Diurnal behaviour of bottlenose dolphins (*Tursiops truncatus*) in the Cardigan Bay, West Wales

A dissertation presented in partial fulfillment of the requirements for the degree of Magister in Scientia in Ecology of the University of Wales

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Abstract

The diurnal behaviour of common bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, West Wales, was investigated by boat based visual surveys from 2001-2007. Data were collected during 435 survey days resulting in 1,469 sightings of bottlenose dolphins exhibiting particular behavioural states. During the study period, traveling and feeding comprised over 85% of their diurnal budget, followed by 'others,' resting and socialising. No difference was found in the budgets of groups with calves present compared to those without calves. Single individuals spent more time feeding while groups greater than 11 individuals spent more time traveling and socialising, and more time was spent feeding during the end of the study season rather than the beginning.

Kernel ranges were estimated using the Animal Movement extension in ArcView 3.3, so as to identify their home range (95% kernel range) and core areas (50% kernel range) within Cardigan Bay. The dolphins used the space within their home range non-uniformly, with core areas varying with behaviours, time of the season, and presence of calves. There was a significant overlap of core areas with all behaviours and the presence of calves. These findings provide important information concerning the spatial use of Cardigan Bay by the resident population of bottlenose dolphins.

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1 Introduction

1.1 Behavioural Budgets

The behavioural budget of a species is defined as the proportion of time an animal spends performing an array of behavioural or activity states. It's a balance of costs and benefits of expending energy (Boness, 1984). An animal's budget can be daily, seasonal, or annual and activities can include feeding, socialising, traveling, mating, and resting. Behavioural states will be specific to each population and the habitat in which it lives. Diurnal, or daily, behavioural budgets assesses how much time is spent in each behavioural state per day. Many animals show daily and seasonal patterns in their behaviour (Brager, 1993) resulting from variations in prey distributions, mating opportunities, parental care, and/or the effects of human disturbances e.g. there tends to be a higher number of human interactions in warmer months. Factors related to reproduction, feeding and avoidance of predators appear to be the strongest environmental factors that affect most mammals (Mann *et al*., 2000).

An increase in time spent in one behaviour will decrease the amount of time devoted to other activities that may nonetheless be crucial to an animal's survival, such as resting or caring for young, thus, highlighting the importance of determining activity budgets and the main factors affecting them. In India, it was found that urbanization played a significant role in the activity budgets of bonnet monkeys, *Macaca radiata,* by increasing the time they spent in locomotion, possibly due to human avoidance, loss of resources, and/or destruction of critical habitats (Singh and Vinathe, 1990). From studies of the activity budgets of African elephants, *Loxodonta africana africana*, in Atlanta, Georgia, it was found that they suffered many physiological problems by being chained together at night, but benefited when released by increasing social behaviour and use of available space (Brockett *et al*., 1999) Determining the behavioural budget of a species and the variables affecting it will enable managers to preserve critical habitats essential to specific behaviours, acknowledging any limiting factors affecting the species activities, and to make recommendations to reduce disturbance in order to maintain the species' viability.

Many problems exist when studying marine mammals because they spend the majority of their lives underwater, and only a small portion of the animal is visible during surfacing. Integrated data analysis can provide the best insight to a marine mammal's ecology, such as a combination of underwater visual surveys, photo-identification data, live-capture projects, radio tagging, and acoustic data collection (Bearzi *et al*., 1999). The behavioural budgets of killer whales, *Orcinus orca*, were found to be influenced by prey availability and boat traffic. As prey availability and boat traffic increased, foraging and travel times increased, respectively (Ugarte, 2001), while habitat played a role in the budgets of grey seals, *Halichoerus grypus,* by increasing time in locomotion or alertness when living closer to water (Anderson and Harwood, 1985). Although these animals may be difficult to study, a determination of behavioural budgets has increased our understanding of their movements, feeding, social and mating behaviours which can be useful in managing their habitats and reducing human impacts.

Studying the activity budgets of bottlenose dolphin populations can be vital because many populations live in coastal waters and are increasingly disturbed by human presence. Bottlenose dolphins are top predators and therefore good indicators of the health and vitality of their environment. Bottlenose dolphins are known to show a similar array of behaviours as other dolphin species, including foraging/feeding, socialising, and traveling in relation to environmental cues such as time of day (Saayman *et al*., 1973), prey availability (Bearzi *et al*., 1999), season (Bearzi *et al*., 1999) and tidal cycles (Irvine *et al*., 1981). Understanding how environmental variables affect specific populations will help in designing and implementing conservation measures.

Photoperiodic variables can influence the behavioural budget of bottlenose dolphins for reasons such as prey movements or tidal cycles. In several studies of bottlenose dolphin populations, there is a trend towards increased feeding in the morning and again later around dusk, increased socialising in the afternoon, and increased traveling in the afternoon and evening (Saayman *et al*., 1973; Bräger, 1993; Hansen and Defran, 1993; Bearzi *et al*., 1999).

Prey availability, distribution and movements can all affect a dolphin's feeding budget on a daily or seasonal basis. An abundance of fish may reduce travel time and increase feeding time. Bearzi *et al*. (1999) found extreme variability in bottlenose dolphin behaviour particularly with traveling and feeding behaviours, and they associated this with prey availability in the Adriatic Sea. Conversely, in Southern California, Hansen and Defran (1993) found bottlenose dolphin behavioural budgets were relatively constant throughout the year due to constant prey availability. Prey shifts in the winter may also occur requiring more time searching for other prey items such as crustaceans and cephalopods, rather than fish (Bräger, 1993).

Seasonal shifts in activities, such as courting or dominance displays, mating, and calving may shift the budget during the breeding season (Bearzi *et al*., 1999). Peaks in bottlenose dolphin neonate strandings in the fall and spring, in South Carolina, USA, suggest a bimodal reproductive cycle (McFee *et al*., 2006), while in Cardigan Bay, West Wales, there is an extended calving season from April through September (Evans *et al*., 2003). During these times, certain behaviours may become a priority over others.

Daily tidal cycles affect movements of bottlenose dolphins (Lamb, 2004), both directly and indirectly. Swimming with the flow of the tide requires less energy and would be beneficial for animals. Swimming with the currents rather than against them was recorded in Sarasota Bay, Florida, USA (Irvine *et al*., 1981), the Shannon Estuary, South West Ireland (Berrow *et al*., 1996), and in Cardigan Bay, West Wales; traveling when the tidal flow was least strong, around slack tide (Lewis and Evans, 1993; Gregory and Rowden, 2001). Several studies report that a number of fish species move with the tides in search for food (Gibson, 1978), thus suggesting that dolphin movements coincide with prey movements (Würsig and Würsig, 1979; Berrow *et al*., 1996).

1.2 Home range and core areas

Cetaceans, as all mammals, use an area defined by Burt (1943) as a home range for their 'normal activities such as foraging, mating and caring for young'. Animals will likely have many home ranges throughout their lifetime, especially migratory species, which will have a summer and winter home range. The size of the home range will vary with sex, age, season and the presence of calves (Burt, 1943). Animals generally use space disproportionately within the boundaries of their home ranges. These areas can be identified as 'core areas' and may be safer from predators or contain a dependable food source there (Samuel *et al*., 1985). Identifying them as core areas may help in reducing negative interactions during times when animals are more vulnerable (Lusseau and Higham, 2004). The 'utilization distribution' (UD) concept describes the intensity that an animal uses its home range and with what probability of occurrence an animal is at a particular location (Silverman, 1986). Understanding the extent of an animal's home range and the identification of core areas will provide further information on the ecology and distribution of that species.

Defining home ranges for cetaceans in the marine environment is difficult due to their unpredictable movements. Identifying areas with high cetacean densities and gaining behaviour information will help in defining home ranges and core areas. Analysis of behavioural observation within the home range will provide a more thorough understanding of core areas and the ecological function those areas provide. Bathymetric variables, such as water depth and seabed gradient, as well as and cetacean distribution, have been linked in several studies (Parra *et al*., 2006; Hansen and Defran, 1993). Substrate characteristics will vary among populations and should be investigated on a site-specific basis (Hastie *et al*., 2004).

Long-term residency may be defined as a relatively permanent home range or an area that is frequented over many years (Wells and Scott, 1999). Home ranges of bottlenose dolphins have been extensively studied because of their long-term residency in certain areas as well as topography preferences for specific behaviours. Resident populations have been identified in a variety of locations, such as Massachusetts, Western North Atlantic (Wiley *et al*., 1994); off the Southern California coast (Hansen, 1990); the West coast of Florida (Irvine *et al*., 1981); the Shannon Estuary, South West Ireland (Berrow *et al*., 1996; Ingram, 2000); the Moray Firth, Scotland (Wilson *et al*., 1997); and Cardigan Bay, West Wales (Baines et al., 2000; Ceredigion County Council, 2000). Most activities of the resident population are concentrated within the home ranges, with occasional movement between ranges (Wells and Scott, 1999).

Seasonal shifts of home ranges are common and may be correlated with water temperature changes, either through the change in dolphin's thermal requirements, or a shift in prey or predator distributions (Irvine *et al*., 1981). Irvine *et al*. (1981) found shallow estuarine waters were frequented by bottlenose dolphins during the summer, and coastal waters and passes between barrier islands during the winter, in Sarasota Bay, Florida, USA. At other times, home ranges may form part of a seasonal home range for migratory populations, such as the population in the Northeastern US, which exhibits a north to south seasonal migration (Kenny, 1990) related to temperature changes.

Defining home ranges for animal populations will provide vital information such as distribution, prey distribution and habitat preference on the ecology of that species such as distribution, prey distribution and habitat preference. Using behavioural data and substrate characteristics will help to define site preferences for specific behaviours. Determining home ranges and specifically core areas for resident populations will aid the protection and conservation of both the population and the habitats in which it lives.

1.3 The Common Bottlenose Dolphin

Common bottlenose dolphins are possibly one of the best-known cetacean species in the world for their use in many marine parks and research programs. The common bottlenose dolphin belongs to the family Delphinidae (true dolphins), within the Suborder Odontoceti (toothed whales) and Order Cetacea (Wells and Scott, 1999). Molecular techniques have recently provided evidence that there are two genetically distinct species, *Tursiops truncatus*- the common bottlenose dolphin (referred to here as the bottlenose dolphin) and *Tursiops aduncus*- the Indo-Pacific bottlenose dolphin (Wang *et al*., 1999).

1.3.1 Morphology

Bottlenose dolphins are slate gray in colour on their back and flanks with a white/cream underside. The dorsal fin is located centrally, some with distinguishing nicks and scars. Other distinguishing marks, such as tooth marks or varying colourations can make individuals distinguishable. The rostrum is short with an obvious step to the melon. Dolphins in colder regions have shorter, stockier snouts while those in warmer waters have long, slender beaks (Reichelt, 2002). They are medium sized and range from less than 2m to 3.8m depending on their geographic location (Wells and Scott, 2002); generally larger animals are found in cooler waters. Great variety can be found between populations in body size, colouration, and behaviour.

1.3.2 Life History

The life expectancy has been estimated, by tooth analysis, to exceed 50 years in females and up to 45 years in males (Hohn *et al*., 1989). Age at sexual maturity varies between sex and region. Males reach sexual maturity between ten and thirteen years of age, at about a length of 2.45-2.6 metres, and females between five and twelve years of age, at a length of 2.2-2.35 metres. Females are thought to breed throughout their lifetime starting in their teens when they reach sexual maturity. Seasonal calving has been reported with peaks in the warmer months, but may occur throughout the year. The gestation period lasts about 12 months and a single offspring is born, while twins are very rare. Calves stay with their mother for several years learning survival techniques such as foraging. Weaning is gradual and is often linked to the calving interval, which is generally 3 to 6 years (Wells and Scott, 2002).

The bottlenose dolphin uses echolocation to locate fish hiding within the substrate. The range of echolocation frequencies used for locating prey is 40-130kHz. Feeding behaviours are diverse, consisting of individual and co-operative group foraging, pursuing solitary or schools of prey throughout the water column, hunting prey hiding within the substrate or chasing prey at the water's surface (Connor *et al*., 2000), and have been known to be opportunistic feeders in times when prey availability is low (Bearzi *et al*., 1999). Various fish species, such as salmon, sea bass, mackerel, pipefish, and garfish (Baines *et al*., 2000), as well as squid and other crustaceans, have been seen in their diets.

1.3.3 Social Structure

Bottlenose dolphins live in a fission/fusion society (Goodall, 1986) in which individuals move from small groups that continually change in composition and behaviour (Connor *et al*., 2000). The size of the group may depend on its habitat and sex. The social structure varies between multiple males and female groups to male-male alliances, females and calves, and mother-calf pairs. Male-male alliances are strong and stable, and females may be highly social or solitary, associating with related and unrelated females. Females should prefer larger group sizes with small calves (0-3 months) whether for protection and/or help in foraging (Mann *et al*., 2000). Groups of dolphins often include less than 20 individuals in the inshore areas, and sometimes hundreds offshore. Larger groups are thought to provide protection from predators in the open sea and foraging benefits in the pelagic environment (Speakman *et al*., 2006).

1.3.4 Distribution and abundance

Bottlenose dolphins have a worldwide distribution in tropical and temperate waters, occupying a variety of habitats such as harbours, bays, lagoons, rivers and estuaries. The species' range appears to be limited by temperature, either directly or indirectly through distribution of prey. This species is the most widespread of all dolphins and seems to occur in abundance throughout its distribution (Wells and Scott, 1999). In the North

Atlantic, bottlenose dolphins are found as far north as New England in the west and the Faroe Islands in the east.

Populations live both offshore and inshore. Little is known about the distribution patterns of the pelagic populations. The inshore, or coastal, populations receive the most attention because of their accessibility and local home ranges, such as in Galveston Bay, Texas (Brager, 1993), the Shannon Estuary, South West Ireland (Berrow *et al*., 1996), the Moray Firth, Scotland (Wilson *et al*. 1997) and Cardigan Bay, West Wales (Lewis and Evans, 1993; Baines *et al*., 2000, Ugarte and Evans, 2006), making them one of the most studied of cetaceans (Connor *et al*., 2000). The inshore ecotype shows an array of movement patterns from year-round residents, short-tem residents to transients (Speakman *et al*., 2006), and appear to occur in limited, overlapping home ranges, whereas, the offshore populations have more extended ranges (Arnold, 1993; Reichelt, 2002).

In recent years, Cardigan Bay, West Wales, has become an important area for many studies since there are important long-term concentrations of the species there. It is thought that the population is comprised of both residents and transient individuals (Grellier *et al*., 1995). The population is extremely fluid and thought to be an “open” population (Grellier *et al*., 1995), where immigration and emigration maybe of greater importance to the dynamics of the population (Gregory and Hartley, 2001), whereas, the population in the Moray Firth is believed to be a “closed” population (Wilson *et al*., 1997) where immigration and emigration do not change the dynamics of the population.

The population of bottlenose dolphins in Cardigan Bay was chosen for this study because of their protection and accessibility. Currently the status of this population is unknown. To date, studies have found that time of day, tidal cycle (Gregory and Rowden, 2001) and vessel presence (Lamb, 2004) all affect the behaviours and movements of the dolphins in Cardigan Bay. This study hopes to add to this information on the activity budgets and home ranges of the dolphins in Cardigan Bay.

1.4 Aims and Objectives

The aim of this study was to determine the diurnal behavioural budget of the bottlenose dolphins in Cardigan Bay, West Wales with special attention paid to the Cardigan Bay Special Area of Conservation (CBSAC). This was done using boat based visual surveys combining data collected in 2007 with data collected from 2001-2006. The budgets were compared between years and seasons, and possible variations due to group size and presence of calves were investigated. Home ranges and core areas for specific behaviours were also investigated and analysed to understand if patterns were observed between bottlenose dolphin distribution and specific behaviours, calf presence or seasonality. This study was conducted in Cardigan Bay because of the protected, resident population of bottlenose dolphins within the bay. With increasing knowledge of the bottlenose dolphins and the factors affecting their distribution and behaviours, this population can be continually monitored to help maintain its conservation status.

The main objectives of this study were to:

- Determine the diurnal behavioural budget of the population of bottlenose dolphins in Cardigan Bay.
- Compare budgets annually from 2001-2007 and identify differences due to season, group size, and the presence of calves.
- Identify home ranges and specifically core areas for specific behaviours, and then determine if they shift within 2001-2007.
- Compare differences in home range utilizations according to behaviour due to calf presence and seasonality.

2 Study Area

2.1 Cardigan Bay

2.1.1 Geography

Cardigan Bay is situated on the west coast of Wales, forming the northeastern end of the north Celtic Sea Trough (Dobson and Whittington, 1987), bounded by the Irish Sea to the north and the Celtic Sea to the south. It is the largest bay in the British Isles, encompassing an area of ca. 5500 km^2 (Baines *et al.*, 2000). Cardigan Bay measures over 100 km from St. David's Head at the southernmost point to the Llyn Peninsula and Bardsey Island at the northernmost end.

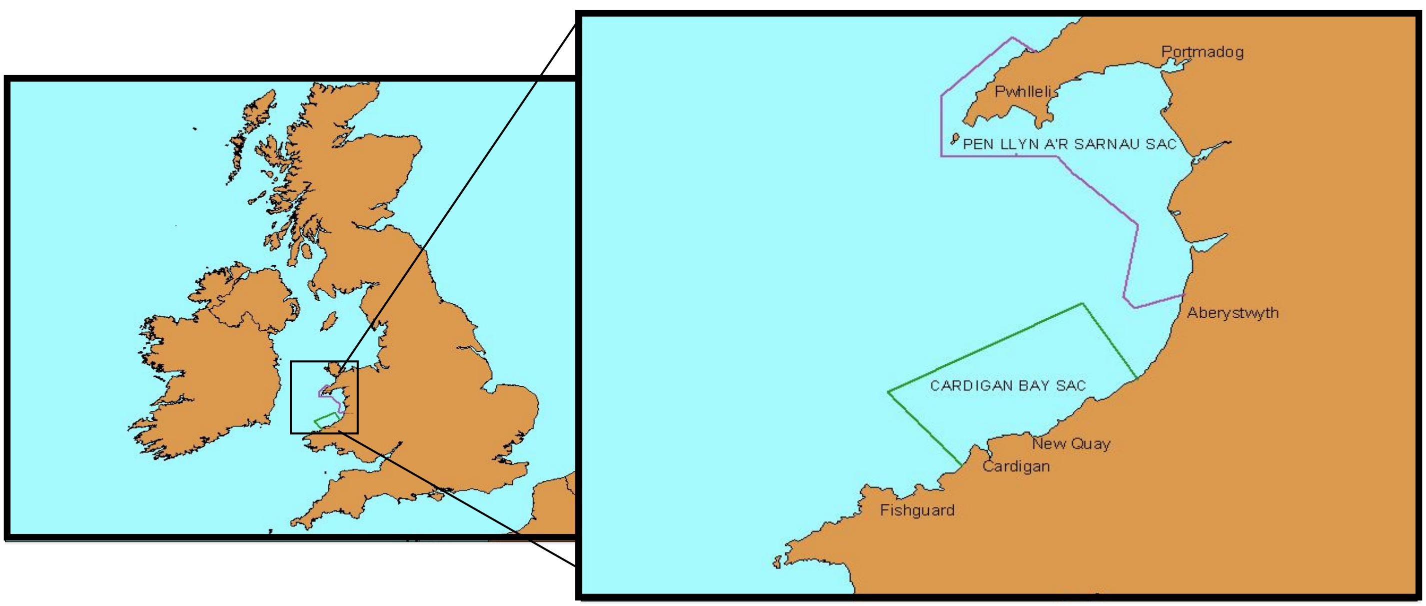


Figure 2.1 Map of Great Britain. Black polygon designates Cardigan Bay: the Cardigan Bay SAC (green polygon) and the Pen Llyn a'r Sarnau SAC (pink polygon).

2.1.2 Bathymetry

Cardigan Bay is a shallow, gently sloping embayment with a heterogeneous seabed, ranging from fine sand and broken shell to gravel, shingle and muddy sand. The distribution of seabed sediments is dependent on the tidal strengths; gravel occurs where the currents are strongest and muds where they are weakest. The water depth does not exceed 50 metres and becomes shallower from west to east. The northern part of the bay is even shallower with the seabed dominated by a series of shore-transverse ridges, known as Sarnau (Evans, 1995).

2.1.3 Oceanography

Tides in the bay exhibit two high tides and two low tides during a 12-hour cycle, with approximately 6 hours between high and low waters. The mean spring tide ranges from four to five metres. The tide enters the bay from St. George's Channel, running north during flood tides and south during ebb tides. Tidal strength is relatively weak in Cardigan Bay, generally lower than 1.8 metres; the weakest currents are within the northeastern curve of the bay increasing to the south and west, and are slightly stronger near headlands and estuaries (Evans, 1995).

Cardigan Bay is relatively sheltered and the majority of the wave action develops locally with short and steep waves producing a well-mixed, turbid body of water due to high winds in the winter months. In the summer months, suspended sediments settle, reducing turbidity, and stratification occurs with warmer freshwater overlying denser, cooler and more saline waters. A front approximately 5-10 km wide can occur, separating the stratified and the well-mixed areas of the Irish Sea. A large swell can develop during prolonged periods of high winds, highlighting the influence wind can play on the oceanography of this area (Evans, 1995).

Within Cardigan Bay, there are large fluctuations in sea surface temperature influenced by seasonal changes, its shallowness, and input of freshwater from rivers and rainfall. Sea surface temperatures are coldest in February/March ranging between 5º to 8.5ºC, and warmest in August/September ranging from 14º to 16ºC offshore and 20ºC inshore (Evans, 1995). The variation of the temperature of coastal waters is twice as high as the variation in offshore waters (Reichelt, 2002).

The salinity within Cardigan Bay is influenced by saltwater from the Atlantic and freshwater from rainfall and rivers, the biggest river being the Teifi Estuary in the south. In Cardigan Bay, surface salinities are generally less than 34 parts per thousand, decreasing towards the coast and are generally greater in the summer months than in the winter (Anon., 2000).

