A SURVEY OF BOTTLENOSE DOLPHINS

(Tursiops Truncatus)

IN THE SHANNON ESTUARY

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Abstract

The bottlenose dolphin *Tursiops truncatus* is a ubiquitous species found throughout the temperate and tropical oceans of the world. The bottlenose dolphin population that occurs in the Shannon is one of only six known resident European populations. Since 1994, a small dolphin watching industry has been operating in the estuary, with plans for expansion. The objectives of the this were to a) assess the degree of residency of bottlenose dolphins in the Shannon; b) estimate the population size and assess the production of calves; c) examine the social structure of the population; d) study habitat use and e) examine the effects of boats on dolphin behaviour. Boat-based surveys and photo-identification techniques were used to derive a population estimate and to examine distribution and movements of individually identifiable dolphins over a two-year period. Land-based scan samples were used to examine behavioural activity and interactions of dolphins with all categories of boat traffic. Trips on dolphin watching boats examined whether these boats were interacting with the same individual dolphins on a trip, daily or weekly basis.

Dolphins were recorded in all months of the year but with a seasonal peak between May and September. Many of the identifiable dolphins were resighted throughout the study indicating a high degree of residency. Using photo-identification and mark-recapture analyses, the population estimate for the Shannon is 113 dolphins (CV 0.14, 95% C.I. 94 - 161). The presence of neonatal calves only from July - September indicates that there is a marked breeding season for this population and that the area is important as a nursery area. Group sizes ranged from singletons to groups of 32 animals and while dolphins were seen throughout the study area, groups were frequently encountered in the narrow water at Kilcredaun and in the mouth of the estuary. A second area of concentrated sightings was identified further up-river around Moneypoint and Tarbert/Killimer. This group comprised a smaller number of individuals, and the re-encounter rate of these individuals in the same area suggests a degree of habitat partitioning. These dolphins may be more vulnerable to dolphin watching activities than the more diffuse numbers in the outer estuary. The influence of tidal cycle was recorded at Kilcredaun and at Killimer/Tarbert with a distinct peak in sightings in the four-hour period before low tide. The frequency distribution of association indices shows that there are few "strong" associations between individuals and supports the notion of a fluid and gregarious social structure. Dolphin watching boats were involved in 61.8% of all interactions with dolphin groups, higher than any other category of boat. At present, two operators make approximately 200 dolphin watching trips annually, carrying a total of 2,400 passengers per year. The operators are highly successful in locating dolphins (97%) and the tour boats rarely come into contact with each other on the water and generally search in different areas and watch different groups. The potential for land-based dolphin watching was examined and possible sites identified. The information from this study provides a basis from which sound conservation management strategies can be developed, in order to properly conserve the species and its habitat, to develop a sustainable dolphin watching industry and to develop/monitor other coastal zone industries such as oil and gas exploration and shipping development within the Shannon.

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1 INTRODUCTION

Bottlenose dolphins (*Tursiops truncatus*) are one of 21 species of cetaceans (whales, dolphins and porpoises) found in Irish waters (Berrow and Rogan, 1997). The bottlenose dolphin is a cosmopolitan species found throughout the temperate and tropical oceans of the world (Leatherwood and Reeves, 1983). Bottlenose dolphins are a dark grey colour with pale undersides. Calves are often a much lighter shade than adults and darken with age. Adults typically measure between 3 and 4 metres in length, with males growing to a slightly larger size than females (Leatherwood and Reeves, 1983). New born calves are about one metre in length and remain in close association with their mothers for three to four years, suckling for at least the first 18 months (Cockcroft and Ross, 1990).

The bottlenose dolphin population, which inhabits the Shannon, is one of only six known resident European populations. It is not known how long bottlenose dolphins have inhabited the Shannon but anecdotal records date back to 1835 (Knott, 1835). Previous work on the Shannon bottlenose dolphin population (Berrow *et al.,* 1996) has shown a degree of residency of recognised animals and highlighted their abundance in the mouth of the Estuary during the summer months.

Nature-related coastal activities are a major source of income in Ireland, valued at IR£9.1 million (Anon, 1997). The Shannon dolphin population has been the centre of a growing tourism industry since 1994 with boat trips taking tourists onto the water to view the animals in the wild. Dolphin watching has the potential to provide employment and environmentally sustainable economic development in isolated coastal areas. This activity is a growth industry in the Shannon estuary with several operators, and with proper management, there is room for further expansion (Hoyt, 1995).

