A FINE-SCALE STUDY INVESTIGATING THE TEMPORAL AND SPATIAL USE OF NEW QUAY BAY, WALES, BY BOTTLENOSE DOLPHINS (*Tursiops truncatus*)

By

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Thesis submitted in partial fulfilment for the degree of Master of Science

For my parents,

Sally and David Stone

DECLARATION

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

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This dissertation is the result of my own independent work/investigation, except where otherwise stated. Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

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Abstract

This study is an investigation into the use of a small bay by a coastal bottlenose dolphin population. New Quay Bay, Wales, is a shallow, sheltered bay, which has been frequented by dolphins since at least the 1920's. Using land based observations, dolphin presence was recorded between May and September in 2004, 2005 and 2006. In addition, more detailed information about the numbers of animals, their behaviour and habitat use was collected in 2006. A digiscope system was also tested, during 2006, for the purpose of taking dolphin photo identification images. Dolphins were found to be present in an average of 29.6% of 15-minute observation intervals, although there was significant monthly variation, with an increased presence later in the year. This increase was due to greater numbers of animals in the area, coupled with an increase in group size at this time. Nevertheless, the majority of sightings were of single individuals, with a mean group size in all three years of only 1.8 animals. Tidal state was shown to have a strong influence on dolphin presence, with an increase during the ebb stage. Dolphins were found to use the bay predominantly for feeding, with this behavioural state being observed 71.1% of the time. Feeding was shown to occur primarily in two areas at either side of the bay, with the majority of travelling behaviour being across the bay between the two feeding spots. The digiscope was successfully used to take photo identification images of dolphins, but the quality of images was dependent on the range and behaviour of animals and the sea conditions. New Quay Bay is thus an important area for bottlenose dolphins, especially as a feeding hotspot, and continued monitoring of this area is vital for the management of the Cardigan Bay bottlenose dolphin population.

1. Introduction

1.1 The Bottlenose Dolphin (Montagu, 1812)

Bottlenose dolphins (*Tursiops truncatus*) have been studied extensively, both in the wild and in captivity and are arguably the cetaceans that are understood in the greatest detail. They are medium sized delphinids, although there is regional variation in body size, with larger animals typically found in colder waters (Wells & Scott, 2002). Bottlenose dolphins are long lived, especially in the wild, with females known to live to over 50 years and males over 40 years (Reynolds *et al.*, 2000). Females reach sexual maturity between about five and ten years old and reach physical maturity soon after, whereas males are sexually mature between eight and twelve but not physically mature until about twenty years old (Reynolds *et al.*, 2000). Gestation is 12 months and the single calf is dependent on its mother for three to five years (Connor *et al.*, 2000). These figures are based on a population of dolphins in Sarasota Bay, Florida that has been studied for over 30 years, but considerable variation in these life history traits has been found between geographically different populations (Reynolds *et al.*, 2000).

Bottlenose dolphins are widely distributed throughout temperate and tropical waters and populations are found both in shallow coastal waters and offshore deeper waters. Distribution is dependent on several factors, including demographic traits and anthropogenic influences. However the most important factors governing dolphin distribution are ecological, such as prey abundance and distribution (Forcada, 2002). It has been proposed that the inshore and offshore ecotypes represent different subspecies (Wells & Scott, 2002), but further studies are needed to resolve this. More is known about the behaviour, structure and life history of inshore populations of bottlenose dolphins, due to the relative ease of studying them, compared with offshore populations.

Dolphin behaviour is inherently difficult to study since only a small proportion of it is visible, typically when animals surface to breathe. Behaviour can be categorised according to survival tactics, such as feeding, predator avoidance, movement, sexual, parental, and social behaviour (Tyack, 2002). Bottlenose dolphins are large brained, complex mammals and hence show great adaptability, variability and regional speciality in these behaviours.

Bottlenose dolphins are generalist, opportunistic feeders, taking advantage of a wide variety of prey species. Fish, especially demersal species, tend to form the majority of their diet, although cephalopods, shrimp, rays and small sharks also form an important part of the diet of some populations (Connor *et al.*, 2000; Wells & Scott, 2002). Dolphins exhibit a wide variety of feeding strategies depending on their habitat and the type of prey, as well as having cultural specialisations. Several common coastal fish are non-schooling, which leads to coastal dolphins tending to hunt individually or in small groups (Allen *et al.*, 2001). Conversely, offshore fish species form large, patchily distributed schools. Offshore dolphins will thus maximise their energy intake by forming larger groups to cooperatively find and feed on these patches of food (Barros & Wells, 1998; Shane *et al.*, 1986).

The ability to hunt cooperatively and live in groups reflects the highly social nature of the bottlenose dolphin. All studied populations of bottlenose dolphins live in dynamic fission-fusion societies (Connor *et al.*, 2000). Groups range in size and are highly fluid, with group composition changing on an hourly, daily or weekly basis (Connor *et al.*, 2000). The individual composition of a group is highly variable, although there are often stable bonds between individuals, which persist over time. In Shark Bay, Australia, for example, some males are known to form pairs or trios of stable alliances which persist for at least 14 years (Connor *et al.*, 2000). Mothers and calves have the strongest bonds and these can last long past weaning age, for between five and ten years, depending on the population (Reynolds *et al.*, 2000). Although most members of a population have several associates, the number of associates an individual has seems to be highly variable.

Recorded group sizes from bottlenose dolphin populations are also highly variable. Groups of inshore bottlenose dolphins average between 2 and 15, depending on the population, with offshore dolphin groups sometimes numbering in the hundreds (Shane *et al.*, 1986). Group size can also be influenced by season, group composition, activity state and habitat heterogeneity. Groups tend to be larger when animals are socialising or calves are present. For example Bearzi et al. (1997) found groups with adults only had a mean size of 4.3 animals, whereas those which included calves had a mean group size of 12.03. The dolphins in this relatively large area of the Northern Adriatic Sea had an overall mean group size of 7.4 (Bearzi *et al.*, 1997) whereas in the more enclosed waters of Sanibel Island, Florida, mean group size was 5.5 individuals (Shane, 2004).

Habitat selection by dolphins results from the heterogeneous nature of their environment. Some areas of a habitat offer greater protection from the elements or predation, whereas others will be more productive and have a higher food concentration (Ballance, 1992). Habitats can be characterised by several abiotic factors, such as water depth, substrate, water temperature or salinity (Bräger *et al.*, 2003). These can either influence dolphin distribution directly or indirectly through prey distribution. Patchy prey distribution will lead to animals using different habitats for differing lengths of time, depending on their activity state. This, in turn, will be affected by variables such as season, habitat type, tidal state and reproductive season (Wells & Scott, 2002).

1.2 Cardigan Bay, West Wales

Cardigan Bay is the largest bay in the UK and is shallow and gently sloping, with no areas exceeding a depth of 50m (See Figure 1.1). The seabed consists mainly of gravel and cobbles offshore and silt and sand inshore, interspersed with patches of cobble and boulders (Baines *et al.*, 2000). Cardigan Bay is relatively enclosed and hence has weak tidal currents, with a maximum current strength of 1.8 knots, although this is slightly stronger around headlands and estuaries (Ceredigion County Council). The tide flows northwards through the St. Georges Channel and the mean spring tidal range is 4-5m. Coastal water temperatures range from approximately 5ºC in February to a maximum of about 20ºC by August (Baines *et al.*, 2000).

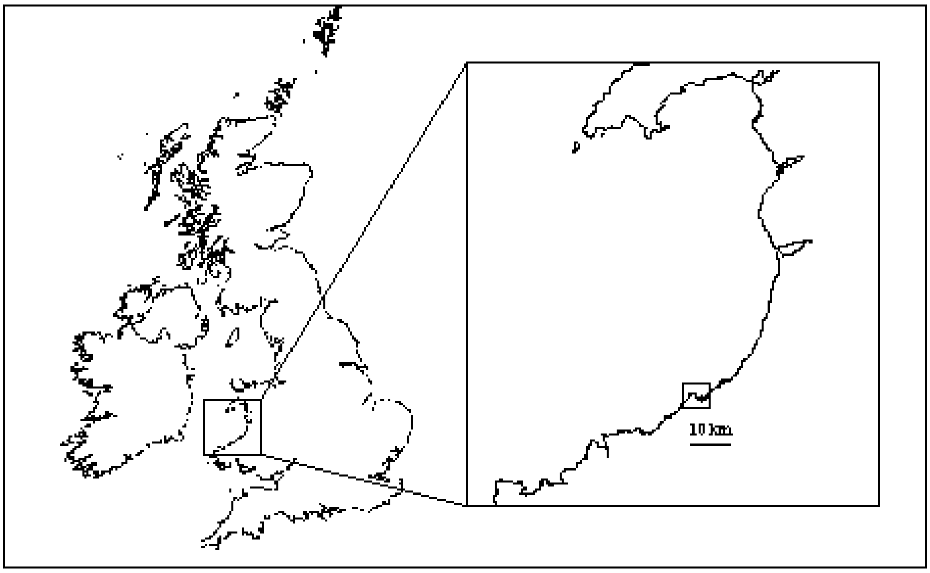


Figure 1.1: Map of the UK. Inset box highlights Cardigan Bay. Within the inset box the black square indicates the location of New Quay Bay.

Cardigan Bay supports a wide variety of marine organisms including invertebrates, seabirds, marine mammals and fish, some of which are exploited commercially. Fish abundance increases in the summer months, when several species move into the coastal waters. Abundant pelagic species include mackerel (*Scomber scombrus*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*), while whiting (*Merlangius merlangus*), pollack (*Pollachius pollachius*) and poor cod (*Trisopterus minutus*) are the most abundant gadoids. Inshore bays and estuaries also support important numbers of flatfish, especially plaice (*Pleuronectes platessa*) and dab (*Limanda limanda*), as well as bass (*Dicentrarchos labrax*), grey mullet (*Chelon labrosus*) and monkfish (*Lophius piscatorius*) during the summer. Estuaries, such as the Teifi at Cardigan, are important areas for migrating Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*) (Baines *et al.*, 2000).

Cardigan Bay is home to one of only two resident populations of bottlenose dolphins in the UK. Anecdotal evidence suggests that bottlenose dolphins (*Tursiops truncatus*) have been found in Cardigan Bay since the 1920's although records indicate that two animals were found stranded in Gwynedd, North Wales in 1916. They are seen throughout the bay (Figure 1.2) all year round but the number of individuals and group sizes seem to increase throughout the summer, reaching a peak in late summer/early autumn (Ceredigion County

Council). In order to help protect this bottlenose dolphin population, a voluntary Marine Heritage Coast was set up in Ceredigion in 1992 by Ceredigion County Council (CCC) and supported by local people.

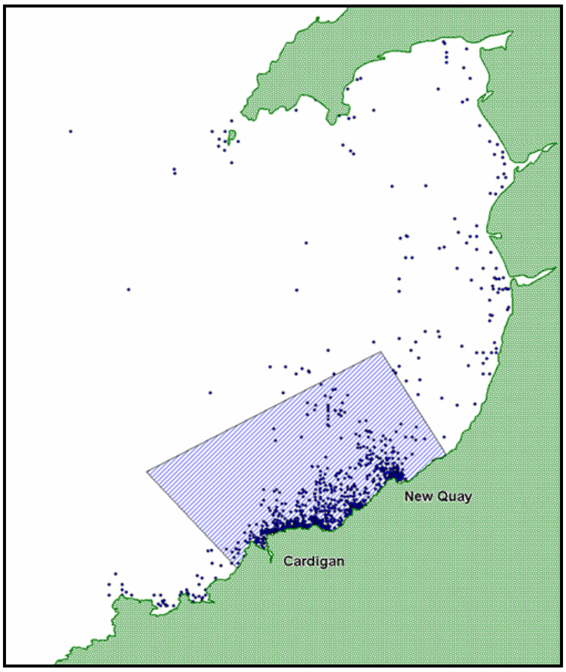


Figure 1.2: Bottlenose dolphin distribution within Cardigan Bay. ● indicates sighting position. Shaded polygon indicates Special Area of Conservation.

In recognition of the national and international importance of this population of bottlenose dolphins, the southern part of Cardigan Bay was submitted as a candidate Special Area of Conservation (SAC), in 1996, under the European Habitats and Species Directive (Ceredigion County Council). The area was subsequently given SAC status in 2005. Figure 1.2 shows the high numbers of sightings in the southern part of Cardigan Bay and consequently this is the area that has been designated a SAC. The Cardigan Bay SAC extends from Aberarth to just south of the Teifi Estuary and approximately 12 miles offshore. Research is now being carried out across the SAC by the Sea Watch Foundation (SWF) and at land based sites by CCC.

Since 2003, SWF have been conducting line transect surveys throughout the SAC in order to calculate bottlenose dolphin abundance estimates, both through distance sampling and photo identification (ID)(Felce *et al.*, 2006). Distance sampling gives an indication of the average number of individuals using the area and this has been estimated at approximately 150. In contrast, photo identification records all the individuals that have ever used an area, and hence over time is likely to continue to increase. Calculating abundance using the SWF catalogue of photographed individuals results in the population being slightly higher, at approximately 175 individuals. Nevertheless, these results show that the SAC is an extremely important and well-used area for bottlenose dolphins.

Photo ID developed in the 1970's as a method of studying cetacean populations through natural markings, such as the nicks on bottlenose dolphin dorsal fins. By taking photographs of animals over a period of time a catalogue of recognisable individuals is built up. This can then provide information on movement patterns, population size, life history parameters and social structure (Whitehead *et al.*, 2000). Despite its merits, photo ID is a laborious and difficult process. It usually involves considerable boat time and harassment of animals, due to the need to closely approach and follow them. Photo ID can only be done from land if animals are regularly seen within a couple of hundred metres of shore, using current cameras and lenses. However, because of the benefits that would be gained, systems for carrying out land-based photo ID are being developed.

The bottlenose dolphins of Cardigan Bay are a predominantly coastal living population, with the majority of sightings occurring within about 2 miles of the coast (pers. obs.). At several sites along the coast, dolphins are easily observed from land and thus land-based watches have been the basis of a CCC study since 2002. Initially, data was collected by local volunteers from June to September at four sites; New Quay Head, Ynys Lochtyn, Aberporth and Mwnt.