2.2 Cardigan Bay Special Area of Conservation (SAC)

In 1992, the European Communities produced the Habitats Directive (Council Directive 92/43/EEC) to help conserve the biodiversity of the habitats and species in European nations by designating them Special Areas of Conservation (SAC). In 1992, the EU Habitats Directive listed the following as requiring protection and conservation in

Cardigan Bay, Wales: bottlenose dolphins, Atlantic grey seals, river and sea lampreys, reefs, sandbanks, and sea caves. For this reason, the UK Government submitted a part of Cardigan Bay as a candidate Special Area of Conservation (cSAC). In 2004, this area received the full status of SAC by the European Union Habitats Directive (1992). The SAC runs from the coast of Aberarth in the north to Cemaes Head in the south and approximately 22 km offshore. The coordinates of the boundaries of the Cardigan Bay SAC are given in Table 2.1.

Table 2.1: Coordinates of the boundaries of the Cardigan Bay SAC study area in degrees and decimal minutes.

Latitude	Longitude
52º 13.90' N	005º 00.0' W
52º 04.70' N	004º 45.9' W
52º 25.25' N	004º 23.1' W
52º 15.25' N	004º 13.5' W

Bottlenose dolphins are the most common marine mammals seen in Cardigan Bay, followed by the harbour porpoise, *Phocoena phocoena*, and the grey seal. Cardigan Bay is one of two areas in the British Isles where the bottlenose dolphins show residency, the other being in the Moray Firth, Scotland. By designating a part of this area a SAC, a management plan has been implemented, aimed at conserving the bottlenose dolphins and their habitat. The management plan's objectives are to protect marine habitats and communities, provide education, and assist in decision-making. One of the schemes developed to help protect the dolphins, porpoises and seals is the Marine Conservation Code of Conduct, which advises boaters not to steer directly towards animals in the water or approach them within 100 metres, to not change speed or course in a sudden or erratic manner, nor to feed, touch or swim with them, to avoid dolphins, porpoises, and seals with their young, and to avoid any unnecessary noise around all animals.

Studies on the bottlenose dolphin population in Cardigan Bay have been focused upon the Cardigan Bay Special Area of Conservation. While this area does appear to be popular for dolphins in the summer months, this study area is probably quite small relative to the entire range of the population. In 2005, surveys in the northern part of Cardigan Bay were started to better understand the distribution and movement of the dolphins. Surveys were conducted in the north to Pwllhelli Harbour, concentrating upon the Pen Llyn a'r Sarnau SAC, and in 2007, boat surveys began in the southern part of Cardigan Bay along the Pembrokeshire coast to St. David's Head. Currently, the population and distribution of the dolphins is poorly known for the winter months because of insufficient effort due to harsh weather conditions. Starting in the winter of 2006, aerial surveys were conducted covering all of Cardigan Bay as a way to estimate bottlenose dolphin presence and distribution in the winter months.

2.3 Pen Llyn a'r Sarnau Special Area of Conservation (SAC)

The Pen Llyn a'r Sarnau SAC is located in Northwest Wales. It is one of the largest of the marine SACs in the UK covering almost 230 km of coastline. The site was submitted to the European Union for the recognition as an SAC in 1995. In 2004, the full status of SAC was obtained. The site extends from Penrhyn Nefyn on the north Llyn coast to the mouth of the Afon Clarach (Clarach River), north of Aberystwyth on the West Wales coast. The Pen Llyn a'r Sarnau SAC qualifies as an SAC for the preservation of the following: reefs, estuaries, subtidal sandbanks, shallow inlets and bays, coastal lagoons, intertidal mudflats and sandflats, Atlantic salt meadows, sea caves, grey seals, bottlenose dolphins, and otters.

The coordinates of the boundaries of the Pen Llyn a'r Sarnau SAC are presented in Table 2.2

Table 2.2: Coordinates of the boundaries of the Pen Llyn a'r Sarnau SAC study area in degrees and decimal minutes.

Latitude	**Longitude**
52º 22.7 N	004º 30.0 W
52º 21.0 N	004º 59.9 W
52º 2.9 N	004º 59.9 W
52º 23.9 N	004º 59.9 W
52º 23.9 N	004º 17.9 W
52º 29.9 N	004º 11.9 W
52º 18.0 N	004º 59.9 W
52º 23.9 N	004º 54.0 W
52º 59.9 N	004º 29.9 W
52º 38.1 N	004º 59.9 W
52º 13.1 N	004º 38.9 W
52º 27.5 N	004º 59.9 W
52º 10.7 N	004º 17.4 W
52º 48.0 N	004º 31.1 W
52º 49.1 N	004º 16.7 W
52º 23.9 N	004º 6.0 W
52º 8. 3 N	004º 49.1 W

The reefs and estuaries support a large variety of marine wildlife. The three estuaries of the Pen Llyn a'r Sarnau SAC are located along the Merionnydd coast in the southern half of the area. These are the best examples of small, drying, bar-built estuaries in Britain and have some of the lowest nutrient inputs of any estuaries in Wales. The three estuaries are predominantly sandy-sandy/mud and support extensive intertidal sediment communities and saltmarsh. There is a continuous gradient between clean sands near the entrance to the sea and mud or muddy sands in the sheltered landward extremes of the estuaries with the different sediment types supporting a range of different communities of worms, crustaceans and molluscs. The estuaries form important nursery areas for a number of fish species, and are designated nursery areas for bass.

The Pen Llyn a'r Sarnau SAC is an area also used regularly by bottlenose dolphins. Currently, the range, distribution and extent of use by the dolphins are poorly known. According to photo-identification studies conducted by the Sea Watch Foundation, a research organization with a base in New Quay, the dolphins use the whole of Cardigan Bay. In 2005, regular boat surveys were started in the Pen Llyn a'r Sarnau SAC to gain a better understanding of the species' movements, distribution, and abundance.

3 Methods

3.1 Field data collection

3.1.1 Boat surveys

Data were collected from boat-based surveys conducted between April and October 2001-2006, within Cardigan Bay and including one or both SACs. Several boats and personnel participated in gathering the data over the years, and both sightings and effort have been archived in the Sea Watch Foundation's national computer database. In 2007, data used in this thesis were collected from May 14th to August 9th, with an additional survey out of the SACs, in the south of the bay, from Cemas Head down to St. David's Head (Pembrokeshire). The three vessels used for this study, in 2007, were:

- **Celine,** a 33-foot sailing vessel powered by a 30 hp inboard diesel engine (Figure 3.1, (a)). This boat was based in Aberystwyth where surveys began and ended. These surveys followed a non-systematic pattern in the northern portion of Cardigan Bay in the Pen Llyn a'r Sarnau SAC. On a few occasions, two-day surveys were conducted on Celine docking in the Pwhelli Harbour on the Llyn Peninsula and returning the following day. 3-5 observers, occupying positions that provided eye level views of around 2 metres height above the sea, took part in each survey.

- **Dunbar Castle 2,** a 32-foot motor vessel powered by a 100 hp inboard diesel engine (Figure 3.1, (b)). The boat was moored in New Quay (where trips started and ended) and had a bench on the roof for primary observers to sit approximately

3.5 metres above the sea level. This boat was used for Distance-sampling line-transect surveys, designed to cover the Cardigan Bay SAC, along with photo-identification studies. Pre-determined track-lines systematically surveyed the entire SAC. A minimum of 5 observers were used: 2 primary observers, 2 independent observers and 1 effort recorder.

- **Scorpius,** a 29.5-foot motor vessel powered by a 230 hp inboard diesel engine. The boat was moored in Milford Haven where surveys began and ended. The trips followed a non-systematic pattern beginning in Milford Haven continuing north around St. David's Head before turning around at Cemas Head. 3 observers, situated approximately 2.4 metres above sea level, took part in these surveys.

Figure 3.1: Research vessels used during boat-based surveys in 2007. (a) sailing boat- Celine, and (b) motor boat- Dunbar Castle 2. (photographs courtesy of E. Magileviciute).

A crew of trained volunteers and at least one experienced researcher or research assistant conducted the boat surveys. All boat surveys were conducted in sea states Beaufort three or less, swells < 2 m, good light and visibility conditions, and in rain no more than moderate strength. Weather conditions greater than these reduce visibility and reliable sightings, and were therefore avoided.

When a survey began, the time, position, boat and crew were noted on the effort form (Figure 3.2). An entry was recorded throughout the survey period and changed with effort status, change of course and/or environmental variables, start of photo-identification, any sighting event, or at 15-minute intervals. Four main effort statuses were used:

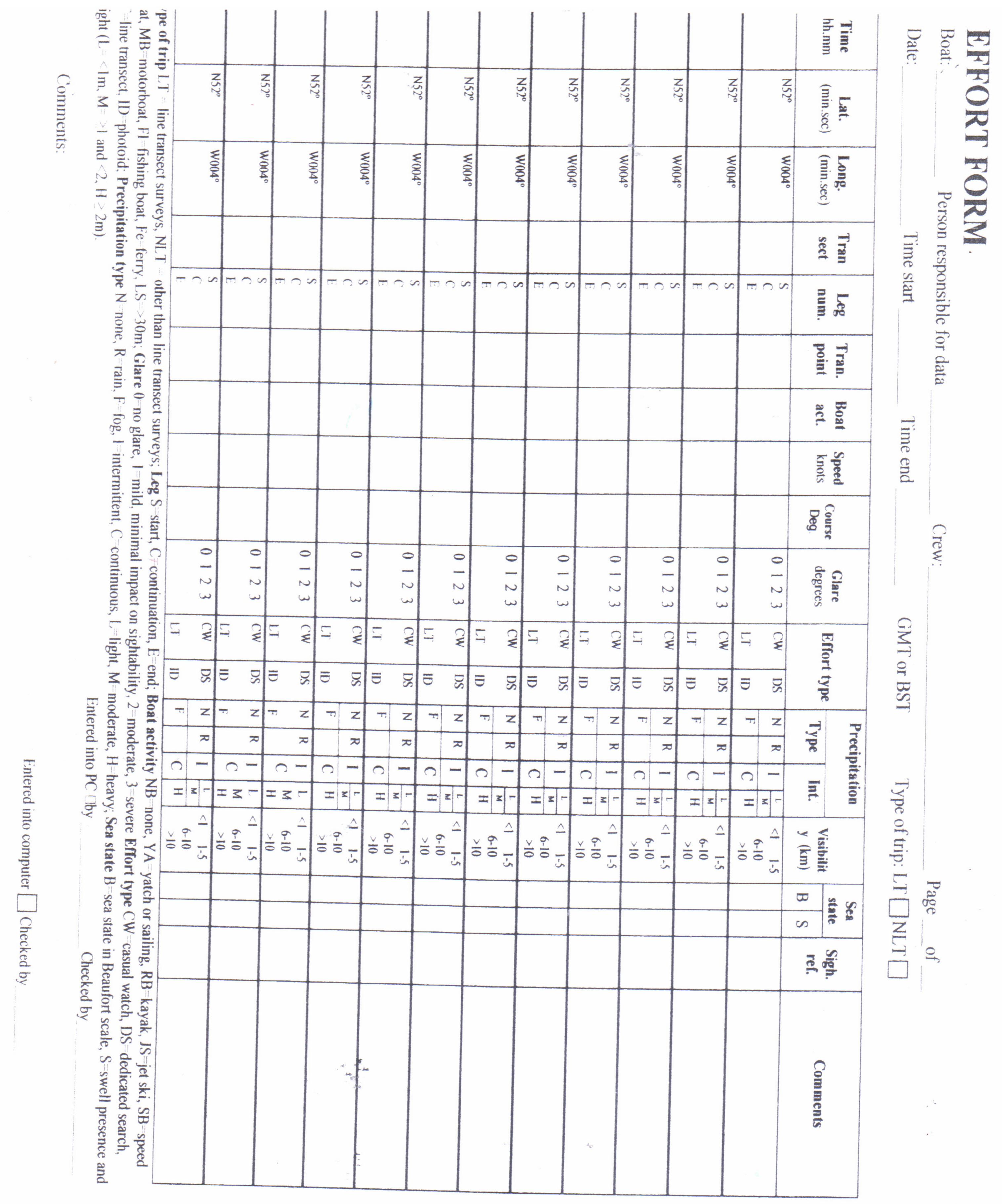
- 'Line transect' was used on the designated transects and this implied having 2-4 observers (depending upon whether two secondary observers were also used) scanning the sea surface for marine mammals;

- ‘Dedicated search’ was used when traveling from the end of a transect point to the beginning of a new transect point or when traveling directly from the end of the survey route to the harbour, and on all Celine trips where line transects were not used; during this type of effort, two observers were positioned on the roof of the boat;
- ‘Photo-identification’ when animals were being photographed and no other effort mode was being performed, and
- ‘Casual watch’ when no systematic watching took place but casual observations were made. If conditions deteriorated, preventing line transect survey mode to operate, casual observations were then conducted.

The effort data recorded were: time, position (latitude and longitude in degrees and decimal minutes), transect number, point and leg, boat activity in the vicinity, speed, course (in degrees), glare intensity and edges, effort type (line transect, dedicated search, photo-identification, or casual watch), precipitation type and intensity, visibility, sea state and swell height, and a unique sighting reference number was applied when an animal(s) was sighted. The reference number was used on the Sightings Form (Figure 3.3), filled out by the observers on the roof. On completion of the survey, the time and end GPS position were recorded.

When an animal(s) was sighted, it was recorded on the Sightings Form. Data included: sighting reference number, time, species, group size and composition, the angle between the centre of the group and the boat’s bow, distance from the boat, associated behaviours, the cue used to see the animal(s), and the reaction of the animal to the research vessel.

Behaviour was recorded as one or more of the following categories: slow, normal or fast swim, suspected feeding, observed feeding, leaping, bow riding, resting, milling, and socialising (a detailed description of these behavioural states is given on pages 31-32). Cues consisted of splashing, leaping, presence of a dorsal fin, tail flukes or back, head out of the water (mainly for grey seals), blow, presence of birds or the reflection on the wet skin of the cetacean. The Effort and Sighting Forms were filled out during all surveys in all weather conditions.



EFFORT FORM

Boat: ________ Person responsible for data ________ Crew: ________ Page __ of __

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

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

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

Entered into PC ☐by ________ Checked by ________

Comments:

Entered into computer ☐ Checked by ________

Figure 3.2: Effort Form.

SIGHTING FORM

Entered into PC ☐ Checked by ________

Date:______________ Type of trip: LT ☐ NLT ☐ Page:___of___ GMT or BST

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

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

Figure 3.3: Sightings Form.

3.1.2 Line Transects surveys

Distance-sampling line-transects were only conducted in the Cardigan Bay SAC which was divided, for research purposes, into an inshore and an offshore zone along a median line approximately 11 km from the coast (Figure 3.4). The area of the Cardigan Bay SAC and its main subdivisions are given in Table 3.1.

Table 3.1: Area (km^2) of the Cardigan Bay SAC and its main divisions.

Area type	Area (km^2)
Inshore SAC	517
Offshore SAC	522
Total SAC	1039

Each day the transect route was chosen at random. 'Inshore transects' followed a zigzag pattern between the coast and the median line (Fig.3.4 right). 'Offshore transects' followed a similar pattern between the coast and the outer boundary of the SAC (Fig. 3.4 left).

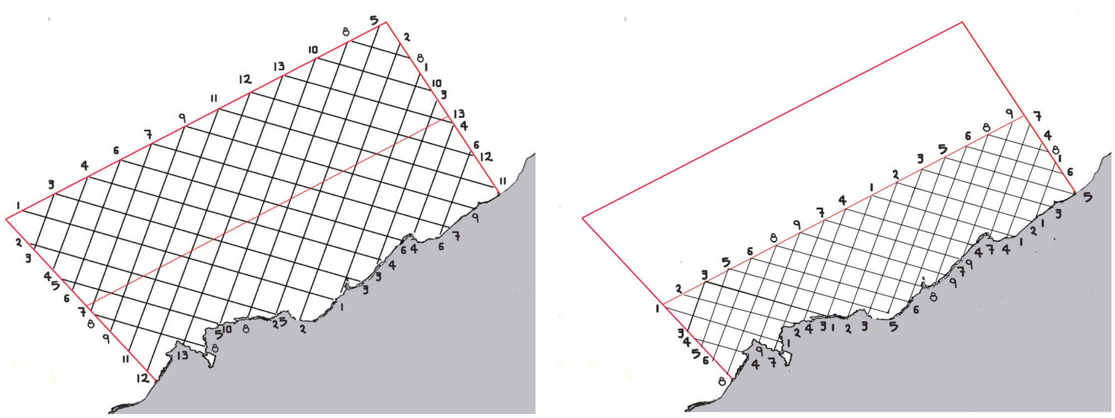


Figure 3.4 Left: the 13 transect routes used to sample the offshore strata. Right: the 9 transect routes used to sample the inshore strata.

These boat surveys always departed from New Quay. While traveling to the first transect point, the effort was ‘dedicated search’, consisting of two primary observers only. Once the transect point was reached and the first leg of the survey was to begin, effort changed to ‘line transect’, and two independent observers joined the primary observers. This procedure was also used when traveling from the end of the survey route back to New Quay Bay. If dolphins were encountered while on ‘dedicated search’, ‘casual watch’ or ‘line-transect’, effort was changed to ‘photo-identification’ until the encounter was finished.

Two primary observers were stationed on the roof, continuously scanning the forward 180°, paying particular attention to the trackline. The observers scanned the horizon with the naked eye and used binoculars when cues were seen. When a sighting was made, the position and angle at which the animal(s) when first seen was recorded on the Sightings Form, to ensure the position of the animals on the trackline, followed by the additional data.

Two independent observers were positioned at the rear of the boat, continuously scanning with binoculars the trackline and the forward 90°. When a sighting was made, the independent observer marked the position, distance and angle of the animal(s) on a separate Sightings Form, the Independent Observer Form. Once the animal(s) reached the rear of the boat, the independent observer conferred with the primary observers to see if they had recorded the sighting. If both primary and independent observers made the sighting, the independent observer recorded the sighting reference number used by the primary observers. If the primary observers did not record the sighting, then the independent observer used their own reference number.

Once a sighting was made, the animals were approached to at least 40 metres to obtain photographs, location and behavioural information. The animals were followed until all animals were photographed, or one lost sight of the animals, or a maximum of 40 minutes had passed. The effort was recorded as ‘photo-identification’ status. In order to resume ‘line-transect’ effort, the boat returned to the position at which effort ended before continuing ‘line transect’ effort status.

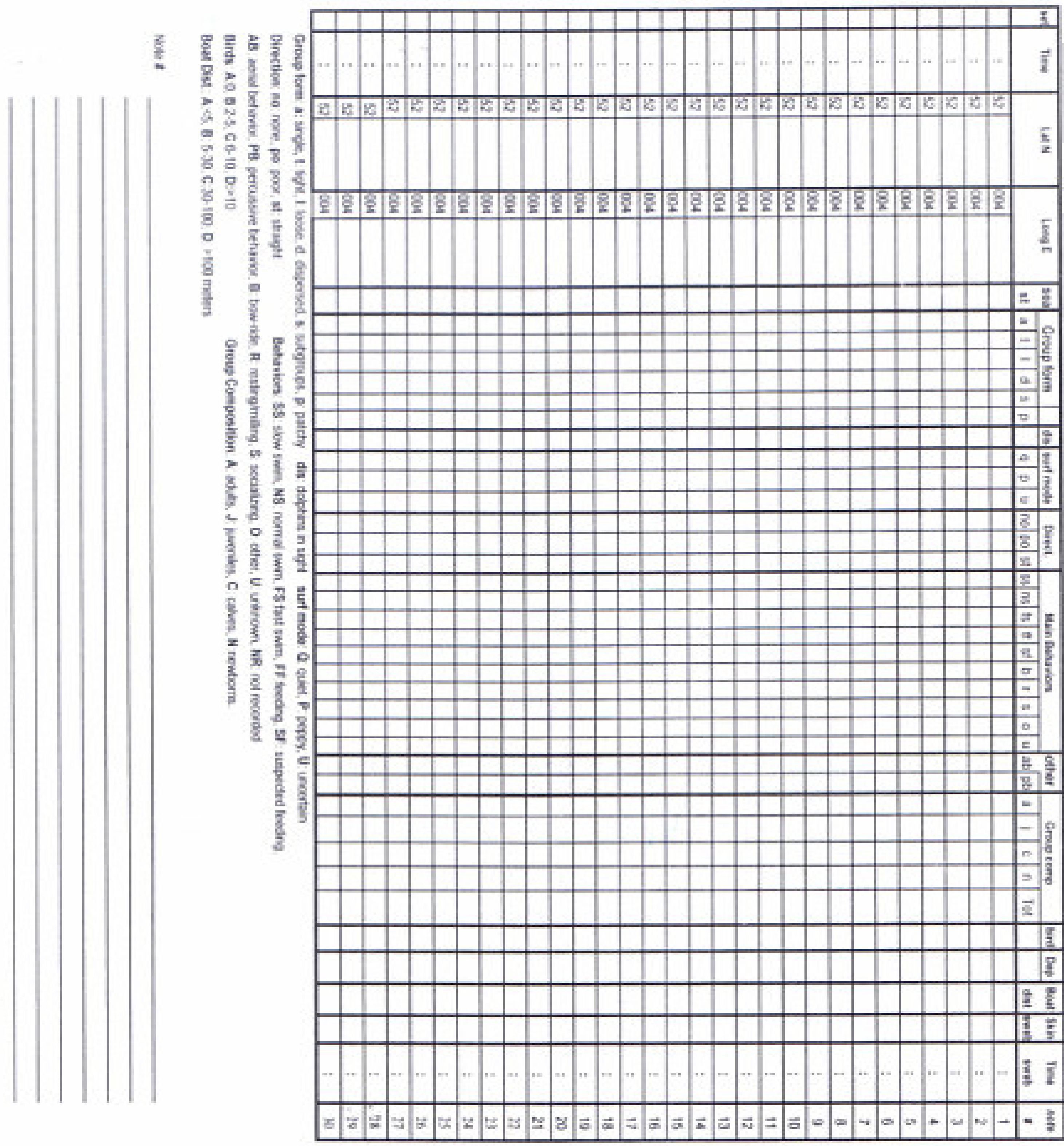
3.1.3 2007 Behaviour data collection

The behavioural data recorded in 2007 were collected rather differently to data collected from 2001-2006 and were analysed separately than the previous years. Behaviour data were collected from May 15th-August 9th in addition to the regular collection of effort and sighting data.

