect surveys. This supports the suggestion that dolphins seem to be feeding more closely to the coast in the areas frequented by the wildlife tours, such as known hot spots, New Quay Head, Ynys Lochtyn and Mwnt. The difference in these behavioural budgets, combined with the steady increase in travelling time over the last three years may indicate that prey has become more difficult to find than in previous years, and animals are increasingly focussing their efforts on the known coastal hotspots.

Unfortunately, it is difficult to identify prey species unless there is photographic evidence, of which we have relatively little. In May 2014 a dead bottlenose dolphin washed up at Hell's Mouth having choked on a brill (*Scophthalmus rhombus*): its stomach also contained red gurnard (*Chelidonichthys cuculus*) and common sole (*Solea solea*), all of which are predominantly demersal species, and a salmonid believed to be Atlantic salmon (*Salmo salar*) (Deaville and Jepson, 2014). Another animal that stranded in September 2015 was found to have in its stomach several dogfish (*Squalus acanthias*), another demersal species in its stomach (Penrose, 2015). In July 2014, individual 004-90W was photographed taking a sea trout at New Quay pier. In 2015 photographs were taken of dolphins pursuing garfish (*Belone belone*) once off New Quay pier in June, and again chasing garfish at the surface close to shore off Aberporth in October. In 2016, bottlenose dolphins were observed feeding on sea trout close to shore near Aberporth in July and in October a dolphin was photographed throwing a small shark, probably a tope (*Galeorhinus galeus*), near New Quay pier. Notably, all photographed feeding events took place in coastal areas. In further support, the yearly comparison of behavioural budgets involving confirmed feeding events and suspected feeding events also shows a steady decline in the last three years, confirmed feeding events dropping to the lowest value they have been since 2006.

Seasonal comparison of behavioural budgets based on data collected from 2011 to 2016, suggests that most confirmed feeding events generally are recorded early in the season during April and May, and late in the season, during September and October. This has changed somewhat with the inclusion of data from the last three years, previous reports prior to 2014 describing a gradual decline in confirmed feeding activities through the season (Feingold and Evans, 2014a). Again, this may reflect a change in prey abundance and subsequent behavioural adaptation and this might in part be a reason for the increase in sightings of Cardigan Bay dolphins further afield in North Wales and Liverpool Bay, even during the summer months.

Behavioural budgets for northern Cardigan Bay typically differ from those for Cardigan Bay SAC which has led to the suggestion that bottlenose dolphins use the two areas differently (Feingold and Evans, 2014a; Norrman *et al*, 2015). This is supported by the fact that sightings rates are consistently lower and group sizes usually larger further north (Feingold and Evans, 2014a; Norrman *et al*. 2015; Lohrengel & Evans; 2016). Although differences in group sizes and sightings rates were less apparent in 2016 than in either 2014 or 2015, these assumptions still broadly hold true. Similarly, the behavioural budgets for the last three years for the area do show consistently lower levels of feeding and foraging behaviour, while the proportion of social behaviour recorded is comparatively higher. Social behaviour was recorded at 7%, 13% and 7% for 2014, 2015 and 2016 respectively in northern Cardigan Bay whilst it was recorded at 3%, 1% and 5% in Cardigan Bay SAC. Overall, however, there has been a decline in social behaviour recorded, compared to earlier years. In 2011, 2012, and 2013 social behaviour made up 21%, 29% and 25% of behavioural budgets for northern Cardigan Bay respectively.

If, as previously suggested, the increase in time spent traveling is an indication of a decrease in prey abundance, it is possible that animals now spend, overall, more time travelling and foraging, and therefore less time socialising than in previous years when food may have been more abundant. Nevertheless, it remains true to say that bottlenose dolphins use the two SACs in different ways, utilising Cardigan Bay SAC as a feeding and nursery ground, whilst spending more time socialising in northern Cardigan Bay. Interestingly, in the last three years, three neonate calves have washed up on the coast of Pen Llŷn a'r Sarnau SAC: one at Barmouth in August 2014, a second near Pwllheli in September 2014, and finally a male calf near Ynyslas in 2016, which was later concluded to be the first confirmed case of infanticide recorded in Cardigan Bay. Furthermore, in August 2015, we observed what appeared to be an aggressive social interaction within a large group of dolphins including a newborn calf and its mother near the Aberdovey estuary. Large groups such as this may pose a greater risk to dolphin calves and would explain why comparatively more females with newborn calves have been sighted in Cardigan Bay SAC.

9.4.2.2. Infanticide

Infanticide in bottlenose dolphin was first reported to occur in the UK in the Moray Firth in the 1990s, and has since then been documented a number of times in this area (Patterson *et al*., 1998; Robinson, 2014). It has also been reported in other populations around the world including Florida and Virginia (Dunn *et al*., 2002; Kaplan *et al*., 2009). In August 2016, a dead newborn dolphin with conspecific rake marks on its head was washed up near Ynyslas, and a post-mortem conducted by the CSIP revealed traumatic injuries consistent with blunt force trauma, similar to those observed in harbour porpoise killed by bottlenose dolphins (R. Penrose, personal communication) (compare Figure 61, Appendix 8.7). This is the first recorded instance of infanticide in Cardigan Bay.

Very few aggressive interactions involving calves have been observed. In September 2011, Sea Watch staff and interns observed a newborn calf being aggressively pushed at the surface and subsequently thrown out of the water by an adult bottlenose dolphin near New Quay harbour (Appendix 8.8). However, the dolphin which threw the calf was later identified to be its mother. The calf, which repeatedly approached our survey vessel, seemed unharmed by the interaction and was seen swimming next to its mother immediately after it happened (SWF, unpublished data). This was interpreted as strong disciplinary behaviour and followed the mother repeatedly pushing the calf away from the vicinity of the vessel.

A second aggressive incident involving a newborn calf was witnessed in 2015 between Aberdovey and Ynyslas. A large group of dolphins was observed socialising aggressively, rushing at the surface, breaching and surfacing rapidly. The group contained a female with a newborn calf. The calf was constantly flanked by its mother and another adult dolphin while two other dolphins attempted to surface between them and jump on top and in front of them (Appendix 8.7). The mother was identified as 024-05S and the adult accompanying her was 233-09S, a known male. The dolphins involved in harassing the pair could not be identified. Although we were unable to observe the end of the interaction, the calf was seen alive in 2016 with its mother.

In 2014, a bottlenose dolphin neonate was found dead near Barmouth in August and a second neonate was found dead near Pwllheli in September. No cause of death could be determined due to the advanced decomposition of the bodies.

The most common explanation for infanticide in bottlenose dolphins is that male bottlenose dolphins may be able to improve their reproductive fitness by killing a young calf and increasing their mating opportunities (Patterson *et al*., 1998).

9.4.2.3. Interspecific interactions

Interspecific aggressive interactions between bottlenose dolphins and harbour porpoise in Wales were first recorded in 1991 and account for up to 20% of harbour porpoise mortality (Jepson and Baker, 1998; Evans and Hintner 2010; Deaville and Jepson, 2014; Boys, 2015). Despite this, attacks are rarely witnessed, with only two observed and photographed in Cardigan Bay prior to 2014. Since then, three further attacks have been observed.

In May 2014, a harbour porpoise was pursued by two dolphins and beached on Dolau Beach, New Quay, where it was later successfully refloated.

In June 2014, SWF staff and interns observed and photographed several dolphins attacking a harbour porpoise south of New Quay (Figure 56). The outcome of the attack is unknown but a harbour porpoise carcass stranded several days later.

In early July 2014, three bottlenose dolphins were recorded attacking a porpoise at Ynys Lochtyn. One of the individuals involved was identified to be 223-09S, or “Effy”, an individual of unknown sex. Later that month two bottlenose dolphins were seen attacking a harbour porpoise. The dolphins involved were identified as 074-03W, or “Bond”, a confirmed male, and 023-03W, or “Voldemort”, a suspected male.

Figure 56: Bottlenose dolphins attacking a harbour porpoise in the Cardigan Bay SAC in 2014. Photos: copyright Sea Watch Foundation

No direct attacks were observed in 2015 but at least six incidents of suspected bottlenose dolphin kills in Welsh waters were reported in the annual Marine Mammal & Marine Turtle Strandings Report for 2015 (Penrose, 2016).

Figure 57: Two dead harbour porpoise, suspected to have been killed by bottlenose dolphins, stranded in the Cardigan Bay SAC in April 2016. Photo: copyright Sea Watch Foundation

No incidents were observed in 2016 although two harbour porpoise carcasses (Figure 57) that washed up in April 2016 were thought to be potential bottlenose dolphin kills (R. Penrose, personal communication). However, post mortem results have not yet been released to confirm this.