In 2004, New Quay Bay was added to the CCC study sites. This was in recognition of the importance of this area for dolphins and the comparatively high level of boat traffic utilising New Quay harbour, particularly during the summer. Volunteers have therefore been collecting data on dolphin presence, behaviour and interactions with boats within New Quay Bay since 2004. During the summer of 2004 a more in depth study was carried out, primarily to determine the potential effects of boat traffic on dolphin behaviour (Lamb, 2004). It concluded that although boats could potentially cause disturbance, the continuing high levels of dolphin presence displays a high degree of boat tolerance. However, as yet no detailed investigations have been made as to how many dolphins use New Quay Bay, their behaviour patterns and their habitat use. Consequently, this is the focus of this study.

1.3 <u>The Study Site: New Quay Bay</u>

New Quay Bay (52º 13'N, 004º 21'W), situated within the Cardigan Bay SAC (See Figure 1.1), is a shallow, predominantly sandy bay facing NNW (See Figure 1.3). The bay is characterised by a reef, which extends approximately 600m offshore on its eastern side. At New Quay Head, on the western side of the bay, there is a fish processing factory, which is licensed by DEFRA. This discharges whelk (*Buccinum undatum*) shells directly into New Quay Bay at a current rate of 2000 tonnes a year (Pierpoint & Allan, 2004). Although initially these were contained within 50m of the discharge point, recently shells are being washed up on the neighbouring beach. Organic matter is also being discharged, despite plans to stop this, and these discharges may be affecting the local biodiversity. A harbour wall, in place since 1836, protects the busy harbour and this acts as the observation platform for the study since it provides a good view of the whole bay.

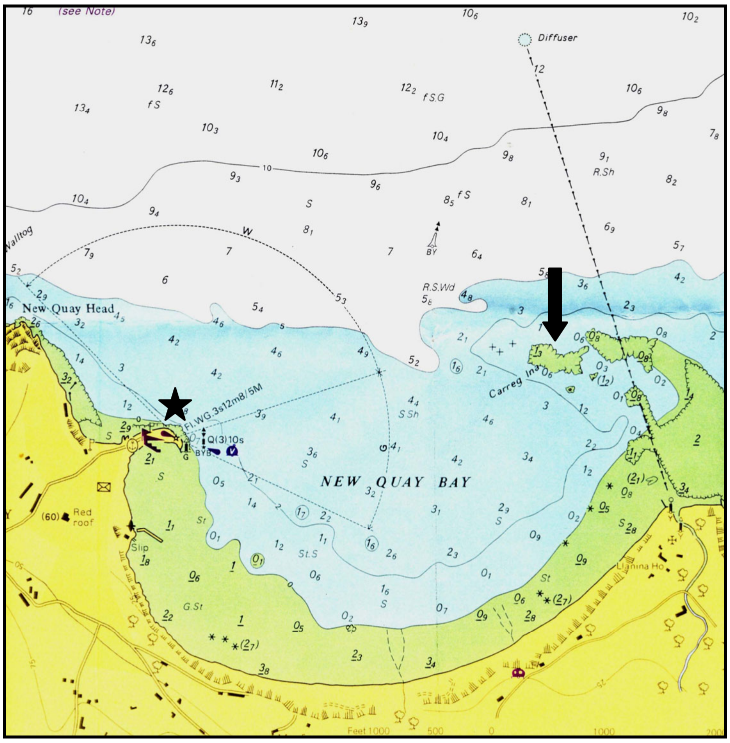


Figure 1.3: Navigation chart of New Quay Bay.
★ indicates observation platform at New Quay Harbour.
➡ indicates Llanina Reef

1.4 <u>Study Aims</u>

The aim of this study is to use land based observations to explain the temporal and spatial use of New Quay Bay by bottlenose dolphins.

The main objectives are:

- To quantify dolphin presence/absence
- To investigate behavioural patterns of use of the bay.
- To examine the habitat use of different areas of the bay.
- To trial a digiscope system, for the purposes of photo ID and hence individual usage of the bay.

2. Methodology

2.1 The Pilot Study

A pilot study was carried out during the first five days of the study, to ensure that the data collected would fulfil the aims of the study and be as accurate as possible. It was realised that the data forms currently used by the CCC study recorded some unnecessary effort information and did not record sufficiently detailed sightings information, for the purposes of this season's investigation. The effort form, (see Appendix 1) recorded weather and wind direction, which have already been shown to have no significant effect on dolphin presence (Lamb, 2004). Other marine mammal species and boat interactions were not going to be analysed in this study so these sections of the form were not needed. However, in order to determine broadly whether boat presence affected dolphin presence, a boat tally over a shorter time scale than the 2 hours on the CCC form was required. The sightings form, (see Appendix 1) only recorded dolphin numbers, behaviour and position every 15 minutes, which was not precise enough for this study. The revised effort and sightings forms are described below. Nevertheless, the CCC data will be used to some degree to examine patterns between years, in order for the data sets to be comparable.

Since 2004, volunteers from SWF and the Cardigan Bay Marine Wildlife Centre (CBMWC) have collected the CCC data from the end of New Quay pier. Data is collected between 9am and 5pm, in two-hour blocks, with each block divided into eight 15-minute intervals. Dolphins seen are plotted on a map of the area, with one map corresponding to each effort interval. The group size is also noted and the behaviour of the animals is recorded using several codes.

It was also realised that it was difficult to accurately plot the position of dolphin groups and movements. Therefore 3 sets of marker buoys were placed in the bay, within easy sight of the observation platform, to facilitate plotting and tracking of dolphins.

2.2 Data Collection

Visual observations were carried out from the end of New Quay pier, located at 52˚ 13'80"N, 004˚ 21'05"W and at an observation height of 6-10m, depending on the tidal state. Observations were carried out daily between the 9th May 2006 and the 18th September, dependent on weather conditions. Due to the low observation height, and the need for fine scale observations of behaviour and movement, data was only collected when the sea state was less than Beaufort 3 and visibility was good enough to observe the whole study area. Observation periods ranged throughout the day, between 7am and 8pm, and were carried out in differing length blocks, depending on the number of observers available. Typically there were at least two trained observers present, to ensure the whole study area could be scanned and that different dolphin groups could be tracked. Throughout observation periods, the bay was continually scanned by eye and 8x22 binoculars were used to confirm dolphin sightings, movement and group numbers.

2.2.1 Effort Data

Effort data was collected every 15 minutes during observation periods and recorded on Form 1 (Figure 2.1). Each 15-minute interval was given an associated Effort Index (EI), a 4 digit number that increased sequentially throughout data collection, to allow for cross referencing with sightings data. Sea state was recorded on the Beaufort scale and effort was aborted if the sea state reached Beaufort 3 anywhere within the study area. During every 15-minute interval a boat tally was recorded, with boats divided into 5 different categories:

- MOTOR – recreational motor boats, dinghies with outboard motors or visitor passenger boats
- SPEED – speed boats or RIBs
- FISHING – commercial fishing boats
- SAIL – any boat under sail including windsurfers
- CANOE – any boat being paddled

DATE

EI	TIME	SS	BOAT TALLY				
			MOTOR	SPEED	FISHING	SAIL	CANOE

Figure 2.1: Form 1: Effort form, each line was filled in every 15 minutes.

2.2.2 Sightings Data

Dolphin sightings were recorded on Form 2 (Figure 2.2), consisting of a map of the study area and a notes section. Also noted on the form were the date and EI's corresponding to the duration of the sighting that was recorded on that particular map. When an individual dolphin or dolphin group was sighted, its initial position was marked with a dot and identification letter on the map, using the marker buoys for accurate positioning. Each new dolphin or dolphin group was assigned a new identification letter, so that each identification letter was unique to a dolphin or group during that observation period. Using the identification letter, the time, group composition (number of adults and calves) and behaviour was then recorded in the notes section. All times relating to sightings were to the nearest minute. Animals were considered calves if they were half the length of adults, with paler colouration and seen in close association with an adult. A group was defined as animals that were within close spatial proximity of each other, engaged in the same behaviour and heading in the same direction, if travelling (Shane, 1990). Behaviour was categorised into 5 types, based on Viddi & Lescrauwaet (1995) classifications:

- Feeding: repeated deep dives within a relatively small area, with surfacings in different directions.
- Travelling: regular surfacing with movement in a persistent direction.
- Foraging/Travelling: combination of deep dives with surfacing in different directions, but with an overall movement in a particular direction.
- Resting: logging or slow circling at the surface.
- Quick behaviours: any high-energy behaviour, including leaping, breaching, rushes at the surface and physical contact.

Any changes in dolphin behaviour were recorded with a new dot on the map and with the new behaviour and time in the notes section. Due to the transient nature of 'quick' behaviours, the time they occurred was recorded, but they were classed as events rather than a behavioural state for analysis purposes. Dolphin movements were marked on the map using straight arrows, to allow for analysis of habitat use. If groups of animals formed or split, the new group/s were given new identification letters and dots and were subsequently treated as different groups. When the numbers of dots or arrows on a map caused the data to become unclear, a new map was moved on to. Dolphins leaving the study area or those lost from view were marked with an X on the map and a corresponding time in the notes section.

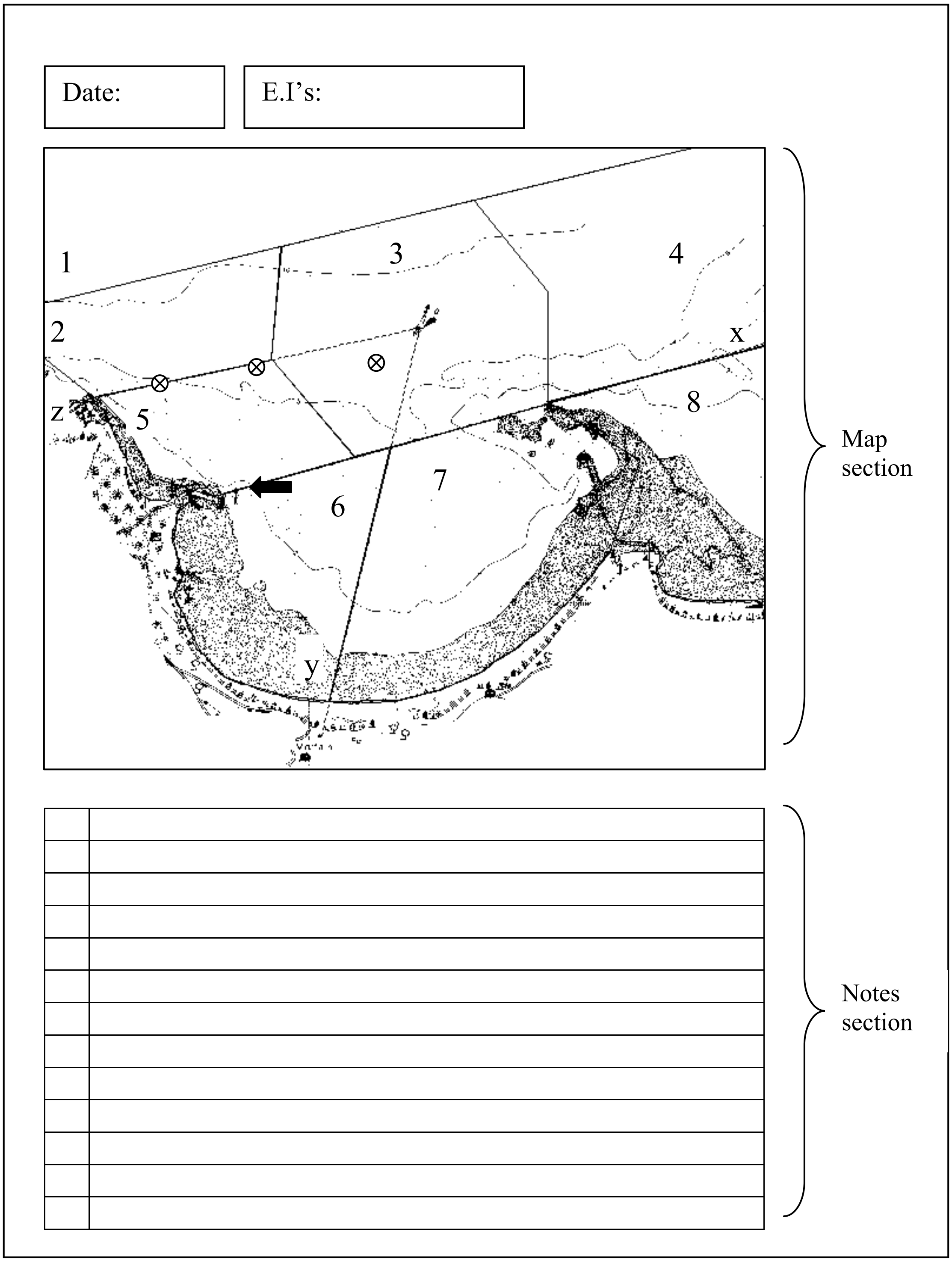


Figure 2.2: Form 2: Sightings form. CCC habitat zones are denoted with heavy lines and a number.

 indicates observation platform at New Quay pier.

⊗ indicates marker buoy.

 indicates cardinal buoy, marking the end of the reef.

2.3 The Digiscope

The digiscope describes the camera and telescope system that was tested in this study, for the potential collection of photo identification images at far distances. Figures 2.3 & 2.4 show the configuration of the digiscope system.