When dolphins were sighted, the boat reduced its speed to approximately 3–5 knots, and dolphins were approached as close as possible in order to record location, take photographs, and obtain behavioural data. The sighted animals were approached carefully and followed in a parallel fashion so as not to disturb the animals. Photographs were attempted on all the animals in the school. Behavioural data started once the animals were within 100 metres of the boat to ensure behaviours could be distinguished. A stopwatch was set to ring at 3- minute intervals. When the watch beeped, data were collected for the 3-minutes prior to that. The school was scanned from front to back to determine the behaviour of the majority of the school. One observer continuously scanned the group throughout the encounter giving commentary, while another observer recorded the data on the Behaviour Form (Figure 3.5). Encounters lasted for a minimum of 3 minutes and a max of 40 minutes, by regulation. The behaviour survey ended when all photographs and behavioural data were collected, or the animals were not sighted for several minutes. Data collected every three minutes included: set number, time, latitude and longitude, sighting number, sea state, group formation, other dolphins in view, surfacing mode, directionality, main behaviours, other behaviours, group composition, number of birds present, water depth, distance of animals from the boat, skin swab attempt, and time of skin swab (if taken). If animals were further than 100 metres, data were continuously collected until animals were lost from view, and behaviour data were recorded as unknown or uncertain unless they were obviously distinguished through binoculars.

Focal groups were defined as ‘an aggregation of dolphins within 100 metres of all other members of the school and involved in similar activities’ (Parra, 2006). Dolphin school position was recorded using a handheld Global Positioning System (GPS) with position accuracy = ± 10 metres. Time spent with the focal group was recorded as an encounter. If another school of animals were sighted in the distance, the boat left the previous group to sample of the new encounter.

A focal animal or group was recorded as 'sets'. During the encounter, if the school changed in number and/or composition, a new set was marked. At the beginning and throughout the encounter the animals were constantly counted to define the group size and age classes of the group. Group size was defined as the maximum number of individuals, including calves, in proximity to one another, moving in the same direction and engaged in similar activities (Shane, 1990). A unique sighting number was given to each encounter that coincided with the Sightings Form used by the primary observers. Skin swabs were taken when possible to determine the sex of the animals. These data were collected on the Behaviour Form but not used in any analysis for this study.



Date ______ sight # ______ Hour ______ Crew ______

set	Time	Lat N	Long E	sea st	Group form (a, t, l, d, s, p)	dis	surf mode (q, p, u)	Direct. (no, po, st)	Main Behaviors (ss, ns, fs, ff, sf, b, r, s, o, u)	other (ab, pb)	Group comp (a, j, c, n, Tot)	bird	Dep	Boat dist	Skin swab	Time swab	note #
	:	52	004													:	1
	:	52	004													:	2
	:	52	004													:	3
	:	52	004													:	4
	:	52	004													:	5
	:	52	004													:	6
	:	52	004													:	7
	:	52	004													:	8
	:	52	004													:	9
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	:	52	004													:	26
	:	52	004													:	27
	:	52	004													:	28
	:	52	004													:	29
	:	52	004													:	30

Group form: **a**: single, **t**: tight, **l**: loose, **d**: dispersed, **s**: subgroups, **p**: patchy **dis**: dolphins in sight **surf mode**: **Q**: quiet, **P**: peppy, **U**: uncertain

Direction: **no**: none, **po**: poor, **st**: straight **Behaviors**: **SS**: slow swim, **NS**: normal swim, **FS** fast swim, **FF** feeding, **SF**: suspected feeding

AB: aerial behavior, **PB**: percussive behavior, **B**: bow-ride, **R**: resting/milling, **S**: socializing, **O**: other, **U**: unknown, **NR**: not recorded

Birds: A:0, B:2-5, C:6-10, D:>10 **Group Composition**: **A**: adults, **J**: juveniles, **C**: calves, **N**: newborns.

Boat Dist.: A:<5, B: 5-30, C:30-100, D: >100 meters

Note # ______

Figure 3.5: Behaviour Form.

3.1.3.1 Behaviour data

The following provides a short description of the behaviour data collected during the encounters:

Table 3.2 Description of the focal group categories recorded during fieldwork.

Group formation	**Description**
Single (a)	Single individual.
Tight (t):	Each dolphin in school is less than 1 body length from each other.
Loose (l):	At least one dolphin is 1-5 body lengths from the others.
Dispersed (d):	At least one dolphin is over 5 body lengths from the others.
Subgroups (s):	Tight groups are dispersed from each other.
Patchy (p):	Large groups of dolphins that are irregularly spread over an area.
Surfacing mode	**Description**
Quiet (q):	Consistent occurrence of surfacings that do not produce foam or water turbulence.
Peppy (p)	Consistent occurrences of surfacings that are fast and produce foam or water turbulence.
Uncertainty (u)	A clear choice could not be made.
Directionality	**Description**
None (no)	No directional heading and geographic movement within the 3-minute sample.
Poor (po)	Zigzagging, changes of direction and short stops may occur, although geographic movement does occur.
Straight (st)	Steady directional heading and geographic movement

Table 3.3 Descriptions of the main behaviours recorded for the focal group.

Main Behaviours	**Description**
Slow swim (ss)	Regular surfacing with no associated splash at a very low speed < 3

	knots.
Normal swim (ns)	Regular surfacing with no associated splash at a speed between 3 and 6 knots.
Fast swim (fs)	Rapid surfacing, creating splashes and white water at a speed >3 knots.
Feeding (ff)	Animal changes direction as if in pursuit. Little or no geographic movements. Dives associated with flukes up. Predatory events seen.
Suspected feeding (sf)	As feeding but definite predatory events are not seen.
Bow-riding (b)	Coming close to boat and riding in bow wave.
Resting/milling (r)	Very slow swim. No geographic movement. Dolphins may lie motionless at surface for few seconds.
Socialising (s)	Physical contact among two or more animals, may be mating or aggressive behaviour. Fins and flukes often break the surface of the water.
Other (o)	Described in notes.
Unknown (u)	Behaviour could not be verified.

Table 3.4 Descriptions of the secondary behaviours recorded for the focal group.

Secondary Behaviours	**Description**
Aerial behaviour (ab)	Behavioural events where dolphins clear the water with all or most of their body including bows and leaps.
Percussive behaviour (pb)	Behavioural events when a dolphin hits the water with any body part including breach, leap tail slap, leap chin slap, chin slap, head slap, tail slap, inverted tail slap, and motorboating.

Courtesy of Peter Evans Courtesy of Giovanna Pesante

Courtesy of Giovanna Pesante

Figure 3.6: Pictures A-E represent behaviours seen during this study: Aerial behaviour (A), Percussive behaviour (B), social behaviour (C), Feeding behaviour (D), and bowriding (E). (Photographs courtesy of the Sea Watch Foundation).

3.1.3.2 Age Classes

The age of dolphins was estimated in the field by body size and distinguishing marks. Four age classes were used to identify the animals: newborns, calves, juveniles, and adults. *Newborns* were defined by their very small size, generally less than half of an adult, swimming in close proximity with an adult, showing visible foetal folds, and a small, dark and sometimes floppy dorsal fin. *Calves* were generally half the length of an adult, sometimes swimming in close association with an adult, and occasionally having foetal folds along their flanks, and a clean dorsal fin. *Juveniles* were approximately two-thirds the size of an adult, sometimes swimming in association with an adult, but generally swimming independently. *Adults* were defined as animals with a body length approximately 2.5 to 4 metres in length, and generally nicks or marks on the dorsal fin. Age class was recorded every three minutes and confirmed after the sighting ended. For this study, newborns and calves were categorized together as calves due to the difficulty to classify some animals in the appropriate age class.

3.2 Data Analysis

Prior to analysis, the data were cleaned under several criteria. Sightings repeated between primary and independent observers were deleted. Sightings that occurred within 15 minutes of one another with the same group size and composition were combined and counted as one sighting. Sightings that occurred within 5 minutes of one another and their total distance from the boat equaled 100 metres were combined and counted as one sighting. The 5 behaviour categories used in all analysis were as follows: *Traveling* combined slow, normal, and fast swimming. *Foraging* combined suspected feeding and directly observed feeding. *Socialising* represented only socialising, *Resting/Milling* represented resting and/or milling, and *Other* represented any other behaviour not included in the main behaviours such as bowriding and leaping. These behaviours are not indicative of undisturbed behaviours, but were counted because they do represent time spent in a behavioural state.

3.2.1 Behavioural budgets

One of the two main objectives of this study was the determination of the behavioural budgets of the bottlenose dolphins in order to assess the percent of time the animals spent in different behavioural states over the 7-year study period. In order to have independent samples, only one behavioural sample per encounter was selected, at random, to construct the budget, and then used for statistical analysis.

The overall budget was determined for the years 2001-2007 combined, and each year separately. The budget for each year was compared to identify any changes in the budget over the 7-year study period. The budget was then determined separately for groups with and without the presence of calves for all years combined, to determine if the budget shifted when calves were present. To determine if the budget changed throughout the study season, the budget was separated into two seasonal periods. The beginning of the season was defined as April 4th to July 15th and the end of the season was defined as between July 16th and October 29th. This was done only for years 2001-2007 combined. The budget was also determined according to group size to see if varying group sizes spend a different percent of time in different activities. The group sizes were categorized as follows: 1 single animal, 2-4 animals, 5-7 animals, 8-10 animals, and 11-20 animals.

The effect of the presence of calves and season on behaviour was tested for significance using a General Linear Model (GLM). Univariate analyses were used to test the quality of the data and to identify significant differences. The data were initially tested for normality using the Kolmogorov-Smirnov (one sample) test. The results were based on the P-values at $\alpha = 0.05$. If the P-value was less than 0.05, the distribution was unlikely to be normally distributed and non-parametric statistics were used. To determine significant differences, non-parametric tests were used between two sets of data (Mann-Whitney) or between three or more sets (Kruskal-Wallis).

Appropriate statistical analyses were conducted using the statistical software SPSS 14.0 for Windows.

3.2.2 2007 Data

. The Sea Watch Foundation collected data such as effort, sightings and behaviours as normal for its protocols. For this particular study, additional behaviour data were collected at 3-minute intervals (as discussed in section 3.1.3). These data combined a different series of collection strategies and was more intensive, and, therefore, was analysed differently. The budget was determined and compared to the previous years. Due to a low number of samples per behaviour, all data from 2007 were combined, in order to visualize a kernel home range. Correlations between group size, behaviour and group formation were tested for significance using the Pearson's correlation test.

3.2.3 Habitat use and Home range

Using ArcView 3.3 (AV3), a Geographic InformationSsystem (GIS), the distribution of dolphins was integrated onto a map of Cardigan Bay. Studying the distribution and movement of aquatic animals is informative concerning population abundance, migrations, marine reserve designs, and habitat selection. GIS provides a framework to analyze animal movements by allowing multiple layers of habitat data into a two- or three-dimensional analysis. Data from 2001-2007 were analysed to identify home ranges and core areas used for specific behaviours by the bottlenose dolphins in Cardigan Bay.

In AV3, all sightings were plotted for the years 2001-2006 combined and then each year separately; 2007 was plotted separately. Groups displaying different behaviours simultaneously were put in all relevant categories in order to represent behaviour frequencies rather than time budgets. A new view was added for each behaviour group and each year and all years combined were plotted under each of the 4 behaviour views. A new view was added for each behaviour group and 2001-2006 combined was further separated into groups with and without the presence of calves. A new view was added for each behaviour group and 2001-2006 combined was further separated into two seasonal periods. The projection chosen was the World Mercator projection in the spheroid WGS84.

3.2.2.1 Kernel Home Range

Once the sightings were plotted in AV3, the kernel ranges were mapped to visually represent home ranges throughout the bay, and to determine core areas. Kernel density distributions were derived for all dolphin encounters when first seen so as to avoid any bias created by the presence of the boat (see, for example, Wilson *et al*., 1997). The ranging patterns of dolphins were described using the kernel home range probabilistic technique, in the Animal Movement Extension. Kernel methods are favoured over other methods that are biased by outliers and sample size, and consist of a non-parametric probability density not requiring a particular statistical distribution (Kernohan *et al*., 2001). The Kernel Home Range calculates a fixed kernel home range utilization distribution (UD) as grid coverage using *ad hoc* as the smoothing parametre, which is thought to provide a less biased estimator. The smoothing parametre determines how abruptly each kernel tapers. This extension provides grid coverage of the UD, or the probabilities, and a polygon shapefile for each selected probability.

For the data from 2001-2007, the intensity of use of various areas in the bay was investigated analysing the 50% and 95% contour probability of the total space. In this study, the areas used with a utilization distribution of 50% were defined as 'core areas', while the 95% UD were defined as 'home ranges'. The 50% and 95% UD represented the probability that an animal was seen in that area. The optimum sample size for kernel density estimates has been evaluated by simulation studies. A minimum of 30 observations per behaviour should be used, and 50 are preferred (Seaman *et al*., 1999).

Due to the difficulty in obtaining large sample sizes for certain behaviours, many studies examining cetacean distributions are forced to use a smaller sample (Ingram and Rogan, 2002). In 2007, the kernel estimators were calculated for a minimum of 33 samples. Socialising is a behaviour that is often unidentified or misidentified as other behaviours resulting in obtaining only 13 samples in the years 2001-2006 combined. Each socialising and resting behaviour sightings from 2001-2006 were therefore combined for all analysis, due to the small samples recorded each year.

4 Results

4.1 Effort

4.1.1 Survey effort

Boat-based surveys were conducted from April to October, 2001-2006, resulting in 1,436 sightings of dolphins involved in a particular behavioural state. Survey days varied by month and year, as seen in Table 4.1. Surveys were conducted from May to August in 2007, resulting in 33 sightings on 17 survey days.

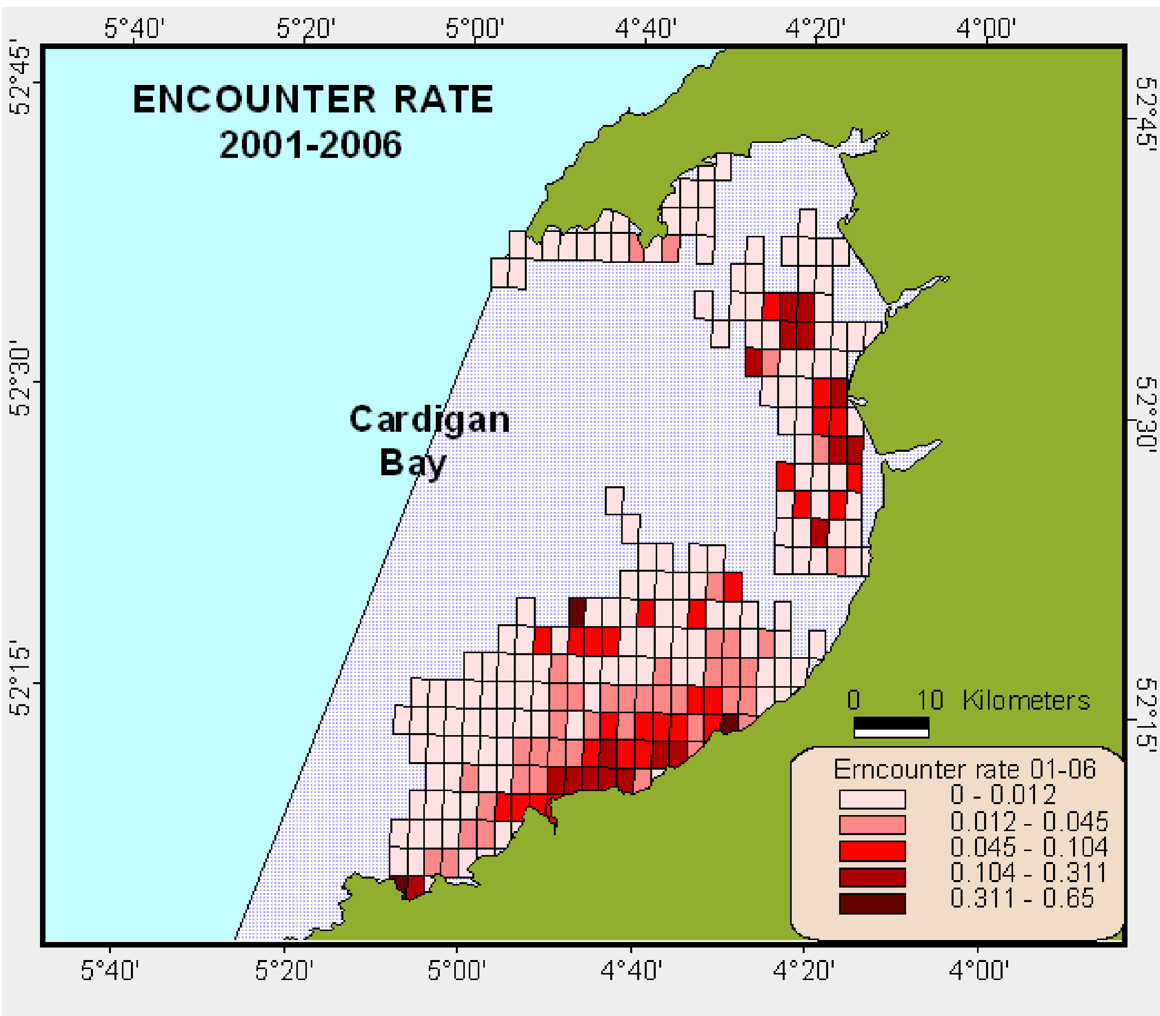
Table 4.1: Monthly summary for total number of days spent surveying for bottlenose dolphins from 2001-2006.

Year	N of days		Year	N of days		Year	N of days	
2001	*April*	0	**2002**	*April*	0	**2003**	*April*	0
	May	5		*May*	2		*May*	6
	June	5		*June*	3		*June*	17
	July	11		*July*	16		*July*	22
	Aug	23		*Aug*	24		*Aug*	23
	September	5		*September*	17		*September*	14
	October	0		*October*	0		*October*	2
	Total: 48			**Total: 62**			**Total: 84**	
2004	*April*	1	**2005**	*April*	4	**2006**	*April*	7
	May	10		*May*	4		*May*	10
	June	15		*June*	12		*June*	17
	July	20		*July*	14		*July*	20
	Aug	22		*Aug*	16		*Aug*	16
	Sept	7		*September*	11		*September*	18
	October	0		*October*	4		*October*	3
	Total: 75			**Total: 64**			**Total: 91**	

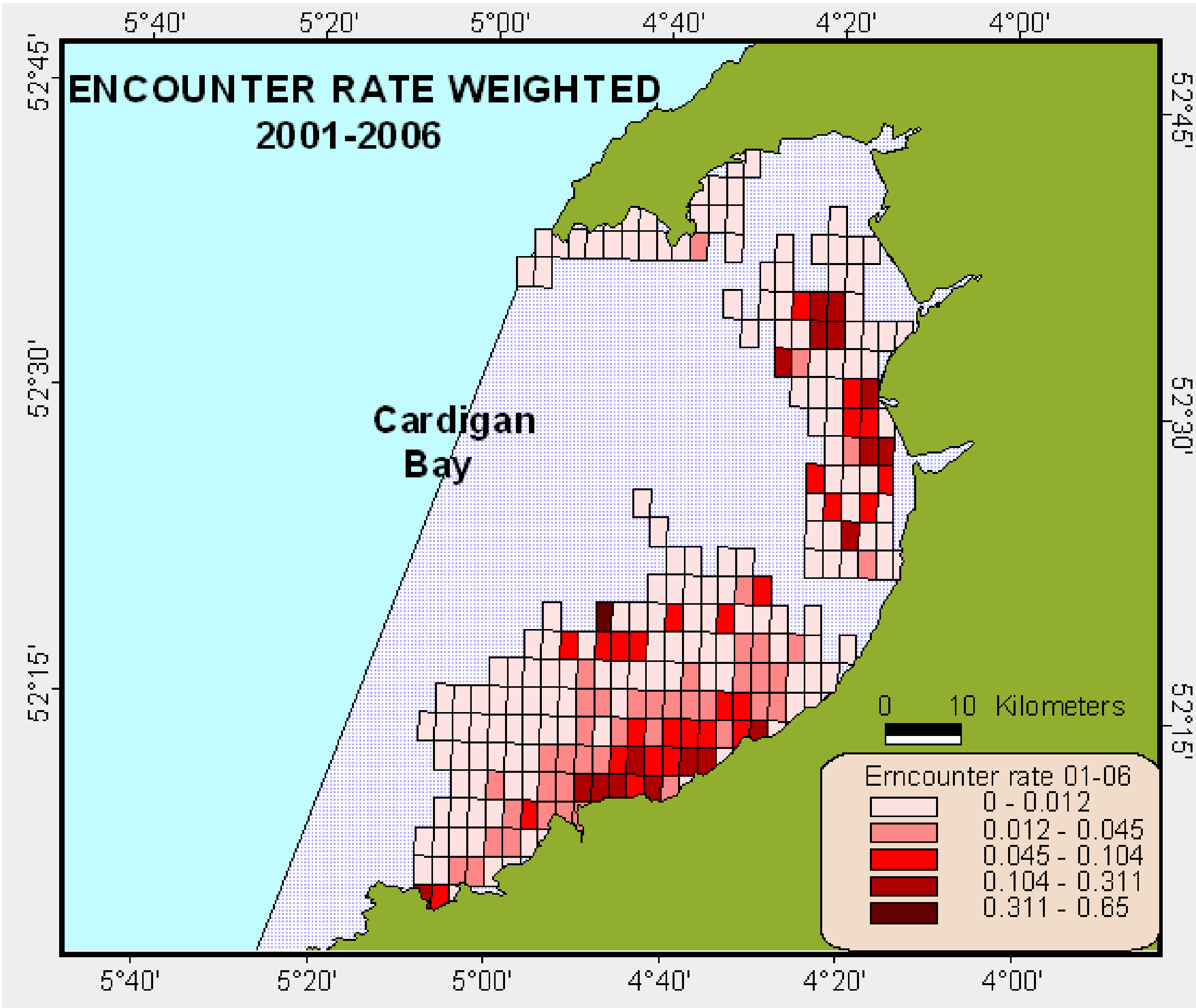
A significant difference was observed in the days spent surveying between months (Kruskal-Wallis test, df = 6, χ^2= 23.625, P= 0.001) but not between years (Kruskal-Wallis test, df = 5, χ^2= 1.963 P= 0.854).