All cetaceans in Irish waters are protected under the 1976 Wildlife Act and in 1991 the Irish government declared the Irish Economic Exclusion Zone (EEZ) a whale and dolphin sanctuary. In addition, cetaceans are protected by European legislation and are listed in Annex IV of the EU Habitats Directive (species of interest in need of strict protection). The bottlenose dolphin is also listed in Annex II of the Habitats Directive (species requiring the designation of Special Areas of Conservation). Proposals to manage the Shannon Estuary as a Special Area of Conservation (SAC) are being drawn up by Dúchas - The Heritage Service and will include a code of practice for tour boats operating in the Shannon.

Given the protected status of bottlenose dolphins, within both Irish and European legislation, it is important that any long or short-term management decisions impacting on either the dolphins or their habitat are made with the support of detailed and current scientific information (Rogan and Berrow, 1995).

This project was initiated in order to extend the knowledge of the population of bottlenose dolphins in the Shannon estuary and as an aid for future management decisions relating to conservation and tourism development in the region.

The main objectives of the project were to:

- Assess the degree of residency of bottlenose dolphins in the Shannon
- Estimate the population size
- Assess the production of calves
- Examine the social structure of the population
- Study habitat use
- Examine the effects of boats on dolphin behaviour

These issues are addressed in the following report.

2 FIELD STUDY SITES & METHODOLOGY

The river Shannon is the longest waterway in Ireland, 240km in length, meeting the Atlantic between the counties of Clare and Kerry at 52° 30'N, 9° 50'W. The Shannon has traditionally been regarded as one of the most important Atlantic salmon (*Salmo salar* L.) rivers in Ireland (Went, 1970) and is a typical example of a manipulated river system with a hydroelectric scheme at the lower end of the system. The tidal waters of the River Shannon extend 80km inland to the city of Limerick, with deep water as far up as the port of Foynes on the southern shore.

The Shannon estuary is a major shipping route with 10 million tons of traffic per annum. The deep water channel and shelter provide ideal shipping access with the biggest vessels entering Irish waters (180,000 tons) servicing the Moneypoint power station. The estuary is narrow and steep-sided from Foynes to Kilrush, beyond which it broadens out and extensive mud flats are exposed at low tide. This study focused on the outer parts of the Shannon Estuary from Tarbert to Ballybunnion (see Figure 1). This area of the river is known to be used by bottlenose dolphins from previous work (Berrow *et al*., 1996) and is the area of the river covered by the existing dolphin watching industry.

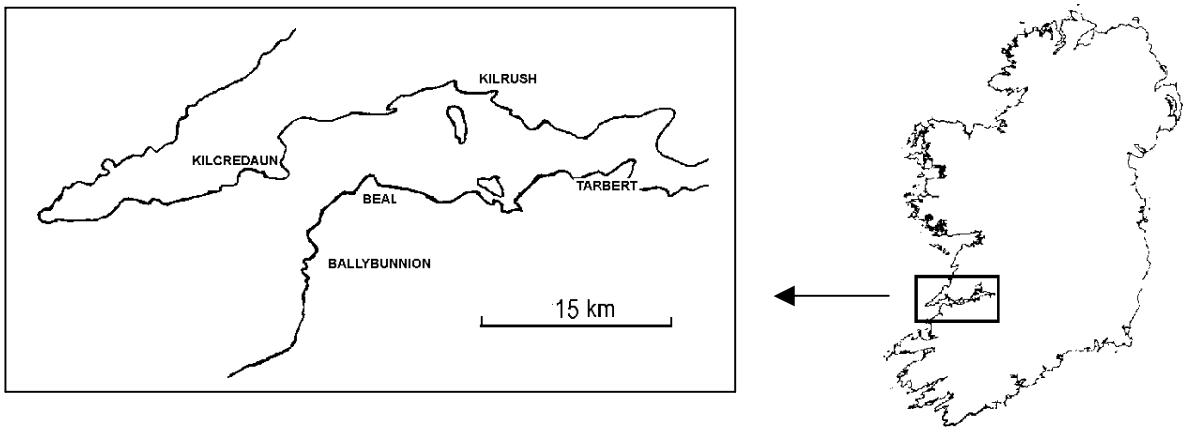


Figure 1 The Outer Shannon Estuary

The study of cetaceans in the field is a relatively new science. However, over the past twenty years some techniques, including acoustics, telemetry and photo-identification have become well established. Details of these methods are well described in the scientific literature (see Wursig and Jefferson, 1990; Wursig *et al*., 1991; Wilson, 1995). In this study, a number of different approaches (listed below) were used.

2.1 Shore watches

Land based observations of cetaceans provide the opportunity to collect data over a wide area without the risk of observer/subject interference. Shore watches were used in this study to record behaviour, habitat use, and movements of dolphins, where the presence of a research boat may have affected the natural behaviour of dolphins.