Several SWF interns also reported a bottlenose dolphin throwing a juvenile Atlantic grey seal out of the water during an *ad libitum* survey. It was a one-off occurrence and not a sustained attack and the seal escaped unharmed. The report came from experienced observers but there was unfortunately no photographic evidence to support it.

9.4.2.3.1. Interspecific interactions: Discussion

Bottlenose dolphin attacks on harbour porpoise have been recorded in several populations including Cardigan Bay, the Moray Firth and California (Patterson *et al*., 1998; Cotter et. al, 2012; Norrman *et al*., 2015; Boys, 2015). In the UK, bottlenose dolphin attacks on harbour porpoise are one of the leading causes of death in stranded porpoise (Deaville and Jepson, 2014; Penrose, 2016). In 2015, 46% of porpoises stranded in Wales and undergoing a post mortem examination were found to be bottlenose dolphin kills, however it is likely that this is a slightly inflated percentage as not all stranded porpoise could be autopsied due to budget constraints (Penrose, 2016). Despite the high level of attacks that occur, the event itself is rarely witnessed and most evidence is collected through post mortem examinations (Boys, 2015).

The behaviour was first recorded in the 1990s in Scotland (Ross and Wilson, 1996), first witnessed in Wales in 2004, and first photographed by SWF in 2008 (SWF, unpublished data). The year 2014 was unusual in that four separate events of bottlenose dolphins attacking harbour porpoise were witnessed during SWF surveys (Norrman, *et al*., 2015). It is still unclear what the cause of these attacks is although several explanations have been put forward including competition for resources and feeding interference, elevated testosterone levels in male dolphins during breeding season, practice fighting, and infanticide (Boys, 2015).

In some areas, such as the Moray Firth and California, the majority of bottlenose dolphins involved in agonistic interspecific interactions with harbour porpoise were found to be male (Ross & Wilson, 1996; Cotter *et al*., 2012; Boys, 2015). Although relatively few such interactions have been observed in Wales, all known attackers have been confirmed or suspected males (Norrman *et al*., 2015). There are a number of reasons that could lead male bottlenose dolphins to attack harbour porpoises more than females, such as elevated testosterone levels during the breeding season causing a higher level of aggression as has been suggested in California where attacks coincide with the breeding season (Cotter *et al*, 2012). However, this is unlikely to be the case in the UK where attacks occur throughout the year (CSIP, 2013; Boys, 2015).

Similarities in the size of harbour porpoise and infant dolphins as well as the pattern of the attack have led some authors to suggest that this behaviour could also be linked to infanticide (Patterson *et al*., 2016). In some bottlenose dolphin populations, infanticide is a regular occurrence and these attacks could be a form of object directed play, allowing young males to practice skills used in fighting or infanticide (Patterson *et al*., 1998; Boys, 2015). This was thought to be an unlikely major explanation in Cardigan Bay because, besides the recent single instance, infanticides had not been recorded at all in this population.

Dietary overlap and competition for limited resources have been put forward as the most likely explanations for these interactions in Cardigan Bay, with an increase in numbers of attacks during periods of high co-occurrence (Boys, 2015). This would also be in accordance with our observations that bottlenose dolphins are spending an increasingly large proportion of time travelling and less time feeding in recent years Notably, 2014, the year with the highest frequency of observed porpoise attacks also coincided with the lowest level of feeding/foraging behaviour observed since 2006 (Appendix 8.4).

While it is likely that food interference is one of the main factors driving these interactions, other variables such as heightened aggression during calving and the mating season in the summer months, are also relevant factors affecting the frequency of these attacks (Boys, 2015).

9.5. Dead dolphins

On 3 May 2014, an adult male bottlenose dolphin (3 m length) was found dead at Hell's Mouth, Llŷn Peninsula. Cause of death was asphyxiation, with a probable brill (*Scopthalmus rhombus*) of >30cm length found blocking its gullet (Deaville, 2014). The stomach was full of fish, and species identified from photographs by Ivor Rees included common sole (*Solea solea*), red gurnard (*Chelidonichthys cuculus*), and a salmonid thought to be Atlantic salmon (*Salmo salar*). Within the SWF Photo-ID catalogue, we identified the animal as 128-02S (Figure 58), first identified in 2002, and recorded every year since then.

Figure 58: Left: Individual 128-02S found choked on a fish at Hell's Mouth, Llŷn Peninsula on 3 May 2014. Right: The same individual photographed in Cardigan Bay on 26th Sept 2011. Photos: copyright CSIP (left), Sea Watch Foundation (right)

A bottlenose dolphin neonate (female, 1.46m length) was found dead near Barmouth on 20 August 2014 (cause of death unknown as it was in an advanced state of decomposition), and a second neonate was found dead near Pwllheli on 14 September 2014.

An adult female was also found floating dead in the water offshore Aberystwyth in September 2015 during a Sea Watch line transect survey. Due to the advanced state of decomposition, it was not possible to recover the body.

A sub-adult male bottlenose dolphin was found dead near Clarach, Ceredigion, in September 2015 (Figure 59). Few external injuries were apparent besides abrasions and one small injury in the abdominal area. Cause of death was determined to be physical trauma consistent with by-catch injuries by the CSIP (Penrose, 2015). The animal was unmarked and could not be matched to the Sea Watch catalogue.

Figure 59: Unidentified by-caught bottlenose dolphin washed up in Clarach, Ceredigion in 2015. Photos: copyright Sea Watch Foundation

A small, male bottlenose dolphin calf was found dead at Ynyslas, Ceredigion, on the 5th August 2016 (Figure 60) and collected by the CSIP. The body was 145cm long; foetal folds and vibrissae were still visible, indicating the animal was probably less than four weeks of age. Conspecific rake marks were visible around the head and a subsequent post mortem, carried out by the Cetacean Strandings Investigation Programme of the Zoological Society London (ZSL), found multiple areas of focal bruising in the abdominal area and body wall consistent with blunt force trauma caused by ramming by another dolphin (R. Penrose, personal communication; Patterson *et al*., 1998).

Figure 60: Left: conspecific rake marks clearly visible on dead neonate bottlenose dolphin that stranded at Ynyslas, Ceredigion in 2016. Right: internal bleeding consistent with blunt force trauma uncovered during post-mortem. Pictures courtesy of CSIP and ZSL

9.6. Sightings of other species of marine wildlife in Cardigan Bay

In addition to bottlenose dolphins, Sea Watch observers recorded sightings of other marine mammals, such as grey seals, harbour porpoise and common dolphins, as well as other marine megafauna such as leatherback turtles and basking sharks, following the same protocols as described in the methodology for bottlenose dolphin data collection (Figures 61 and 62).

9.6.1. Sightings maps of marine wildlife in Cardigan Bay 2014-2016

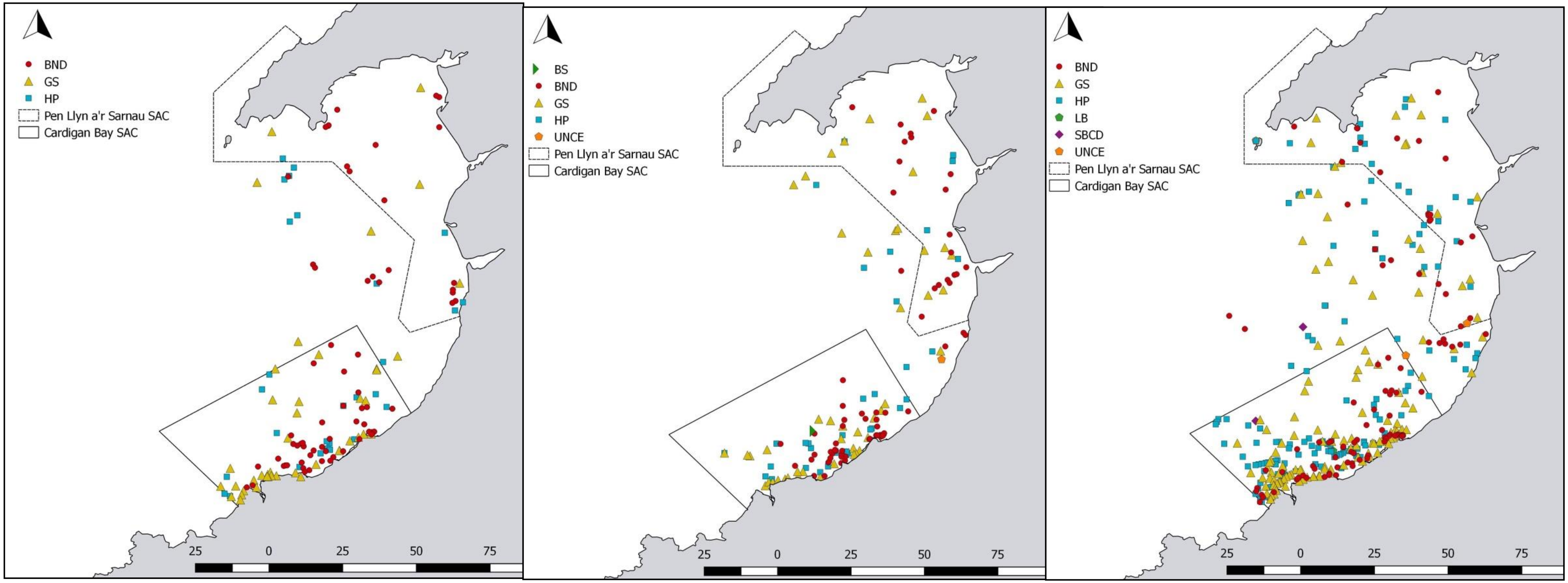


Figure 61: Sightings of marine wildlife on dedicated line transect surveys in Cardigan Bay in 2014 (left), 2015 (middle) and 2016 (right). BND = bottlenose dolphin, GS = Atlantic grey seal, HP = harbour porpoise, SBCD = short-beaked common dolphin, BS = basking shark, LB = Leatherback turtle, UNCE = unidentified cetacean