4.1.2 Encounter rate

Encounter rates (*n*/Km, where n is the number of sightings) were calculated for bottlenose dolphins for each 2'x2' cell in AV3 (Figure 4.1 (a,b)), and weighted relative to the proportion of land which intersects the cell. The darker areas represent areas where dolphin encounters are greatest and the encounter rate decreases with colour. When analysing the kernel home ranges, which plot sightings only, the encounter rates must be taken into account. Figure 4.1 (a) shows the encounter rates before the cells were weighted and Figure 4.1 (b) represents the weighted encounter rate.



(a)



(b)

Figure 4.1: Encounter rates for bottlenose dolphin sightings in Cardigan Bay. (a) represents dolphin encounter rates before the cells were weighted with land intersection and (b) represents encounter rates after the cells were weighted. The lighter areas represent the lowest amount of sightings increasing with colour. (Figures provided by Laura Barba Villaescusa with support from The Mammal Trust).

4.2 Behavioural Budget

4.2.1 2001-2007

From 2001-2006 there were 1,436 sightings, and 33 sightings in 2007 (Table 4.2). Figure 4.2 represents the overall behavioural budget for 2001-2007, and Figure 4.3 represents the budget for each year from 2001-2007.

Table 4.2: Number of bottlenose dolphin sightings with behaviours per year.

Year	Number of sightings	Year	Number of sightings
2001	207	2002	225
2003	351	2004	199
2005	246	2006	208
2007	33		

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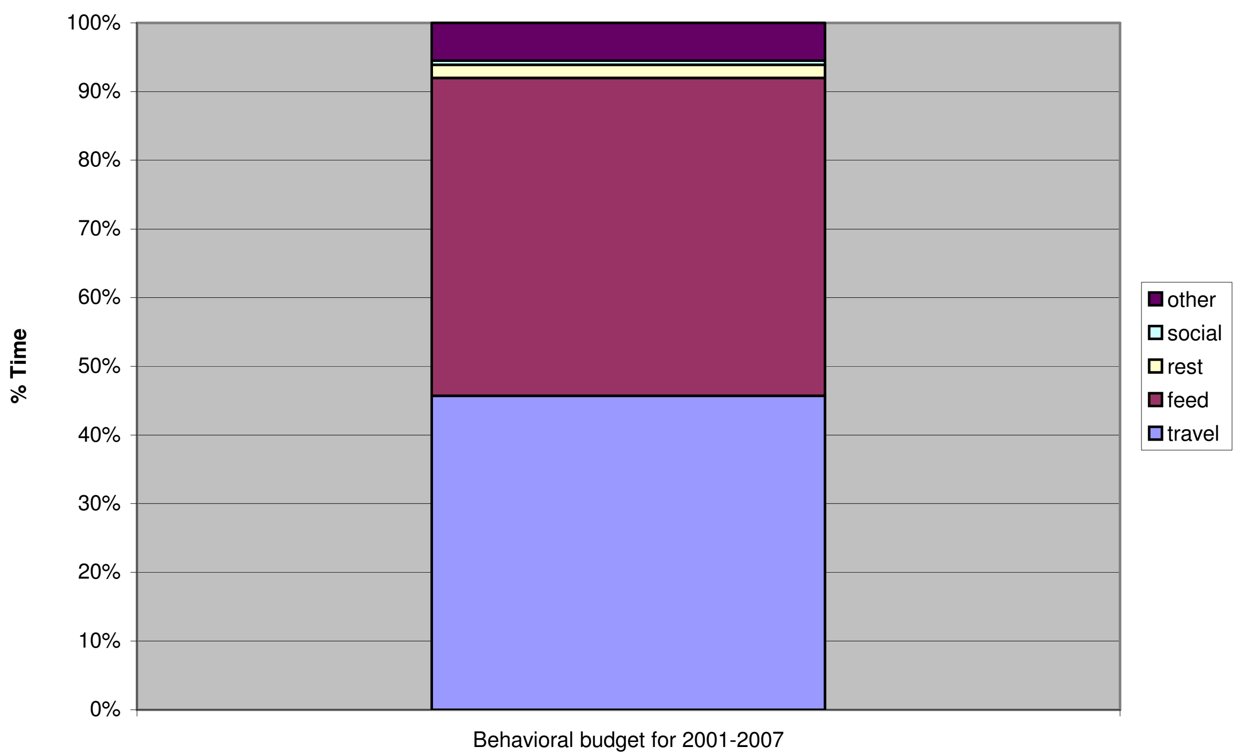


Figure 4.2: Overall behavioural budget for 2001-2007.

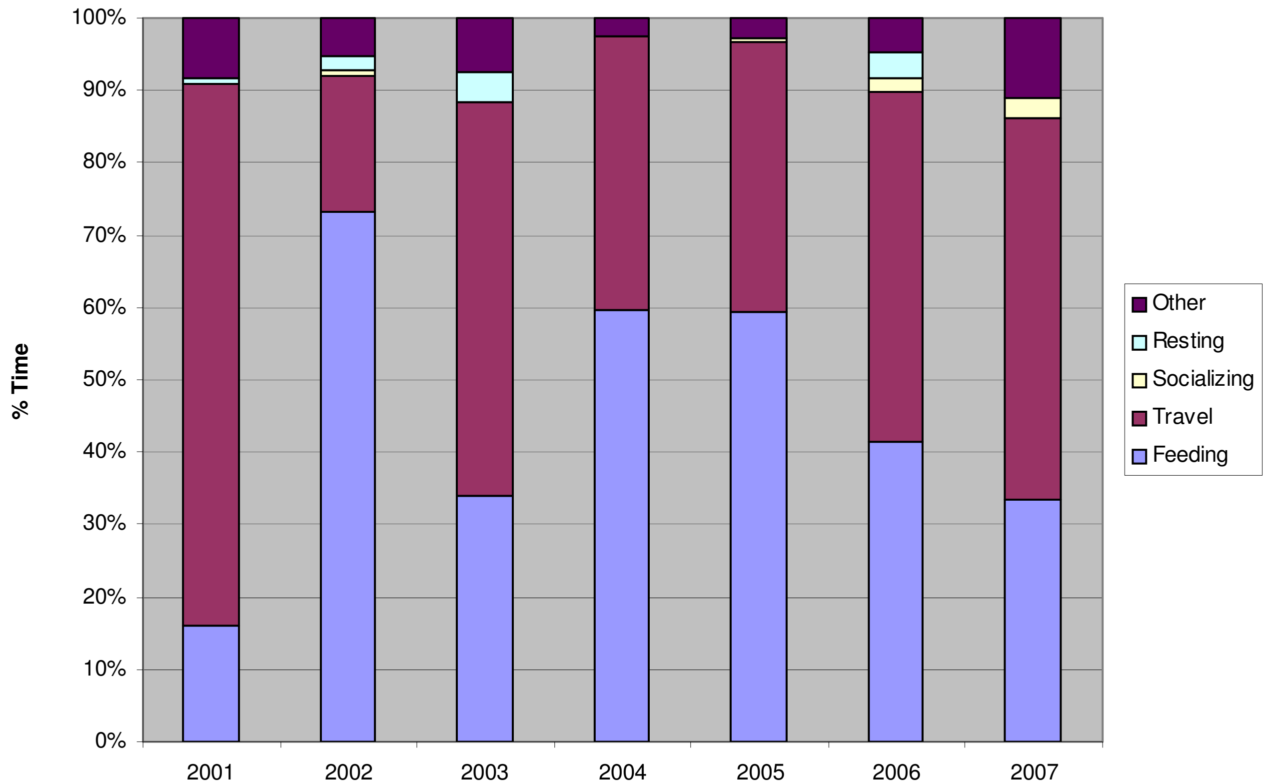


Figure 4.3: Behavioural budget for each year. Percents total 100% of the budget.

Feeding was greatest in 2002 at 73.3%, and lowest in 2001 at 15.9%. Traveling was greatest in 2001 at 74.9%, and lowest in 2002 at 18.7%. Resting varied per year and was greatest in 2003 at 4.3%, and lowest at 0% in both 2004 and 2005. Socialising was recorded minimally and greatest in 2007 at 3%, and lowest at 0% in years 2001, 2003-2005.

4.2.2 Presence of calves

The budget was determined separately for groups with calves present and without calves present for the years 2001-2007, as represented in Figure 4.4. Of the 1,469 of sightings for 2001-2007, 279 sightings had calves present, and 514 sightings had no calves present. The remaining sightings had no data about the presence or absence of calves.

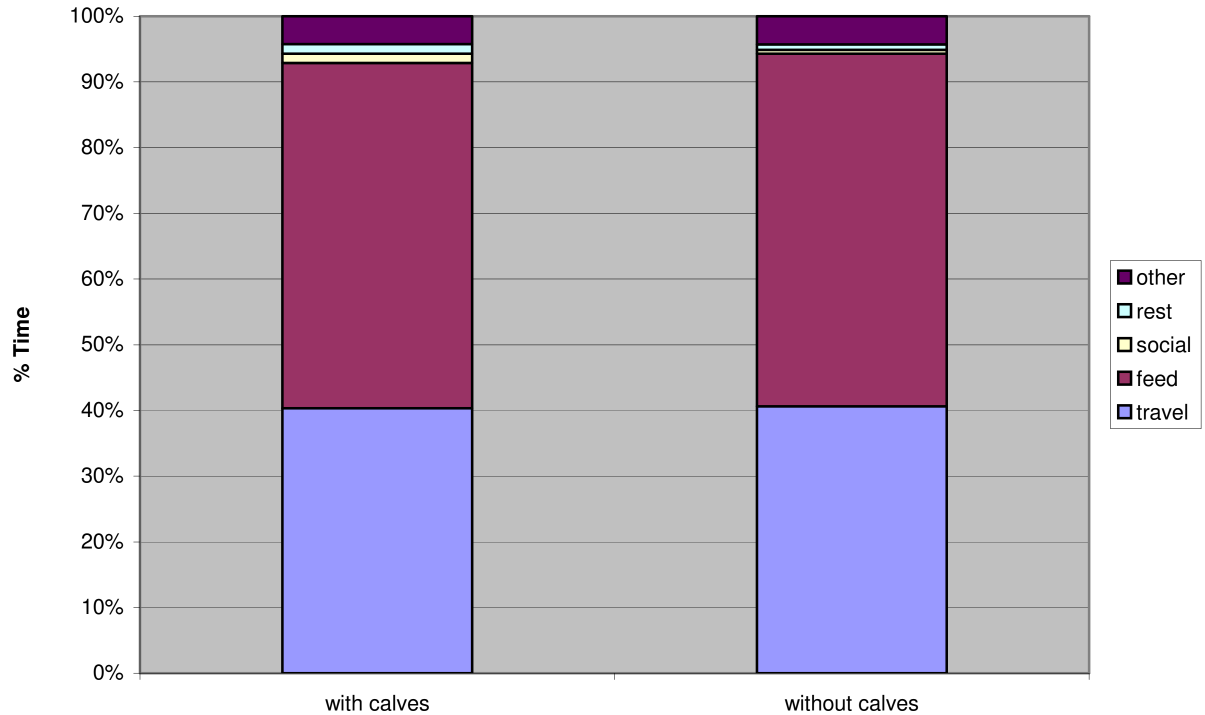


Figure 4.4: Behavioural budget for groups with and without the presence of calves for years 2001-2007 combined.

The presence of calves had no significant effect on traveling (GLM, df=1, F= 1.816, P= 0.208), feeding (GLM, df= 1, F= 1.988, P= 0.189), socialising (GLM, df= 1, F= 1.237, P= 0.292), resting (GLM, df=1, F= 1.173, P= 0.304) or other behaviours (GLM, df=1, F= 2.689, P= 0.132).

4.2.3 Group size

The budget was determined for varying group sizes (Figure 4.5). The categories were as follows: a single animal (N= 398), 2-4 animals (N= 707), 5-7 animals (N= 204), 8-10 animals (N= 90), and 11-20 animals (N= 58). Only two sightings represented the >20 animal category and were not considered due to the small sample size.

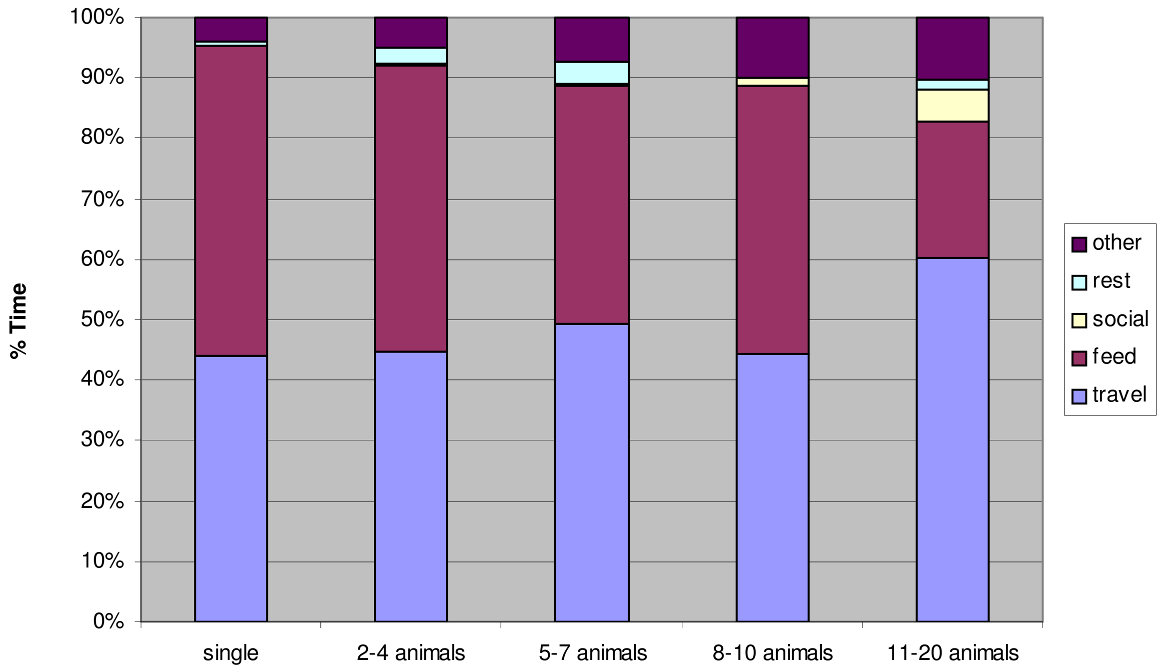


Figure 4.5: Behavioural budget according to group size for years 2001-2007 combined.

Of all the group sizes, single individuals spent the most time feeding at 51.5% and the least time socialising at 0%. Feeding gradually decreased as group size increased and traveling and socialising increased as group size increased.

4.2.4 Seasonal changes

Figure 4.6 represents the behavioural budget from the beginning of the season to the end of the season for 2001-2007.

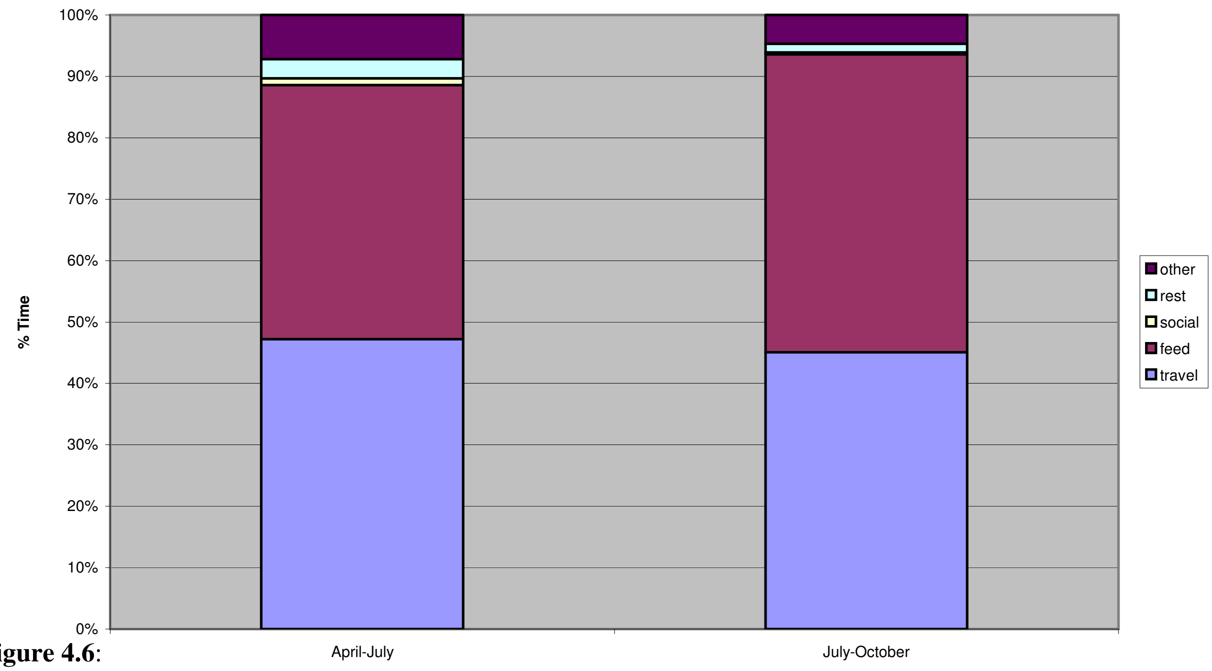


Figure 4.6:
Behavioural budget from the beginning of the season (April- July) to the end of season (July-Oct) for years 2001-2007 combined.

The percentage of feeding behaviours was greatest at the end of the season at 48.5%, whereas the percentage of time traveling, resting, and socialising were greatest at the beginning of the season. Season had no significant effect on traveling (GLM, df= 1, F=0.003, P=0.961), feeding (GLM, df=1, F= 0.179, P= 0.681), socialising (GLM, df= 1, F= 1.159, P= 0.307), resting (GLM, df= 1, F= 0.466, P= 0.510), or other behaviours (GLM, df=1, F= 2.273, P= 0.163).

A significant difference was observed for sightings of traveling individuals between months (Kruskal-Wallis test, df=6, χ^2= 17.769, P= 0.007), but not between years (Kruskal-Wallis test, df=5, χ^2= 8.030, P= 0.155). May was significantly different to June (Mann Whitney-U, U= 4.500, P= 0.030), July (Mann Whitney-U, U= 0.500, P= 0.005), August (Mann Whitney-U, U= 0.000, P= 0.004), and September (Mann Whitney-U, U== 1.500, P= 0.008). October was significantly different from July (Mann Whitney-U, U= 0.000, P= 0.046) and August (Mann Whitney-U, U= 0.000, P= 0.040), but June, July, August and September were not significantly different from one another (Figure 4.7).

A significant difference was observed for sightings of feeding individuals between months (Kruskal-Wallis test, df=6, χ^2= 16.982, P= 0.009) but not between years (Kruskal-Wallis test, df=5, χ^2= 2.983, P= 0.703). May was significantly different to July (Mann Whitney-U, U= 9.000, P= 0.006) and August (Mann Whitney-U, U= 0.000, P= 0.006), October was significantly different from July (Mann Whitney-U, U= 0.000, P= 0.020) and August (Mann Whitney-U, U= 0.000, P=0.020), April was significantly different from July (Mann Whitney-U, U= 0.000, P= 0.020) and August (Mann Whitney-U, U= 0.000, P=0.020), but June, July, August and September were not significantly different from each other.

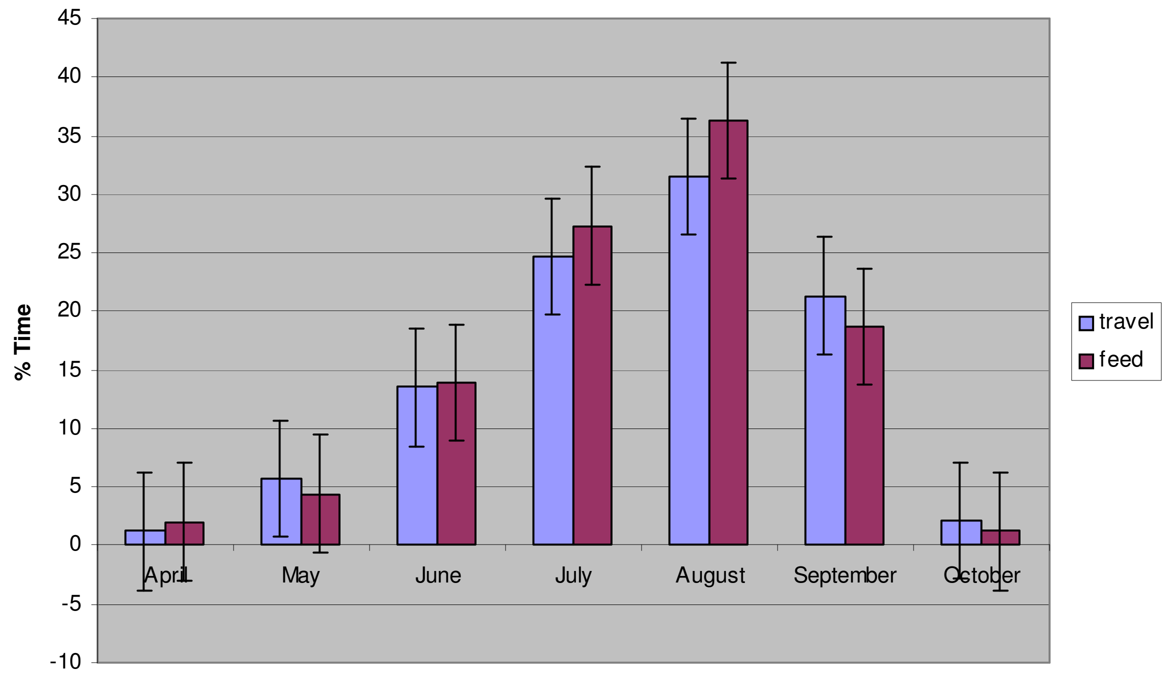


Figure 4.7: Mean percent of time spent traveling and feeding per month as a portion of total time feeding during that year for the years 2001-2006 combined. These percents do not represent a proportion of the total behavioural budget.