Shore watch site locations were chosen on the following criteria:

- Good field of view (to allow large area of water to be surveyed from a single place)
- Accessibility and suitability for public access
- Height (important for accuracy of theodolite bearings)

2.1.1 Methodology

Typically, shore watches lasted for four hours and were made at fixed times in order to cover all tide states. Watches either took place during the morning (09:00-13:00) or during the afternoon (15:00-19:00). Dolphin numbers, positions, behaviours and direction of movement were recorded onto data sheets during ten-minute scan samples (Altmann, 1973). Scans were made on the hour and half hour throughout every watch. Scans were made using Minolta 10x50 binoculars and a Kowa TSN telescope with a 30x eyepiece. Dolphin positions were derived using a surveyor's theodolite (Wursig *et al.,* 1991) equipped with a monocular 30x eyepiece. A theodolite is an instrument for measuring angles in two planes with a high degree of accuracy (+/- 5 seconds of arc). A horizontal bearing is found by measuring the angle between the subject and a predefined zero point on the horizontal plane. The angle of dip below horizontal in the vertical plane is also found from which the range value is derived. Since the height of the observation point is known accurately this angle is used to calculate the distance of the subject from the observer. The number and type of shipping vessels in the area were also recorded.

Regular standardised shore based observations were made from Kilcredaun Head (grid ref. Q 843 489) throughout the project. Watches were also made from Money-point (grid ref. R 055 516, Figure 2) during the summer of 1996 to examine the abundance and movement patterns of dolphins upriver.

2.2 Boat based surveys

Surveying and photographing cetaceans from small boats has proved a successful technique employed by many studies, further details can be found in the scientific literature (Wursig and Jefferson, 1990). In order to survey a large part of the outer estuary and to collect photographic data, standardised boat based surveys were regularly undertaken throughout this study.

Boat survey work was conducted in the outer Estuary (see Figure 1) from Tarbert, in the East, to Ballybunion, in the West.

2.2.1 Survey methodology and protocol

Boat based surveys were made within a predefined survey area and the route was designed to cover the area of the Estuary visited by dolphin watching boats. The 75km survey route was planned to cover as complete an area of the outer Shannon estuary as possible within a single day (see Figure 2).

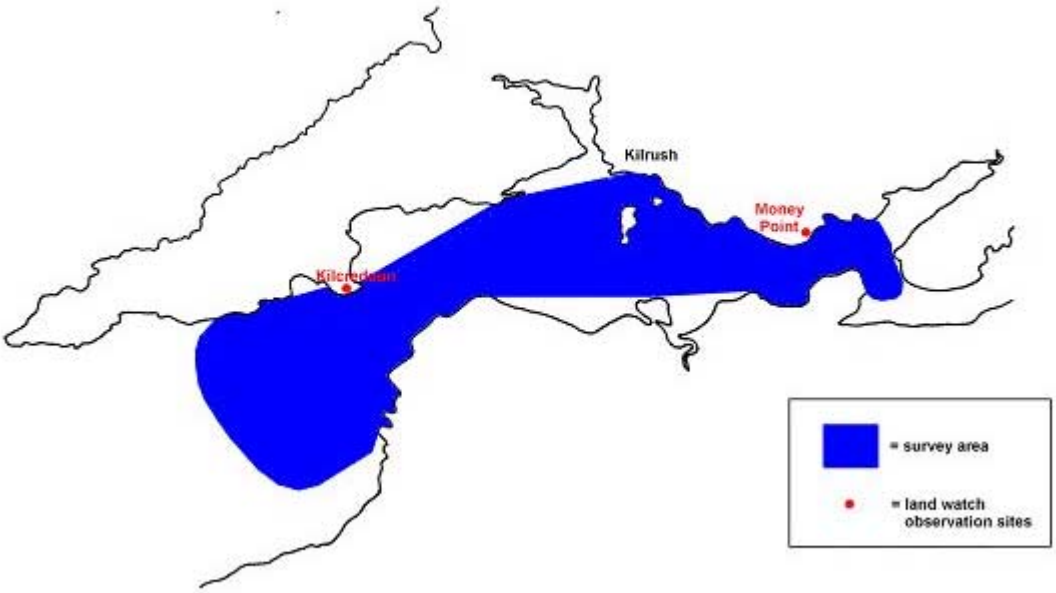


Figure 2 Boat survey study area and survey route, and land watch study sites

Two surveys were made each month during the summer (April to September) and once a month during the winter (October to March). Surveys were conducted in sea states of three or less in order to minimise the effects of sea state on the probability of sighting and photographing of dolphins.

The surveys were conducted at a steady speed of about 20kmph and lookout was maintained by each crew-member throughout. Each crew concentrated their observation over different sectors of the boat's path in order to maximise the search effort. The track of the boat was continually logged using an on-board Garmen G.P.S. (Global Positioning System) unit and notes were recorded on a hand held dictaphone.

