Bachelor's thesis

Coastal habitat use of harbour porpoise (*Phocoena phocoena*) in Cardigan Bay Special Area of Conservation (Wales)

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ABSTRACT

The small cetacean populations of Cardigan Bay Special Area of Conservation (SAC) have been monitored by boat line-transect surveys and four stationary land-based vantage points since 1989 and 1993, respectively. The transects, however, are not ideal for understanding movements and habitat use of the harbour porpoise at least in the near shore zone. The present study used non-intrusive land-based method to investigate the patterns in harbour porpoise habitat use in the southern part of the SAC where the species is found abundant. Timed watches were carried out at 5 vantage points during a two-month-period in summer 2006. Previous research has indicated that local porpoise abundance may respond to several oceanographic and bathymetric features, substrate type, and anthropogenic point sources. Using geographic information software, this study confirms that harbour porpoise habitat use can be site-specific even at small scale. To test if harbour porpoise sightings are randomly distributed in the area, nearest neighbour-method was used in ArcView 9.1. Whereas sighting rates did not differ from vantage point to another, observed distance between sightings was found to be significantly lower than expected distance, therefore indicating more localized clustering. Sighting rates responded both to ebbing tide and the time of day. Staying behaviour and associations with birds were more frequently observed during ebb tide. To evaluate the second hypothesis that the sightings are randomly distributed in relation to depth and substrate type, query results from the software were analysed (here I will add the results once I get the queries done next week). The slope will be constructed and its role analysed using Spatial Analyst extension.

Contents

1. INTRODUCTION

The harbour porpoise *Phocoena phocoena* (Linnaeus 1758) is a small cetacean with a wide coastal distribution in the Northern Hemisphere. Due to its cold living environment, small body size relative to its surface area and energetically demanding reproductive schedule, the species is confined to the proximity of its prey more than many other cetaceans (Lockyer 2003, Evans *et al*. 2006). Consuming energy-rich prey, the porpoise is often affected by fisheries conflicts. Declines in fish stocks might have forced changes in food preference by porpoise to those with less nutritional value. Entanglement of harbour porpoises in fishing gear is wide ranging in ASCOBANS waters. In UK, porpoises are caught in a variety of gear ranging from bottom-set gill nets and pair trawls for species like hake, cod, turbot and saithe to salmonid, sea bass, clupeid and mackerel driftnets, salmonid fish traps (pound nets) and other fixed gear (Kaschner 2003). The sustainability of set gill-net fisheries of the Celtic sea, where 6 % of the minimum population estimate is removed, is of special concern (Tregenza *et al.* 1997). The harbour porpoise is considered vulnerable in the IUCN Red List of Threatened Species (Cetacean Specialist Group, 1996). Therefore, understanding the distribution of the harbour porpoise in relation to its environment, especially its prey, is vital for the conservation of this species.

The small cetacean populations of Cardigan Bay Special Area of Conservation (SAC) have been monitored by vessel-based line-transect surveys and photo-identification surveys (Baines *et al.* 2000, 2002, Ugarte & Evans 2006) and four stationary land-based vantage points (Pierpoint and Allan 2000, 2001, 2004) since 1989 and 1993, respectively. Although analyses of habitat use by harbour porpoises have been undertaken extensively offshore in the SAC, for the nearshore zone, there are few data available between the four main coastal study sites.

This trial study combines non-intrusive land-based observation methods with the more extensive coverage area achieved by line-transect surveys. Timed watches will be conducted along an elevated coastal path during June and July 2006. The study will examine the local distribution of harbour porpoise and sighting clusters, aiming to find hotspots for the species in the area and to relate these to environmental variables.

2. ON THE DISTRIBUTION AND HABITAT USE OF HARBOUR PORPOISE

The harbour porpoise *Phocoena phocoena* (Linnaeus, 1758) is a small, robust odontocete (order Cetacea) rarely more than 2 m in length, males being slightly smaller than females. The species has a wide coastal and circumpolar distribution in temperate and sub arctic waters (mainly 11-14 °C) of the Northern hemisphere. Harbour porpoises are usually seen solitarily or in groups of several animals, although relatively little is known about their social interactions. Displaying little aerial activity while they briefly roll at the surface, studying this small cetacean faces special challenges (Evans *et al.* 2006).

Within the monophyletic population assemblages of the North Pacific and North Atlantic-Black Sea, there is limited gene exchange due to the coastal nature of the species. The Northeast Atlantic populations are thought to have originally diverged from the smaller populations observed today in the Northwest. The low genetic diversity of the former indicates a rapid expansion of the population since the last glacial period (Rosel *et al.* 1999). Today, the harbour porpoise population in the Celtic, North and southern Baltic seas is estimated at more than 340 000 (Hammond *et al.* 2002). Despite the evident declines in the southern North Sea, English Channel and the Irish Sea in the 1960s-1980s, where pollution, disturbance and over-exploitation of food resources threatened the species, the harbour porpoise remains the most common and widespread cetacean in British waters and widely distributed over the north and central North Sea (Evans 1980, Northridge *et al.* 1995, Evans *et al.* 2003).

Multiple local populations have been suggested for the North Sea and adjacent waters. An analysis of porpoise mitochondrial DNA indicated some gene flow by male dispersal between porpoise populations around UK waters, or a continuum of patchy porpoise groupings that exchange genes in a decreasing manner with geographical distance (Walton 1997). Females tend to be more philopatric than males (Walton 1997, Andersen *et al.* 2001). Walton's (1997) results support a broad categorization of harbour porpoises into the North Sea and Irish or west Britain populations. Near-shore western Denmark and off-shore northwest North Sea porpoises stand out as discrete groupings in distribution data during the winter months (Northridge *et al.* 1995). Similarly, Andersen *et al.* (2001) described distinct populations for the British, Danish and Norwegian sectors of the North Sea, as well as for Greenland. The Dutch waters receive both British and Danish migrants, whereas the Irish, British and Greenland porpoises were found to be more related to each other than to Norwegian and Danish ones. The Irish/Welsh porpoise population was confirmed and further sub-structuring within the regions rejected.(*– for the latest genetic results, see summaries in the Handbook of British Mammals species account together with papers by Lockyer and Andersen in the NAMMCO (2003) volume on the harbour porpoise.)*

At many sites around the British Isles, a peak of abundance is observed between July and September (Evans 1980, Northridge *et al.* 1995, Evans *et al.* 2003). In the southern North-Sea and South-west England the peak is observed in January-March, and in the south-west, also in October-December. There may be off-shore movement associated with calving in May-June (Evans *et al.* 2003). Areas of highest population densities appear to be in the Belt Sea to the east of Denmark and in the north-eastern North Sea (Reid *et al.* 2003). Porpoises are abundant also in North-east Scotland, western and southern Ireland and off the coast of South-west England (Evans *et al*. 2003).