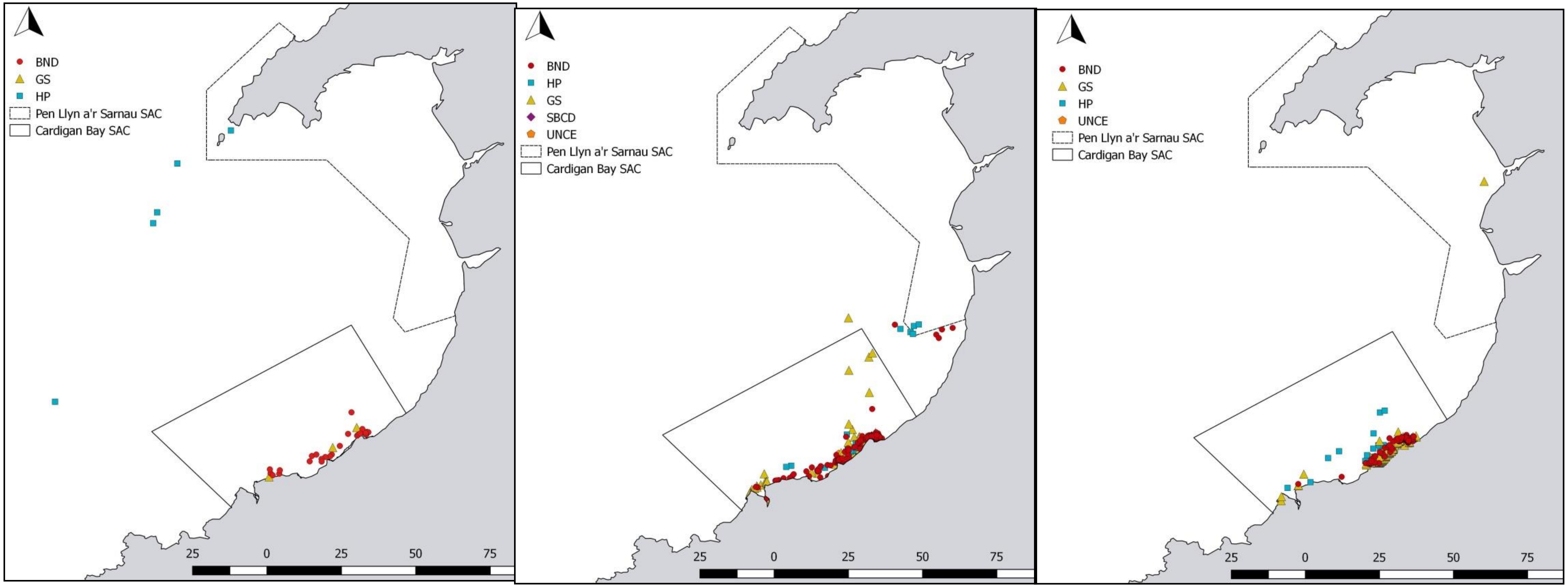


Figure 62: Sightings of marine wildlife on dedicated NLT surveys and opportunistic observations from tourist boat operators in Cardigan Bay in 2014 (left), 2015 (middle) and 2016 (right). BND = bottlenose dolphin, GS = Atlantic grey seal, HP = harbour porpoise, SBCD = short beaked common dolphin

9.6.2. Harbour porpoise

Harbour porpoise group size remained similar over the study period with averages of 1.5, 1.9 and 1.8 in the years 2014, 2015 and 2016 respectively. They were distributed fairly evenly throughout Cardigan Bay over the study period, with the exception of 2016 when sightings were most frequent in the southwestern part of the Cardigan Bay SAC (Figure 62).

9.6.2.1. Harbour porpoise abundance estimates Cardigan Bay SAC

Abundance estimates and detection curves for harbour porpoise were calculated using Distance sampling (Table 20, Figure 63). Observations further from the track line than 600m were considered outliers and truncated from further analysis in 2016. In 2015, the data set was limited and therefore a wider limit, 1,000m, was set to improve sample size. Data from 2014 were not included as they did not provide systematic coverage of the area. Estimates have fluctuated over the years with a clear peak of 340 in 2011. Since then, they have decreased overall although estimates since 2013 show an increase, reaching the highest value of 236 since 2003 (when 232 were estimated). The peak in numbers in 2016 also coincides with a higher sightings rate in Cardigan Bay SAC.

Table 20: Abundance estimates between years of harbour porpoise in Cardigan Bay SAC, 2001-16 (estimates for Distance sampling have not been obtained every year)

Year	Abundance	95% CI	CV	Observations
2001	108	81-146	0.15	144
2003	236	148-337	0.24	50
2004	215	136-339	0.23	46
2005	170	121-240	0.17	81
2006	161	109-238	0.20	57
2007	182	123-269	0.20	49
2011	340	140-828	0.46	20
2012	169	96-296	0.29	32
2013	147	97-222	0.29	32
2015	183	56-606	0.64	12
2016	232	129-419	0.30	24