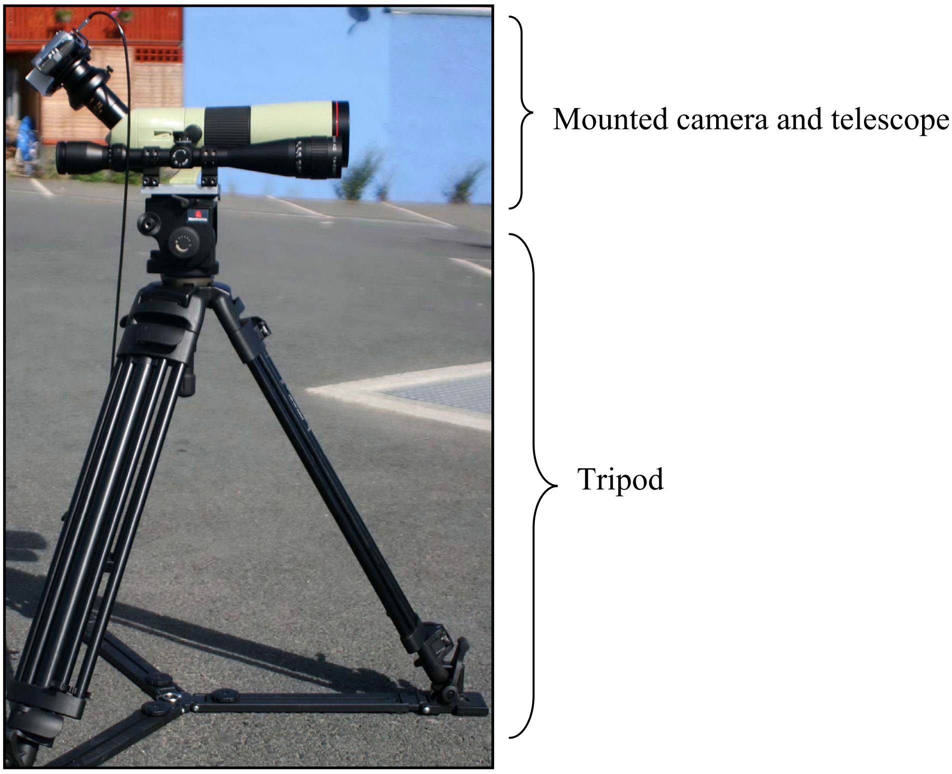


Figure 2.3: Assembled digiscope

Figure 2.4: Close up of mounted digiscope

The telescope used was the Nikon Fieldscope 82ED. This has an 82mm clear aperture and is fitted with extra low dispersion glass, which reduces aberrations in image focussing. This is also used in the camera, a Nikon Coolpix P3, to ensure the images are of a high quality. Image quality is also increased as the camera has 8.1 million pixels and active vibration reduction. The camera has a 3.5x Zoom-Nikkor lens with a 7.5-26.3mm focal length. In addition, it has a 4x digital electronic zoom. The camera was fitted to a Nikon FSB3 bracket that was then attached to a Nikon digiscope eyepiece on the telescope. This eyepiece has a 30 times magnification in addition to the magnification of the telescope. A rifle sight was used in order to track the dolphins. The telescope and rifle sight were mounted completely parallel to each other on the plate, to ensure that the image formed through the telescope and captured on the camera was identical to that seen through the rifle sight.

The digiscope was initially trialled on land using a target at approximately 275m, (see Figure 2.5). The target had several details marked on it in order to test the power and precision of the digiscope. This included an A4 piece of paper with small, notched details, as seen in Figure 2.6. The digiscope was also tested in the field, using buoys as targets, including the cardinal buoy, to determine its possible range when photographing objects on the sea.

Figure 2.5: Land target used to test the digiscope. The width of the bottom of the black triangle is 81cm. Note that this image was taken using the camera only, not the assembled digiscope.

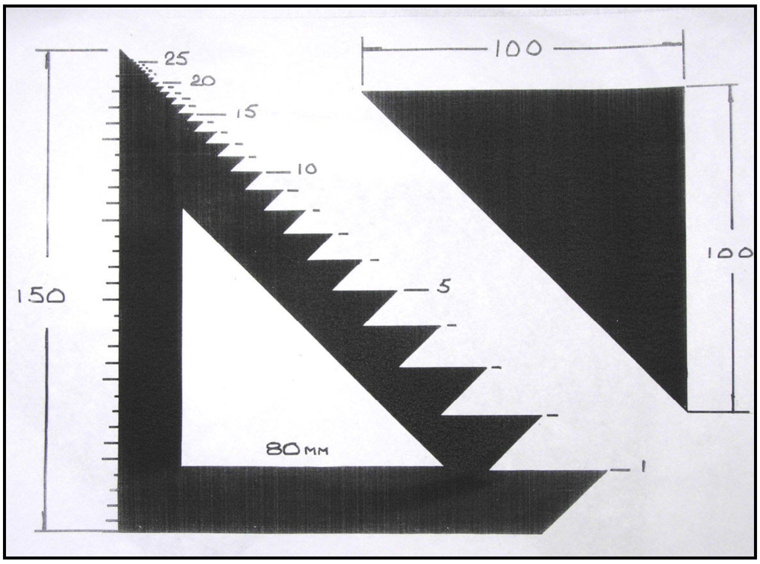


Figure 2.6: A4 target attached to the larger target. The height of the 'notched' triangle is 150mm.

Subsequently, the digiscope was used opportunistically to photograph the dolphins using New Quay Bay. It was used when sea and weather conditions were good enough and there were sufficient observers to continue tracking the dolphins. Images were taken of dolphin dorsal fins of as many dolphins in the group as possible. These were then compared with known individuals from the Sea Watch Foundation's Cardigan Bay catalogue and given ID numbers where possible.

2.4 <u>Data Analysis</u>

All data was entered into Microsoft Excel and subsequently analysed using this and Minitab 14. Where CCC data was used, 15-minute intervals in which dolphins were seen were classified as 'bottlenose dolphin positive' (BND +ve). This indicates dolphin presence, although it does not quantify the amount of time dolphins spent in the bay, or the total number of dolphins using the bay. Analysis of dolphin presence was thus done using the CCC data since this is a much larger data set and does not require detailed behavioural or spatial information.

For the purposes of analysing any effect of tide, tidal state was divided into 4 categories: ebb, flood, low and high. 'Low' and 'high' were defined as being one hour either side of low or high tide, a time when water movement in either direction is minimal. Although the behaviour codes used in CCC data collection were different, there were codes that were comparable to those used in this study, ('S3' for 'feeding', 'T1' for 'travelling' and 'T2' for 'foraging/travelling), and so these were used where needed.

Habitat use was analysed using a grid system, placed over the sightings form maps. A 200m x 200m grid was created to cover the area of the bay that was visible from the observation platform and that was utilised by the dolphins. A frequency table of type of behaviour in each grid square was then completed. Therefore this represents the number of times each square was used for each type of behaviour, rather than the duration of time spent in each square.

3. Results

Data was collected in the modified format, for the purposes of dolphin numbers, behaviour and habitat use, on 78 days between May and September 2006. There was a total of 409.5 hours of effort, with 110.4 hours when dolphins were present. Effort was not evenly distributed between months, mainly due to poor weather conditions in May, August and September.

CCC data was collected between May and September in 2004, 2005 and 2006. The numbers of days of data collection and effort hours are shown in Table 3.1. The amount of effort was again higher in June and July than other months due to weather conditions and greater numbers of volunteers available to collect data.

	Days	Hours
2004	91	532.25
2005	117	664.5
2006	121	778.75

Table 3.1: Number of days and hours of data collection for the three years of the CCC study.

3.1 Bottlenose Dolphin Presence

Using the CCC data, the percentage of dolphin positive 15-minute intervals (BND +ve) was calculated monthly, as seen in Table 3.2 and Figure 3.1.

	2004	2005	2006
May	10.7	9.6	19.3
June	39.3	33.0	24.4
July	31.9	27.3	19.9
August	35.8	33.3	32.4
September	54.4	31.0	41.8

Table 3.2: Percentage of BND +ve intervals in each month for each of the three years of the CCC study.

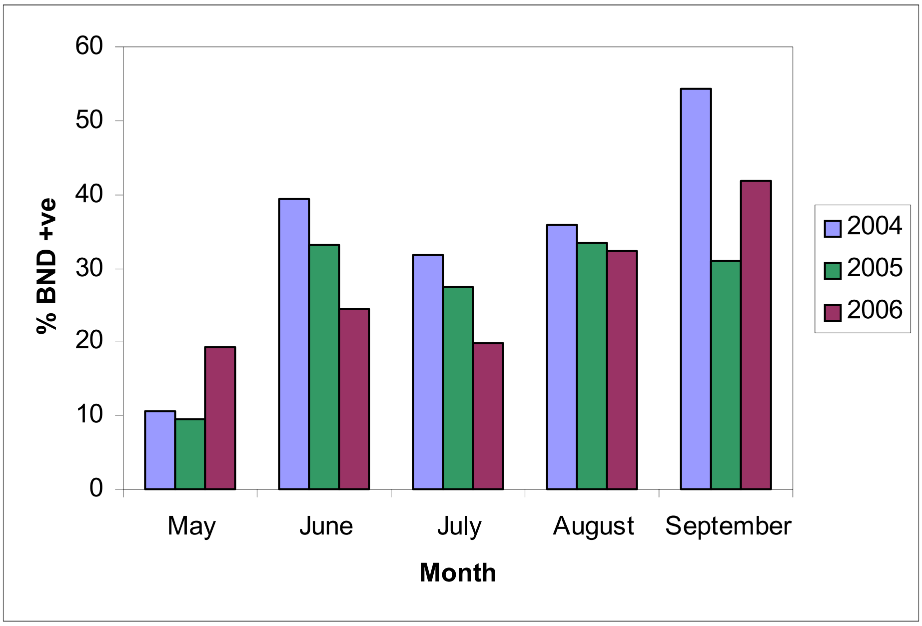


Figure 3.1: Percentage of BND +ve intervals in different months.

It was found that there was no significant difference between the percentage of BND +ve intervals in the different years (One-way ANOVA: F=0.60, p=0.565), however there was significant monthly variation (One-way ANOVA: F=6.72, p=0.007). Pairwise comparisons indicate that May has significantly fewer BND +ve intervals than all other months and September has significantly more (Fishers pairwise comparisons: p=0.05).

Although this gives an indication of dolphin presence, it does not resolve whether this is due to changing numbers of dolphins or whether dolphins are spending differing amounts of time in the bay. This is because dolphins were marked on the map every 15 minutes, regardless of whether they were the same as the animals on the previous map or not. However, using the data collected in 2006 in the modified format, actual dolphin numbers could be analysed (see sub-section 3.2).

Tidal Effects

The effect of the different stages of tide on dolphin presence was examined using BND +ve intervals pooled from the three years. Firstly, dolphin presence in relation to the ebb and flood stages of tide was considered. There were clearly a higher percentage of BND +ve intervals during the ebb stage, in all months (see Figure 3.2). However, it was noticed that in all months there was also a higher number of ebb intervals compared with number of flood intervals. Therefore a chi-squared test of association was carried out to determine whether this difference in dolphin presence was simply due to the greater number of ebb intervals. However, it was found that in all months, there were a significantly higher number of BND +ve intervals during the ebb stage of tide (May: χ^2= 16.25, p<0.001; June: χ^2= 78.35, p<0.001; July: χ^2= 75.77, p<0.001; August: χ^2= 81.37, p<0.001; September: χ^2= 19.01, p<0.001).

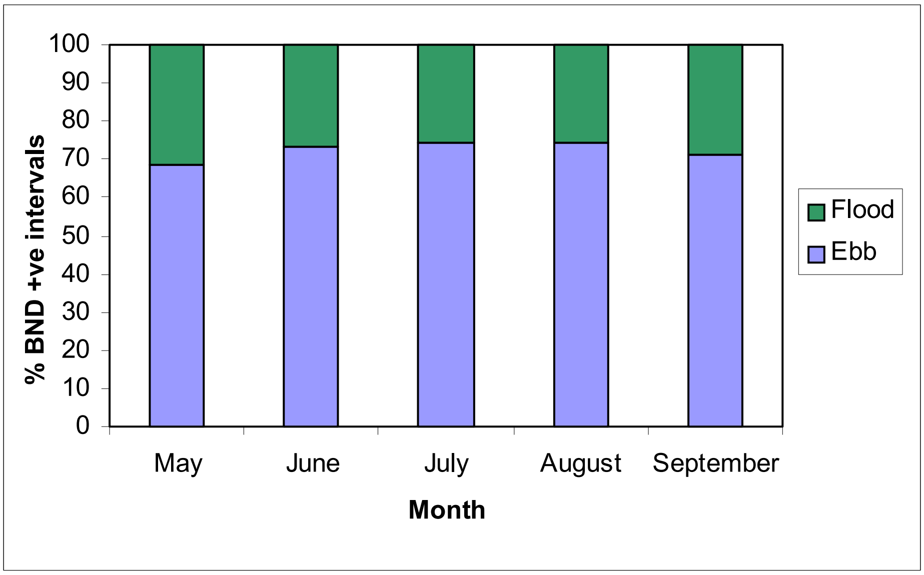


Figure 3.2: Percentage of BND +ve intervals in different tidal stages across different months.

Secondly, the effect of the low and high tidal states was considered. No significant difference was found when comparing the number of BND +ve intervals in either high or low water, pooled from all months (Chi-squared test: χ^2= 1.04, p<0.308). The low and high tidal states represent the time when there is very little water movement in either direction and can therefore be termed as times of slack water.

Finally therefore, the number of BND +ve intervals during slack water was compared with those during the ebb and the flood stages, when water movement is considerable (see Figure 3.3). There were a significantly higher number of

BND +ve intervals in the ebb stage compared with the slack stage (Chi-squared test: χ^2= 77.69, p<0.001). However, there was also a significantly higher number of BND +ve intervals in the slack stage compared with the flood stage (χ^2= 81.22, p<0.001).

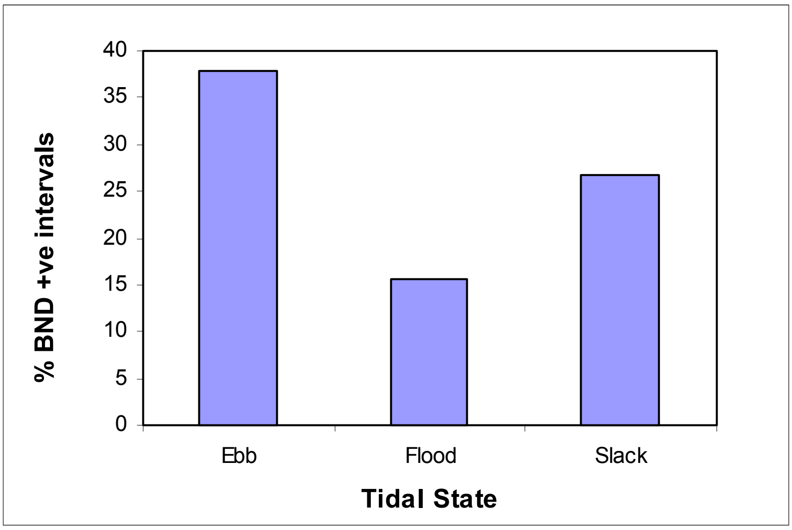


Figure 3.3: Percentage of BND +ve intervals during different tidal stages. Note that the percentage of ebb and flood intervals is lower than in Figure 3.2 as some intervals fall into the 'slack' category.