4.2.5 2007 data

Group size in dolphins often varies with habitat and activity (Shane *et al*., 1986). The overall percent of sightings spent traveling and feeding was analysed as a function of group formation (Figure 4.9) and group size for 2007 (Figure 4.10).

The size of the groups varied from 1-10 individuals with a mean of 4 animals. Groups were smallest during travel and feeding, and largest during socialising. Fifty percent of the groups seen feeding and/or traveling consisted of 2-4 animals. No correlation was observed between group size and traveling, feeding, socialising, resting or other behaviours (Pearson's correlation test, n=23, r^2= -0.054, P=0.805) or between group formation and traveling, feeding, socialising, resting or other behaviours (Pearson's correlation test, n=33, r^2= 1.35, P=0.455). A correlation was found between group size and group formation (Pearson's correlation test, n=23, r^2=0.693, P=0.000), seen in Figure 4.8. During travel, sightings of focal groups were equally tight and dispersed (31.3%) most of the time and equally single and loose (18.8%) the least time. During feeding, focal groups spent the most time in tight groups (33.3%) followed by single and loose (25%), and the least time in dispersed groups (16.7%).

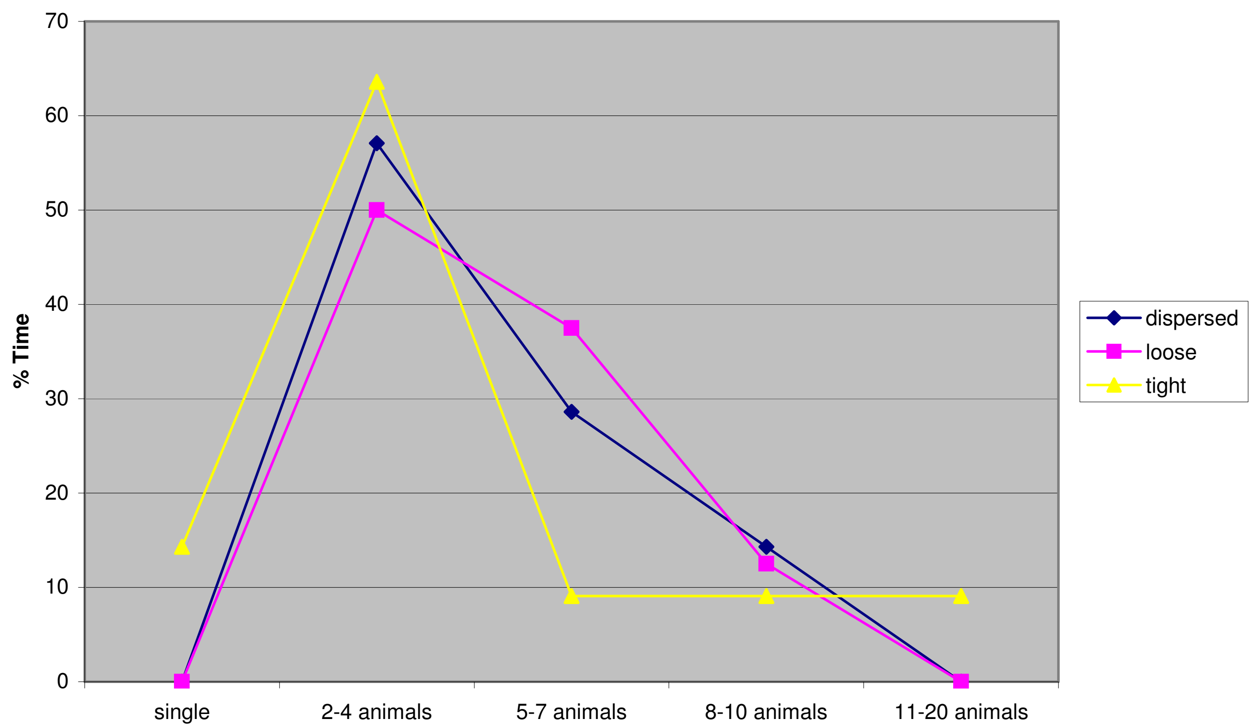


Figure 4.8: Correlation between group size and group formation in 2007.

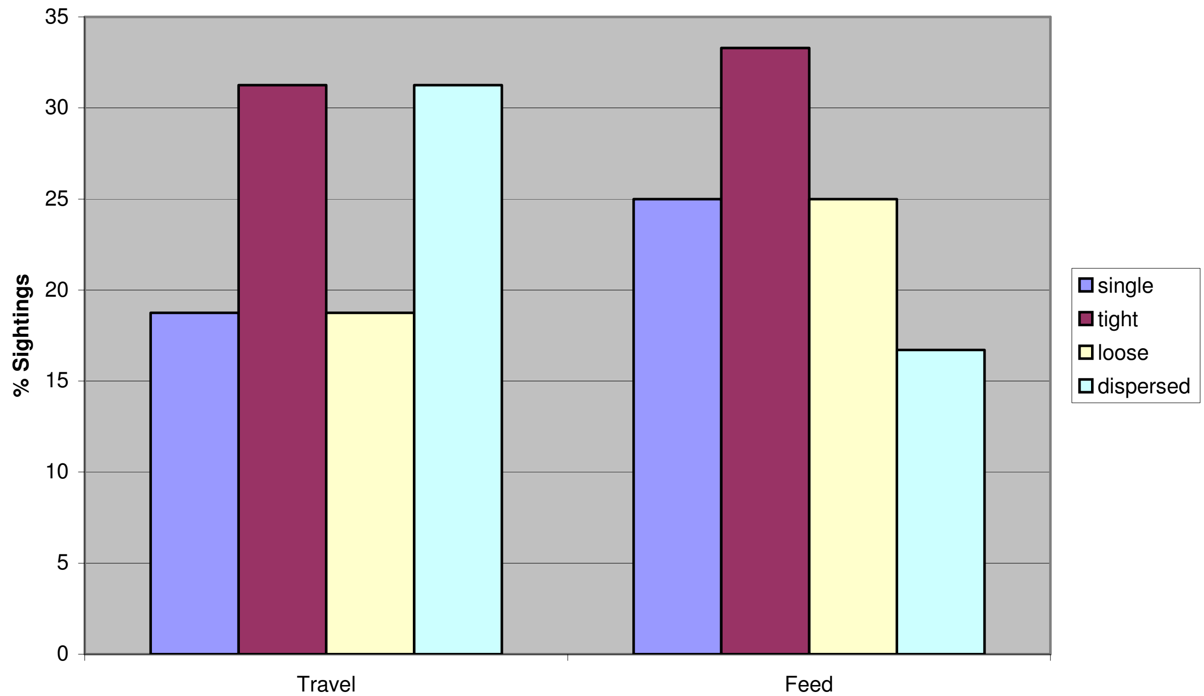


Figure 4.9: Percent of sightings of dolphins traveling and feeding as a function of group formation in 2007.

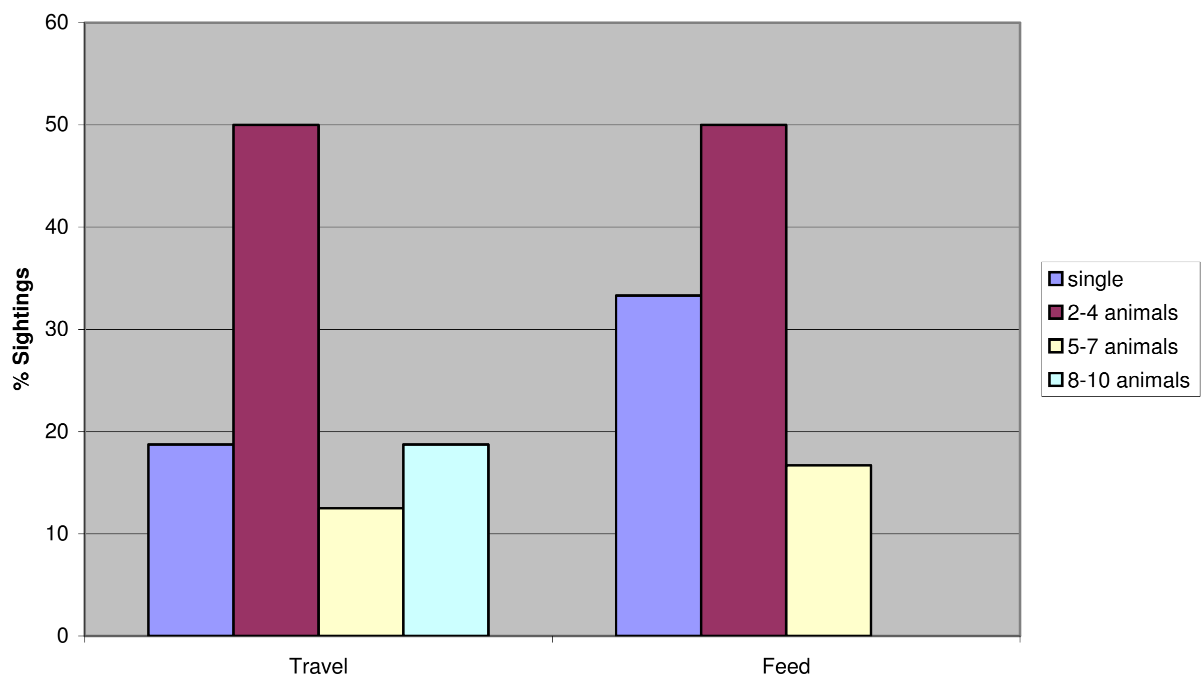


Figure 4.10: Percent of sightings of dolphins traveling and feeding as a function of group size in 2007.

4.3 Home range

Spatial distribution of the home ranges (95% UD) and core areas (50% UD) were analysed for all years combined, and by each year separately, for each of the four behaviour categories, as well as for the presence and absence of calves, and for seasonal changes. Maps of all the sightings locations for each year are represented in APPENDIX A.

4.3.1 2001-2006

All bottlenose dolphin sightings, with associated behaviours, are plotted in Figure 4.11 to represent the extent of use of the two Cardigan Bay SACs for all behaviours. Figure 4.12 (a-f) represents the home ranges and core areas for each year separately. In 2001, there were 207 dolphin sightings, 225 in 2002, 351 in 2003, 199 in 2004, 246 in 2005, and 208 in 2006. The kernel UD analysis showed that the home ranges for 2002-2004 consisted of three main areas at New Quay, Ynys Lochtyn and Mwnt, as well as having similar core areas at New Quay and Ynys Lochtyn. Years 2001 and 2006 covered similar areas as the other years with core areas also at New Quay and Ynys Lochtyn, but only around New Quay in 2005. New Quay was used as a core area for every year.

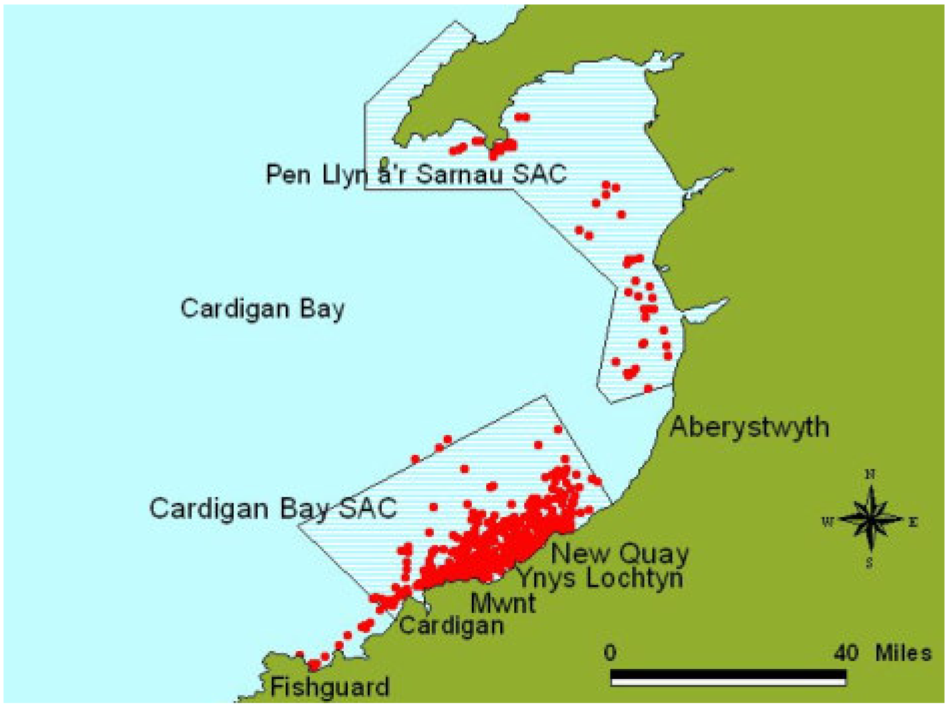
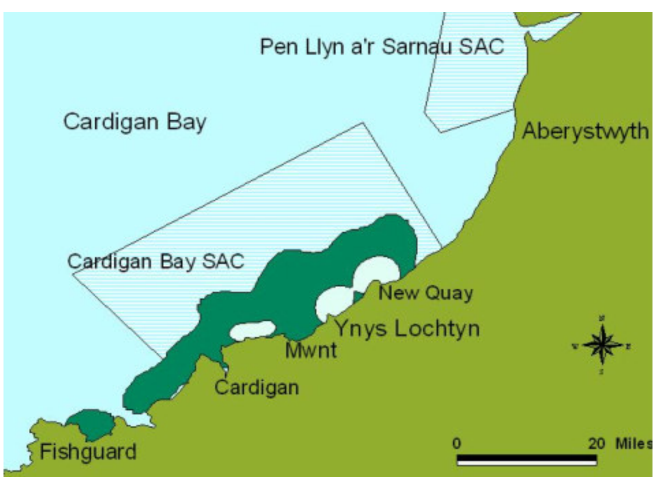
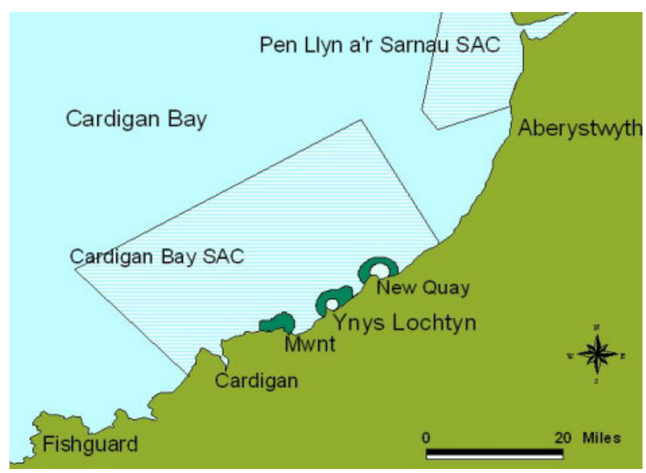


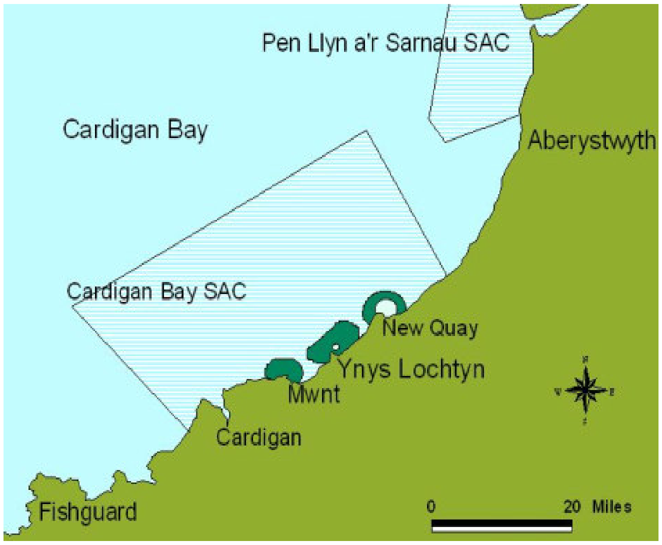
Figure 4.11: All bottlenose dolphin sightings in 2001-2006 with associated behaviours. Sightings have not been corrected for effort.



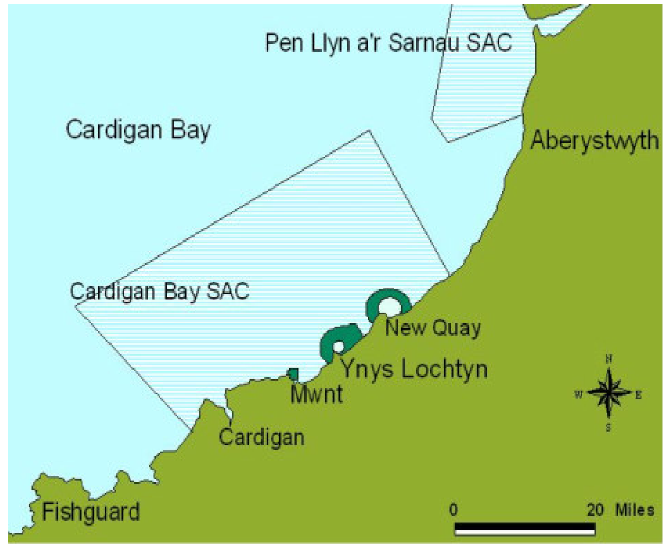
(*a*) 2001



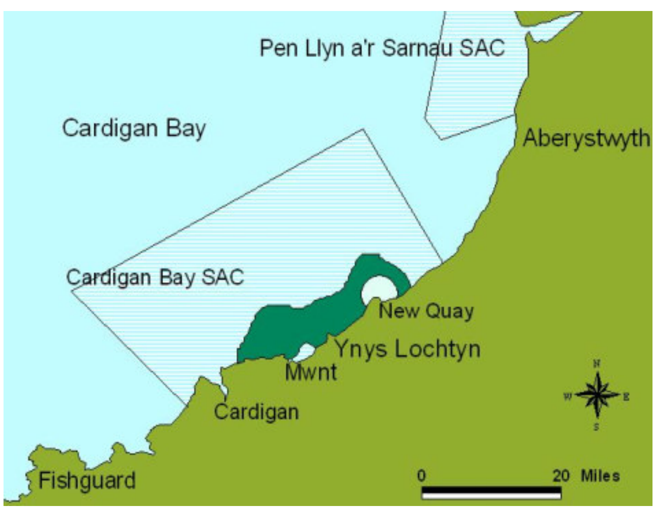
(b) 2002



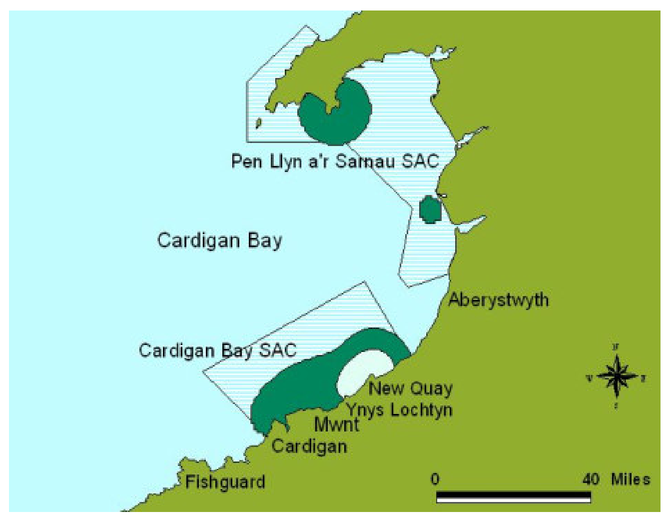
(c) 2003



(d) 2004



(e) 2005

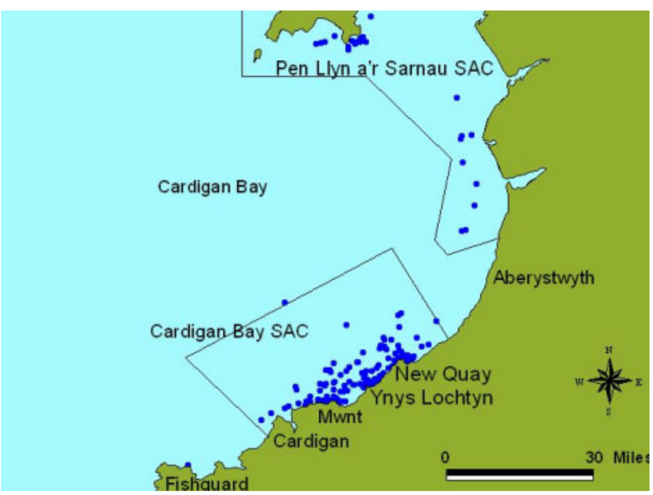


(f) 2006

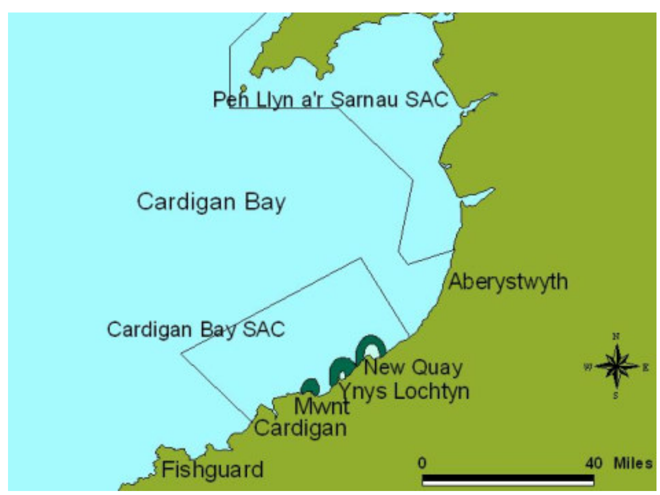
Figure 4.12: Kernel home ranges for 2001 (a), 2002 (b), 2003 (c), 2004 (d), 2005 (e), and 2006 (f). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

4.3.2 Feeding

Bottlenose dolphin sightings involving in feeding behaviours and the kernel home range, from 2001-2006 combined, are represented in Figure 4.13 to show the range of area used for feeding activities. Figure 4.14 (a-f) represents the kernel home ranges for feeding behaviours per year. In 2001, there were 40 dolphin sightings showing feeding, 176 in 2002, 127 in 2003, 126 in 2004, 151 in 2005, and 94 in 2006. The kernel UD reveals very consistent feeding home ranges throughout the years, especially in 2001-2005 showing three distinct areas in the home range around New Quay, Ynys Lochtyn, and Mwnt, and core areas around New Quay and Ynys Lochtyn. In 2006, a similar pattern can be seen with the exception of a broader home range in the north. New Quay is used as a core area for feeding in each year. Ynys Lochtyn was also used as a core area in every year except 2005. The core areas at New Quay and Ynys Lochtyn for feeding overlap with the animal's core areas for each year.