The social organization of small groups, most frequently less than ten animals, appears fluid.

Aggregations of hundreds of animals have been reported, but are likely to be temporary (Evans 1980, Evans *et al.* 2006). Individual movements appear to be highly variable and discrete without temporal coordination (Read & Westgate 1997). These observations could be explained in terms of the species' high mass-specific metabolic rate which results in foraging in the vicinity of the prey. Associations of harbour porpoise with areas of upwelling have been demonstrated in the Bay of Fundy and the northern California Current System (Watts & Gaskin 1985, Tynan *et al.* 2004). Furthermore, the relative abundance of harbour porpoise and greater group size correlates with the mixed side of the Irish Sea front more nutrient rich than the thermally stratified side (Weir & O'Brian 2000). Apparently, this is due to the higher primary, and hence secondary, production. – *there are much more examples of this: summarised in Evans et al., 2006 as well as in Evans, 1990 (Lutra 33: 95-125).*

Harbour porpoise abundance often declines as a function of depth of area, decreasing markedly in numbers below 40-60 m (Carretta *et al.* 2001) and 200 m (Hammond *et al.* 2002). However, marked exceptions have been observed (Northridge *et al.* 1995). Avoidance of shallow water (<10m) may be due to turbulence (Watts and Gaskin 1985). In the southern Bay of Fundy, Watts and Gaskin (1985) revealed an inverse relationship between porpoise abundance and depth of area up to 100 m, and individual satellite tracking by Read *et al.* (1997) showed highest frequencies in depths of 98-183 m. Harbour porpoises have been recorded to dive to 230 m in the region (Westgate *et al.* 1995). Intriguingly, deeper and longer dives occurring during the night contradict the vertical movement of herring (Westgate *et al.* 1995). – *ultimately, this paragraph will need updating with other newer references.*

Distribution along a horizontal depth gradient may arise from interannual movements in response to temperature. Porpoise abundance may respond negatively to high surface temperature (Watts & Gaskin 1985, Carretta *et al*. 2001). The effect of surface temperature could be indirect as an indicator of thermal stratification and, again, production.

The harbour porpoise is more restricted to the proximity of its prey than many other cetaceans due to its cold living environment, small body size relative to its surface area, and energetically demanding reproductive schedule. Harbour porpoises become sexually mature at 3-4 years and reproduce every 1-1.6 years thereafter. Parturition occurs after 10-11 month gestation in May-July, and mating in June-August. Therefore females are simultaneously pregnant and lactating (lactation lasts at least for 8 months) most of their lives (reviewed by Lockyer 2003). Growth rates of many body components contribute to the early maturation of the animal. Proportion of blubber in total body weight accounts for 24-26% in adults (McLellan *et al.* 2001). Harbour porpoise gas exchange and heart rates are adapted to relatively short, shallow dives and fast surfacing; as determined from captive animals, the high mass-specific metabolic rate limits aerobic dive (ADL) to an estimated 5 minutes (Reed *et al.* 2000). Approximately 30 dives were made per hour, with a mean duration for a single dive of 65 seconds and a maximum of 5 min 35 s in the wild (Westgate *et al.* 1995).

The seasonally and regionally varying diet of the harbour porpoise comprises mostly small (75-200 mm in length) schooling fish in the water column and near the bottom, as well as an occasional cephalopod (Santos *et al.* 2004, Evans *et al.* 2006). Sandeel (*Ammodytidae*) and whiting (*Merlangius merlangus*) comprise 80% of the diet in Scottish waters (Santos *et al.* 2004). The relationship between the distributions of harbour porpoise and sandeel has been demonstrated in the Shetland Islands, and may at least partially explain the interannual variations in the porpoise populations (Evans *et al.* 1996). When monitoring mobile cetaceans within regional constraints, it is challenging to determine whether change in abundance are a consequence of changes in distribution or in population status (Evans & Hammond 2004). As shown earlier, this is especially true for the highly mobile harbour porpoise.

In conclusion, the spatial distribution of harbour porpoises may be affected by several factors in the biotic and abiotic environment, and may therefore be strongly clustered.

3. METHODS

3.1 Background

The methods that have been used to study small cetaceans in Cardigan Bay have some major advantages and disadvantages for understanding harbour porpoise population status, abundance and distribution. Acoustic devices are especially useful for this highly vocal species. In contrast, visual observations for the solitary and inconspicuously swimming harbour porpoise are difficult to make, particularly at sea level, and the effect increases with increasing sea state. The Beaufort scale (0-12) of describes the state of the sea (Evans & Hammond, 2004; Northridge *et al.* 1995). Harbour porpoise sightings are affected even by sea state values of 1 (Northridge *et al.* 1995, Evans & Hammond 2004). Detectability may not only be a consequence of visibility itself, but shorter surfacing times (Westgate *et al.* 1995). Correction factors for a given Beaufort sea state value can be calculated using the equation

$$cn = sr_n / sr_0$$

where sr_n is the mean sightings rate at sea state n, and sr_0 is the mean sightings rate at sea state 0 (reviewed by Evans & Hammond 2004)

Dedicated surveys, though more costly, tend to be better than opportunistic surveys because they can control for evenly distributed observation effort and overall sampling procedures (Evans & Hammond 2004). Both mobile and fixed observation platforms have been in use in the area in the past. Land-based vantage points are situated at New Quay Headland, Ynys Lochtyn, Aberporth and

Mwnt (Figure 1). Three 2 h watches have been conducted at 11.00, 13:00, 15:00 h on a daily basis during the summer months. Number of animals, behaviour and environmental variables are recorded for successive 15 min periods (Pierpoint & Allan 2000). The major disadvantage of fixed stations is that observations are constrained to the immediate vicinity. On the other hand, standardizing data is easier in this non-intrusive method, in contrast to boat transects where responsiveness of harbour porpoise can be significant (reviewed by Evans & Hammond, 2004). Given the raised elevation of a cliff-top observation point, porpoise movements and general behaviour may be easier to track from a land-based situation.