Boat Presence

From the boat tally recorded every 15 minutes, the average number of boats per effort interval was calculated. This was then divided into the BND +ve and BND –ve intervals to see if there was a clear difference in the number of boats when dolphins were present (see Figure 3.4). It can be seen that there is no large difference between the numbers of any type of boat when dolphins were present compared to when dolphins were not present. As a previous study has examined in detail the effects of boat traffic on bottlenose dolphin behaviour in New Quay Bay, this will not be looked at further in this study.

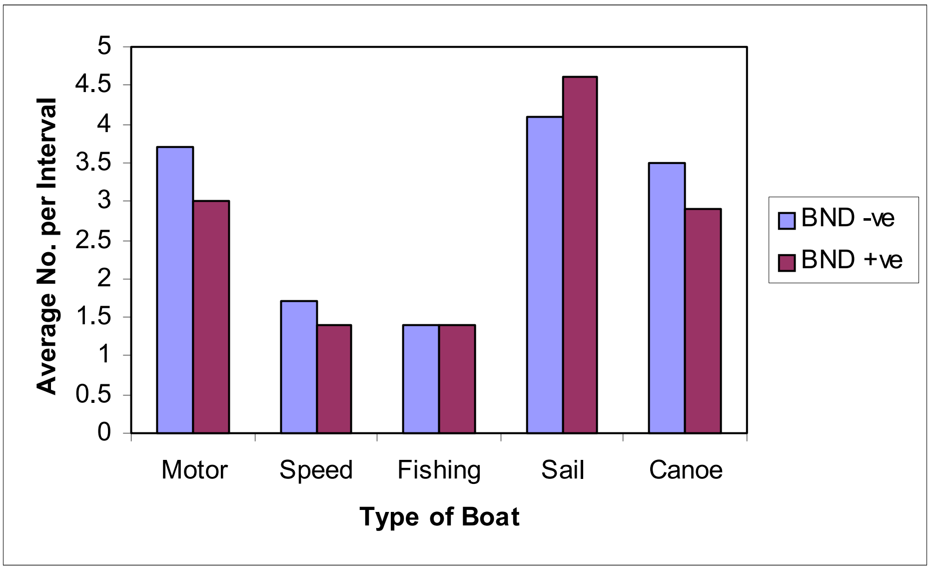


Figure 3.4: The average number of boats per 15-minute interval during BND – ve and BND +ve intervals.

3.2 Bottlenose Dolphin Numbers

The data collected in 2006, in the modified format, allowed for absolute numbers of dolphins to be calculated. This was then converted into a weekly sightings rate of number of dolphins per hour of observation (see Figure 3.5). The numbers of dolphins fluctuates around an average of 0.61 per hour until week 15 (15^{th} – 21^{st} August), after which there is a sharp increase. This increase is apparent even in week 17 when there was only 5.75 hours of observation.

The numbers of calves in each group was also counted. No calves were seen in May or June, but were present in July, August and September. Calves were seen on four days in July, two in August and three in September. On all occasions except one, in July, at least two different calves were observed during the day. However, the small sample size restricts any further analysis.

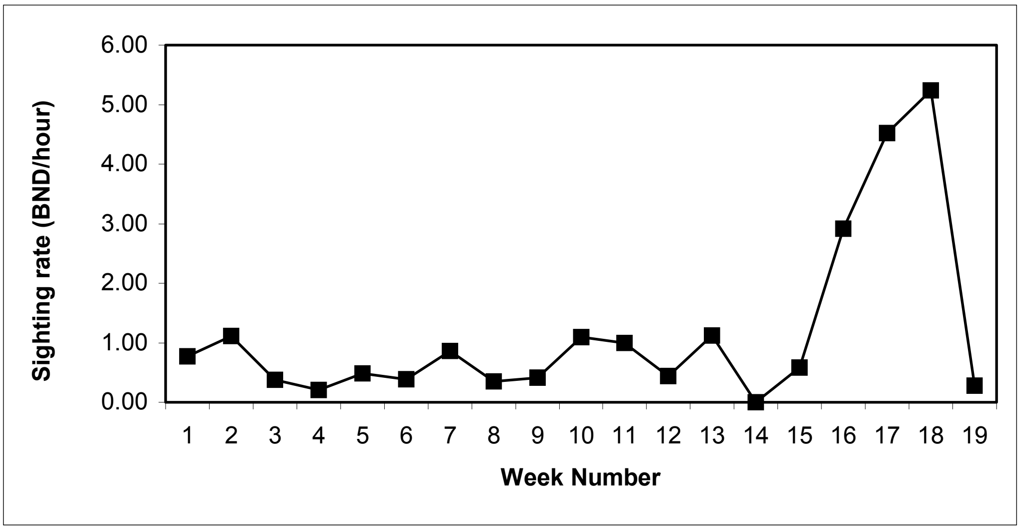


Figure 3.5: Weekly sightings rates of numbers of dolphins per hour of observation.

Group Size

Group sizes in 2006 ranged from 1 up to a maximum of 8 individuals, although this occurred only once and the group included 2 calves. Mean group size over the 5 months was 1.8. By far the most common group size consisted of a single individual, accounting for 52.9% of all groups sighted. Groups of 2 or 3 animals accounted for 28.4% and 10.5% of all groups respectively. Groups of 4 or more animals only accounted for 8.2% of all groups.

Group size varied over the 5 months, as seen in Figure 3.6. This monthly variation was found to be significant (Kruskal-Wallis: $H=15.92$, d.f.= 4, $p= 0.003$). Pairwise comparisons indicate that group size in September was significantly greater than in June, July and August (Mann-Whitney U: June: $W=10358.0$, $p<0.001$; July: $W=8531.5$, $p=0.05$, August: $W=9778.0$, $p=0.01$), although this is mainly due to a few unusually large groups. Group sizes in May were over a much larger range than in other months, but were only significantly bigger than those in June (Mann-Whitney U: $W=3721.0$, $p=0.01$). There were no other significant differences between months.

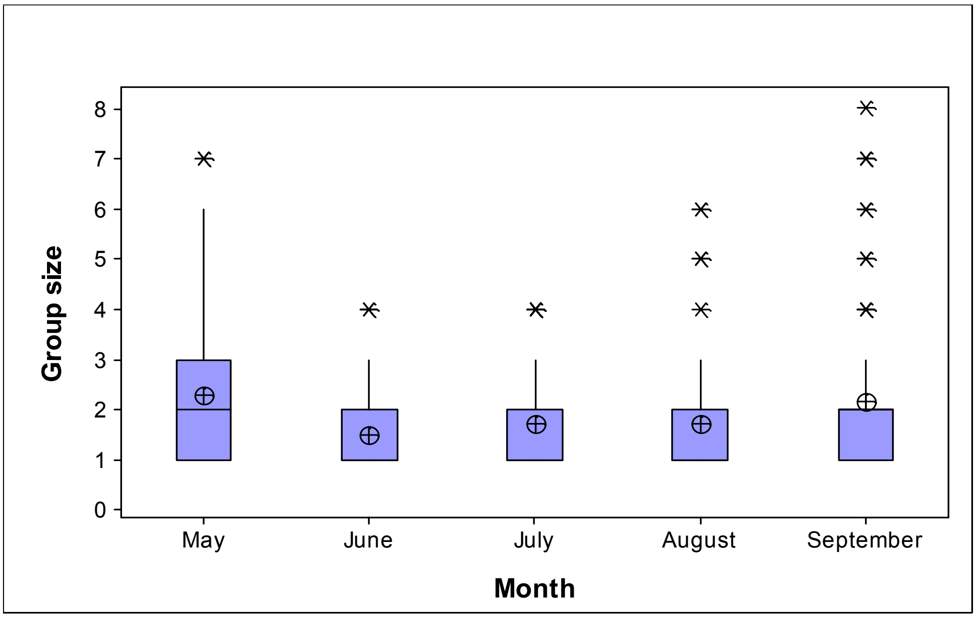


Figure 3.6: Box plot showing monthly variation of group size.
⊕ = Mean group size
* = Outliers

Using the CCC data for comparison, group size was seen to be fairly consistent over the three years (see Figure 3.7). Although the 2006 data is more variable, possibly due to different methods of classifying groups, the mean group size in all three years was 1.8.

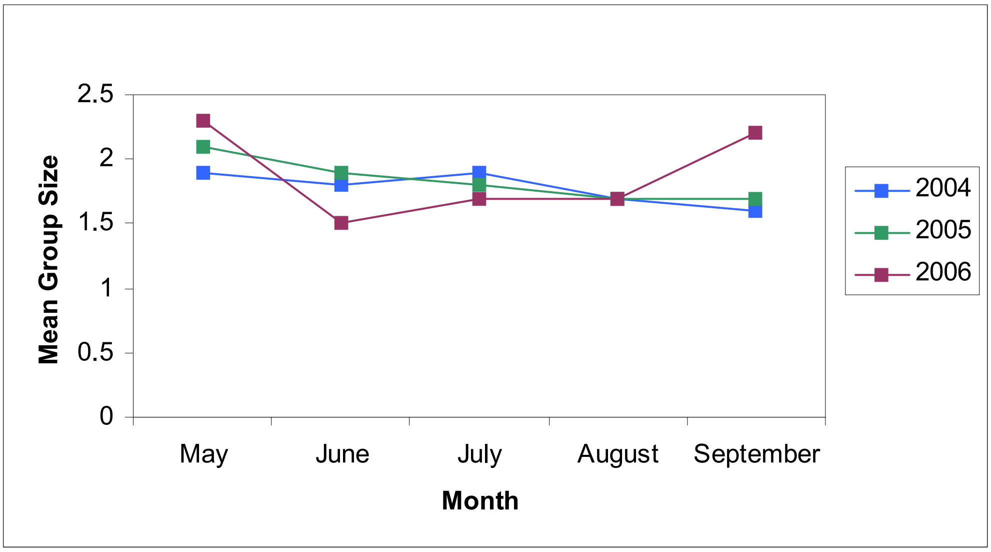


Figure 3.7: Mean group sizes in different months in the three different years.

Bottlenose dolphin groups are known to be highly dynamic and changeable. Using the modified format of data collection in 2006 it was possible to analyse the length of time a group remains in the same composition whilst in the bay. This was found to range from 1 minute up to 3 hours & 6 minutes, with a mean duration of 30 minutes and an interquartile range between 11 and 37 minutes (see Figure 3.8). All durations over 2 hours consisted of single individuals, with the exception of one adult and calf group of two animals.

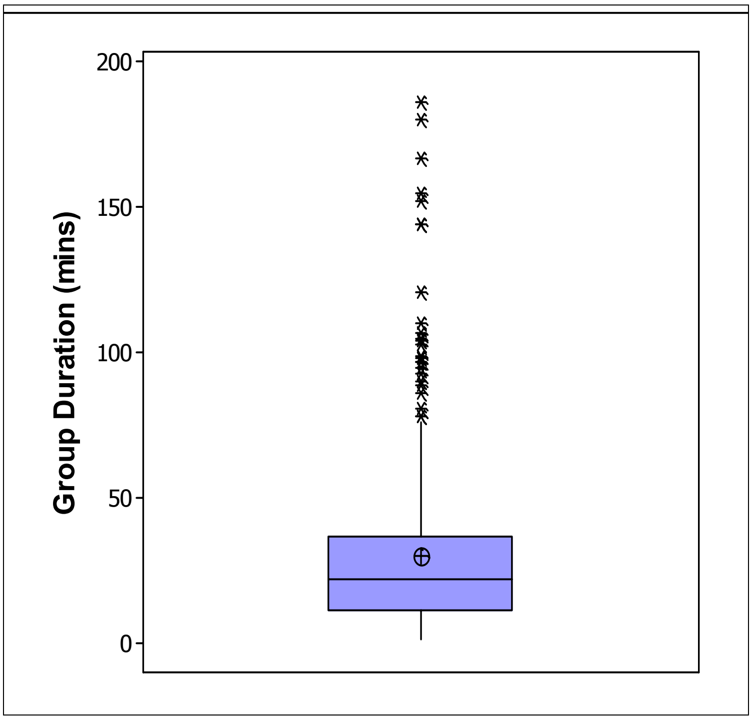


Figure 3.8: Box plot showing the length of time a group remains in the same composition.
⊕ = Mean group duration
* = Outliers

3.3 Behavioural Patterns

To understand how dolphins use the bay, the percentage of time spent engaged in each behavioural state was calculated, using data from 2006. The average percentage of each type of behaviour over the 5 months is shown in Table 3.2 below. Resting was only seen four times, for a total of 10 minutes and is therefore not considered further.

	% Time
Feeding	71.1
Travelling	12.8
Forage/Travel	16.0
Resting	0.1

Table 3.3: The average percentage of time spent by dolphins engaged in each type of behaviour over the 5 months of 2006.

Data was then broken down to examine any differences in behaviour patterns across the months. Nevertheless, in each month, feeding was the predominant behaviour, as seen in Figure 3.9. Foraging/travelling was the second most common behavioural state in all months except July and August, when there was slightly more travelling behaviour. However, although the amount of time spent feeding was significantly greater than either travelling or foraging/travelling (Mann-Whitney U: W=40.0, p=0.01), there was no significant difference between the amount of travelling and foraging/travelling (Mann-Whitney U: W=22.0, p=0.30).