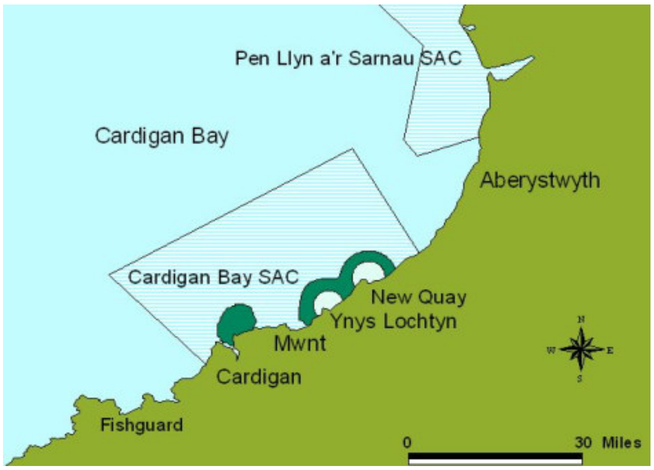


(a)

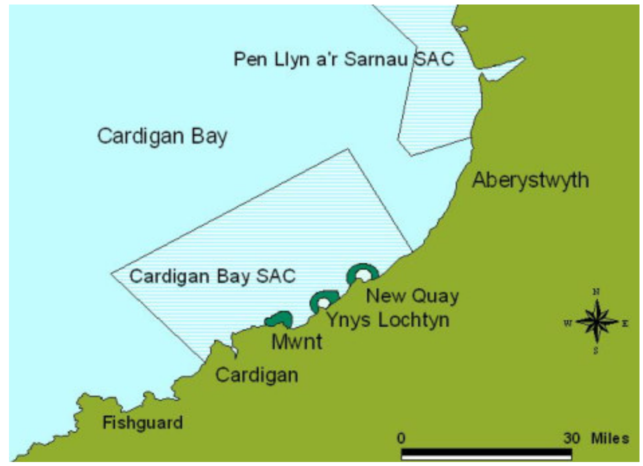


(b)

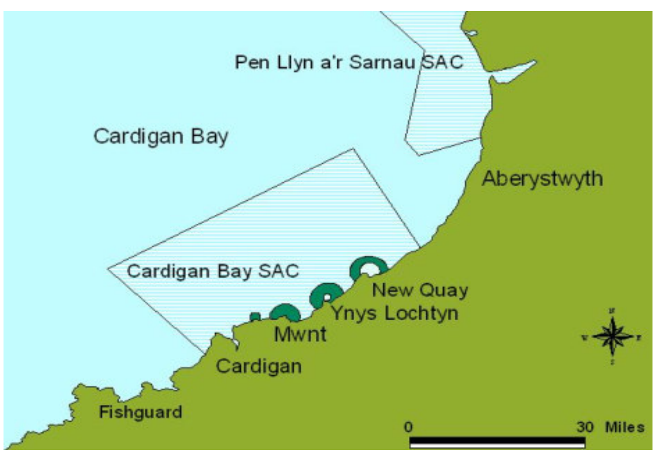
Figure 4.13: All sightings of feeding behaviours from 2001-2006 combined (a) and the kernel home range for 2001-2006 combined (b). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.



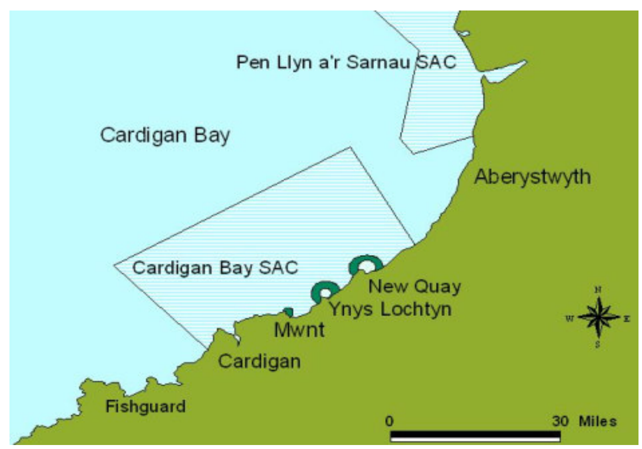
(a) 2001



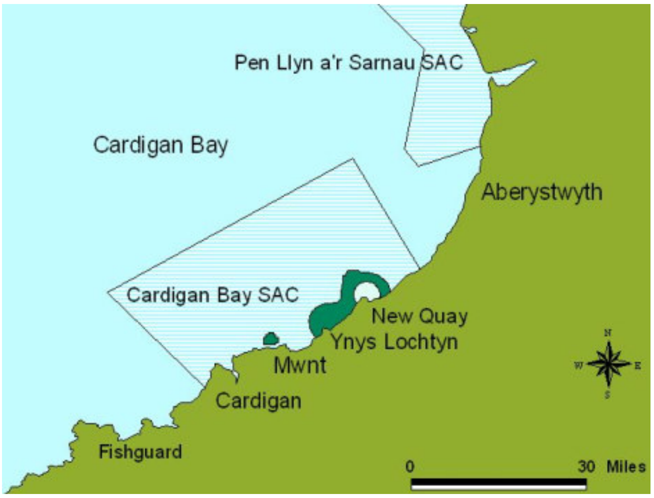
(b) 2002



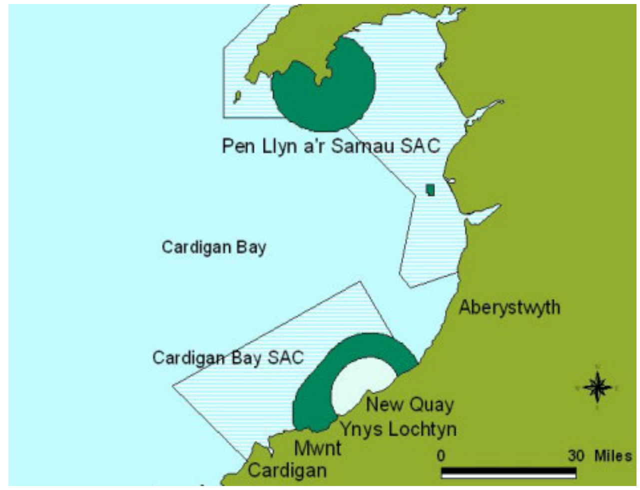
(c) 2003



(d) 2004



(e) 2005

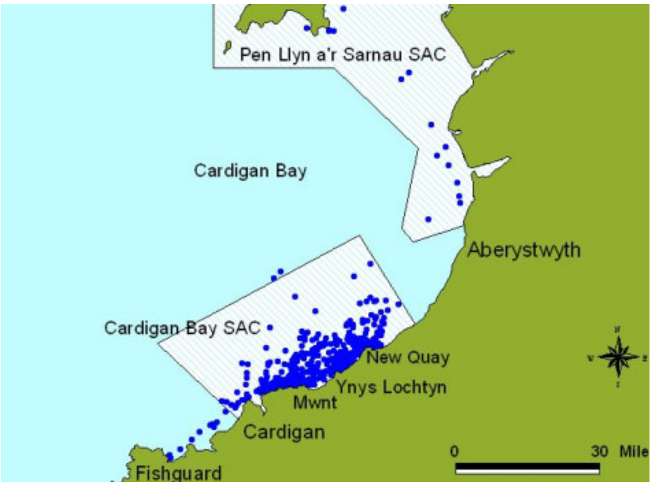


(f) 2006

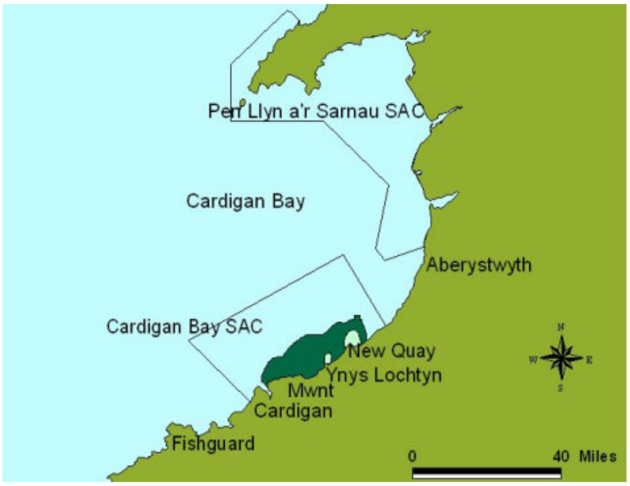
Figure 4.14: Kernel feeding home ranges for 2001 (a), 2002 (b), 2003 (c), 2004 (d), 2005 (e) and 2006 (f). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

4.3.3 Traveling

Bottlenose dolphin sightings and kernel home range involving traveling behaviours are represented in Figure 4.15 to show the area used for traveling. Figure 4.16 (a-f) represents the kernel home ranges for traveling behaviours per year. In 2001, there were 173 sightings of traveling behaviour, 50 in 2002, 195 in 2003, 80 in 2004, 103 in 2005, and 113 in 2006. The kernel UD reveals a similar home range in the Cardigan Bay SAC for all years, stretching from around New Quay down to Cardigan, with the extension of the range south to Fishguard in 2001 and north to the Llyn Peninsula in 2006. The core areas are consistent around New Quay for all years, with the additional core area around Mwnt in 2001. New Quay to Ynys Lochtyn is used as a core area in 2001 and 2006.

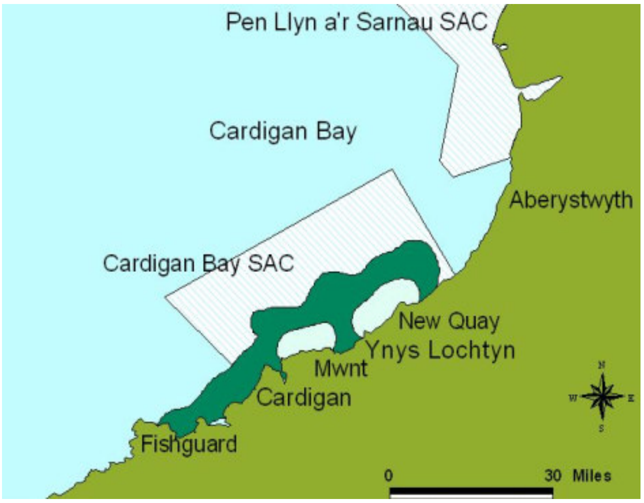


(a)

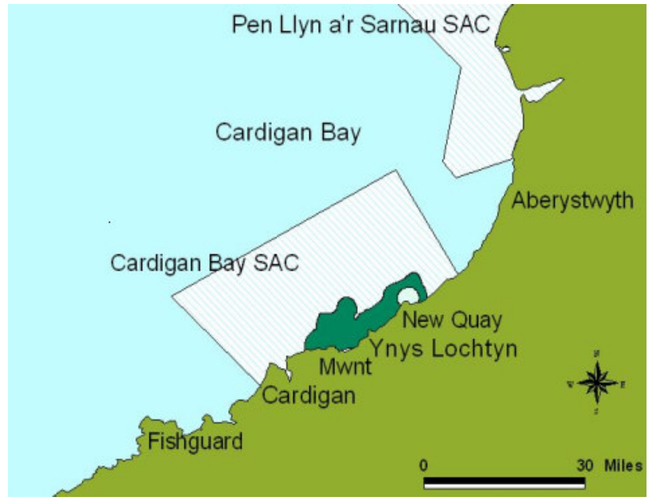


(b)

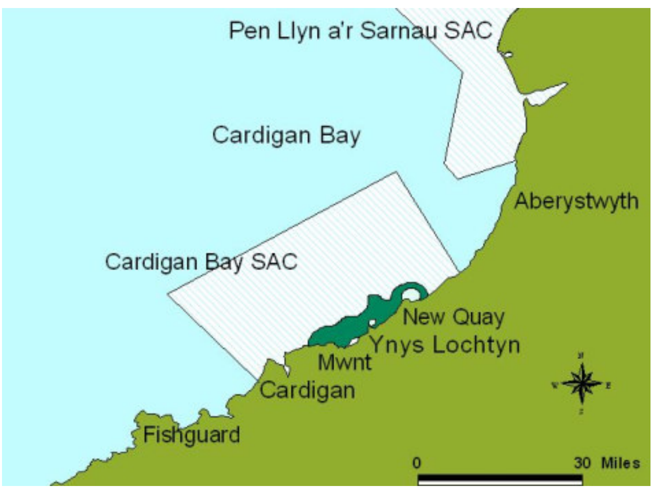
Figure 4.15: Sightings of traveling behaviours for 2001-2006 combined (a) and the kernel home range for 2001-2006 combined (b). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.



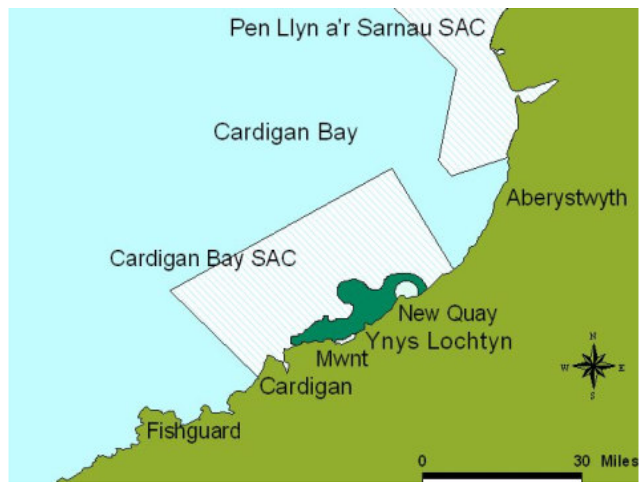
(a) 2001



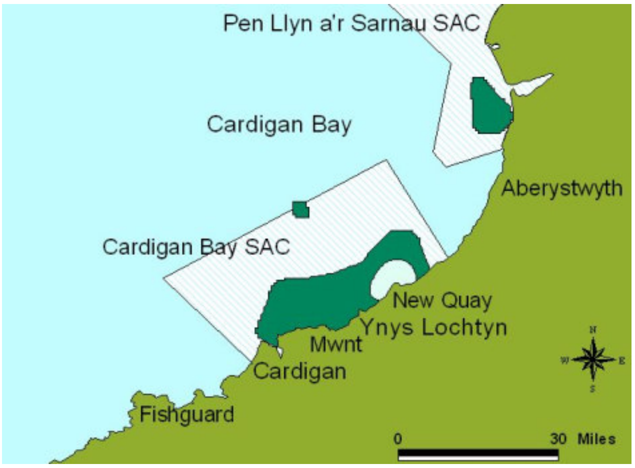
(b) 2002



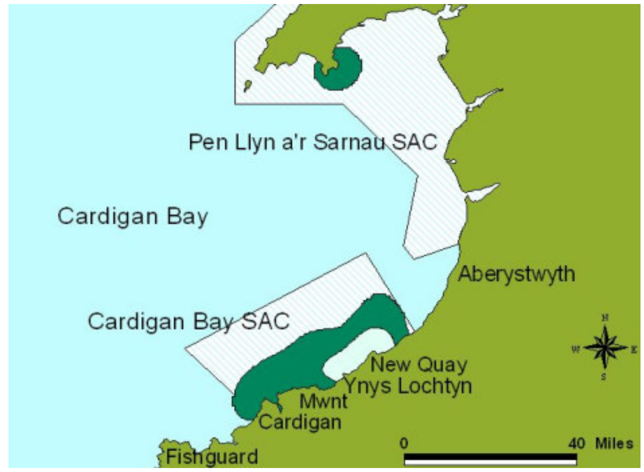
(c) 2003



(d) 2004



(e) 2005



(f) 2006

Figure 4.16: Kernel traveling home ranges for 2001 (a), 2002 (b), 2003 (c), 2004 (d), 2005 (e) and 2006 (f). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

4.3.4 Resting

The kernel home range was determined only for the years 2001-2006 combined, due to low samples of data per year (Figure 4.17). The kernel UD revealed a resting home range throughout the Cardigan Bay SAC and in the Pen Llyn a'r Sarnau SAC. The core area (in pale green) can be seen to cover the area from Aberaeron in the north to Aberporth in the south.

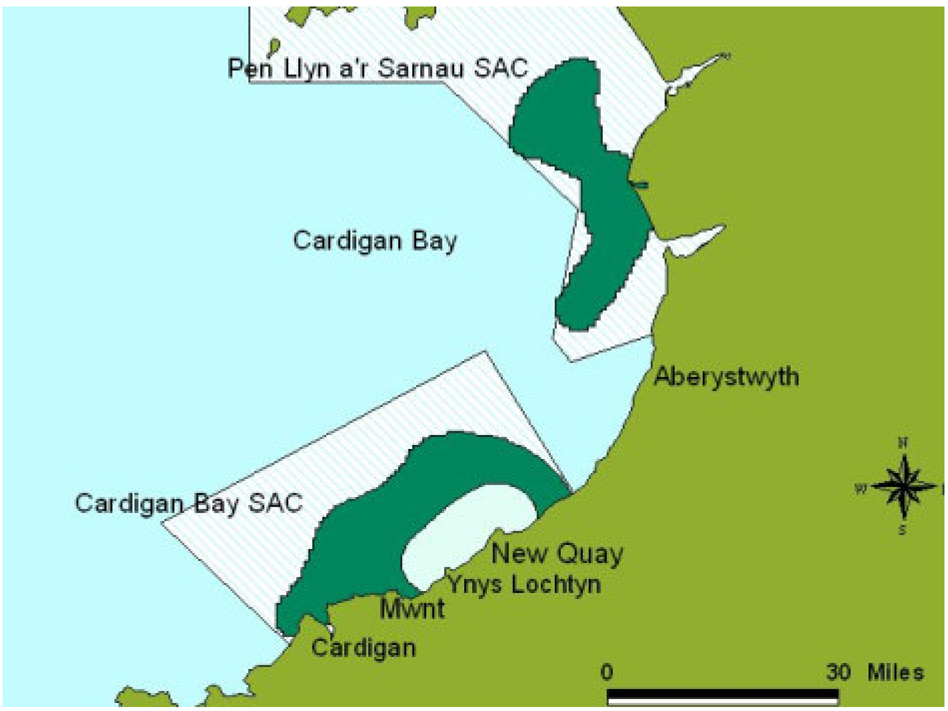


Figure 4.17: Kernel resting home range for years 2001-2006 combined. The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

4.3.5 Socialising

Figure 4.18 represents the kernel home range for socialising behaviour for the years 2001-2006 combined. The kernel UD reveals a large home range due to the small sample set (N=13). The home range covers most of the Cardigan Bay and Pen Llyn a'r Sarnau SAC from Cardigan in the south to the Llyn Peninsula in the north with core areas from New Quay to Cardigan and off the coast of Barmouth.