3.2 Data collection

In the present study, data was collected each week on three successive days chosen according to wind forecast 16.6-28.7.2006. 5 lookouts were situated on an elevated cliff path in the southern part of the SAC. 26.6, 28.6-19.7 random design was used to choose a track of five watches each day (randomized tracks fig!). In this design, 10 different tracks cover 50 watches with different combination of location, time and direction. Each location and time is replicated 5 times, respectively. Trial walks were conducted on 16.6-25.6, 27.6 during which also longer (3 hour) watches were experimented. Last three days 27.-28.7 was used to cover those locations and times that were not drawn in the hat.

90-minute watches were conducted within two-hour intervals starting at 8, 10, 12, 14, 16 and 18 hours. Track was randomly chosen to run from 8 or 10 o'clock each day. A watch at a location was subdivided into 15 minute intervals to record effort and sightings. For each 15 minute interval, effort including time and location; sea state in Beaufort scale, wind direction and temporal currents; general weather conditions and visibility; presence of animals and different types of boats, were recorded (effort form fig!). For each sighting, distance and angle was estimated; number of individuals, behaviour, presence of calves and associations with birds or temporal currents and encounters with boats were recorded (sightings form fig!). See fig for classifications and codes that were used. Each sighting was defined as an associated group of porpoises behaving the same way at the same location. Distance was estimated using the naked eye and available reference points. Angle was determined in degrees from magnetic north using a compass and an angle. 15.6-28.6 sightings were plotted on maps instead of recording degrees and distances. Animals were counted with binoculars (8x50) and the naked eye.

3.3 Data management and analysis

Prior to analysis, intervals with sea state of 3 or more and visibility of 1 km or less were removed, respectively. Observation periods with 3 intervals or less were further removed. Locations of the sightings plotted on maps were transformed into angles and distances. Estimates of visibility were classified as follows: visibility affected at 1 km or less; 2-5; 6-10; and visibility more than 10.

Data were stored in Microsoft Access relational database. Locations were calculated from the distances and angles and converted to the British national grid system using Grid InQuest coordinate converter software.

To be able to analyze independent units, several period-specific indexes had to be constructed:

- Sighting rate: total individuals per interval divided by total number of intervals in a period
- Site occupancy: count of intervals in which porpoises were detected divided by total number of intervals in a period
- Average sea state: mean interval sea states in a period
- Tide class: sum of interval tide (ebb -1 and flood +1) reclassified into ebbing (<-2), turning (-2-2) and flooding (>2)

Sightings and their attribute tables were imported as a layer to ArcView 9.1 together with a sediment and bathymetric contour map (courtesy of..?). The sediment map was digitized using control points along the SAC boundaries (provided by...). The first null hypothesis that porpoise sightings are randomly distributed in the study area was tested using the Average Nearest Neighbour –method. In order to remove autocorrelation within periods, only sightings from one randomly chosen interval was used per period. 5 samples were drawn and tested against the study area. The area was defined as the union of visible areas from the vantage points up to 2500 meters.

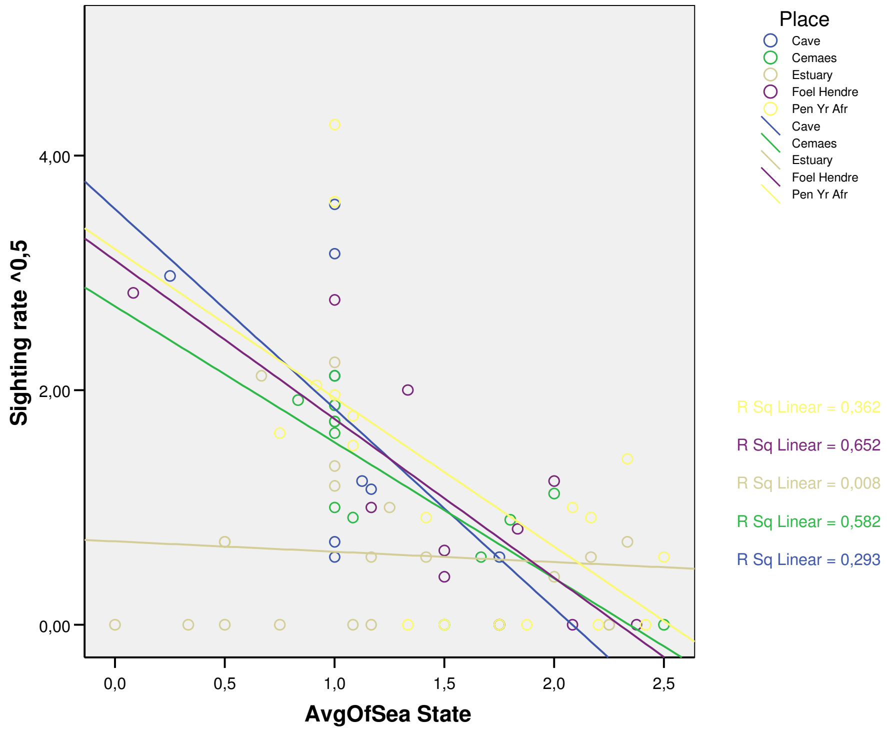
The second null hypothesis is that porpoise sightings are distributed randomly in relation to depth, slope and sediment type. Query results from ArcView were analysed in SPSS. To extrapolate the porpoise habitat selection results in the study area, a suitability model for porpoises in the SAC coastline was constructed based on the coefficients in ANOVA. To test the model, suitability was compared with sighting results from Mwnt, Aberporth, Ynus Lochtyn and New Quay.