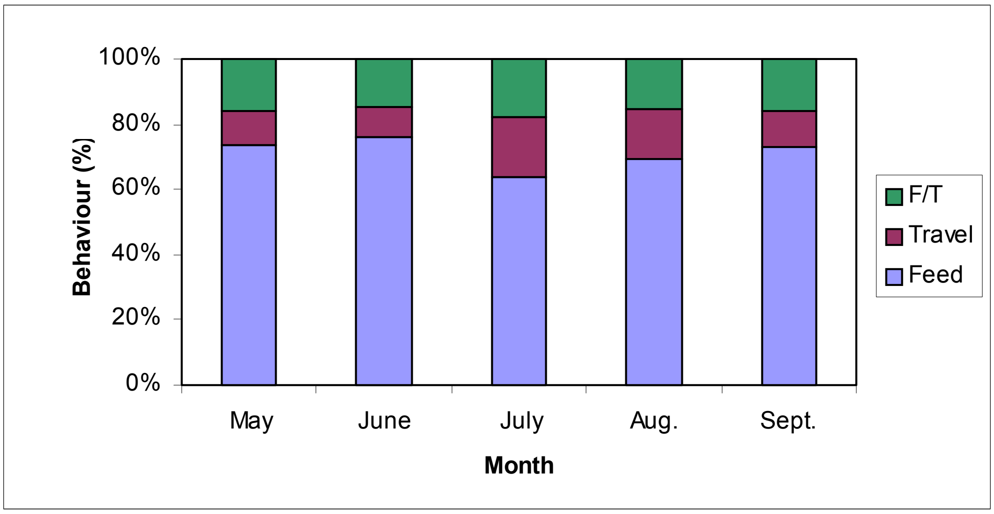


Figure 3.9: Percentage of time engaged in each behavioural state in each month during 2006.

The modified format of data collection in 2006 allowed for precise allocations of time for each behaviour, which was not possible with the CCC data, as it records all behaviours seen within each 15-minute interval. However, some comparison is possible, using the percentage of BND +ve intervals in which each type of behaviour occurred. Therefore this gives an indication of the frequency that each type of behaviour is seen, rather than an actual amount of time engaged in each behaviour. These results are shown in Figure 3.10 below.

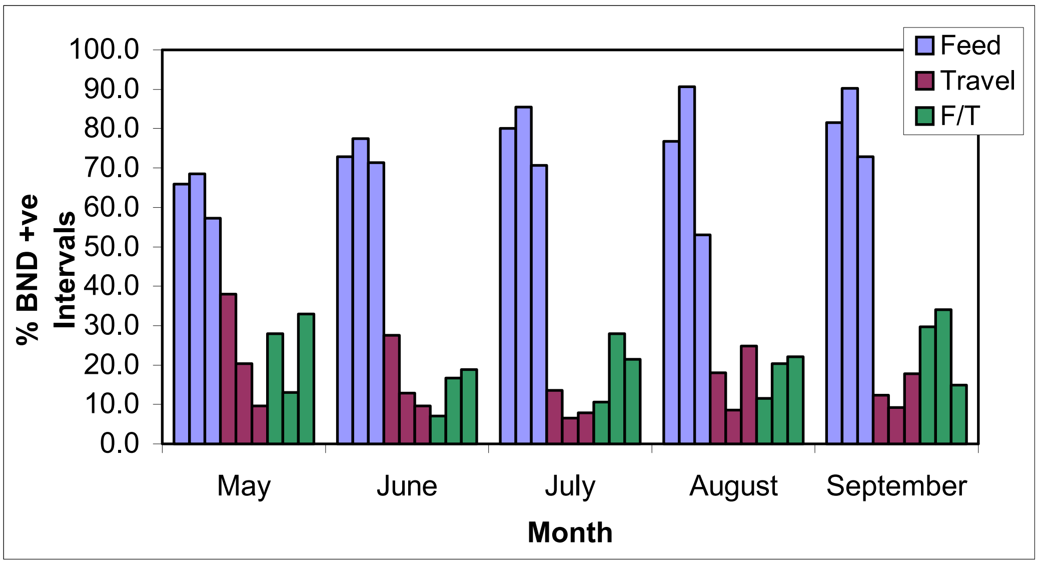


Figure 3.10: Percentage of BND +ve intervals in which each type of behaviour was seen. Left hand bars represent 2004 results; middle bars represent 2005 results; right hand bars represent 2006 CCC results.

These results also show that feeding is the most commonly observed behaviour. However, there is a lot more variation in the frequency with which the types of behaviour are seen both between months and between years. It can be seen from the average values that the more precise 2006 data falls between the CCC values for feeding and travelling (Table 3.4). Foraging/travelling behaviour actually occurs for a shorter percentage of time than is estimated by the CCC method.

	% Intervals			% Time
	2004	2005	2006	2006
Feed	75.5	82.5	65.1	71.1
Travel	21.9	11.5	14.0	12.8
F/T	17.4	22.4	22.1	16.0

Table 3.4: Average percentages of each type of behaviour in the 3 years.

In 2006, any high-energy behaviour was classified as 'quick' and recorded as an event. From this, a rate of how often quick behaviours were seen was calculated for each month (see Table 3.5). The highest rate of quick behaviours was May and there was a slightly higher rate in September, compared with the other months. This monthly variation in the rate of quick behaviours was found to be significant (Kruskal-Wallis: H=13.52, d.f.=4, p=0.009).

	Rate of Quick Behaviours (events/hour)
May	4.7
June	1.9
July	1.6
August	1.9
September	2.3

Table 3.5: The rate of quick behaviours seen in each month of 2006 data collection.

In order to try and resolve the function of these quick behaviours, the behaviours that they were associated with and the size of groups when they occurred was then examined. The behavioural state that preceded and followed each quick event was tallied and converted to a percentage. This percentage of associated behaviours was then compared with the percentage at which that behaviour occurred (see Figure 3.11). This shows that although the majority of quick behaviours were associated with feeding animals, it is not significantly greater than would be expected, given the percentage of time during which feeding occurred (Chi-squared: χ^2=0.513, p=0.774).

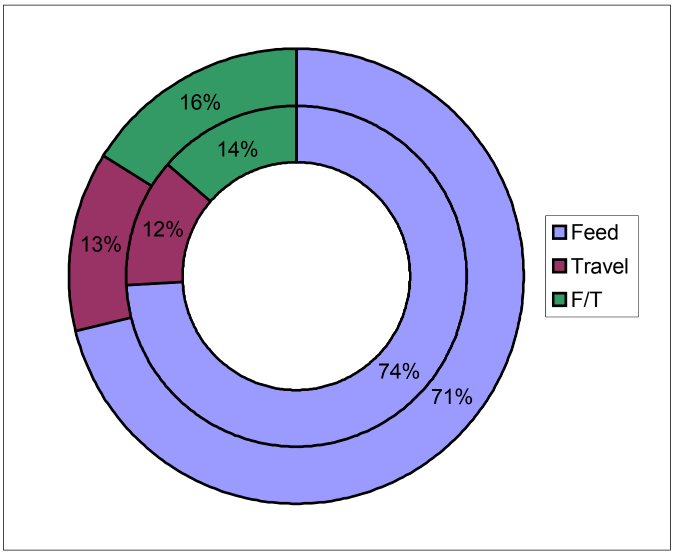


Figure 3.11: Behavioural states associated with quick behaviours are represented in the inner circle. Percentage of each behavioural type is represented in the outer circle.

The group sizes when quick behaviours occurred was then examined and compared with the group sizes that were observed during all the other behavioural states. Due to a small sample size all groups of 4 animals or above were pooled. From Figure 3.12, it can be seen that quick behaviours occurred more frequently in larger groups than would be expected. Although the overall mean group size was 1.8, the mean group size when quick behaviours occurred was 2.2. Group size was found to be significantly larger during quick behaviours (Kruskal-Wallis: W=16.27, d.f.=1, p<0.001).

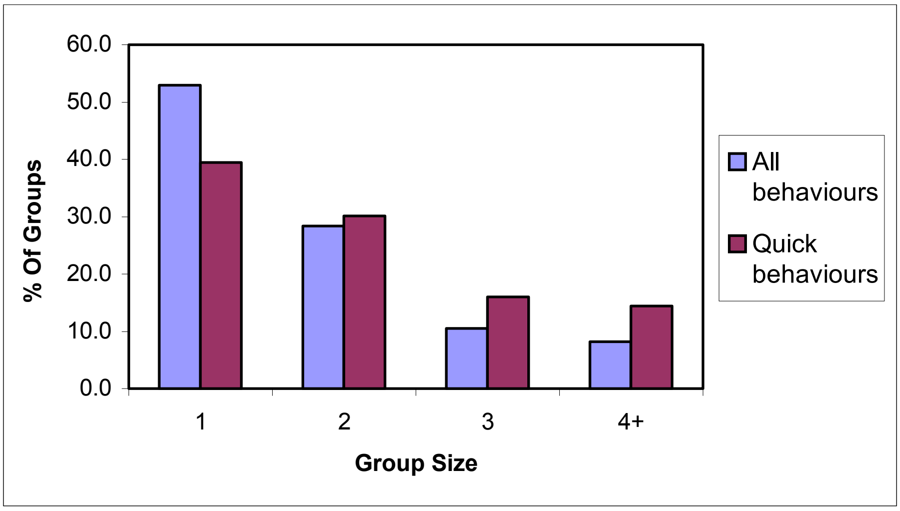


Figure 3.12: Percentage of groups of different sizes during all behaviours and during quick behaviours.

3.4 Habitat Use

Dolphin habitat use of the bay was analysed by examining the frequency of use of each of the 200m x 200m grid squares, as seen in Figure 3.13.

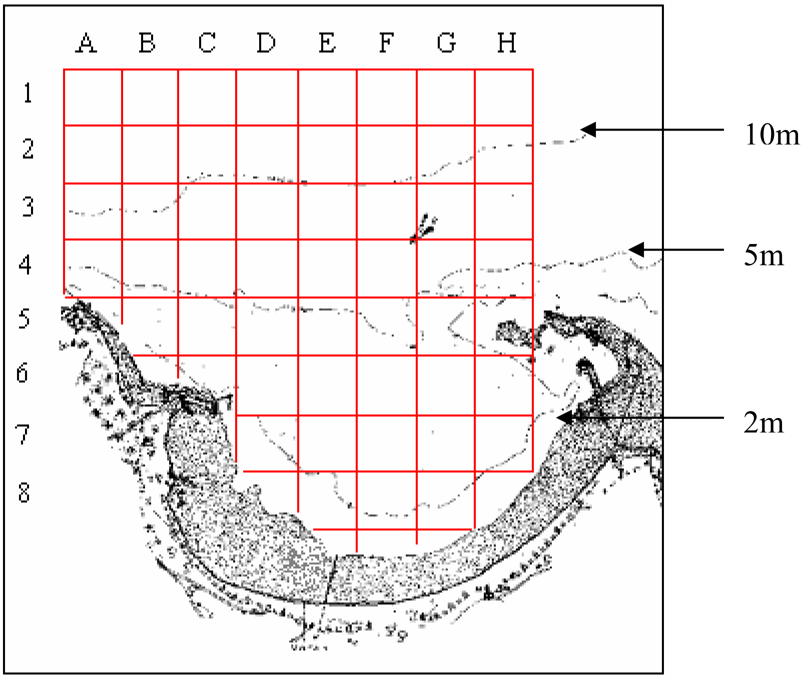
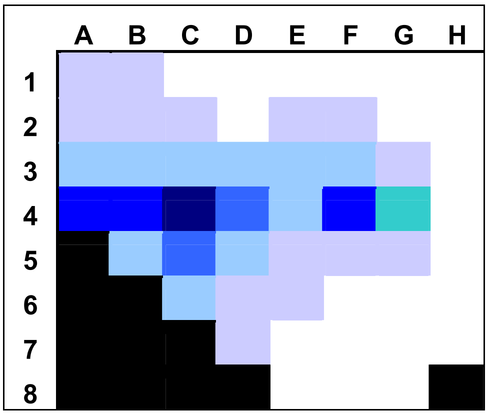
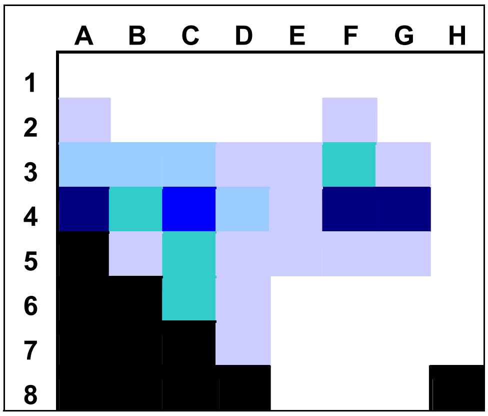


Figure 3.13: Grid system used to analyse habitat use of the bay. Arrows indicate depth contour lines.

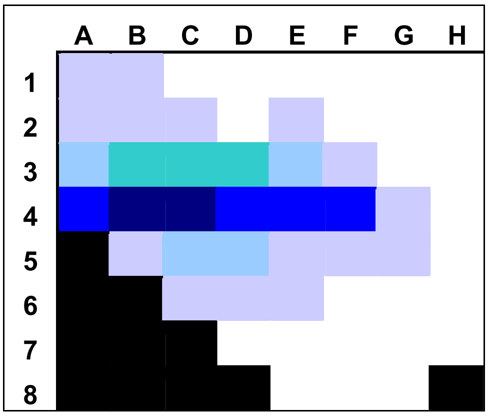
From the frequency tallies of behaviours, the percentage usage of each square could be calculated, both for the overall use of the bay and for the different behaviours. It can be seen from Figure 3.14 below that grid squares were not all used to the same extent. In all cases, the differential usage of the grid squares was found to be significant (G-tests: $p<0.001$).



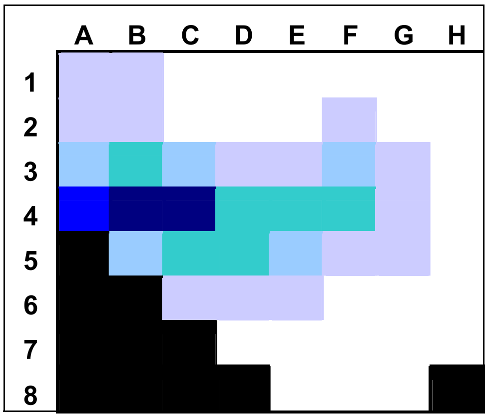
a) Total Use



b) Feeding



c) Travelling



d) Foraging / Travelling

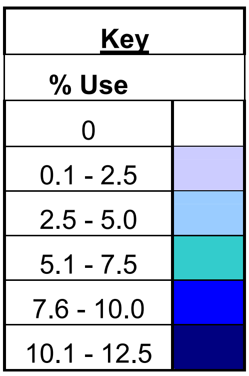


Figure 3.14: Representation of usage of different areas of the bay. Colours indicate the percentage of each behavioural type in each grid square. Black squares indicate land.