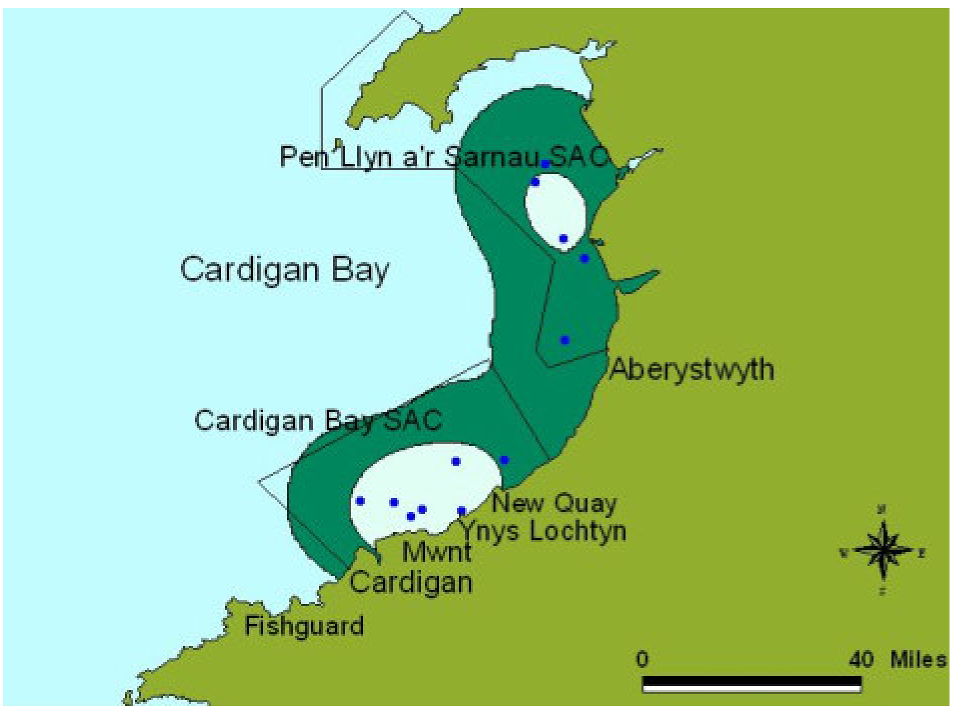
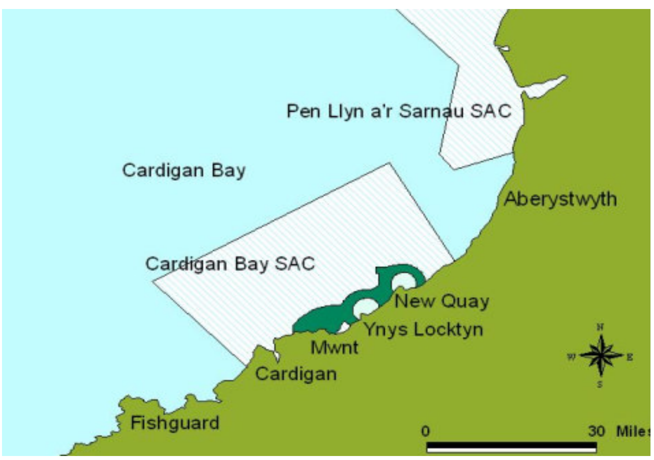


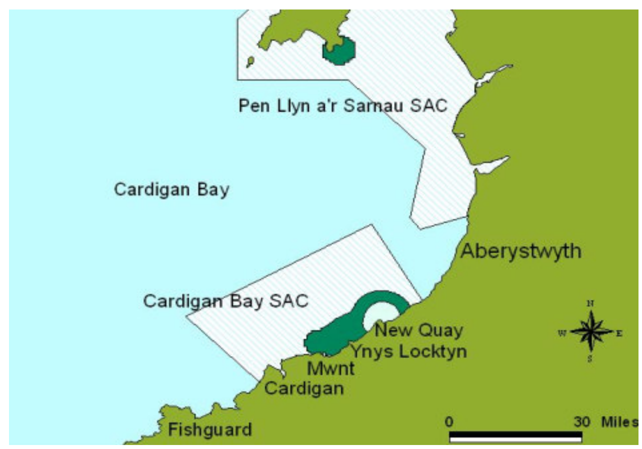
Figure 4.18: Kernel home range for socialising behaviour in 2001-2006 combined. The blue dots represent a bottlenose sighting involving dolphin socialising. The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

4.3.6 Presence of calves

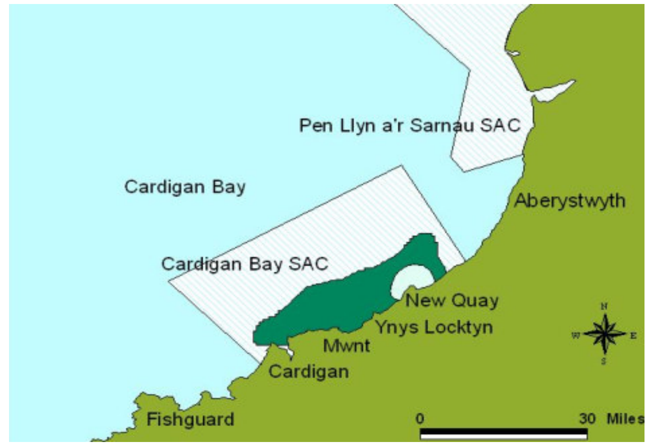
Bottlenose dolphin sightings were plotted separately for groups with the presence of calves and groups without calves present, for traveling and feeding behaviours only, due to small samples of encounters for the other categories. The kernel home ranges were further plotted in Figure 4.19. The kernel UD revealed a core area around New Quay for groups with and without the presence of calves (Figure 4.19 a-d). Two additional core areas are seen around Ynys Lochtyn and Aberporth for groups with calves present, for traveling behaviours (Figure 4.19 a, c), and only Ynys Lochtyn for feeding behaviours.



(a) Feeding behaviours with calves present present



(b) Feeding behaviours without calves



(c) Traveling behaviours with calves present present

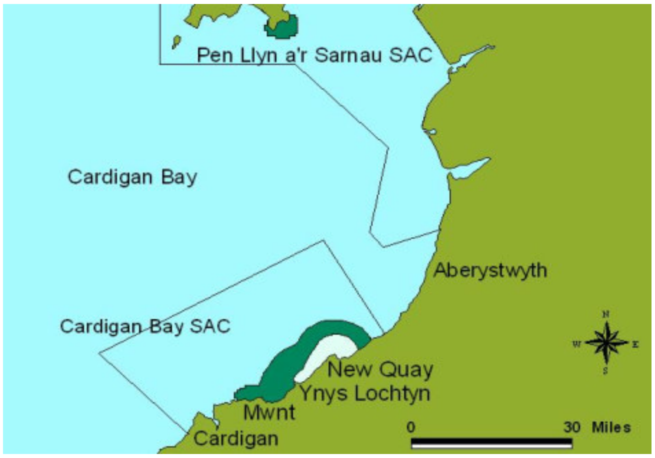
(d) Traveling behaviours without calves

Figure 4.19: Kernel home range for sightings involved in feeding behaviours with calves (a) and without calves (b) and traveling with calves (c) and without calves (d). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

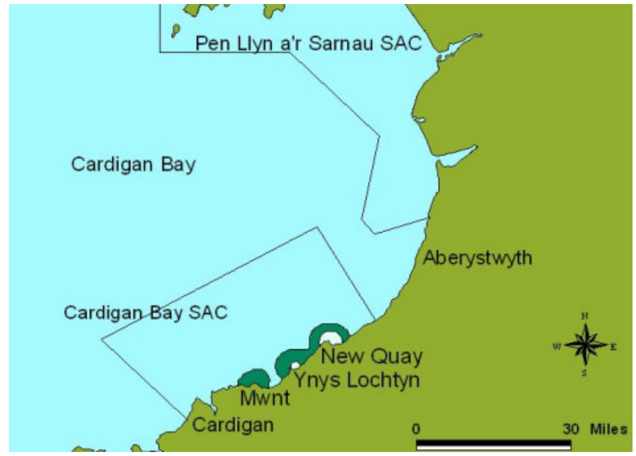
A significant difference was observed in the number of groups with calves traveling between months (Kruskal-Wallis test, df= 6, χ^2=15.573, P= 0.016) but not between years (Kruskal-Wallis test, df= 5, χ^2 =1.600, P= 0.901). A significant difference was also observed in the number of groups with calves feeding between months (Kruskal-Wallis test, df= 6, χ^2=18.656, P= 0.005) but not between years (Kruskal-Wallis test, df= 5, χ^2=3.972, P= 0.553).

4.3.7 Seasonal changes

The two seasonal periods were plotted separately in ArcView for traveling and feeding behaviours only. This was done for the years 2001-2006 combined. The home ranges are shown in Figure 4.20 (a-d). The home ranges for the beginning of the season have a larger core area covering an area from New Quay to Ynys Lochtyn, whereas, at the end of the study season, feeding and traveling behaviours are concentrated around New Quay as a core area.



a) Feeding behaviour from April- July



b) Feeding behaviours from July-October

c) Traveling behaviours from April-July

d) Traveling behaviours from July-
October

Figure 4.20: Kernel home ranges for feeding behaviours from April-July (a) and July-October (b) and traveling behaviours from April-July (c) and July-October (d). The dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

4.3.8 2007

Data were collected from May 15th – August 9th, resulting in 33 bottlenose dolphin sightings involved in a particular behavioural activity. Due to the small sample size per behaviour, the kernel home range was only conducted on all sightings combined (irrespective of behavioural state) (Figure 4.21). The kernel UD reveals a home range that covers the Cardigan Bay SAC and majority of the Pen Llyn a'r Sarnau SAC, with a core area from Aberaeron in the north to Cardigan in the south. The home range covers a larger area, due to the small sample set; as the data set becomes larger, the kernel home range becomes better defined.

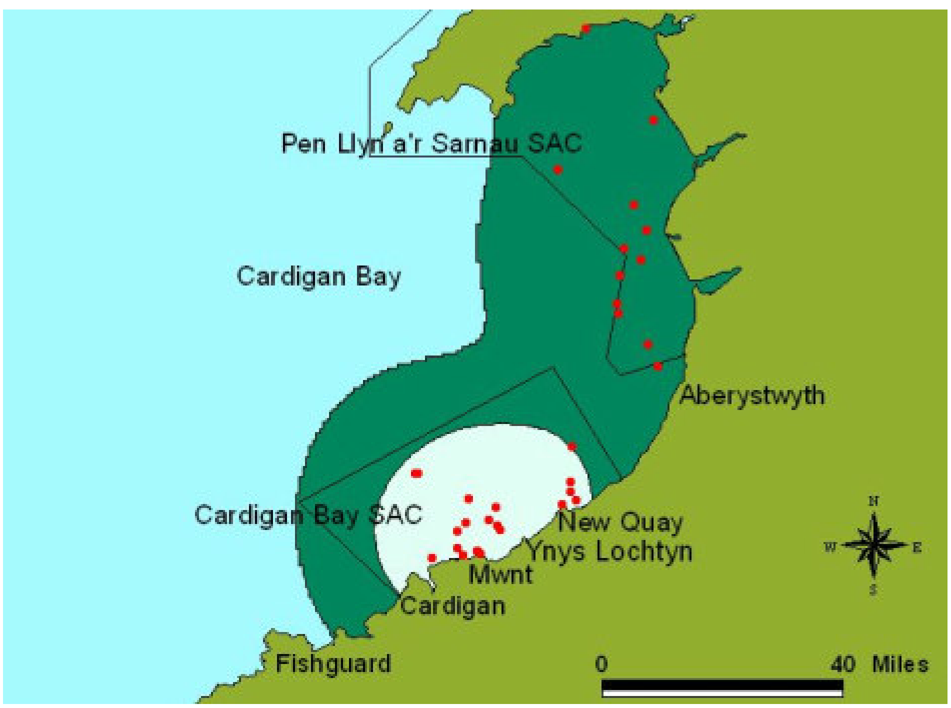


Figure 4.21: Kernel home range for all sightings in 2007. The red dots represent individual sightings, the dark green area represents the 'home range' at 95% probability and the white circles represent the 'core areas' at a 50% probability. Sightings have not been corrected for effort.

5 Discussion

5.1 Behavioural budget

A range of variables unique to the environment may influence bottlenose dolphin behaviour. Understanding which variables are involved and how they affect an animal's behaviour is difficult to assess. Since cetaceans live underwater and much of what they do is unseen by us, one can only speculate on their behaviour by what is seen at the surface. While surface behaviour may be indicative of some behaviours, such as feeding or socialising, it is not always so clear.

In this study, the bottlenose dolphins in Cardigan Bay spent most of the time in travel, an intermediate amount of time in feeding, and the least amount of time socialising. These proportions are similar to other studies on humpback dolphins in Plettenburg Bay, Africa, and bottlenose dolphins in Arkansas Pass, Texas, Sanibel Island, Florida and off the San Diego coast, California (Saayman and Tayler, 1979; Shane, 1986; Hansen and Defran, 1993). Three exceptions to this are years 2002, 2004 and 2005 where the dolphins spent more time feeding than in travel.

Feeding behaviours are of great importance to the behavioural budget of bottlenose dolphins. Dolphins take all opportunities to feed when prey is available. In several years of this study, feeding behaviours made up over 50% of the budget, while in the other years, feeding behaviours were just under 50%. Furthermore, this number only represents the percent of time that feeding was observed on the surface. While feeding behaviours are characterized as short dives near the surface, lack of persistent direction, visible fish seen at the surface, or fast, quick lunges, long dives can also be associated with feeding behaviour as a dolphin may dive to locate prey at a deeper depth (Gunter, 1954). In those cases, it is not possible to identify such behaviours as feeding. Long dives, also associated with a fluke-up before diving, were only counted as suspected feeding if other criteria were met (as mentioned above). If the dolphin made a protracted movement, then a long dive was recorded as travel when it could have been foraging. Feeding can also be misidentified as other behaviours such as socialising, where there is splashing, physical contact, and lunges. Feeding and traveling behaviours combined to make up over 85% of the yearly budget each year. The relatively constant percentages of feeding and traveling behaviours per year could indicate the presence of prey species throughout the study season, each year. In Southern California, Hansen and Defran (1993) found relatively constant feeding behavioural states, and correlated this to a year-round occurrence of prey, whereas, Bearzi *et al*. (1999) found extreme variability in feeding and traveling behavioural states over years, and suggested this was due to fluctuations in prey availability from year to year. An increase in feeding behaviour, such as in 2002, could have been caused by decreased prey availability resulting in an increased amount of time spent in hunting for food (Brager, 1993).

Traveling behaviour varied from 18%-75% of the budget over the 7-year study period with an average of 47%. Traveling behaviour can also be associated with feeding behaviours, as dolphins need to travel to locate prey and conspecifics. An animal’s budget is centreed on feeding; therefore, in order to forage successfully, an animal must be able to travel to where the food supply is high. An increase in travel time might suggest low prey availability and an increase in the time needed to search for food or other food sources, such as shrimp or crustaceans, and this could explain the rise in travel time in 2001 to 75%. Conversely, a decrease in travel time may suggest an increase in prey availability and an increase in feeding.

Traveling is also a way to locate conspecifics, communicate and utilize different areas within a home range. Travel time will likely increase with a larger home range or where there are several core areas to investigate. In Figure 4.14, it can be seen that the dolphins in Cardigan Bay prefer three areas for feeding: New Quay, Ynys Lochtyn and Mwnt, while in Figure 4.16, the home ranges for traveling connects these three locations as the dolphins travel from one feeding area to another moving along favorite “tracks” (cf. Bearzi *et al*., 1995).

Socialising behaviour ranged from 0% - 3% with an average of 0.9%. This is a small percent compared to other studies such as Bearzi *et al.* (1999) who recorded 6% of the bottlenose dolphin’s budget spent socialising in the Mediterranean and Hansen and Defran (1993) found 12% in Southern California. Undoubtedly, socialising has not always been recorded. Commonly, this behaviour can be confused with feeding with the fast movements and splashing. In this study, socialising was identified by splashing, leaps, belly-to-belly views, and physical/sexual contact among animals. Since 2005, the percent of time seen socialising has increased probably due to increased attention to this behaviour.

Resting behaviour ranged from 0% to 4.3% with an average of 1.5% over the 7-year study period. Resting is a fundamental behaviour in any animal's daily budget. A reduction in rest is likely to result in a reduction of energy reserves, which could affect foraging efficiency, vigilance levels, and the level of parental care. Resting behaviour is another behaviour that may be misidentified as slow travel. As mentioned by Shane *et al*. (1986), "true resting behaviour has never been as clearly identified as it has in some other cetaceans." No resting behaviour was seen in 2007, but it was recorded in 4 previous years by other researchers. For this reason, behavioural budgets should be taken with caution realizing that because resting was not recorded in 2007, it does not mean that it does not occur or play a role in the behavioural budget of bottlenose dolphins. It must be mentioned that some level of disturbance by the boat may greatly reduce the time spent resting or the ability to see animals resting.

'Other' behaviours included bow-riding or playing, and averaged 6.7%. In 2007, 'other' behaviours accounted for 12.1% of the behaviour budget, made up only of bow-riding. While leaping and jumping may be indicative of traveling or foraging, bow-riding is obviously related to the presence of a boat and may be regarded as disturbed behaviour (though not necessarily in a negative sense). Saayman *et al*. (1973) associated leaping, splashing and chasing with feeding, and Wursig and Wursig (1979) associated clean leaps with feeding and noisy leaps with socialising. While these behaviours take up a proportion of the budget, they may not be indicative of natural behaviours that would occur without the presence of the research vessel, nor distinctively fall into one of the four behavioural categories. Therefore, these behaviours were all grouped together.

Caution must be used when including 'other' behaviours as part of the budget due to the fact they may not occur in the natural budget of bottlenose dolphins, or other researchers may place them into other behavioural categories based on different criteria.

The behavioural budget showed no change between groups with and without the presence of calves, suggesting activities do not change when calves are present. The hypothesis at the start of this study was that budgets would change when calves are present, perhaps leading to an increase in feeding or socialising behaviours. This rejects the hypothesis that budgets shift when calves are present.

Lone individuals spent more time feeding, while this behaviour decreased with group size. This might suggest that prey is plentiful, and larger groups are not necessary to hunt and capture food. Conversely, this may also suggest that hunting alone is more difficult and thus more time is needed to forage in order to find ample food. Individuals tend to feed alone closer inshore than offshore, possibly due to less predation risk and smaller schools of fish.

The largest group size, 11-20, usually consisted of adults, juveniles and calves. This group spent a greater amount of time socialising than any of the other age group categories, possibly due to the playfulness of younger animals or the social behaviour of males and females including mating, courting or dominance displays during the breeding season (Bearzi *et al.*, 1999). This group also spent the most time traveling, accounting for 61% of the yearly budget. As seen in section 4.3.6, groups with calves preferred two core areas, at New Quay and Ynys Lochtyn, compared with groups without calves, which preferred only New Quay as a core area; thus, larger groups with calves spend more of their budget traveling between the two core areas.

Seasonality had no significant effect on any behaviour in this study, although a 7% increase in feeding behaviours was recorded from the beginning of the season to the end of the season. Prey shifts in the winter may require more time searching for food, such as crustaceans and cephalopods, rather than fish (Brager, 1993). Mackerel, a favoured prey item for bottlenose dolphins in Cardigan Bay, are plentiful from April to late September, disappearing in September with the introduction of whiting in October (Baines *et al.*, 2000). Plaice, Monkfish, Bass, and Salmon are also known to be common prey items living in the coastal waters of Cardigan Bay (Baines *et al.*, 2000). A peak in feeding behaviours, particularly in the autumn, may also be associated with dolphins building up fat stores for winter. Bottlenose dolphin's blubber will become thicker in the winter to compensate for the cooler water temperatures (Bräger, 1993). The study season for this project spans only the warmer months of the year. To gain a better understanding of how the seasons affect the yearly budget, these data would benefit from being compared to the winter months.

5.1.1 Limitations

While determining the behavioural budget allows researchers to gain a better understanding of how a population spends its time in certain activities and what factors affects their budgets, such as seasonality or the presence of calves, there are many limitations in the interpretation of these data. The budget is determined by the behaviours recorded at any one time and may not be indicative of the true behavioural budget. As mentioned earlier, the behavioural state is recorded based on surface behaviours. Cetaceans spend a majority of their time underwater. When we do see them, we can only see a proportion of their body and only for brief periods. Due to this, surface behaviours can be misidentified or recorded as a single behaviour seen at the surface, while the animal may be performing another behaviour underwater that cannot be seen. Not only are many behaviours hidden from view, even with the most strict protocol each researcher will interpret behaviours slightly differently. In this study, previous data from 2001-2006 were combined with data collected by myself in 2007. Over the 6 years of previous data, several people have participated in the collection of these data. A behaviour protocol is in place, but researchers' interpretation must be taken into account when using these data. However, surface behaviours can be useful in allowing a daily budget to be determined, keeping in mind the limitations of this method.

Boat-based and land-based surveys are useful ways to observe cetaceans in their environment but do not provide the entire picture. Visual observations of bottlenose dolphins can only be conducted during daylight hours in fair weather conditions. Therefore, the budgets constructed only represent the daily budget and not the complete budget of these animals. This is crucial when reviewing these results as they would likely change significantly if the animals could be observed for a 24-hour period. The budgets determined in this study can be useful in looking at proportions of time spent in a particular behaviour compared to another, but caution should be used when looking at the budget as a whole, keeping in mind the minimal opportunities for observations. The data used in this study were typically collected in good to fair weather conditions during daylight hours. Lastly, one must recognize a level of disturbance by the research vessel itself, particularly during a behavioural study. Behavioural data were collected at the initial sighting of the dolphins, hoping to gain information before any boat disturbance might start to have an influence. In Cardigan Bay, it has been found that 69% of dolphins showed a neutral response to motorized boats, and 23% showed a negative response, highlighting the effects that boats may have on dolphin behaviour (Kosarew, 2003).

5.2 Home ranges

Many studies have shown cetacean distribution to be related to habitat features, but what that habitat provides is sometimes unclear. Only when behavioural observations are made in relation to habitats can a correlation be made. This study aimed at focusing on home ranges in order to gain ecological information on the bottlenose dolphins in Cardigan Bay.

Kernel home range size is highly variable with populations, habitat size and resources, and should be treated with caution when comparing populations. Hung and Jefferson (2004) suggest that resources may be scarce in habitats where the home range is large, and abundant where home ranges are small, which appears to be the case in Cardigan Bay. Seaman and Powell (1996) suggest that the kernel density estimator may overestimate home ranges when sample sizes are small.

The size and distributions of home ranges are important indicators of social and mating systems in marine mammals (Boness *et al*., 2002). The overall home ranges of the population in Cardigan Bay were not distributed evenly, covering an area from New Quay to Fishguard, and in several years were clumped into three main areas at New Quay, Ynys Lochtyn and Mwnt (Fig. 4.12 (a-f)). Core areas were located at New Quay, Ynys Lochtyn and Mwnt, overlapping with the feeding and traveling core areas. According to the encounter rate, dolphin sightings were higher less than 10 km from the coast, and occurred more frequently between New Quay and Cardigan.

Feeding techniques of bottlenose dolphins' range from individual fish capture to group coordination, and may represent a part of habitat selection. Data from 2007 found that 50% of the groups seen traveling and feeding consisted of 2-4 animals. Foraging closer to the shore, where fish aggregate, may increase foraging efficiency for smaller groups, and decrease the risk of predation. These results are consistent with bottlenose dolphins in Sarasota Bay, Florida, where small groups are found near the coast, associated with sea grass areas, which probably represent an important area for food, as well as a refuge from predators, or aggregating areas for fish. Bottom substrates may play a role in habitat selection in the coastal waters of Cardigan Bay but unfortunately little is known about this relationship.

When determining home ranges, an important factor affecting the distribution of dolphins is the presence or absence of calves in the dolphin groups (Watson-Capps, 2005). Although groups of adults only and groups with calves showed a similar core area around New Quay, an additional core area extending to Ynys Lochtyn was seen only for groups with calves. Gubbins (2002) defined the areas of high presence of females with calves as 'areas with a high concentration of resources to support the energetic needs of lactation'. Similarly, in this study, Ynys Lochtyn represents an area that provides resources or protection necessary for females with calves.

While it was not tested in this study, it has been seen in other studies that cetacean distributions can often be related to environmental variables. Selzer and Payne (1988), for example, found a significant correlation between sea surface temperature and bottom topography with the distributions of two dolphin species in Northeastern United States, Wilson *et al*. (1997) found bottlenose dolphin's core areas to occur near deep, narrow channels in Northeast Scotland, Ballance (1992) observed that bottlenose dolphins preferred to feed in estuaries in the Gulf of Mexico, and Lewis and Evans (1993) found bottlenose dolphins preferred areas with strong currents, around headlands, in Cardigan Bay. Steep topography has been seen to be used by dolphins as preferred areas, either because of high aggregations of prey or to help dolphins during foraging activities (Ballance, 1992). These environmental variables may not be strictly casual but may reflect prey distributions. Common dolphin distribution in New Zealand was affected by varying sea surface temperatures (Neumann, 2001). Dolphins moved closer inshore with rising temperatures, and farther offshore with low temperatures. This may be the case in Cardigan Bay where bottlenose dolphins become more dispersed in the winter months, whereas they are regularly seen near the coast in the warmer months.