4. RESULTS

4.1 Effort

Total 85 sighting periods were conducted, comprising 489 intervals. Most effort concentrated on the Estuary, Cemaes Head and Pen Yr Afr (Study area and intensity fig!). Porpoises were present at 53 periods out of analysed 73. Mean sighting rate was 2.2 (Std. Dev. 3.5) and mean site occupancy 47% (Std. Dev. 39).

Due to poor visibility (≤ 1 km) or high sea state (Beaufort ≥ 3), 69 intervals were removed out of analyses. Of the remaining intervals, 72.9% were conducted in a sea state of 1.5 or less. Sea state affected sighting rate strongly at all locations but the Estuary (Slopes fig!). To remove the interaction term therefore the Estuary was excluded in covariance analysis, in which sea state was the covariate. Observation place didn't have a significant affect on the sighting rate (ANCOVA, df=3, P=0,884) whereas sea state was very significant (ANCOVA, df=1, P<0,001).

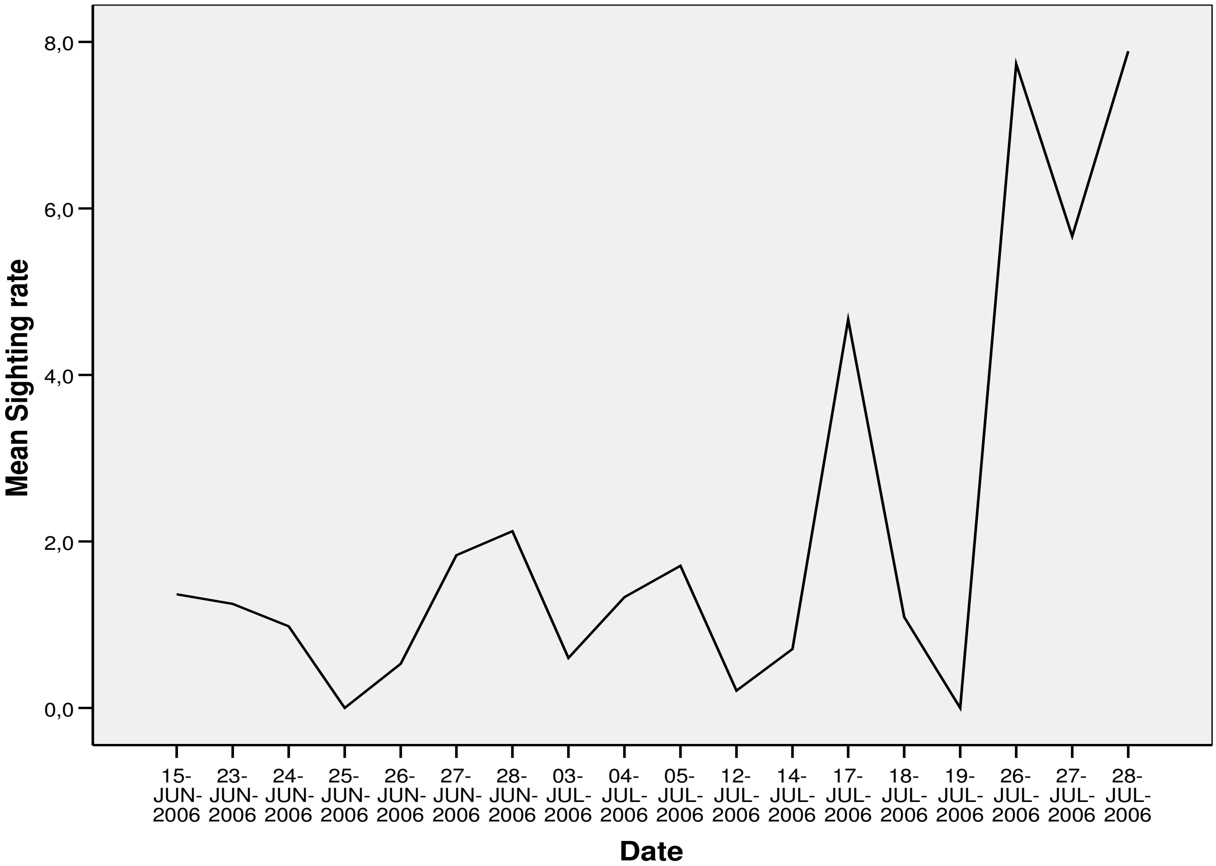


Vantage point had some effect on the distances that porpoises could be detected (table!). Maximum distances were nearly the same, but mean distance was lower for the Estuary and slightly lower for Cemaes head. Overall mean distance was 1304 m (Std. Error 23,3).

Descriptive Statistics

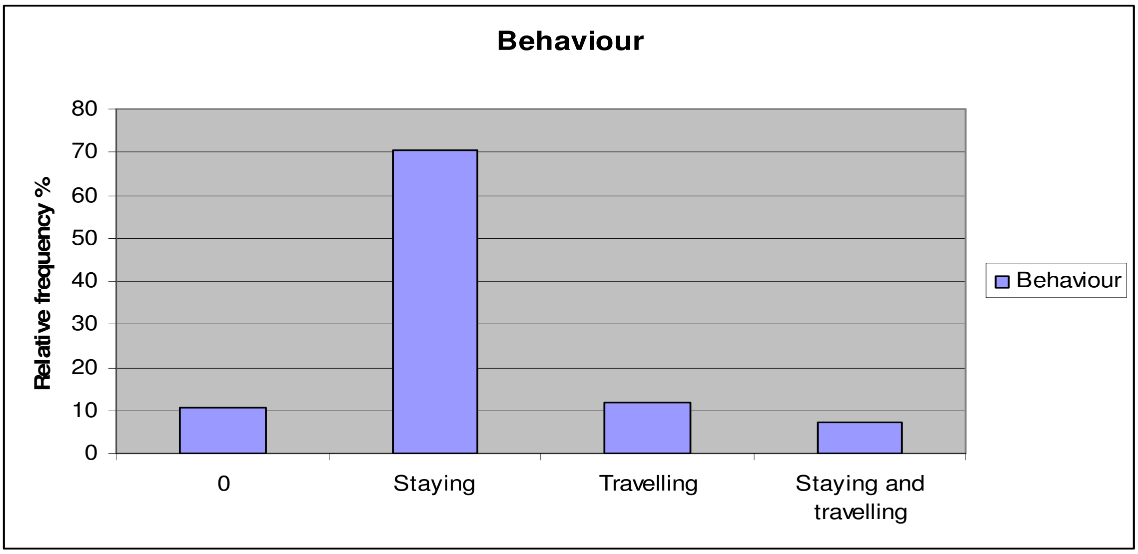
Place		N	Minimum	Maximum	Mean	Std. Deviation
Estuary	Distance	50	300,00	2500,00	1095,3600	470,66405
	Valid N (listwise)	50				
Cemaes	Distance	83	200,00	2800,00	1252,0482	645,54265
	Valid N (listwise)	83				
Pen Yr Afr	Distance	151	300,00	2500,00	1333,7351	539,76461
	Valid N (listwise)	151				
Foel Hendre	Distance	66	663,00	2500,00	1391,6818	440,20618
	Valid N (listwise)	66				
The Cave	Distance	118	700,00	2500,00	1343,2203	345,78755
	Valid N (listwise)	118				