The area most commonly used (see Figure 3.14 (a)), is along the 5 metre depth contour, while areas shallower than this or deeper than 10 metres are used a lot less frequently. Feeding was predominantly seen in 2 areas: firstly, just off New Quay headland (grid square A4) with 12.1% of all feeding behaviour and secondly, at the end of Llanina Reef (grid squares F4 & G4) with 23.5% of all feeding behaviour collectively. Travelling and foraging/travelling behaviour was seen in a similar pattern to that of the total use representation, predominantly along the 5 metre depth contour. However, there was a very high frequency of both of these behaviours just past New Quay headland (grid squares B4 & C4) with 23.4% of all travelling and 22.4% of all foraging/travelling behaviour.

3.5 The Digiscope

3.5.1 *Land Trial*

The digiscope was initially tested on a land target at a distance of 275m. Images of this target taken with the digiscope are shown in Figure 3.15 below. The target can be clearly seen without any zoom, including the definition of the black triangle with an 81cm wide base. The A4 sized target, attached to the larger one, can be seen, but with no definition. With the camera on full zoom, the target takes up a greater proportion of the frame and hence has greater detail. The three largest notches in the black triangle can be seen, as well as four of the 'notches' on the A4 target. With the electronic zoom on as well, more details on the A4 target can be distinguished. Although these details are not in complete focus, it should be remembered that they are very small features on a relatively small target.

a) No zoom

b) Full zoom

c) Full zoom plus electronic zoom

Figure 3.15: Images of the land based target taken with the digiscope at different stages of zoom. Images have not been cropped or transformed in any way.

3.5.2 _Sea Trial_

The digiscope was then tested on buoys at sea to test the quality of the images of objects in the water. The first buoys photographed were 1235m away and were approximately 30cm in diameter, with a flag approximately 30cm high. These images can be seen in Figure 3.16. The buoys are just visible without any zoom, but can be clearly defined with full zoom.

a) No zoom

b) Full zoom

Figure 3.16: Images of buoys at sea, with and without zoom. The buoys are approximately 1235m away. Again, images have not been altered in any way.

The cardinal buoy in New Quay Bay was then photographed in different sea states to look at the influence of environmental variables on the quality of images. The cardinal buoy is 900m away and is approximately 1m high. The images can be seen in Figure 3.17. This larger buoy is clearly defined even without zoom, but is a lot clearer in the calm sea state. With full zoom, the details of the triangular upright are clearly visible.

a) Cardinal buoy in sea state 1 with no zoom

b) Cardinal buoy in sea state 4 with no zoom

c) Cardinal buoy in sea state 4 with full zoom

Figure 3.17: Images of the cardinal buoy in different sea states and amounts of zoom.

3.5.3 *Bottlenose Dolphin Photo Identification*

The digiscope was used to take images of dolphins for photo ID on 16 days between the 18th May and 11th September 2006, resulting in images for 22 encounters. In total, seven different individuals were matched to individuals in the SWF catalogue and hence identified. In addition to this, 2 new animals were discovered, both of which were poorly marked, including one individual always accompanied by a calf. Two animals were re-sighted, one of which (number 74) was photographed on four different days. The identified animals have all been part of the SWF catalogue since 2004 or earlier and been seen on several occasions from boat platforms since they were first discovered.

Photo ID images of dolphins using the bay were also available from the SWF, taken with a digital SLR camera with a 300mm lens and taken with the Nikon Coolpix P3 directly, when animals were close enough to the pier or to observers on boats. Five of the animals identified using the digiscope were photographed, as well as two different individuals. The animal photographed with the digiscope four times, was photographed on three other occasions, making it by far the most seen individual in the bay. These results are summarised in Table 3.6 below.

Dolphin ID Number	Year First Seen	Times identified in 2006		
		With digiscope	Within bay	From boats
16	2001	1	0	3
32R	2003	1	2	0
73	2003	1	1	0
74	2003	4	3	5
93S	2001	1	1	1
109	2001	1	1	1
143S	2004	1	0	0

Table 3.6: Details of the number of times the dolphins that were identified with the digiscope were seen in 2006 and the year they were first identified. Times identified 'Within bay' refer to the ID's made without using the digiscope and those 'From boats' refer to the ID's made outside the bay during dedicated photo ID encounters.

However, the ability to take images from land of a good enough quality for photo ID is compromised by the distance of the animals. This is illustrated in Figure 3.18 below. This shows the same dolphin photographed during the same encounter, at approximately the same distance, using the Nikon Coolpix directly and with the digiscope. The dolphin could not have been identified without the increased detail provided by the digiscope photograph.

a) b)

Figure 3.18: The same dolphin, at approximately 150m, photographed with a) the Nikon Coolpix alone and b) the digiscope. The images have not been cropped or resized in any way.

The ability of the digiscope to take usable photo ID images was influenced by the range of the dolphins, their behaviour and the sea conditions. Very good quality images could be taken of dolphins, even without any zoom, up to approximately 250-300m (see Figure 3.19).

Figure 3.19: Dolphin number 74, identified at approximately 275m. The image has been cropped but not zoomed in on.

Dolphins could still be identified up to a distance of approximately 850m, provided the animals were well marked. However, at this distance very small marks could not be distinguished and so less well-marked animals could not be identified (see Figure 3.20). It was also more difficult to track the animals and hence the number of successful and usable images was a lot lower than with closer animals.

Figure 3.20: Dolphins photographed with the digiscope at approximately 850-900m. The top animal is well marked and could be identified (number 109), whereas the bottom animal cannot be identified due to lack of large markings.

Dolphins were more easily photographed when travelling, compared to when feeding or being very active. Travelling dolphins surfaced more regularly and in a more predictable location and could thus be more easily tracked. Feeding animals surface unpredictably both in terms of location and direction and were therefore difficult to actually catch in the frame. This was especially difficult with the digiscope since the field of view was a lot smaller than when using a camera alone. Active animals tended to surface too quickly for photographs to be in focus, even if they were within range (see Figure 3.21).

Figure 3.21: Photograph of an animal during very active behaviours. Although the animal was only approximately 500m away, the speed of the surfacing causes the image to be out of focus.

Sea conditions influenced the quality of the digiscope images in two respects. Firstly, when the sea state was too high, for example a high sea state 2 and above, it was very difficult to take photographs of animals beyond a couple of hundred meters. Due to the small field of view, animals would tend to get hidden behind waves, in addition to being harder to track. In contrast, very flat sea states made it difficult to take photographs that were in focus (as seen in Figure 3.22). This may be due to the need to have the camera pre-focussed before taking the photograph, in order to capture the dolphin image quickly enough. There therefore needs to be a degree of contrast for the camera to have a subject to pre-focus on. A very flat sea, coupled with the small field of view, has very little contrast and thus the images tended to be out of focus. Therefore, the digiscope could be used to take successful bottlenose dolphin photo ID images, but was dependent on several factors.

Figure 3.22: Dolphin photographed in a very flat sea state. Although the animal was only approximately 600m away and travelling slowly, the image could not be focussed.

4. Discussion

Bottlenose dolphins are a common and well-studied species with worldwide distribution. Populations are found both in oceanic offshore waters and in shallow coastal areas. Individual populations show great variability in their behavioural patterns, social groupings and use of their habitat range. This is likely to be dependent on several interacting factors, such as habitat heterogeneity, risk of predators and, most importantly, prey availability and distribution. Nevertheless, it is important to try to understand how and why any individual population uses its resources, in order to successfully manage, sustain and, in some cases, conserve a population.

The results from this study describe in detail how the population of bottlenose dolphins in Cardigan Bay, Wales use an important area within their range. New Quay Bay is a small, shallow and protected bay, situated within an area designated an SAC under the European Habitats directive. It has long been recognised as an area of importance to dolphins and recent increases in boat traffic have prompted the area to be studied in greater detail. This study uses a combination of two similar methodologies to investigate how dolphins use the bay, both over a period of three years (2004-2006) and, in greater detail, during five months of the final study year (2006). In addition, a new method of carrying out photo identification has been tested, by using a digiscope from land to take photographs of animals at far distances.

Bottlenose dolphin presence within the bay was shown to be consistent over the three years, with no significant change in their occurrence. Overall, dolphins were present in an average of 29.6% of all 15-minute intervals, although this ranged between 9.6% and 54.4%, in different months (see Figure 3.1). Monthly variation was shown to be significant, with May consistently having a lower dolphin presence and September consistently having a higher dolphin presence.

Although CCC have only been collecting data in this way in New Quay Bay since 2004, the same systematic surveys have been carried out at New Quay Headland since 1994. These studies have reported a decline in dolphin presence over this time (Pierpoint & Allan, 2004). Between 1994 and 1997, the percentage of two-hour watches that were dolphin positive ranged between 50-56%. Between 1998 and 2000 this dropped to 47% and by 2003 only 36% of two-hour watches were dolphin positive. This is consistent with the percentage of dolphin positive 15-minute intervals seen in New Quay Bay between 2004 and 2006.

This decline could be due to a declining overall population or could simply be due to changing patterns of habitat usage. Although the abundance of bottlenose dolphins in Cardigan Bay had not been studied prior to 2003, since then the population estimate of around 150 animals has in fact been rising to some extent (pers. comm.), suggesting that the animals are utilising other areas of their range at the expense of the New Quay area. This reduction in the use of New Quay Bay may be a temporary or permanent shift to use of other areas with more valuable resources, making the monitoring of dolphins in this area critical.

Monthly variation in dolphin presence has been previously recorded within the whole of Cardigan Bay, with an increase throughout the summer and peaking in September (CCC). The dolphin presence within New Quay bay follows this pattern, although using this method it cannot be determined whether the increase is due to more animals using the bay, as opposed to the same number of animals spending more time in the bay. However, with the modified format of data collection in 2006, this could be clarified further. The weekly sightings rates show a sharp increase at the end of August and start of September (see Figure 3.5) indicating that there were an increased number of dolphins in the bay at this time.

Dolphin distribution is often related to prey distribution and it is likely that this increase in dolphins during the summer months is due to an increase in several fish species at this time. Dolphins in Cardigan Bay have been observed preying on fish with high calorific values, such as bass, mackerel, mullet and herring (Evans *et al*., 2000), and these species move into coastal waters during the summer (Baines *et al*., 2000). Interestingly, local fishermen often report catching mackerel further offshore in July than would be expected, which may explain the slight decrease in dolphin presence within the bay during July (see Figure 3.5).

Another factor that influences dolphin presence within the bay over a smaller time scale is the tidal stage. Dolphins are consistently seen more frequently whilst the tide is ebbing, compared with when it is flooding. This result is highly significant in all months of the year (see Figure 3.2). In addition, there are more dolphins seen during the ebb than during slack water, but dolphin presence is higher during slack water than during the flood (see Figure 3.3).

Tidal movements are known to influence many marine species, either actively or passively. Tidal migrations of fishes and invertebrates are highly variable even between closely related species and between species in different areas (Gibson, 2003) therefore their predators will also show varied responses to the tide. Cetacean species have been shown to move in response to the tide and to take advantage of tidal fronts. Johnston *et al*. (2005) found from line-transect surveys in the open waters of the Bay of Fundy that harbour porpoise (*Phocoena phocoena*) density and relative abundance was significantly higher during the flood tide compared with during the ebb tide. There were 5.3 times more animals within the study area during the flood tide than during the ebb tide (Johnston *et al.*, 2005).

Bottlenose dolphins have also been shown to increase in presence during flood tides. For example, in the Kessock Channel, Moray Firth, bottlenose dolphin presence and abundance was significantly higher in the flood tide. The channel is narrow and relatively deep, and during the flood a front forms where the tidal flow meets the estuarine waters. The dolphins can then take advantage of the resulting aggregation of prey species (Mendes *et al.*, 2002). This substantiates the hypothesis that cetacean movements in response to the tide are associated with prey movements.

Dolphin species have also been seen to increase in presence during the ebb tide, as has been found in this study. A population of marine tucuxi dolphins (*Sotalia guinensis*) that utilise a small bay along the Brazilian coast show a significant increase in numbers during the ebb tide. They use the bay primarily for feeding and are seen to aggregate in those areas of the bay that have high fish abundance (Torres & Beasley, 2003).

An increase in dolphin presence during the ebb tide, as seen in the example above and in the bottlenose dolphins that frequent New Quay Bay, is likely to be the result of a foraging strategy. As the tide falls, the water volume is decreased and the density of fish will be higher. This will therefore make it easier for dolphins to catch prey. Optimal diving theory also favours dolphins feeding in decreasing water volumes, especially if feeding on benthic organisms. This is because as the depth of the prey decreases, the dive times and surface times of the dolphins will also decrease (Kramer, 1988). Therefore, feeding in an ebbing tide reduces the energetic costs of diving. Since New Quay bay is used primarily for feeding, it is to be expected that dolphin presence will increase during the ebb tide.

This would also suggest that there should be an increase in dolphin presence during low water. However, it was found that there was no significant difference between dolphin presence during low water compared with high water (when water volume is at its highest), and that dolphin presence was lower during slack water compared with the ebb. It may be that the lack of water movement during low water is detrimental to catching prey. Nevertheless, the tidal cycle plays an important role in determining when dolphins are present in the bay.

Another factor that could potentially be affecting dolphin presence in the bay is the number of boats. Although this was not analysed in depth, as has been done in a previous study, no clear difference was seen in the number of boats present when dolphins were present to when dolphins were not present. There were a few occasions over the course of the study period when dolphins seemed to react negatively to a boat and times when they actively followed boats, but usually no concrete reactions could be determined. Therefore for the purposes of this study it is assumed that boat presence did not significantly affect dolphin behaviour.

Bottlenose dolphins are highly social and complex mammals that live in dynamic groups. Group size is variable between populations, but inshore coastal populations tend to form smaller groups than offshore populations. The group size of dolphins that use New Quay Bay was found to be relatively small, with a mean group size of 1.8. This was found to be consistent over the three years, although there was also significant monthly variation (see Figure 3.6). Groups were larger in September, as the number of dolphins using the bay also increased. However, overall 52.9% of all groups were single individuals, and only 8.2% of groups consisted of four or more individuals.