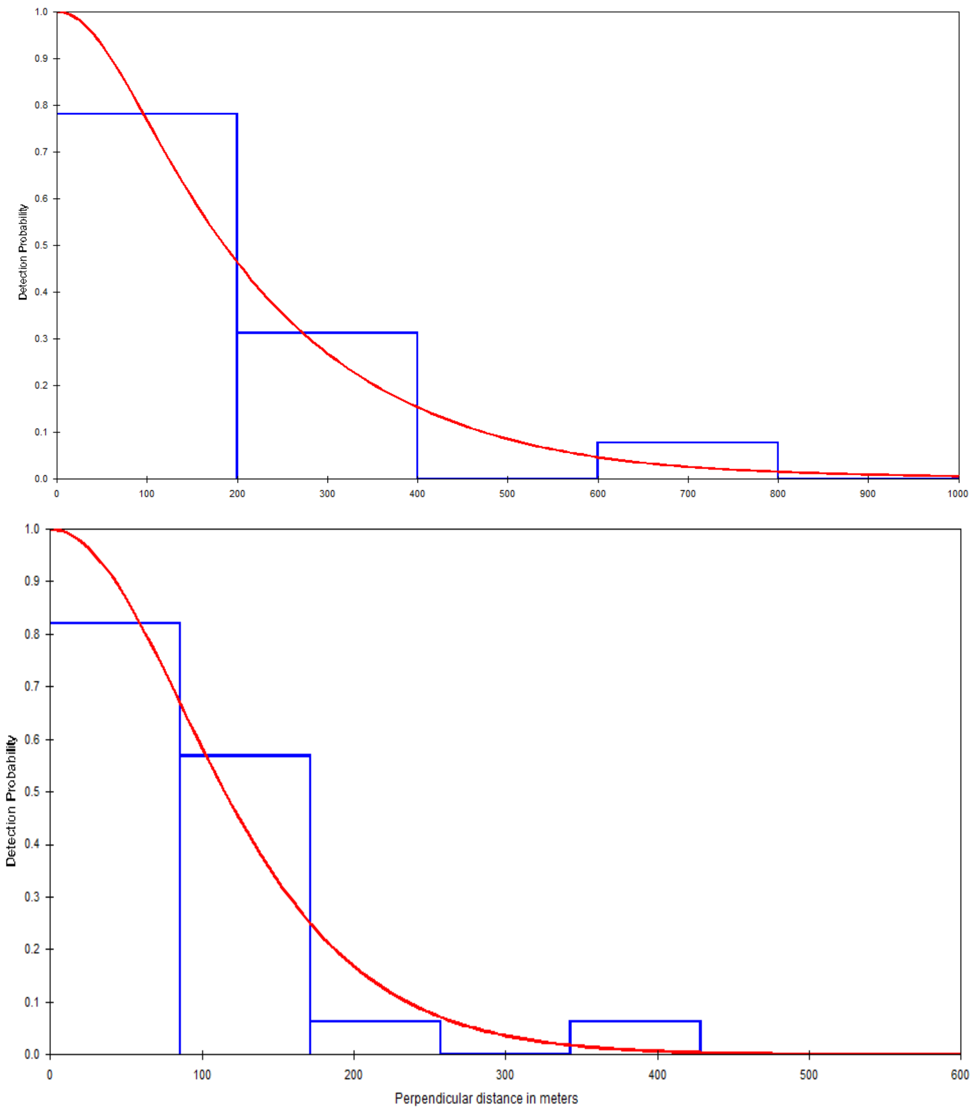


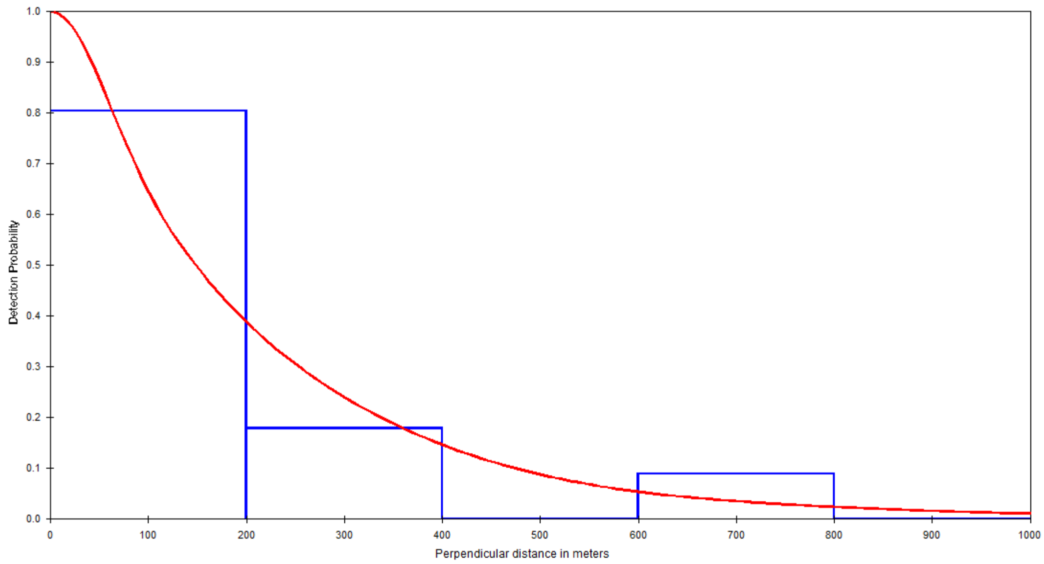
Figure 63: Detection functions of harbour porpoise in Cardigan Bay SAC (top) in 2015 and 2016 (bottom)

9.6.2.2. Abundance estimates of harbour porpoises in the wider Cardigan Bay

Abundance estimates and detection curves were also calculated for harbour porpoise in the wider Cardigan Bay area (Table 21, Figure 64). For 2016, data were truncated at 600m, the distance giving the lowest AIC value. Data from 2015 were truncated at 1,000m due to limited sample size. The abundance estimates for the wider Cardigan Bay show wide variation between years with peaks of 1,074 individuals in 2011 and 828 in 2016.

Table 21: Abundance estimates of harbour porpoise (HP) from line transect surveys in the wider Cardigan Bay

Year	Abundance	95% CI	CV	Observations
2011	1074	634-1821	0.28	42
2012	565	379-840	0.24	57
2013	410	98-564	0.20	88
2015	291	128-661	0.42	15
2016	828	568-1207	0.19	52



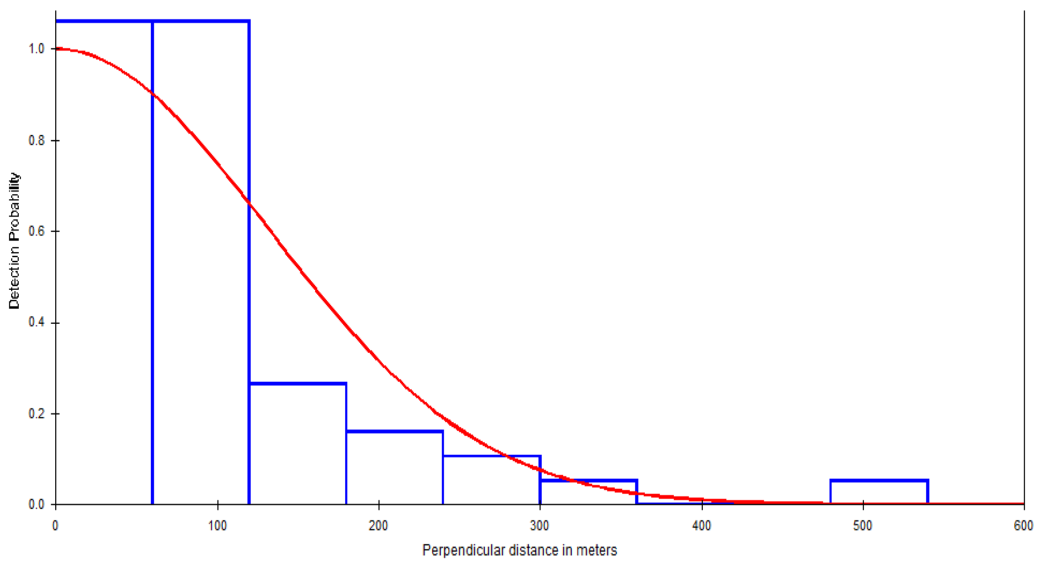


Figure 64: Detection functions of harbour porpoise in wider Cardigan Bay in 2015 (top) and 2016 (bottom)

9.6.2.3. Harbour porpoise distribution: Discussion

Harbour porpoises are known to be more common and widespread in their distribution in the Irish Sea than the bottlenose dolphin (Pesante *et al*., 2008b; Baines and Evans, 2009, 2012; Hammond, 2008). This is reflected in the data for Cardigan Bay. Both in 2016 and in previous years, harbour porpoise have been fairly evenly distributed throughout the bay, whereas the majority of bottlenose dolphin sightings are tightly clustered in localised areas. One exception to this observation is the southwestern corner of Cardigan Bay SAC where a high number of harbour porpoise sightings were logged in 2016. Notably, there were also relatively few bottlenose sightings in this area that year. This is consistent with past studies that have shown concentrations of harbour porpoise near Cemaes Head and off Pembrokeshire (Pesante *et al*., 2008b; Baines and Evans, 2012), and that spatial and temporal habitat partitioning between bottlenose dolphins and harbour porpoise is taking place in Cardigan Bay (Baulch, 2007; Simon *et al*., 2010; Nuuttila *et al*., 2013; Nuuttila *et al*., 2017). The reason for this is probably the high occurrence of agonistic interspecific interactions resulting in the death of harbour porpoise; in 2014, a report by the Cetaceans Stranding Investigation Programme concluded that bottlenose dolphin attack was one of the most common causes of mortality in harbour porpoise, 20% of porpoise brought in for post mortem examinations exhibiting signs of bottlenose dolphin attack (Deaville and Jepson, 2014).

9.6.2.4. Harbour porpoise abundance estimates Cardigan Bay SAC: Discussion

Harbour porpoise abundance estimates have varied considerably in recent years but generally appeared to be declining since 2011, reaching an all-time low in 2015. Abundance estimates for 2016, however, were much higher, more than doubling on the previous year, in accordance also with the increase in sightings rates. It is possible that the low coverage in 2015 affected the estimates; CV values were more than double that of 2016, and the abundance estimates were based on very few observations. As with the bottlenose dolphin abundance estimates, there is a strong correlation between high levels of line transect survey effort and more robust estimates with smaller CV values. CVs of c. 0.2 have been achieved in Cardigan Bay in those years with high survey effort (c. 600km in Cardigan Bay SAC and c.1,500km in the wider Cardigan Bay). Sustained, systematic line transect effort is therefore essential for reliably estimating harbour porpoise numbers. This is particularly important as there are few options for accurately estimating harbour porpoise numbers in the area, since, unlike bottlenose dolphins, they are not a species suitable for photo-identification, thus ruling out CMR analysis as an alternative way of assessing numbers. This species faces a number of threats across Europe such as prey depletion, chemical pollution, noise and physical disturbance, climate change and fisheries bycatch, some of which are considered to be at unsustainable levels in North West Europe (see Evans and Prior, 2012 for a review). Harbour porpoise, along with bottlenose dolphins, are listed under Annex II of the EU Habitats Directive, and the UK has recently proposed much of Cardigan Bay as a candidate West Wales Marine SAC for harbour porpoise. The inclusion of harbour porpoise in the systematic line transect surveys of this region, targeting bottlenose dolphin, will monitor the two qualifying features and support assessments of favourable conservation status.