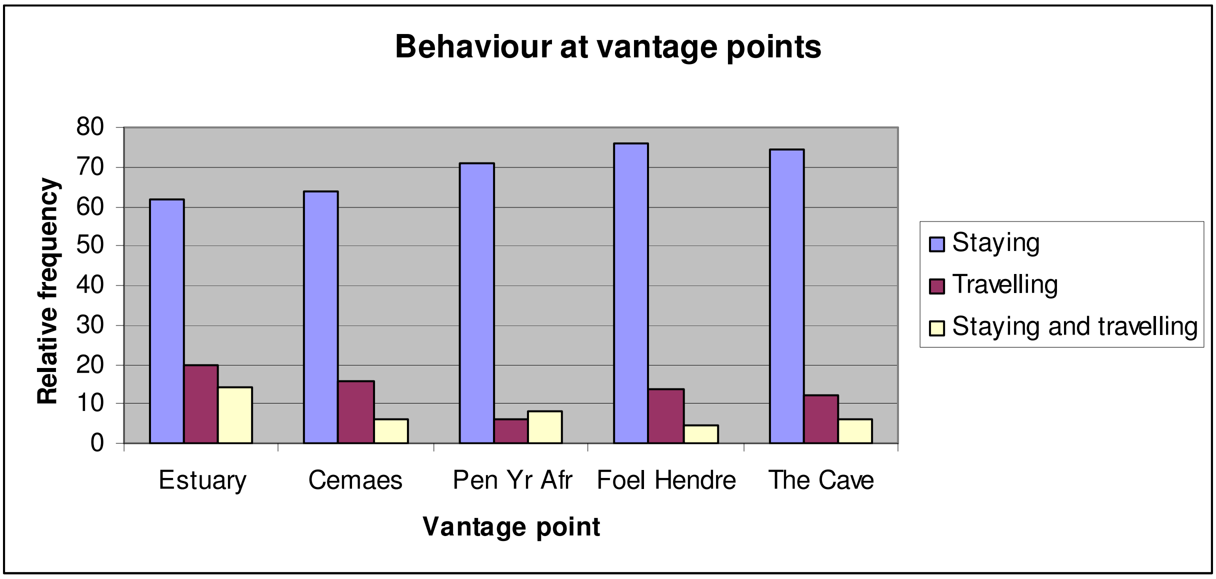
Even though day to day variation is great, mean daily sighting rate increased towards the end of the study period (fig!).



4.2 Behaviour

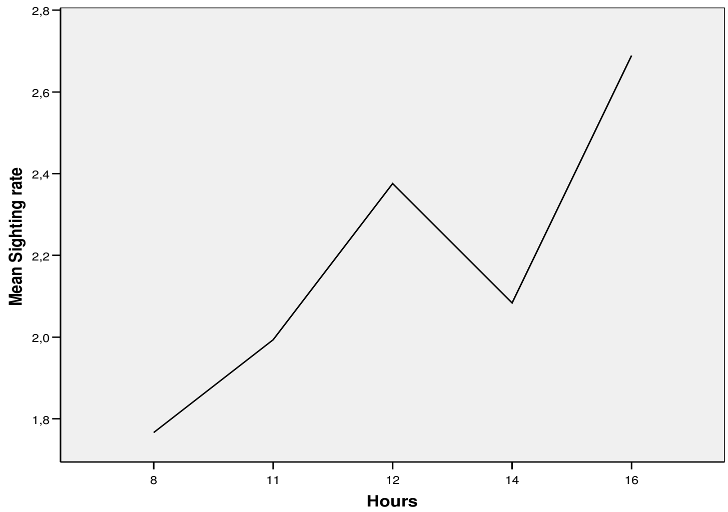
Most behaviour observed was assigned to "staying" (fig!). The Estuary and Cemaes Head appeared to be the most transient sites (bar graph fig!). 34 % of sightings in Estuary and 21,7 % around Cemaes Head involved travelling.