This tendency for small groups and single individuals has been increasing over the years. Between 1989 and 1997, opportunistic study found that only 36% of groups consisted of 1 or 2 animals, but this increased to 67% between 1998 and 2000 (Bristow *et al*., 2001). However, the CCC study at New Quay headland found mean group sizes of 2.7 and 3.8 in 2002 and 2003 respectively (Pierpoint & Allan, 2004), suggesting that animals may travel towards New Quay in larger groups and split into smaller groups once in the bay itself.

This is further supported from boat based studies. Mean group size throughout the SAC has been estimated at 5.85, although this ranged from 1 to 42 animals (Lott, 2004). Furthermore, surveys over the whole of Cardigan Bay between 1990 and 1993 found that mean group size of offshore dolphin groups was 12.35, whereas those of inshore groups was 8.52 (Grellier *et al*., 1995), thus supporting the hypothesis that as animals move closer inshore they split into smaller groups.

Nevertheless, the high frequency of single individuals and small groups within New Quay Bay is uncommon, compared with other populations. Coastal bottlenose dolphins off San Diago, California had a mean group size of 19.8 and although this ranged from 2 to 90, solitary animals were never seen (Defran & Weller, 1999). Although this population is found in inshore waters, the shoreline is very exposed, with little protection and a patchy distribution of prey, which is thought to be why these larger groups form. However, even in the more sheltered waters of the Kvarnerić, Northern Adriatic Sea, groups are still larger than that in New Quay Bay, with a mean group size of 7.4 and only 6.1% of sightings were of single individuals (Bearzi *et al*., 1997). Although these studies are over a larger area than New Quay Bay, the high frequency of single animals seen in New Quay Bay is unusual.

The definition of a group used in this study is a common one and takes into account close spatial proximity of animals as well as their behaviour and direction of travel. Other definitions of a group can also be used, which usually vary in the distance apart animals are before being considered a different group. In the Defran & Weller example above, animals were still considered as part of the same group even when 500m apart, which may be influential in the large mean group sizes recorded. If this group definition were to be applied to the dolphins using New Quay Bay, the mean group size would be significantly larger, as there was often more than one animal or small group within the area. However, behavioural observations suggest that these groups do not interact to any great extent and that the group definition used is appropriate.

All observations of group size however are based on the subjective decision of the observer, which can influence the sizes of groups recorded. It can be difficult to determine proximity of animals and coordination of behaviour, especially at far distances. It is also difficult to categorise animals that are in close proximity to one another, but not engaged in the same behaviour, or animals that are not close, but clearly are interacting with each other (Mann, 2000). It is important therefore to be consistent when defining groups, in order to detect any changes within any particular population.

Although groups within New Quay Bay were small, they showed a high degree of fluidity. The mean duration of a group was only 30 minutes, with the majority of groups remaining in the same composition for between 11 and 37 minutes (see Figure 3.8). This indicates that there was frequent mixing of groups and that animals interacted with a large number of individuals, despite the small group sizes. This frequent changing of group composition is observed in other dolphin populations, and gives rise to their fission-fusion societies. Bearzi *et al*. (1997) also found a considerable variety in group composition, with group durations ranging from 3 to 543 minutes. Although mean group duration was found to be 54.4 minutes, the mode was only 15 minutes, indicating a large amount of group fluidity (Bearzi *et al*., 1997). This interaction and group fluidity indicates the highly social nature of the bottlenose dolphin, even though animals within New Quay Bay are relatively solitary.

The solitary nature of dolphins in New Quay Bay may be due to their behaviour within the bay. It was found that feeding was the most predominant behaviour, in all months and over all three years of the study (see Figures 3.9 & 3.10). Inshore dolphin populations are known to feed on non-schooling prey (Barros & Wells, 1998) and hence maximise energy intake by feeding individually or in small groups, aggregated to take advantage of a common resource (Heithaus & Dill, 2002). By modifying the method of data collection in 2006, precise time allocations for each behavioural type could be made, which reduces the fluctuations in results from previous years' study. Nevertheless, feeding was always found to be the most frequent behaviour.

Studying behaviour is inherently difficult in cetaceans, due to the small amount of time animals are visible. Animals are also highly mobile, making it difficult to track them, especially when groups regularly split and reform. When planning a study of behaviour, it is important to decide which animals to follow and how to detail the behaviour recorded in order to reliably record unbiased data (Mann, 1999). The area of New Quay Bay is relatively small, making it easier to follow animals and observe several groups at one time. By reducing the number of behavioural categories data collection was simplified and allowed continuous sampling of several animals. This ensured that the data collected was as reliable and accurate as possible.

Categorising behaviour also needs to be taken into consideration when studying cetaceans and when comparing different populations. Although all decisions about animal behaviour are intrinsically subjective, certain key actions can be used in order to assign a behavioural state, as was done in this study. Nevertheless, behaviour categories vary with different studies, which can lead to results appearing very different. For example, in this study behaviour was classed as ‘feeding’ even when fish weren’t seen, but when animals were displaying typical foraging dives. In other studies, ‘feeding’ is only recorded if fish are actually seen which may lead to this behaviour being underestimated. This is highlighted by a study of New Quay Bay between 1989 and 1997, which found travelling to be the most predominant behaviour followed by feeding, but only classed behaviour as feeding if fish were actually seen (Bristow & Rees, 2001). This would imply that New Quay Bay is not as an important feeding area as has been consistently found in this study.

Given the high proportion of feeding behaviour, New Quay Bay is clearly an important feeding area for Cardigan Bay dolphins. It can be considered a feeding hotspot, since the percentage of feeding behaviour is a lot higher than the usual average percentage of time allocated to feeding. It has been estimated that feeding usually takes up between 15-36% of a bottlenose dolphin’s time budget (Reichelt, 2002), depending on prey availability. For example, bottlenose dolphins in two locations in the coastal waters near Clearwater, Florida spent 28.5% and 24.9% of time foraging (Allen *et al*., 2001), values that are comparable to several other studies.

However, in areas where there is significant prey depletion, animals may have to spend more of their time foraging. For example, in the Adriatic Sea, where food resources are limited, dolphins were shown to spend 82% of their time foraging (Reichelt, 2002). Although dolphins frequenting New Quay Bay spent a high proportion of time feeding, there is no evidence that there is significant prey depletion in the area (Evans *et al*., 2000). Surveys within the SAC have found that the most common behaviour across the whole area was slow/normal swimming, similar to the travelling behaviour recorded in this study, which occurred in 58% of all sightings and that feeding was observed infrequently (Reichelt, 2002). It is therefore more likely that New Quay Bay represents a feeding hotspot within the animals’ larger home range.

Feeding hotspots have been found for other cetacean species and are thought to be related to the heterogeneity of their habitat leading to unequal prey distributions. Marine tucuxi dolphins (*Sotalia guianensis*) in Brazil use two small bays preferentially for feeding (Daura-Jorge *et al*., 2005) whereas bottlenose dolphins in NE Scotland feed primarily in deeper waters, where migrating salmon are thought to aggregate (Hastie *et al*., 2004).

In addition to behaviour classed purely as 'feeding', there was a second category of 'foraging / travelling' (F/T) which occurred at approximately the same percentage as travelling (see Figure 3.9). F/T behaviour suggests that although animals were moving across or through the area, they were still hunting and taking advantage of any prey that was found. Therefore the addition of this behaviour increases the understanding of the importance of New Quay Bay for feeding dolphins.

Animals using New Quay Bay tend to be as individuals or small groups. Therefore it was inappropriate to have a separate behavioural state of socialising, since this did not appear to occur and could not have been classified accurately. Instead, high energy behaviours, such as leaping, surface rushing or physical contact was classified as a 'quick' event, which was then converted into a rate of events per hour (see Table 3.5). This was seen to be relatively low, although was significantly higher in May than in other months. Although the amount of high energy behaviours was not particularly high, actual resting was only observed on a very few occasions and for a very short period of time.

The function of aerial behaviours is not well understood, but there are several theories, which are not mutually exclusive. It could be a form of play behaviour, a method for ectoparasite removal or a method of communication, although these are very difficult to prove (Whitehead, 2002). More substantial evidence however suggests that aerial behaviour acts as a social facilitator or helps with feeding. Group size has been found to increase as high activity behaviours increase, and this has been seen in Cardigan Bay dolphins (Reichelt, 2002; Shane, 2004; Viddi & Lescrauwaet, 2005). Within New Quay Bay, overall mean group size was 1.8; however mean group size of dolphins during quick behaviours was 2.2, which was significantly larger. Although this suggests that aerial behaviours have a social function, it may simply be as a result of more animals increasing the probability that a quick behaviour will occur.

Nevertheless, when groups of animals engaged in high energy behaviours, most of the animals in the group usually displayed this behaviour, supporting the hypothesis that they have a social function.

It has also been suggested that aerial behaviours are part of a foraging strategy to aid in prey capture. This could be by scaring or stunning fish or by herding and trapping fish (Whitehead, 2002). This is supported by a study of bottlenose dolphins in Costa Rica, that also hunts in small groups and which were found to increase aerial behaviours during feeding and not when in larger groups (Acevedo-Gutierrez, 1999). However, there was no evidence that fish intake was actually increased as a result of this aerial behaviour. In this study, although the majority of quick behaviours were associated with feeding behaviour, this was not found to be significant (see Figure 3.11). Nevertheless, it cannot be concluded that the quick behaviours did not aid in prey capture, since actual prey capture was rarely observed, and thus the function of quick behaviours within New Quay Bay could not be fully resolved.

New Quay Bay is used by dolphins predominantly for feeding, however not all areas of the bay were used with the same frequency. The most used region of the bay was around the 5-metre depth contour, with little use of shallower waters or the further offshore, deeper waters (see Figure 3.14). However this does not necessarily represent a preference for water of this depth, since the depth will change significantly with the tidal swing. This pattern can be better resolved by breaking down the habitat use of the bay by behavioural state.

Feeding was predominantly seen in two distinct areas, one off New Quay headland and a larger area off Llanina Reef. In contrast, both travelling behaviours (direct travelling and foraging/travelling) were spread across an area from New Quay head to Llanina Reef. Animals would typically be first sighted coming around New Quay head, moving across the bay towards Llanina Reef, where they would then engage in feeding behaviour. Animals would then usually leave the bay by this same route, travelling across the bay and disappearing around New Quay head. The region along the 5-metre depth contour represents the most direct, and hence most energetically favourable, route from New Quay head to Llanina Reef and this is likely to explain its high usage.

The two feeding areas have been recognised as important foraging spots in previous studies, although the importance of each appears to be changing. Between around 1995 and 1997, 44-56% of feeding behaviour occurred around New Quay head, whereas only 12-13% was around Llanina Reef. In contrast, between 1998 and 2000, feeding around the reef had increased to 36-65% of the time and decreased around the headland to 20-22% of the time (Bristow *et al.*, 2001). However, the actual definitions of these areas were not clear and the large numbers of observers used makes it difficult to determine whether this is a true change in feeding patterns.

Nevertheless, both the headland and the reef are clearly longstanding foraging areas for dolphins using New Quay Bay. Headlands and reefs have been found to be good foraging hotspots for other populations of cetaceans. For example, Indo-Pacific humpback dolphins (*Sousa chinensis*) in South Africa showed a feeding preference for shallow, rocky reefs within their bay habitat (Karczmarski *et al.*, 2000). It is known that the reefs act as nursery areas for many fish species, making it an area of high prey abundance, and it is likely that this is also the case with Llanina reef in New Quay Bay.

Headlands are also areas of high prey abundance and are thus used preferentially as feeding areas by cetaceans. Harbour porpoises (*Phocoena phocoena*) in the Bay of Fundy have been shown to forage primarily in areas around headlands (Johnston *et al.*, 2005). It is thought that headland and reef areas concentrate cetacean prey species because of an increase in primary production. Although the effects on primary production of large scale oceanographic features, such as upwellings and shelf breaks have been studied extensively, smaller ocean processes are not well understood.

However, studies have shown that headlands and reefs, which act as protrusions into the tidal flow, create areas of high turbulence. This mixes the water, which increases concentrations of nutrients and hence primary production escalates.

This has been demonstrated in the Lambert Channel, British Colombia at a shingle spit approximately 100 metres long. A plume of turbulent water forms at the end of this spit, which has higher nutrient concentrations than in the surrounding area (St. John & Pond, 1992). It would be expected that primary production would thus be higher around the spit, although this was not measured in the study. In the same manner, it is likely that New Quay headland and, to an even greater extent, the submerged Llanina reef cause increased mixing of the surrounding water, leading to an increase in primary production and hence are valuable foraging areas for dolphins.

The area around New Quay headland has recently been affected by an anthropogenic source, which may influence its potential as a feeding area for dolphins. A fish factory that processes whelks (*Buccinum undatum*) is situated on New Quay headland and is licensed to dump waste matter directly into the bay. The amount of discharged clean, crushed shell waste increased from 750 tonnes per year in 1996 to 2000 tonnes per year in 2003, and has continued at this rate until the present day (pers. comm.).

Initially this shell waste was contained within a 50 metre radius of the discharge point, and hence was not thought to be having any significant effect (Pierpoint & Allen, 2004). However, recently shell waste has been washed up on beaches a few hundred metres away from the discharge point (pers. obs.), suggesting that they are having a greater effect than first appeared. The shells may be affecting the seabed and benthic organisms, which in turn will affect the dolphins that feed on these organisms. If the headland is indeed being used less as a foraging area, as suggested by Bristow *et al*. (2001), this may be the cause of that reduction.

However, it is not just shell waste that has been discharged from the factory, but organic matter as well. Whelk meat was discharged at a rate of 100 kilograms a day, until around 2002, when the practise was discontinued. Although officially whelk meat is no longer discharged, it is likely that there is still some organic matter being dumped into the area, since large groups of seagulls flock to the area to feed during discharge (pers. obs.). This could subsequently draw dolphins to the area to feed on fish that are scavenging on the whelk. Therefore, New Quay headland may continue to be an important feeding area for dolphins, due to this increase in prey.

The results discussed above describe how dolphins use New Quay Bay between May and September only. Unfortunately, due to weather conditions and lack of observers, systematic watches could not be carried out over the winter months. However, opportunistic sightings suggest that dolphins are seen much less between late November and March (pers. comm.). Although this could be a result of low sampling effort, results from acoustic T-POD data show that dolphins do not frequent the area as much during the winter. Nevertheless, when dolphins are present in the bay during the winter, they still appear to be predominantly feeding (Bond, 2006, unpub.).