9.7. Home ranges and individual sightings histories

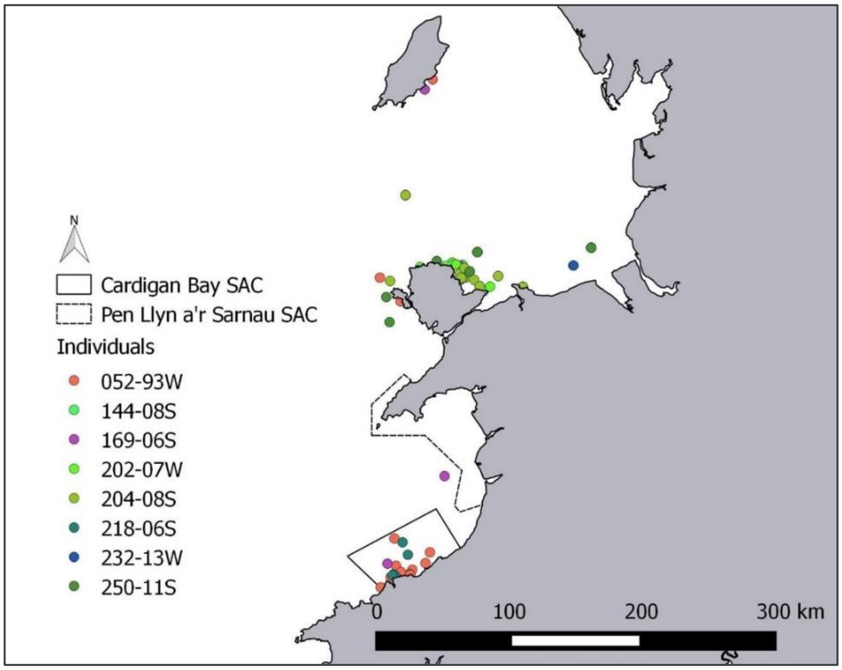


Figure 65: Individual sightings histories from 2001 to 2016 of identified bottlenose dolphins identified during the 2013 Liverpool Bay survey

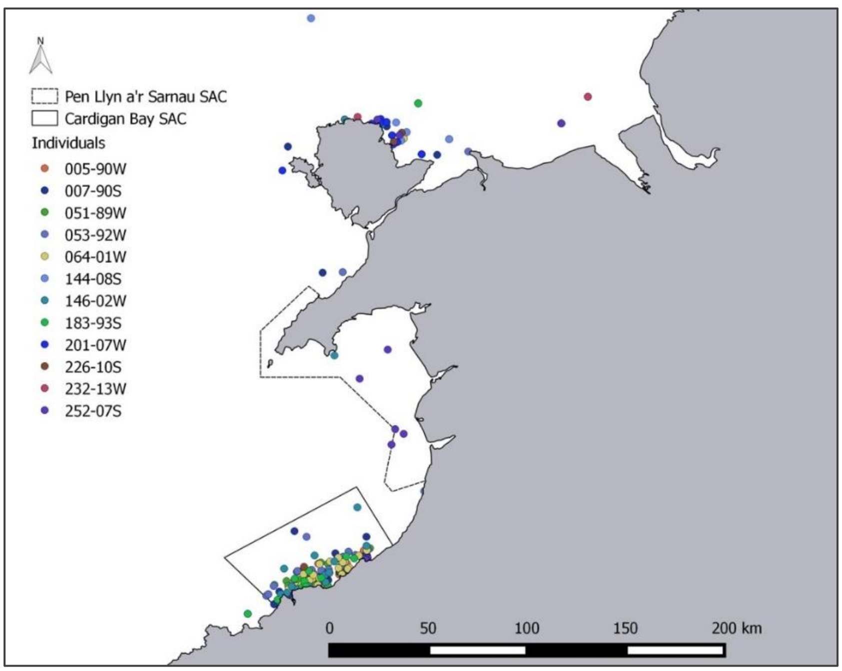


Figure 66: Individual sightings histories from 2001 to 2016 of bottlenose dolphins identified during the 2014 north east Wales survey

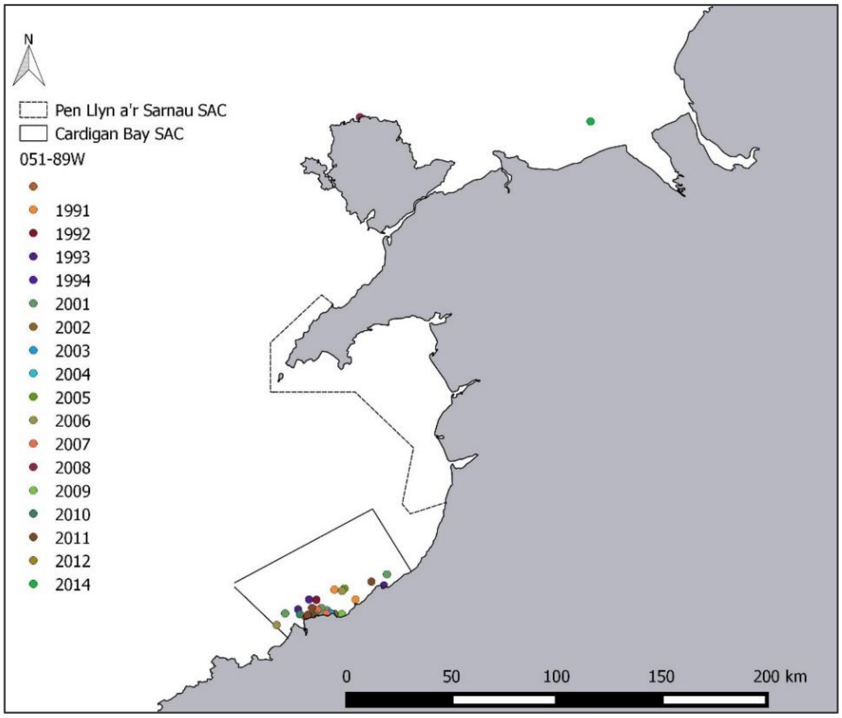


Figure 67: Known range of individual 051-89W a former resident of Cardigan Bay SAC that has not been sighted in that area since 2011

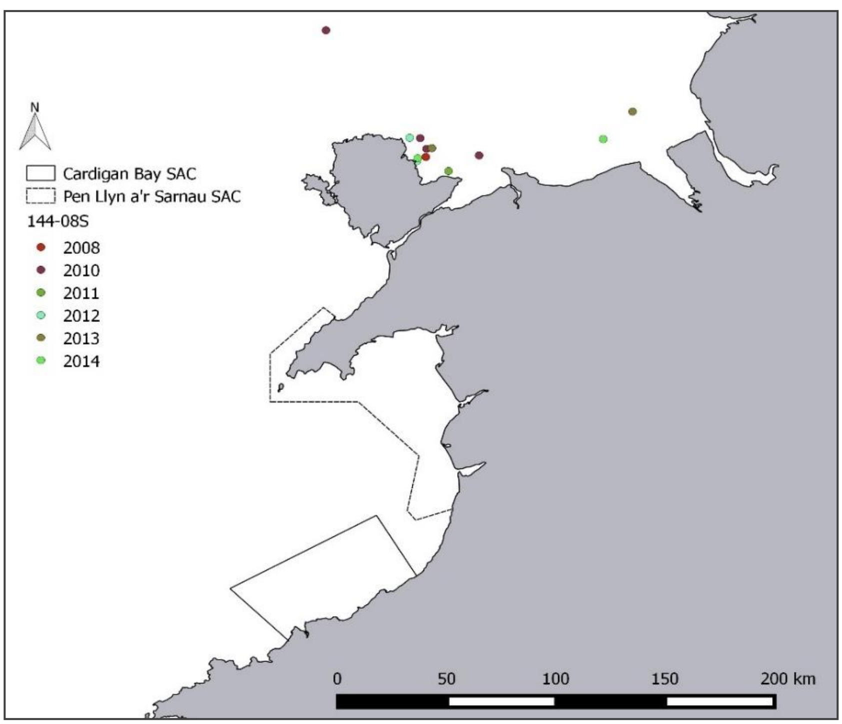


Figure 68: Home range of individual 144-08S showing strong preference for North Wales

9.8. Photographs of aggressive interactions of adult dolphins with newborn calves observed in Cardigan Bay

Figure 69: Female bottlenose dolphin aggressively pushing her calf at the surface in September 2011. Photos: copyright Sea Watch Foundation

Figure 70: Left: Two adult bottlenose dolphins closely flanking newborn calf (arrow indicates mother) Right: Aggressive head to head posturing by third dolphin which was followed by aggressive pursuit and breaching close to the two adults with the calf. Photos: copyright Sea Watch Foundation

9.9. Trend analysis methods and output

9.9.1. Description of the analysis

A combination of two approaches was used:

Step 1: a linear regression was fitted to the estimated abundances, versus year, but not taking into account the error of the estimates (i.e. assuming that the figures of abundance were exact, as if they were an accurate census or count). Results appear in Table 22. Where no significant negative trend is detected, we assume that no trend exists. However, the significance of the trend may be artificially inflated by ignoring errors around the estimates, hence where a significant negative trend was detected, an additional test is needed.