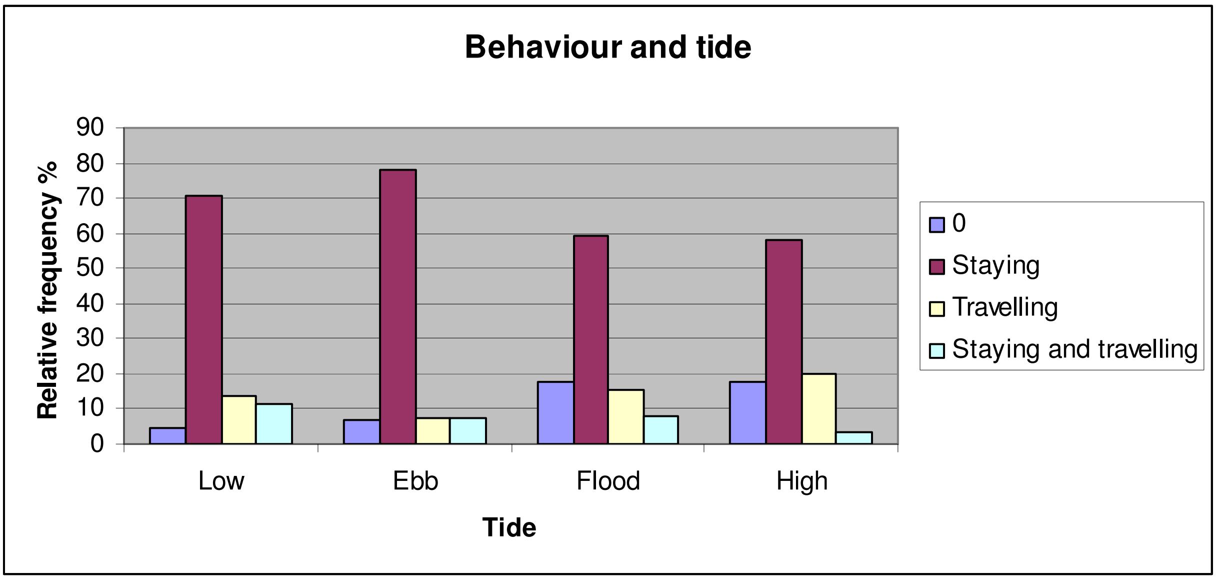


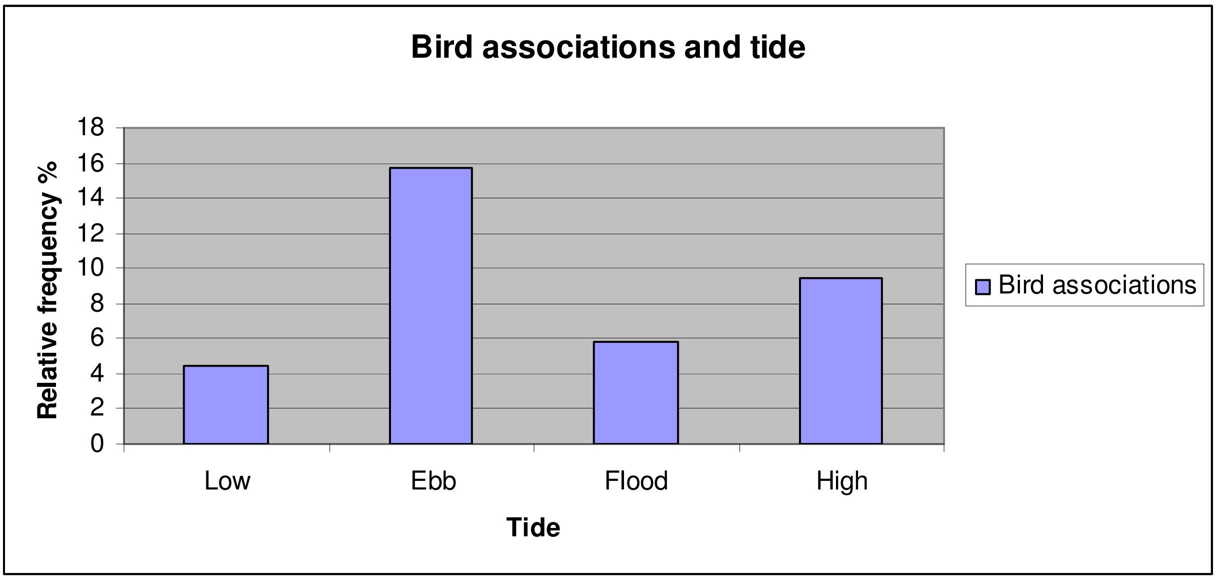
4.3 Time of day and tides

Harbour porpoise sighting rates were higher during periods starting after 16 o'clock (Line fig!) but no significant relationship could be found (Kruskal-Wallis, df=5, P=0,738)



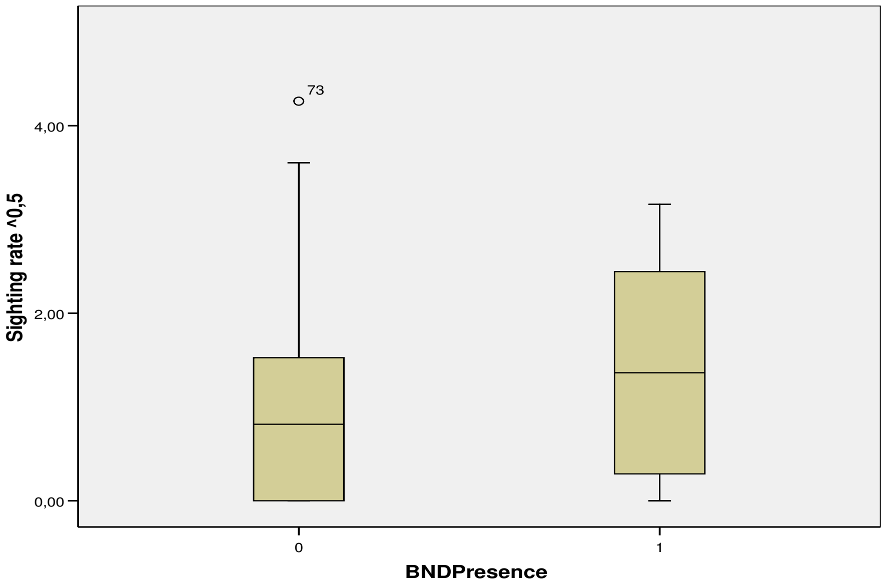
Harbour porpoise individual counts tended to be higher and detection during intervals more likely when the water level was falling. Sighting rate and site occupation were similarly higher during the ebb and flood, and lowest when tide was turning, but not enough to be statistically significant (Kruskal-Wallis, df=2, P=0,374). During ebb and low tide, 78 and 70.5 % of behaviour were recorded staying whereas during flood and high tide the percentages were 59.3 and 58.3 % respectively (chart fig.!). Similarly, travelling was more commonly seen during high tide (20.2%) in comparison with ebb tide (7.5%). Also more associations with birds were recorded during ebb tide (chart fig!). Associated group sizes did not appear to change with tidal fluctuation.