Sea surfaces temperatures show large seasonal variation in shallow coastal waters, which influences dolphin distribution both indirectly through changes in prey distribution and directly due to thermoregulatory challenges (Bräger *et al*., 2003). New Quay Bay is very shallow and enclosed by land, and thus shows a large seasonal temperature swing. Given the importance of the bay as a feeding hotspot, it is likely that it is not frequented as much during the winter due to a lack of prey species. This may also be coupled with animals moving offshore into relatively warmer waters, to reduce the energetic requirements of thermoregulation.

Given the shallow, protected nature of New Quay Bay, it may be expected that it acts as a nursery area for dolphins with calves. In this study, the presence of calves was recorded, but they were seen too infrequently to analyse in detail. In total, calves were seen on nine different days, with none being seen in May or June, and no more than two calves ever seen at one time. Although calves have been seen in Cardigan Bay in earlier months (Grellier *et al*., 1995), the majority of sightings across the SAC have been in the warmer months (Lott, 2004). This implies that the warmer months are the peak months for giving birth in this area, possibly due to the increased water temperature during this time.

It has been estimated that an average of five calves are produced in Cardigan Bay per year (Grellier *et al*., 1995). If this is the case, the use of New Quay Bay by at least two different calves in one season shows that it is an important area for calves. It is possible that New Quay Bay is beneficial for calves due to its shallow depth and sheltered nature. This means it would be easier for adults to train hunting methods and for calves to catch prey. The enclosed area may also offer calves protection from aggressive male dolphins or potential predators.

New Quay Bay has been shown to be a key foraging area for bottlenose dolphins and a significant region for rearing calves. Nevertheless, the bay is clearly only a small part of the animals' home range, as identified individuals have been seen at both extremes of Cardigan Bay, a distance of approximately 103 kilometres (Grellier *et al*., 1995). However, it has not been known whether New Quay Bay is favoured by some individuals more than others or is equally significant for all animals within the population. Since it is not known how many different dolphins use the bay, its full importance cannot be resolved. The least invasive method of determining which individuals are most frequently seen within the bay is through photo identification.

Photo identification is most commonly done from a boat platform and involves approaching and following animals. As this is deemed as harassment, it is not permitted within New Quay Bay. Previously, in order for photo ID to be carried out successfully from land, animals have had to be within about 100 metres of the platform. However, the trial of the digiscope system in this study has shown that usable photo ID images can be taken of animals that are up to about 850 metres away. Although this system is still in the initial trial stage, its potential for carrying out photo ID from land is evident.

The system was tested on land and sea targets, before being used to take photographs of dolphins. This showed that the system could produce images of a very high resolution at far distances, even of fine details. This was especially true of images of a still target on land. Nevertheless, small moving buoys and bottlenose dolphins could also be captured in focus. As with all photo ID systems, there were limitations, such as the range, behaviour and markings of the animals and the sea conditions, but the digiscope was still successfully used to identify bottlenose dolphins at long range.

Over the course of the study in 2006, one individual was seen in the bay much more frequently than any others. This suggests that that individual shows preferential use of New Quay Bay, compared with other animals, although concrete conclusions cannot be drawn due to the small sample size. This individual has also been seen five other times from boat platforms, and is one of the most frequently sighted animals (pers. comm.). It has been seen several kilometres north and south of New Quay Bay, indicating that although it frequents New Quay Bay, its home range is much larger. Its high sighting frequency, both from boats and within busy New Quay Bay, may be as a result of a tolerance to boats and human disturbance. Due to concerns over the effects of increasing boat traffic on dolphins using the bay, it is important to follow changes in individual usage, as well as overall utilisation. Using the digiscope, it will be possible to build up a sub-catalogue of individuals within the bay, to observe whether certain individuals use the bay more than others and whether this persists over time.

This study has shown that a digiscope system is a successful and useful tool for photo identification. It is not only bottlenose dolphin populations that could benefit from this new methodology. Any cetacean population that can be seen within about 1 kilometre of land could potentially be photo identified, possibly at even further distances for large whales. Indeed, it is probable that it would be even more successful when used for photographing larger, slower moving whales, since they would be easier to track and images would be more likely to be in focus. There is also a large potential for using the digiscope for photo identification of seals, when they are on land. This is usually very challenging because of lack of accessibility to the animals, or difficulty in approaching them. However, using the digiscope, it was possible to take images of a seal mother and pup that could be used for photo ID, at a distance of at least 200m with no disturbance to the animals.

Further Studies

This study has examined several aspects of how bottlenose dolphin use New Quay Bay, including presence, behaviour, habitat use and individual usage. Although this has helped explain why dolphins frequent the bay and what they use the bay for, future work is recommended to ensure that dolphin usage of New Quay Bay is monitored and understood in greater detail. New Quay Bay is clearly an important area for the Cardigan Bay dolphin population, especially as it is a foraging hotspot, and this monitoring is vital to ensure that it remains a valuable resource for the dolphins.

The modified format of data collection in 2006 added precision and additional information to the data and, if possible, should be continued. Long term monitoring at this level of detail will allow trends to be picked up more readily and on a smaller scale. More winter observations would also be useful to determine the year round importance of the bay. It would also be possible to examine many of the factors in this study in greater detail, to further explain why dolphins use New Quay Bay.

Since a strong tidal effect was discovered in this study, it would be useful to fully resolve the reason for this. The strength of the relationship between tidal state and dolphin presence may be different in spring, mid and neap tides, as the volume of water movement changes according to the type of tide. Tidal state may also affect dolphin behaviour or length of time dolphins remained in the bay. This could be more easily analysed if all animals within the bay were classed as one group. Combining all animals in the bay into one group would also give an indication of the total number of animals the bay could support at any one time.

The bay has been shown to be predominantly used for feeding, but it is still not clear what the animals are feeding on. Although there are several probable prey species, there are very few occasions where prey capture is actually observed. If there is any potential fish depletion in the area, it will be important to know which species are fundamental dolphin prey species. There is little opportunity for stomach contents analysis in this area, and this would not necessarily give an accurate indication of what healthy animals are feeding on. Given the shallow and accessible nature of New Quay Bay, it would be possible to carry out underwater filming or diving surveys to directly examine potential dolphin prey species in different areas of the bay and at different times of year.

The digiscope could also be used to examine individual usage of the bay in greater detail. Individual reactions to boats could be recorded as well as individual behavioural patterns. If used more frequently, the digiscope could also show whether individuals use the bay for periods of days, weeks, months or years, as well as building up a sub-catalogue of all the different individuals that are seen.

5. Conclusions

Bottlenose dolphins have been seen in New Quay Bay since at least the 1920's and it has long been recognised as a significant area within their broader home range. Increasing boat traffic in and around New Quay harbour have given rise to concerns over the impact this may have on the dolphins, and has prompted the area to be studied in greater depth. This study has investigated how and why bottlenose dolphins use the bay, both on a temporal and a spatial scale, leading to the following principal conclusions.

1) Although dolphin presence in the bay may have decreased within the last two decades, it was found to be consistent over the three years of the study. There was a consistent increase in dolphin presence during the summer, peaking in September, due to an increase in numbers of dolphins frequenting the bay. Dolphin presence in all months was significantly higher in the ebb stage of the tide, compared with either the flood or slack stages.
2) Dolphin groups were found to be small, with the majority of sightings being of single individuals. Group size also increased during the summer, although groups of four or more individuals were rarely seen, regardless of the time of year. Although groups were small, they were also highly fluid, indicating that this population has a typical fission-fusion society.
3) Dolphins used the bay predominantly for feeding, regardless of the month. The high percentage of feeding behaviour suggests that the bay acts as a feeding hotspot for bottlenose dolphins.
4) Not all areas of the bay were used with the same frequency. Two regions were used preferentially for feeding; one at New Quay headland and the other at the end of a submerged reef, indicating that prey density is highest in these areas.
5) A digiscope system can be used successfully to take bottlenose dolphin photo identification images of animals at far distances.

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Appendix 1: CCC Recording Forms

Effort Form

Name :　　　　Location :　　　　Date :

MAP	15 Min INT.	WEATHER			CETACEANS	BOAT ENCOUNTER (Closest boat to cetaceans at the start of 15 min)					NOTES
	Start Time	General	Wind Direction	Sea State	Species Seen	Type	Range / Distance	Total no. of boats within 300m	Boat Behaviour	Cetacean Behaviour	
A											
B											
C											
D											
E											
F											
G											
H											

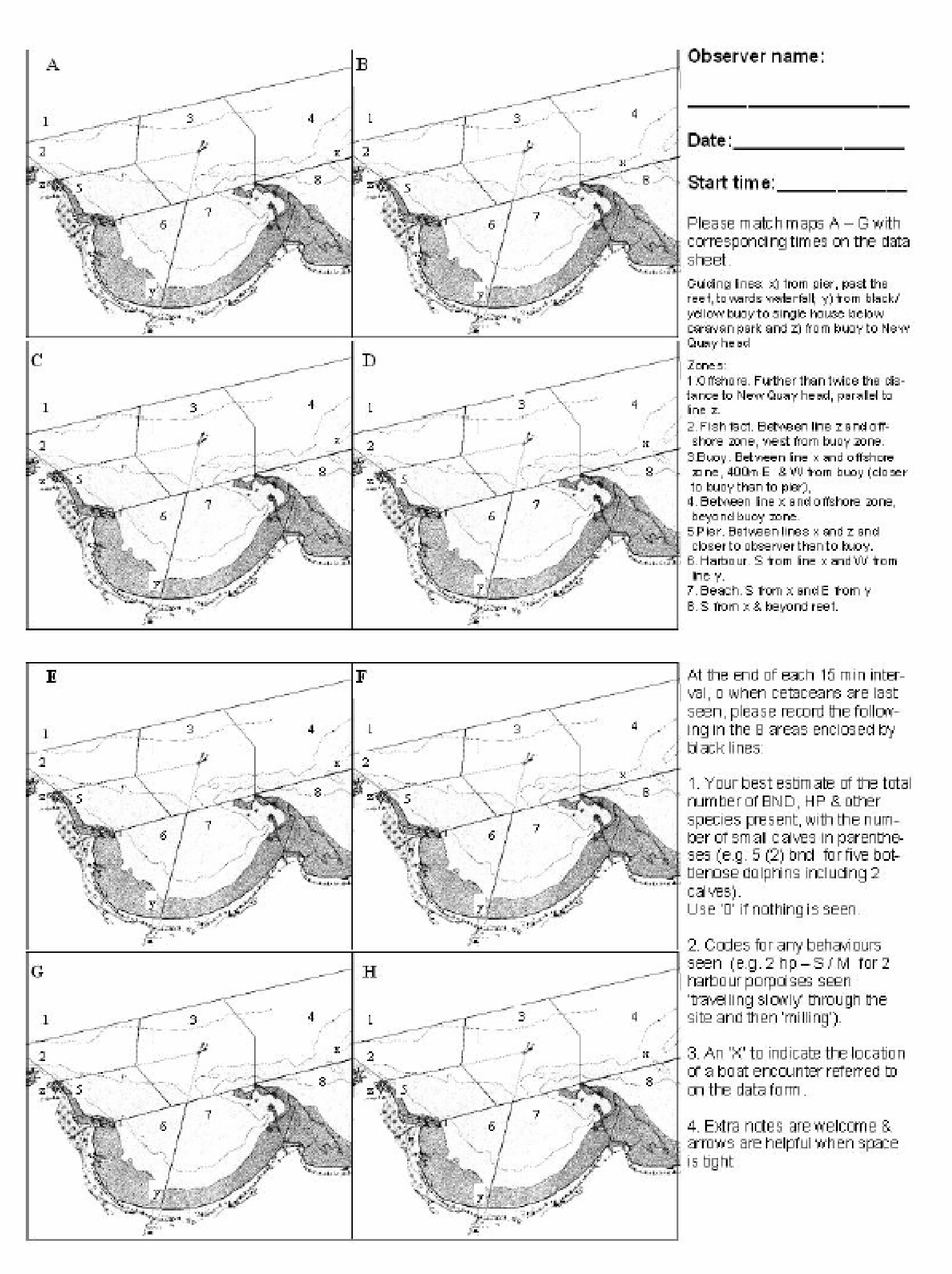
The Number of Different Boats Seen in 2 Hours

(If none seen – '0' in Total column please; if no count made, leave blank)

BOAT TYPE		LOG	TOTAL
MB	Recreational motor boat, cabin cruisers, dinghies with outboard		
SB / SS	Racing type speedboat or RIB / Water-skier		
SAIL	Any boat under sail including windsurfer		
CF	Commercial fishing boat		

BOAT TYPE		LOG	TOTAL
VPB	Visitor Passenger Boat		
C	Canoe		
J	Jetski, personal water craft		
R	Cetacean Research Boat (please record boats name)		

Sightings Form



Observer name: ____________________

Date: ______________

Start time: ___________

Please match maps A – G with corresponding times on the data sheet.

Guiding lines: x) from pier, past the reef, towards waterfall, y) from black/ yellow buoy to single house below caravan park and z) from buoy to New Quay head

Zones:
1. Offshore. Further than twice the distance to New Quay head, parallel to line z.
2. Fish fact. Between line z and offshore zone, west from buoy zone.
3. Buoy. Between line x and offshore zone, 400m E & W from buoy (closer to buoy than to pier),
4. Between line x and offshore zone, beyond buoy zone.
5. Pier. Between lines x and z and closer to observer than to buoy.
6. Harbour. S from line x and W from line y.
7. Beach. S from x and E from y
8. S from x & beyond reef.

At the end of each 15 min interval, o when cetaceans are last seen, please record the following in the 8 areas enclosed by black lines:

1. Your best estimate of the total number of BND, HP & other species present, with the number of small calves in parentheses (e.g. 5 (2) bnd for five bottlenose dolphins including 2 calves).
Use '0' if nothing is seen.

2. Codes for any behaviours seen (e.g. 2 hp – S / M for 2 harbour porpoises seen 'travelling slowly' through the site and then 'milling').

3. An 'X' to indicate the location of a boat encounter referred to on the data form.

4. Extra notes are welcome & arrows are helpful when space is tight.