Step 2: 1000 random values for each annual abundance were generated using the mean and SD for the annual estimate, assuming a log-normal distribution of the annual estimates. Thus we generated 1000 replicates of each abundance series and fitted a linear regression to each one. We consider that if more than 95% of the resulting trends were negative this is equivalent to a significant negative trend. Results appear in Table 23.

Table 22: Linear Regression results on bottlenose dolphin abundance estimates in Cardigan Bay

Area	Method	Time period	Regression result
CB SAC	CMR	2001-16	NS
CB SAC	CMR	2007-16	Negative, $p=0.013$
CB SAC	Distance	2001-16	Negative, $p=0.031$
CB SAC	Distance	2007-16	NS
Wider CB	CMR	2007-16	Negative, $p=0.015$
Wider CB	CMR	2011-16	Negative, $p=0.022$
Wider CB	Distance	2011-16	NS

Table 23: Results of trend analysis of bottlenose dolphin abundance estimates in Cardigan Bay using 1000 simulations

Area	Method	Time period	Simulation % negative
CB SAC	CMR	2001-16	42.0%
CB SAC	CMR	2007-16	89.8%
CB SAC	Distance	2001-16	98.7%
CB SAC	Distance	2007-16	84.7%
Wider CB	CMR	2007-16	95.7%
Wider CB	CMR	2011-16	82.2%
Wider CB	Distance	2011-16	62.1%

9.9.2. Trend Analysis Output

9.9.2.1. Cardigan Bay Special Area of Conservation (SAC)

9.9.2.1.1. Capture, mark and recapture (CMR)

9.9.2.1.1.1. 2001-2016

9.9.2.1.1.1.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.05611565
Coefficient of determination R^2	0.00314897
R^2 adjusted	-0.0680547
Standard error	26.1754203
Observations (N)	16

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	30.30073529	30.30073529	0.044224796	0.83646581
Residual	14	9592.136765	685.1526261		
Total	15	9622.4375			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	104.275	13.7265062	7.59661625	2.4878E-06	74.8345723	133.715428
Variable X	0.29852941	1.41956148	0.21029692	0.83646581	-2.7461271	3.34318597

9.9.2.1.1.1.2. 2nd approach: Simulation

No trend

42.00% negative trend of which 0.24% are significant

58.00% positive trend of which 0.86% are significant

9.9.2.1.1.2. 2007-2016

9.9.2.1.1.2.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.7485894
Coefficient of determination R^2	0.5603861
R^2 adjusted	0.50543436
Standard error	18.77232
Observations (N)	10

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	3593.7	3593.7	10.1977866	0.01273815
Residual	8	2819.2	352.4		
Total	9	6412.9			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	189.8	24.4979158	7.74759786	5.4962E-05	133.307705	246.292295
Variable X	-6.6	2.06676442	-3.1933973	0.01273815	-11.365967	-1.8340327

9.9.2.1.1.2.2. 2nd approach: Simulation

Significant negative trend (at 90%)

89.80% negative trend of which 20.38% are significant

10.20% positive trend of which 0.00% are significant

9.9.2.1.2. Distance Sampling (DS)

9.9.2.1.2.1. 2001-2016

9.9.2.1.2.1.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.67638477
Coefficient of determination R^2	0.45749636
R^2 adjusted	0.3896834
Standard error	34.8360951
Observations (N)	10

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	8187.17184	8187.17184	6.7464448	0.03174623
Residual	8	9708.42816	1213.55352		
Total	9	17895.6			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	169.470564	22.7397604	7.45260992	7.2465E-05	117.032582	221.908546
Variable X	-5.8056814	2.23519651	-2.5973919	0.03174623	-10.960054	-0.651309

9.9.2.1.2.1.2. 2nd approach: Simulation

Significant negative trend (at 95%)

98.70% negative trend of which 27.46% are significant

1.30% positive trend of which 0.00% are significant

9.9.2.1.2.2. 2007-2016

9.9.2.1.2.2.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.59073709
Coefficient of determination R^2	0.34897031
R^2 adjusted	0.18621289
Standard error	23.1941271
Observations (N)	6

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	1153.4632	1153.4632	2.14411304	0.21696922
Residual	4	2151.87013	537.967532		
Total	5	3305.33333			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	150.12987	41.0337484	3.65869256	0.02160519	36.2019201	264.05782
Variable X	-4.7402597	3.23726536	-1.464279	0.21696922	-13.728349	4.24782982

9.9.2.1.2.2.2. 2nd approach: Simulation

Weak negative trend

84.70% negative trend of which 9.92% are significant

15.30% positive trend of which 2.61% are significant

9.9.2.2. Wider Cardigan Bay
9.9.2.2.1. Capture, mark and recapture (CMR)
9.9.2.2.1.1. 2007-2016
9.9.2.2.1.1.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.44662178
Coefficient of determination R^2	0.19947101
R^2 adjusted	0.11941811
Standard error	29.4017783
Observations (N)	12

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	2154.02098	2154.02098	2.49174004	0.14552495
Residual	10	8644.64569	864.464569		
Total	11	10798.6667			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	186.085082	27.1757753	6.84746175	4.4724E-05	125.533681	246.636482
Variable X	-3.8811189	2.45870022	-1.5785246	0.14552495	-9.3594444	1.59720661

9.9.2.2.1.1.2. 2nd approach: Simulation

Significant negative trend (at 95%)

95.70% negative trend of which 24.35% are significant

4.30% positive trend of which 0.00% are significant

9.9.2.2.1.2. 2011-2016

9.9.2.2.1.2.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.87554324
Coefficient of determination R^2	0.76657597
R^2 adjusted	0.70821996
Standard error	11.4925671
Observations (N)	6

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	1735.016939	1735.016939	13.13619609	0.022270342
Residual	4	528.3163945	132.0790986		
Total	5	2263.333333			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	31.9987227	26.8093486	1.19356584	0.29859655	-42.435962	106.433407
Variable X	0.97454612	0.26888562	3.62438906	0.02227034	0.22799994	1.72109229

9.9.2.2.1.2.2. 2nd approach: Simulation

Weak negative trend

82.20% negative trend of which 7.66% are significant

17.80% positive trend of which 0.56% are significant

9.9.2.2.2. Distance Sampling (DS)
9.9.2.2.2.1. 2011-2016
9.9.2.2.2.1.1. 1st approach: Regular linear regression

Regression statistics

Coefficient of multiple correlation	0.45662825
Coefficient of determination R^2	0.20850936
R^2 adjusted	-0.0553209
Standard error	29.9978681
Observations (N)	5

Analysis of Variance

	Deg freedom	*Sum of squares*	*Mean square*	*F*	*Probability*
Regression	1	711.183721	711.183721	0.79031645	0.43949172
Residual	3	2699.61628	899.872093		
Total	4	3410.8			

Regression coefficients

	Coefficient	*Standard error*	*t*	*Probability*	*Lower 95%*	*Upper 95%*
Intercept	377.965116	97.8479459	3.86278028	0.03067555	66.5692822	689.36095
Variable X	-6.4302326	7.2331283	-0.8889974	0.43949172	-29.449275	16.5888099

9.9.2.2.2.1.2. 2nd approach: Simulation

Weak negative trend

62.10% negative trend of which 5.80% are significant

37.90% positive trend of which 3.17% are significant

9.9.3. Interpretation of analysis

In the CB SAC, the CMR and Distance results differ in that the latter shows a negative trend over the whole period whereas CMR data suggest that the population initially increased, then decreased later. Only the trend reported by Distance is still clearly significant after variability is factored in, although the CMR trend is negative with 90% certainty after 1,000 simulations.

In the wider CB area, the CMR data again suggest a decrease in the second half of the study period. The Distance data are not really sufficient for a trend analysis as there are too few estimates available.