4.4 Dolphin-porpoise interaction

Dolphin presence did not affect porpoise presence or sighting rates at period level (Boxplot fig!) or porpoise presence or individual counts at interval level. Dolphins were present at 16 periods.



4.4 Aggregation of sightings

Porpoises were significantly ($P<0,05$) aggregated in all of the samples.

4.5 Sediment type

4.6 Depth and slope

Porpoises seem to aggregate near steep slopes. I have nice maps with sightings etc which I will attach here tomorrow. And more of analysis when I get the spatial analyst installed!

Things to do with GIS

- are sightings farther offshore when tide is ebbing

- are sightings attributes spatially clustered e.g. behaviour, calves, heading, group size, tides or time of day, boat encounters, bird associations

- sediment/slope/depth relationships

- which sites along the coast would be potential porpoise habitat (model)

5. DISCUSSION

Frequencies among sightings have to be carefully interpreted as there may be serious auto correlation. This is especially true for Cemaes head, where most intervals were coincidentally conducted during flood tide.

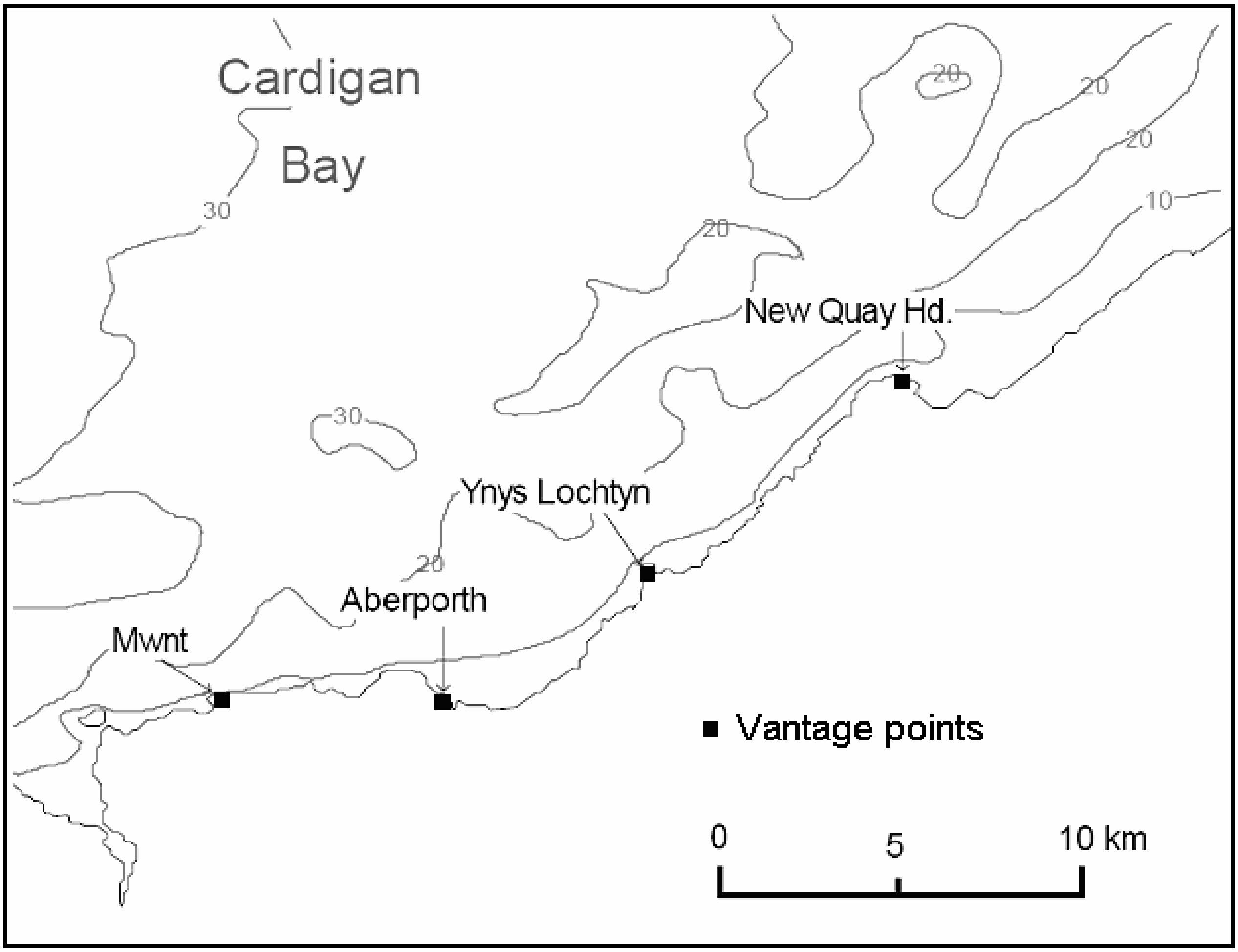


Figure 1. The location of fixed vantage points in Cardigan Bay. Adapted from Pierpoint & Allan 2004.

LITERATURE

Andersen W.L., Ruzzante D.E., Walton M., Berggren P., Bjørge A. & Lockyer C. 2001. Conservation genetics of harbour porpoises, *Phocoena phocoena*, in eastern and central North Atlantic. *Conserv. Genet.* 2: 309-324.

Baines M.E, Reichelt M., Evans P.G.H, Shepherd B. 2002. Bottlenose dolphin (*Tursiops tuncatus*) studies in Cardigan Bay, West Wales. Sea Watch Foundation.

Baines M.E, Evans P.G.H, Shepherd B. 2000. Bottlenose dolphins (*Tursiops tuncatus*) in Cardigan Bay, West Wales. Sea Watch Foundation.

Carretta J.V., Taylor B.L. & Chivers S.J. 2001. Abundance and depth distribution of harbor porpoise (*Phocoena phocoena*) in northern California determined from a 1995 ship survey. *Fish. Bull.* 99: 29-39.