Determining factors that influence the movements and distributions of the dolphins in the study area is a difficult task, and requires additional information and analysis beyond the scope of this study. However, dolphin distribution is thought to reflect the physical environment, prey movements and distributions, and habitat pressures.

5.2.1 Habitat use

The home range of the dolphins coincided closely with the home ranges for feeding and traveling behaviours. The three common core areas, New Quay, Ynys Lochtyn and Mwnt, include protruding headlands which will tend to aggregate fish due to the fast currents and bottleneck effect around them reducing the energetic costs of foraging (Williams *et al*., 1996). The regions between the core areas act as ‘corridors’ along which the dolphins traveled. The use of these core areas for feeding suggests that the coastal waters of Cardigan Bay are an important feeding area for the bottlenose dolphins. Plaice (*Pleuronectes platessa*), Monkfish (*Lophius piscatorius*), Bass (*Dicentrarchos labrax*), Salmon (*Salmo salar*), Herring (*Clupea harengus*), and Mackerel (*Scomber scombrus*) are abundant in the coastal waters of Cardigan Bay in the summer and autumn months (Baines *et al*., 2000). Food availability represents one of the most important factors in determining dolphin distribution and behavioural activity (Neumann and Orams, 2005).

Core areas at New Quay and Ynys Lochtyn overlapped with the core areas used for groups with calves suggesting that these areas are good feeding grounds for females and younger animals. The addition of Ynys Lochtyn as a core area only for groups with calves indicate the presence of other resources important for females and calves such as less disturbance, shallow areas where calves can learn to forage for themselves or areas with enhanced protection from predation.

Resting showed the largest core area of all the behaviours analysed. The resting home range completely overlapped with the home range of the dolphins. The resting home range is larger and less well defined, possibly due to the smaller sample size, and covers the inshore section of the Cardigan Bay SAC with a secondary area near Aberystwyth. The core area covers a broad area from New Quay to Ynys Lochtyn. Although this area is larger it proves that the Cardigan Bay SAC, especially from New Quay to Ynys Lochtyn, are important areas for several behaviours.

The home range throughout the study season shows similar patterns, with a shift in core areas towards the end of the season. The sole use of New Quay as a core area, and a 7% increase in feeding behaviours at the end of the season, could suggest a shift or decrease in prey items. Conversely, this increase in time spent feeding may suggest an increase in prey items around New Quay. Mackerel, the most abundant prey item in Cardigan Bay, are known to disappear from the area around this time (Baines *et al*., 2000). In New Quay Bay, the local fish factory appears to supply a constant food supply to the local birds and dolphins in the area by disposing of fish waste to the waters below. One explanation for the constant use of New Quay as a core area through the study season, and also throughout the winter months (as found from the T-POD acoustic monitoring), may be the constant food supplied by the fish factory when other prey availability is low. The increase in time spent foraging supports this hypothesis.

5.2.2 Limitations

Several biases could be associated with these results. The data used from 2001-2007 are a combination of line transects, casual watches and dedicated search effort types. In some cases, certain tracks may have been covered twice during a single survey trip. On return from a land transect the track followed may cover an area already covered by the transect route. For this reason, it is crucial home ranges are analysed in close association with the encounter rates, which reduces this bias.

The kernel home range estimator can be an important tool in assessing home ranges for animals. One bias is that the UD will provide home ranges based on the locations where data were collected and will be biased towards areas of increased effort. The Cardigan Bay SAC was established for bottlenose dolphin before the Pen Llyn a'r Sarnau SAC was, and therefore effort and sightings are concentrated upon this former area. Again, the data should be analysed in association with the encounter rates, which reduces the effort biases. While these home ranges are indicative of the dolphins sampled in Cardigan Bay, increased effort throughout Cardigan Bay may give different results.

The kernel home range is determined on sighting information only. Although the kernel density estimator has been considered one of the most robust probabilistic techniques, larger sample sizes for some of the behaviours would avoid potential biases and limitations.

Kernel home range estimators are very useful in determining home ranges, but determining habitat use proves more difficult. Understanding habitat use requires the interpretation of many factors such as prey movements and availability, bottom topography and seafloor habitats and the availability of these features in the study area.

Lastly, the data collected over the 6-year study period were derived from several different sources. Many long-term projects suffer from this disadvantage. Although a protocol is set in place, each researcher will collect data slightly differently, and this should be considered when analysing these results.

6 Conclusion

This project aimed at determining the behavioural budget and home ranges of the bottlenose dolphins in Cardigan Bay, West Wales. While this population is protected, understanding their budgets and movement patterns will expand our knowledge for long-term monitoring in this region.

By collecting behavioural data, both the behavioural budget and home range of the bottlenose dolphins could be determined. Determining the budget is useful in understanding what behaviours are affected over time, seasons, with group size and when calves are present. Understanding shifts in the budget will allow managers to reduce impacts when the animals are most vulnerable. Behaviour collection techniques are useful for determining behavioural budgets and home ranges with some limitations. Surface behaviours are good indicators of behavioural states but must be used with caution as they do not indicate all behaviours involved and will vary between researchers. While this data provided information on the percent of time spent in one behaviour compared to another, it must be understood that this data only represents the diurnal behavioural budget.

Cardigan Bay is believed to be home to over 100 dolphins, some have estimated 230 individuals make use of Cardigan Bay (Gregory and Rowden, 2001). The kernel utilization distribution highlighted areas of high use within the known ranges of this dolphin population. Using the kernel home range in ArcView proves to be an important tool for determining home ranges of animals and core areas for specific behaviours.

Analysing the home ranges with encounter rates will help in reducing biases due to varying effort patterns, and should be coupled with environmental data to fully understand home ranges. GIS systems can be used to investigate a range of factors that influence habitat use and distribution. This approach is critical to our understanding of the dolphin's ecology by evaluating both environmental and anthropogenic factors.

The methodology in this study provided an opportunity to determine how much time the dolphins in Cardigan spent in a variety of behaviours and what areas they prefer to use for those behaviours. This study found that traveling and foraging consumed over 85% of the yearly budget. The coastal waters of Cardigan Bay, in particular New Quay, Ynys Lochtyn and Mwnt acted as core areas and seem to provide environmental resources or protection for feeding, traveling, resting, and when calves were present. These areas are on peninsulas which possibly act as bottlenecks, aggregating prey due to environmental variables such as depth, slope or currents. Groups with calves used an additional core area at Ynys Lochtyn and New Quay was consistently used as a core area for all behaviours throughout the study season, every year.

While conservation measures are already in place in Cardigan Bay for the bottlenose dolphins, the preservation of habitat features important to the species will be crucial to the survival of this population. Destruction of inshore habitats is probably the most important threat for coastal dolphins (Parra, 2006), thus using an ecosystem approach may prove more effective than a species specific one. The use of effective codes of conduct and precautionary methods, such as reducing disturbances in core areas where the animals are more vulnerable, in association with long-term monitoring and research will contribute to the conservation of this species and the habitat in which they live.

Recommendations for future research

This study provided important information on the behavioural budgets and home ranges of the bottlenose dolphin in Cardigan Bay, West Wales. Overcoming the limitations of this study could facilitate future research.

A combination of data on environmental variables and behaviour would provide greater insight on the distribution of the bottlenose dolphins in Cardigan Bay. Environmental variables will be specific to each area but are necessary in understanding what influence they have on the behaviour and distribution of bottlenose dolphins. A great range of environmental variables such as water depth and slope, bottom topography, prey distributions, dolphin prey preferences, as well as anthropogenic impacts such as fishery activities and boat interactions coupled with the information found in this study would provide a more complete picture of the dolphin's distribution and ecology.

Beyond the scope of this study, it would prove useful to determine the percent of overlap for the home ranges and behaviours. This information would provide the percent of overlap between the behaviour core areas and the home range core areas in order to assess those particular areas. Once these critical areas are better defined, conservation of these habitats and a reduction of disturbances will help in the long-term protection of this popular species in Welsh waters.

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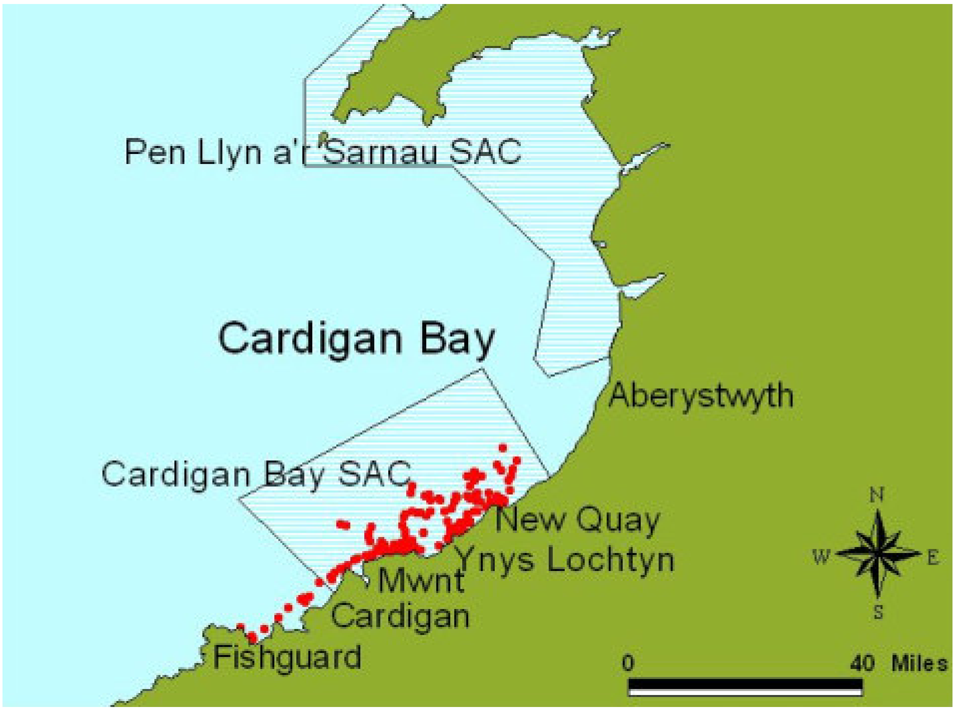
Appendices

Appendix A.

Each map represents bottlenose dolphin sightings involved in a behavioural state per year.

2001



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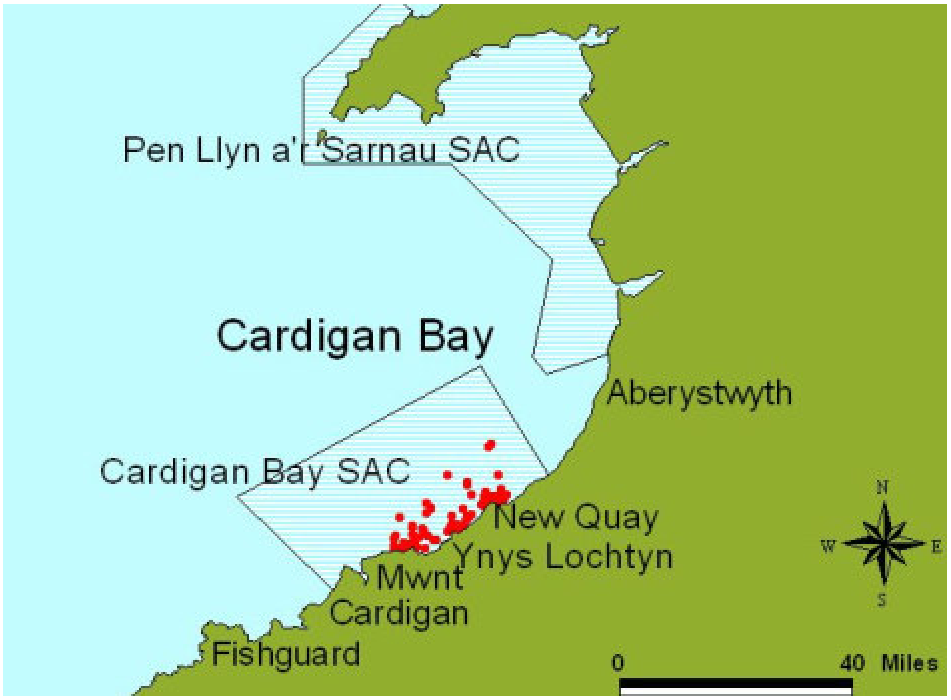
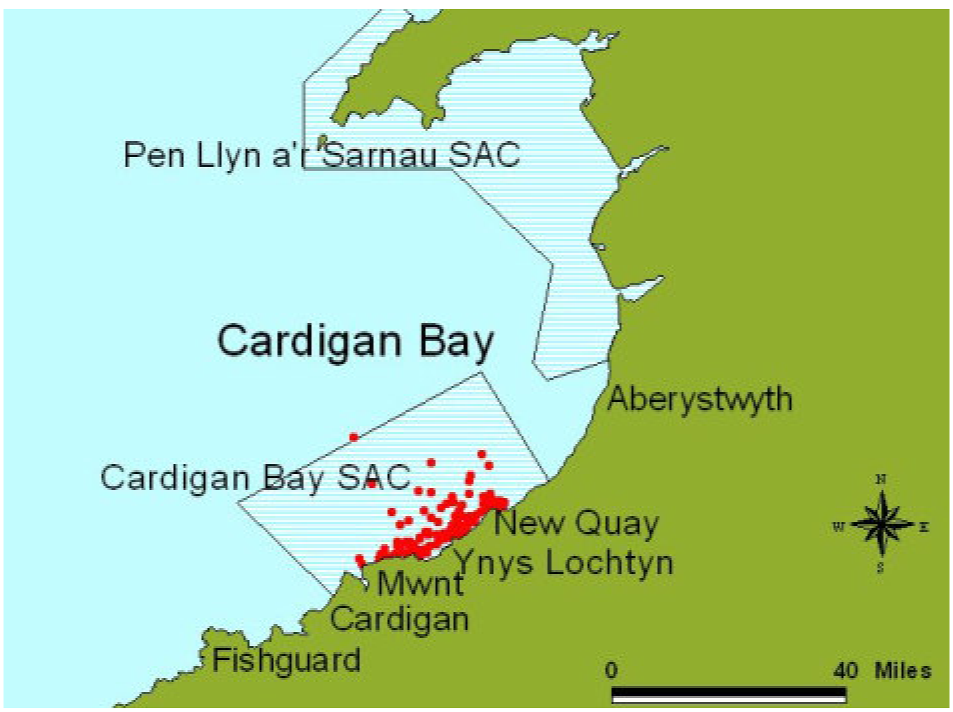


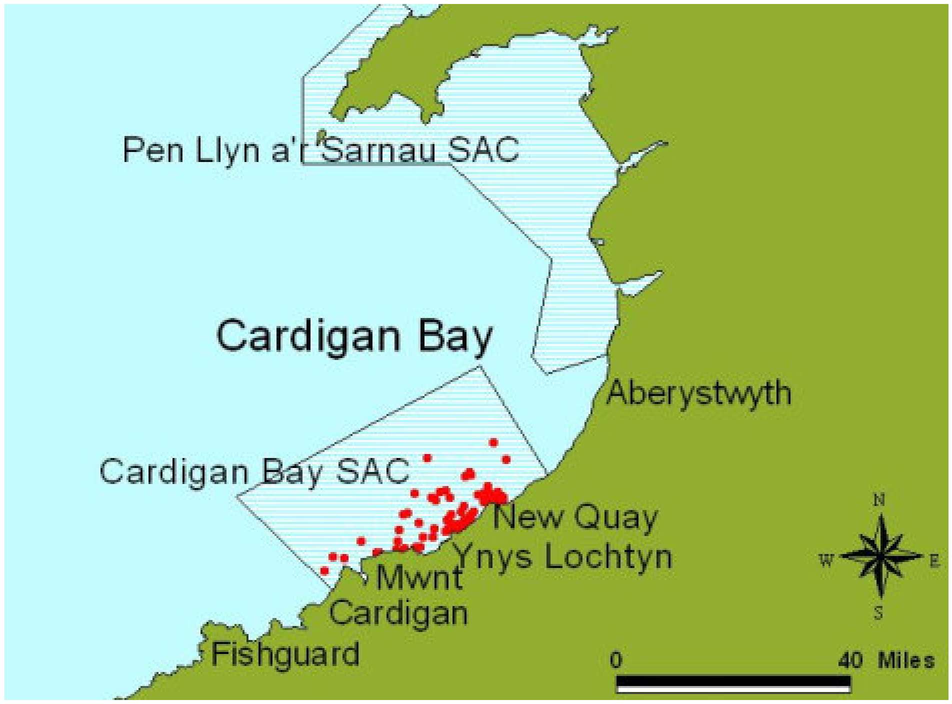
Pen Llyn a'r Sarnau SAC
Cardigan Bay
Aberystwyth
Cardigan Bay SAC
New Quay
Ynys Lochtyn
Mwnt
Cardigan
Fishguard
N
W
E
S
0
40 Miles

2003



Pen Llyn a'r Sarnau SAC
Cardigan Bay
Aberystwyth
Cardigan Bay SAC
New Quay
Ynys Lochtyn
Mwnt
Cardigan
Fishguard
0
40 Miles

2004


Pen Llyn a'r Sarnau SAC
Cardigan Bay
Aberystwyth
Cardigan Bay SAC
New Quay
Ynys Lochtyn
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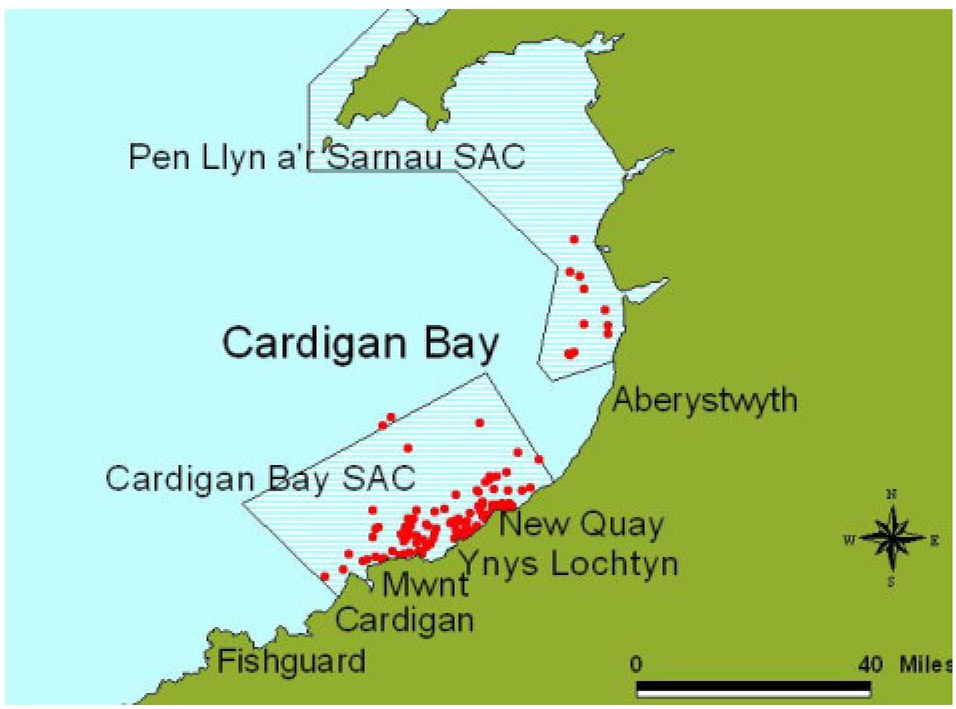
2005


Pen Llyn a'r Sarnau SAC
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Cardigan Bay SAC
New Quay
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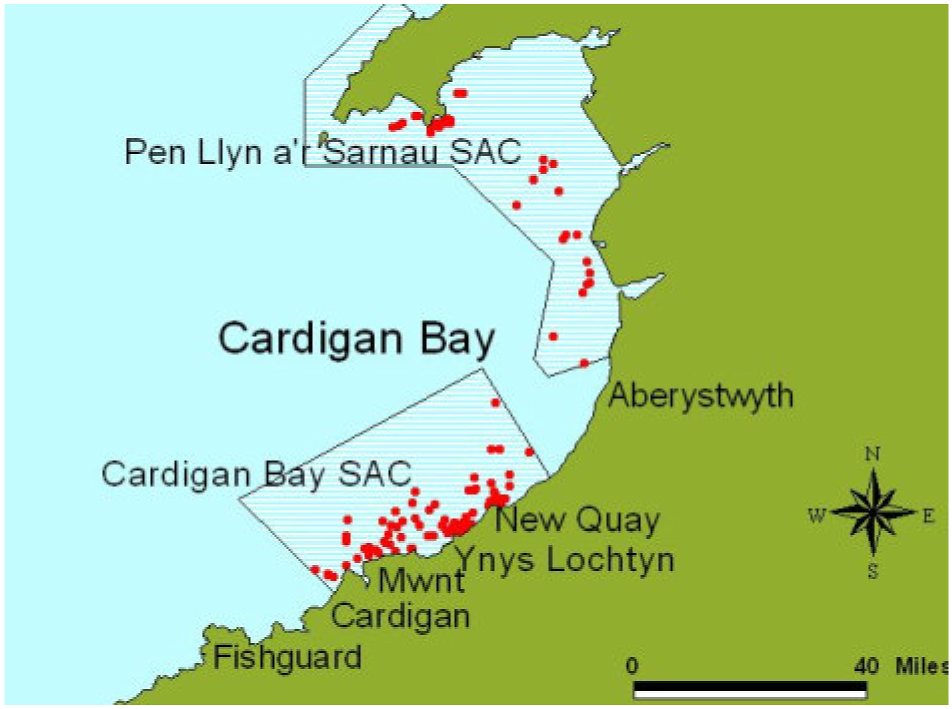
2006


Pen Llyn a'r Sarnau SAC
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New Quay
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