9.10. Student Projects - Thesis Abstracts

During the course of the last three years, Sea Watch has supervised a number of student projects to address various aspects of the biology and ecology of Welsh cetaceans, particularly bottlenose dolphin. The abstracts of these theses are presented below. The full theses are available through the library of the university at which the student was based, or can be provided on request from Sea Watch Foundation. They are organised here by year.

2014:

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

Abstract

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

Vessel and dolphin activities were monitored throughout June and July in New Quay Bay, mid Wales when vessel traffic was approaching its annual peak. Land-based observations were conducted at two locations in the Bay, to assess differences in response behaviour. It was found that the majority (51.2%) of dolphins did not respond to vessel interactions. However, behavioural responses have significantly increased over the past five years, with more positive (18.9%) and negative responses (24.3%), including both vertical and horizontal evasion, recorded this year than previously (2010 to 2014).

Comparisons of residency between individuals in the local population revealed that residents display a degree of habituation to specific vessels, thus resulting in fewer response behaviours. Surfacing interval decreased in the presence of vessels, with a greater effect on mother and calf pairs. In time of day and seasonal comparisons, as vessel activity increased, dolphin sightings decreased, showing that dolphins were engaging in short-term site avoidance.

Short-term behavioural responses may develop into long-term consequences, such as reduced energy acquisition, lowered reproductive success, and site avoidance. This has the potential to result in an overall population decline, and this has been found in the population inhabiting Cardigan Bay SAC.

Massey, D. (2014) Whistle variations within the bottlenose dolphin population of Cardigan Bay, Wales, MSc thesis, University of Bangor

Abstract
Bottlenose dolphins (*Tursiops truncatus*) live in fission-fusion societies and constantly use vocal cues to stay in contact with one another. Of all the sounds emitted by this species, whistles are the most studied and observed vocalisation due to their ease of analysing and categorising. Whistle variations have been studied in many different populations and have been observed to change depending on specific environmental and biological factors. Similarities have also been observed between groups of dolphins due to individuals mimicking whistle characteristics.

A study was conducted looking at the whistle variations of the bottlenose dolphin population in Cardigan Bay by combining acoustic data that was taken for three consecutive summers. This data was collected from a combination of *ad libitum* and line transect surveys and multivariate analysis was used to assess if differences did occur between groups of dolphins and if these differences were due to certain environmental or biological factors.

Whistles produced were similar between groups. However, non-parametric testing revealed that each whistle parameter was significantly different from one another between groups. Whistle characteristics such as beginning frequency and minimum frequency increased at greater depths while minimum frequency decreased and duration increased in larger groups. These differences could be due to the fact that high frequency whistles do not travel as far in deeper waters and that whistles have to travel a farther distance when dolphins are more dispersed. The presence of calves also revealed to effect whistle characteristics, especially whistle contour being more complex in lone mother-calf pairs.

It can be concluded that whistle variation does occur in the Cardigan Bay bottlenose dolphin population. However, further studies are needed to get a better understanding of what is causing these variations and how other factors such as geographic location and season could affect whistle characteristics.

Peña Vergara, A. (2014) Temporal changes in site usage by bottlenose dolphins (*Tursiops truncatus*) in New Quay Bay, Wales. MSc thesis, Bangor University

Bottlenose dolphin *Tursiops truncatus* population is found in significant proportions in the southern zone of Cardigan Bay, which has been established as a Special Area of Conservation (SAC). Within the SAC, New Quay Bay is recognised as an important area for their population in the Welsh waters, with records dating back to the 1920s. Despite the fact that New Quay Bay is part of the Cardigan Bay SAC, the increasing boat activities in the area and their possible effects on the presence and behaviour of bottlenose dolphins are presently a great concern. Therefore, this study aimed to investigate the changes in bottlenose dolphin presence in New Quay Bay over time, as well as to establish any temporal changes in site usage for recognisable individuals.

The population of bottlenose dolphin in New Quay Bay was largely found to be non resident. This may be because the area chosen for analyses was not within the core area of an individual's home range zone. The change in occurrence of individuals can be related to the purpose of their visits to the bay, which is believed to be both a feeding and breeding area for bottlenose dolphin. Depending upon their reproductive status (reflected in particular characteristics such as gender, age, mother or presence of calves), some individuals will use some zones more than others or may use New Quay Bay either early or later in the summer. Even though the present study observed a neutral reaction towards the presence of boats as a frequent behavioural pattern, studies of reactions towards boats are still quite subjective, since bottlenose dolphins are mostly underwater, which makes it very difficult to determine the behaviours and reactions under the water. Therefore, presence of boats and its effects upon the dolphins should be analysed in more detail as it could be that an increase in boat activity is causing some individuals to spend less time in New Quay Bay, which encourages more individuals to be transient. If this is the case, further management actions should be taken in the area to fully protect the bottlenose dolphins.

Akritopoulou, E. (2014) Investigation of spatio-temporal trends in skin lesions of bottlenose dolphins in Wales, MSc thesis, University of Bangor

Abstract

Over the last 20 years, skin lesions in different populations of bottlenose dolphins have been studied worldwide via photo-ID techniques. The classification of skin lesions on bottlenose dolphins have been categorised according to their colour and texture in several studies. Climate change and anthropogenic activities seem to contribute in the appearance and development of skin lesions and diseases. The prevalence of skin lesions on the species has been used among others as a health indicator. The Welsh population of bottlenose dolphins is larger than the populations from the Moray Firth and Shannon Estuary. Cardigan Bay is one out of two main UK coastal areas used by semi-resident bottlenose dolphin populations and with the highest abundance.

The aim of this study was to investigate the spatio-temporal trends of skin lesions on the Welsh dolphins for the period 2001-14 using photo-ID techniques, mainly in Cardigan Bay. The possible effect of age, gender, residency and Sea Surface Temperature (SST) on skin lesion prevalence and extent was explored.

Overall, 260 individuals were analysed for 15 skin lesion categories, out of which nine of them were mainly observed over time. Tooth rakes/scars (84%), white lesions (43.8%) and cloudy lesions (23.4%) were some of them. Additionally, 73% of the individuals were affected by at least one type of lesion and 56% of the population by more than two different types. The females were more prevalent to skin lesions during the period 2010-14 than males. In contrast to other studies, calves were more prevalent in skin lesions than adults. Also, no significant association was found in skin lesion prevalence between SST, different areas, and between resident, visitors and transient individuals. The presence of DFS and WFS (lesions, out of which pox viruses and herpes viruses have been isolated in other studies) and the analysis of photographic data indicated possible presence of pox-viruses and/or tattoo lesions in the Welsh dolphins. Therefore further systematic and quantitative study of the prevalence and extent of skin lesions is needed in order to assess better the patterns of skin lesions on this population. Accurate evaluation is essential for effective management towards the sustainability of this important population.

Stevens, A. (2014) A photo-ID study of the Risso's dolphin (*Grampus griseus*) in Welsh coastal waters and the use of Maxent modelling to examine the environmental determinants of spatial and temporal distribution in the Irish Sea, MSc Thesis, University of Bangor, Wales

Abstract

The Irish Sea is considered to be an area containing important habitat for the Risso's dolphin (*Grampus griseus*), and a number of distribution hotspots have been identified over the years.

The creation of a photo-ID catalogue and database enabled the identification of 144 individuals in Welsh waters, from which it was estimated that a minimum of 162 individuals were encountered from 2003 to 2014. The 32 mother-calf pairings observed suggest the importance of Welsh waters for mating and parturition. Site fidelity in terms of re-sighting rates was relatively low (12.5%), similar to that which has previously been observed around Bardsey Island.

An examination of home ranges by looking for matches between this catalogue and that of five other organisations from around the British Isles, showed individuals to occupy varying ranges. The most individuals (15) matched with the Whale and Dolphin Conservation (WDC) catalogue, indicating mostly localised home ranges, but evidence for large-scale migrations was also found with 2 matches with the Hebridean Whale and Dolphin Trust's (HWDT) catalogue. These results suggest that the Risso's dolphins seen in Welsh waters are part of an open population.

In order to gain a better understanding of the drivers of their distribution, sightings data were analysed with respect to environmental variables: habitat type, energy, bathymetry, slope, oceanic thermal fronts, salinity, sea surface temperature and chlorophyll α concentration. Using Maxent species distribution modelling, the most important environmental variables found to determine habitat suitability were bathymetry, chlorophyll α concentration and salinity. These factors affect primary production and prey abundance either directly or indirectly by influencing oceanographic features including upwellings, fronts and gyres. Chlorophyll α concentration and salinity are also particularly important in the fine scale determination of prey aggregations. Slope was found to be the least important factor affecting distribution.