Cetacean Specialist Group 1996. *Phocoena phocoena*. In: IUCN 2004. 2004 IUCN Red List of Threatened Species. www.iucnredlist.org. Downloaded on 20 February 2006.

Evans P.G.H. 1980. Cetaceans in British waters. *Mammal. Rev.* 10: 1-52.

Evans P.G.H. & Hammond P.S. 2004. Monitoring cetaceans in European waters *Mammal Rev*. 34: 131–156.

Evans P.G.H, Anderwald P. & Baines E. 2003. *UK cetacean status review*, English Nature & Countryside Council, Oxford.

Evans P.G.H., Lockyer C.H. & Read A.J. 2006. In press for the *New Handbook of British Mammals.*

Evans P.G.H., Weir C.R. & Nice H.E. 1996. Temporal and spatial distribution of harbour porpoises in Shetland waters, 1990-95. *Proceedings of the tenth Annual Conference of the European Cetacean Society, Lisbon, Portugal* 10: 234-237.

Hammond P.S., Berggren P., Benke H., Borchers D.L., Collet A., Heide-Jørgensen M.P., Heimlich S., Hiby A.R., Leopold M.F. & Øien N. 2002. Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *J. Appl. Ecol.* 39: 361-376.

Kaschner K. 2003. Review of small cetacean bycatch in the ASCOBANS area and adjacent waters – current status and suggested future actions. *ASCOBANS, MOP 4: Doc. 21.*

Lockyer C. 2003. Harbor porpoises (*Phocoena phocoena*) in the North Atlantic: Biological parameters. *NAMMCO Sci. Pub* 5: 71-90.

McLellan W.A., Koopman H.N., Rommel S.A., Read A.J., Potter C.W., Nicolas J.R., Westgate A.J. & Pabst D.A. 2001. Ontogenetic allometry and body composition of harbour porpoises (*Phocoena phocoena, L.*) from the western North Atlantic. *J. Zool. Lond.* 257: 457-471.

Northridge S.P., Tasker M.L., Webb A. & Williams J.M. 1995. Distribution and relative abundance of harbour porpoises (*Phocoena phocoena L.*), white-beaked dolphins (*Lagenorhynchus albirostris Gray*), and minke whales (*Balaenopteua acutorostrata L.*) around the British Isles *J. mar. Sci.* 52: 55-66.

Pierpoint C. & Allan L. 2000. Cetacean site use & boat traffic on the Ceredigion Marine Heritage Coast 1994-99. A report for Cygnor Sir Ceredigion County Council. http://www.cardiganbaysac.org.uk/english/publications.shtml. Downloaded on 24 February 2006.

Pierpoint, C. & Allan, L. 2001. Cetacean site use at New Quay on the Ceredigion Marine Heritage Coast, West Wales 2000. A report for Cyngor Sir Ceredigion County Council. http://www.cardiganbaysac.org.uk/english/publications.shtml. Downloaded on 24 February 2006.

Pierpoint C. & Allan, L. 2004. Bottlenose dolphins & boat traffic on the Ceredigion marine heritage coast, West Wales 2002 &2003 West Wales 2004. A report for Cyngor Sir Ceredigion County Council. http://www.cardiganbaysac.org.uk/english/publications.shtml. Downloaded on 24 February 2006.

Read A.J. & Westgate A.J. 1997. Monitoring the movements of harbor porpoises (*Phocoena phocoena*) with satellite telemetry *Mar. Biol.* 130: 315-322.

Reed J.Z., Chambers C., Hunter C.J., Lockyer C., Kastelein R., Fedak M.A. & Boutilier R.G. 2000. Gas exchange and heart rate in the harbour porpoise, *Phocoena phocoena. J. Comp. Physiol.* 170: 1-10.

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

Rosel P.E., Tiedemann R. & Walton M. 1999. Genetic evidence for limited trans-Atlantic movements of the harbor porpoise *Phocoena phocoena*. *Mar. Biol.* 133: 583-591.

Santos M.B., Pierce G.J., Learnmonth J.A., Reid R.J, Ross H.M., Pattersson I.A.P. Reid D.G. & Beare D. 2004. Variability in the diet of harbour porpoises (*Phocoena phocoena*) in Scottish waters 1992-2003. *Mar. Mammal Sci.* 20: 1-27.

Tregenza N.J.C., Berrow S.D., Hammond P.S. & Leaper R. 1997. Harbour porpoise (Phocoena phocoena L.) by-catch in set gillnets in the Celtic Sea *ICES J. Mar. Sci.* 54: 896-904.

Tynan C.T., Ainley D.G., Barth J.A., Cowles T.J., Pierce S.D. & Spear L.B. 2004. Cetacean distributions relative to ocean processes in the northern California Current System. *Deep Sea Res*. 52: 145-167.

Thomas L., Buckland S.T., Burnham K.P., Anderson D.R., Laake J.L., Borchers D.L. & Strindberg S. 2002. Distance sampling. *Encyclopedia of Environmetrics* 1: 544-552, John Wiley & Sons Ltd, Chichester.

Ugarte & Evans, 2006 ??

Walton, M.J. 1997. Population structure of harbour porpoises *Phocoena phocoena* in the seas around the UK and adjacent waters. *Proc. R. Soc. Lond., Ser. B: Biol. Sci.* 264, no. 1378: 89-94.

Watts P., Gaskin D.E. 1985. Habitat index analysis of the harbour porpoise (*Phocoena phocoena*) in the southern coastal Bay of Fundy, Canada. *J. Mammal.* 66: 733-744.

Weir C.R and O'Brien S.H 2000. Association of the harbour porpoise (*Phocoena phocoena*) with the western sea front. *Proceedings of the Fourteenth Annual Conference of the European Cetacean Society, Cork, Ireland*. 14: 61-65.

Westgate A.J, Read A.J, Berggren P., Koopman, H.N, Gaskin D.E 1995. Diving behaviour of harbour porpoises, *Phocoena phocoena*.*Can. J. Fish. Aquat. Sci.* 52: 1064-1073.