In accordance with high sightings densities and predicted habitat suitability, the coastal waters around the Isle of Man, Anglesey, Bardsey Island and west Pembrokeshire are the areas identified to be the most important to Risso's dolphins. These areas should therefore be the focus of any future conservation and management strategies in the Irish Sea, to ensure the long-term protection and viability of the population.

2015

Boys, R. (2015) Fatal Interactions between Bottlenose Dolphins (*Tursiops truncatus*) and Harbour Porpoises (*Phocoena phocoena*) in Welsh Waters. BSc thesis, University of Bangor. 133pp.

Abstract
Competition between sympatric species is a well-known phenomenon throughout the animal kingdom and can be direct or indirect. Competition over a shared resource often leads to aggressive interactions, which can be fatal to the inferior species (Polis *et al.*, 1989). Bottlenose dolphins (*Tursiops truncatus*) and harbour porpoises (*Phocoena phocoena*) are two of the most commonly recorded cetaceans in UK waters. Aggressive interactions between these were first recorded in the early 1990s and since have been reported with increasing frequency worldwide Using strandings' data for Wales from 1991 to 2013, a total of 142 porpoises stranded-attacked by bottlenose dolphins were examined.

Sightings data were used to examine geographical overlap and fish stock data were used to examine changes in fish abundance with ICES (International Council for the Exploration of the Sea). Literature was reviewed to examine dietary overlap. These variables were input to a GLMM using R, to examine which variables had an effect of the occurrence of a stranding due to attack by bottlenose dolphins. The study suggests that the cetaceans do compete for resources, and that dietary and geographical overlap significantly ($p<0.05$) affect stranding occurrence. Infanticide, play and hormone levels, suggested in the literature were reviewed and examined for their occurrence where possible, in Welsh waters.

Bottlenose dolphins were found to be the main agonists in many aggressive interactions between odontocetes. In Wales, high co-occurrence and interference feeding appear to explain many of the attacks, but other factors such as object-oriented play and testosterone levels are likely to further influence the seasonality and extent of these attacks.

Frinault, B.A.V. (2015) Maritime traffic effects on the semi-resident population of bottlenose dolphins, *Tursiops truncatus*, inhabiting Cardigan Bay, west Wales, BSc thesis, University of Bangor. 72pp.

Abstract
Anthropogenic activities can widely impact wildlife populations and ecosystems. Cetaceans, when sharing coastal waters with burgeoning vessel activity, can be particularly vulnerable to disturbances.

Bottlenose dolphins *Tursiops truncatus*, inhabiting the coastal zones of Cardigan Bay, west Wales are a key natural resource and currently provide a tangible, important tourist attraction supporting the Welsh economy. However recent years have shown a decline in species count. The presence of vessel activity is known to initiate various short- and long-term responses in cetaceans, some with detrimental effects.

To determine if vessel activity has an effect on dolphin sightings, statistical analyses were performed on refined, sea-based, amalgamated data for the years 2006-2014. Six individual vessel type densities, plus their corresponding cumulative vessel density, were compared to dolphin density.

In several cases, results of linear regression indicated a significant and negative relationship between dolphin and vessel density and in some cases no significance. Of vessels studied, motorboats, including wildlife watching vessels, elicited the strongest negative impact on dolphin density ($p=0.000190$). Total cumulative vessel density showed a strong negative impact on dolphin density ($p = 0.000808$). Overall results indicate that a threshold or cap on vessel activity, or further coastal management considerations, could be envisaged to mitigate potential future decline of bottlenose dolphins in the area.

Sim, T.M.C, (2015) Associations or alliances? Comparisons of social relationships between male bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay and the Moray Firth, MSc thesis, University of Bangor. 102pp.

Abstract

Mating strategies are important aspects of animal social structure, and variation in environmental conditions may drive the formation of conditional tactics which are based on an individual's social rank, age, size or fitness. The social patterns between male bottlenose dolphins (*Tursiops truncatus)* in the Moray Firth, northeast Scotland, and Cardigan Bay, west Wales, were investigated and compared using long-term observational data compiled by the Cetacean Research & Rescue Unit, and the Sea Watch Foundation respectively. The present study aimed to ascertain whether males in these regions formed alliance-type relationships as a mating strategy to improve reproductive success, and whether association patterns were similar between the two discrete populations. A total of 66 males from the Moray Firth, and 50 males from Cardigan Bay were identified over the study periods of 18 and 14-years, respectively.

Associations were examined using only males sighted more than twice during the study period, amounting to 62 individuals from the Moray Firth, and 47 from Cardigan Bay. Whereas non-random preferential alliances were found between certain males in both regions, they were stronger in the Moray Firth. The mean HWI was also higher between males in the Moray Firth, at 0.09± 0.05 (±SD), than Cardigan Bay at 0.03± 0.02 (±SD). Patterns of temporal stability between associations were similar, and were described as 'casual acquaintances', which is typical of bottlenose dolphins in a fission-fusion society. Demographic factors such as mortality, emigration and re-immigration were further shown to affect association patterns between males in both populations.

Results from the present study suggest that male bottlenose dolphins in the Moray Firth and Cardigan Bay use both alliances and solitary strategies to locate receptive females and compete for mating opportunities. The present examination ultimately allows further insight into the long-term social dynamics between male bottlenose dolphins in two semi-resident UK communities, and broadens current understanding of male mating strategies utilised in these regions, which has received limited study to date.

Taylor, V.C. (2015) Spatio-Temporal Variation in the Social Network of the Welsh Bottlenose Dolphin (*Tursiops truncatus*) Population, MSc thesis, University of Bangor. 102pp.

Abstract
Quantitative techniques, initially developed for the assessment of human sociality, are increasingly being used to assess animal social networks. Bottlenose dolphins (*Tursiops truncatus*) are a socially intelligent species displaying complex fission-fusion societies, which are well suited to detailed social network analysis. In this study, the social network of bottlenose dolphins occurring in Welsh waters were investigated over a 14-year period, over an area ranging from southern Cardigan Bay, as far north as Anglesey, the Isle of Man and Liverpool Bay.

The overall network had a low density although individuals were relatively well connected, primarily by indirect associations. Solitary individuals were identified and certain individuals had disproportionately high centrality, occupying key roles within the network. Centrality was not linked to gender. No long-term stable associations lasting the whole 14-year study period were observed. The majority of the population were clustered into two large sub-groups, but there was no evidence of assortative mixing by gender or home range size. Some individuals did have much larger home ranges than others and many undertook seasonal movements resulting in variation in home range usage in different seasons. The true range of some individuals may be much greater than is covered in this study.

There were seasonal differences in network structure on a spatial and seasonal scale. The network was better connected in summer in southern Cardigan Bay than in winter, and was better connected in winter to the north of the study area than in summer, when the networks were highly clustered with defined sub-groups. Seasonal movements and differences in home range usage were concluded as being, at least in part, responsible for changes in the social network on a spatio-temporal scale. Variation in target prey, and area usage for behaviours such as calving, were suggested as major reasons for seasonal changes in area usage.

2016

Whiteley, L. (2016) Variation in bottlenose dolphin (*Tursiops truncatus*) whistle parameters in relation to group composition, surface behaviour and vessel sound profiles, MSc thesis, University of Bangor

Abstract
An increase in wild cetacean watching from tour boats has recently been documented, perhaps as it is considered a more ethical alternative to watching these species in captivity. However, tourist vessels have been widely recorded to have both long and short-term effects on cetaceans. This includes impacts on marine mammal vocalisations, which can be disrupted by underwater noise disturbance. This project investigated the effects of boat noise on the whistles of the bottlenose dolphin (*Tursiops truncatus*) population within Cardigan Bay. Sound profiles of four vessels (A to D) operating in the Bay were captured, allowing for an investigation into the potential impacts of the boats on dolphin whistles. Dolphin behaviour, group composition, and boat activity were also recorded to examine the effects that individual vessel's sound profiles might have on the dolphin population.

The four vessels were found to differ in sound characteristics, with Boat A and Boat D producing the highest frequencies at the loudest band energy, potentially masking dolphin vocalisations. Boat D contained a water jet powered engine, with the longest whistle duration and highest number of inflection points observed. This was hypothesised to be related to the vessel's bubble production output. Larger group sizes (7-9 individuals) were recorded to increase average maximum whistle frequency. Idling sound profiles were different between the four vessels, with higher whistle frequencies observed in the presence of Boat C.

Overall, the four vessels differed in their sound signatures, which might have implications on dolphin communication. Recommendations include restricting loud boat activities such as reversing in the presence of the dolphins. Further monitoring of the four vessels is recommended in order to protect the dolphin population, and increase the sustainability of the dolphin watching industry in New Quay, Wales.

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