The survey route was followed until dolphins were sighted. The dolphins were approached slowly whilst counts and behavioural information were recorded. A slow approach minimised disturbance to the dolphin group. The dolphins were approached from behind or from a perpendicular direction and efforts were made not to cross their path. The boat was brought parallel to the path 'up-sun' of the dolphins allowing the speed to be adjusted to match the progress of the group. The boat driver then closed the gap between the boat and the dolphins to about 20m or less and the photographer took pictures. The encounter continued until all the animals in the group had been photographed, or until the group was lost (a group was considered lost after about 10 minutes without a sighting).

When satisfied that all the animals had been photographed the encounter was ended, and the film marked with a spacer photograph (of any subject other than water or

dolphins), and the time and position recorded. The survey was then resumed until the route was completed. The general route followed on each survey was recorded onto a simple map after completion and the track data was down-loaded from the G.P.S. onto a computer to give accurate information about the boats movements throughout the survey.

2.3 Field equipment

2.3.1 Boats

The platform for photo-identification fieldwork should be a seaworthy boat, which is also small enough to manoeuvre around dolphin groups. Rigid inflatables (RIBs) are ideally suited, being lightweight, fuel-efficient and offering an unobstructed field of view for photography. The boats used in this study were 4.5, 5 and 5.5m Tornado RIBs equipped with 55, 60 and 80 horse power outboard Yamaha engines respectively.

2.3.2 Camera and lens

The success of any study involving photo-identification ultimately depends on the quality of the photographs obtained, necessitating the use of a high quality single lens reflex (SLR) camera. The camera used in this study was a Canon EOS 50 II autofocus with a 75-300 (f4.5-5.6) telephoto zoom lens. It is difficult to obtain sharp focus photographs using a hand held lens with a focal length of more than 300mm from a moving boat. The zoom lens chosen allowed the photography of animals over a wide range of distances close to the boat and as far as 50m away. Photographs were preferably taken with the subject well lit by the sun and perpendicular to the photographer within a distance of 15m. The autofocus lens allowed rapid accurate focusing, necessary during the one second it takes for a bottlenose dolphin to surface. The camera was set to take continuous frames to photograph as much of each animal as possible and to capture several animals as they surfaced in sequence. A data back printed the date and time onto each frame to aid the matching process and any information relevant to photographs was dictated into a dictaphone.

2.3.3 Film type

Colour slide film and black and white print film are usually preferred in cetacean photo-identification studies due to their high resolution and small grain size. Slide film has the advantage that it can be projected onto a wall, so enlarging the image aiding analysis. Slide film also provides colour information, which helps during the matching process. To obtain maximum resolution, the slowest film possible in the prevailing daylight conditions should be used. The films used in this study were 200 or 400ASA Fuji Sensia slide film. In order to obtain well-exposed images of the dark skin of dolphins, the lens aperture was opened by one stop in sunshine and by two stops in overcast conditions. The film was then processed according to the stated ASA rating for the film (i.e. 200 or 400).

2.4 Photo-identification as a tool for dolphin population studies

Capture-mark-recapture studies have been used extensively in field studies on animal populations including bottlenose dolphin populations. Traditionally such studies have relied on the manual tagging of captured animals (Odell and Asper, 1990, Scott *et al.*, 1990) and studying recapture frequencies of these marked animals in deriving population parameters. Using an animal's naturally occurring marks as a means of individual recognition has proven to be a valuable alternative to artificially marking

animals. This technique was pioneered in the study of cetaceans by the Caldwells in the 1950's (Wursig and Jefferson, 1990) and the Wursigs in the 1970's (Wursig and Wursig, 1977). Photo-identification has since been applied to several cetacean species such as; humpback whales, southern right whales, blue whales, fin whales, sperm whales, grey whales, killer whales, Hector's dolphins, and bottlenose dolphins (Wursig and Jefferson, 1990).

Recapture data can be used to analyse associations between individuals (Slooten *et al.*, 1993), social structure (Shane *et al.*, 1986, Scott and Chivers, 1990), reproduction (Scott *et al.*, 1990), habitat use (Ballance, 1992), movements (Irvine *et al.*, 1981, Wells *et al.*, 1980) and distribution (Mead and Potter, 1990, Ballance, 1990); besides providing data for population estimates (Hammond and Thompson, 1991).

Photo-identification of bottlenose dolphins relies mainly on matching marks and nicks on the dorsal fin. The trailing edge of the dorsal fin, in particular, is easily damaged, resulting in a unique dorsal fin profile. Wursig and Wursig (1977) calculated that approximately 50% of bottlenose dolphins are identifiable using these individual markings. Scrapes, scratches and scars may also be used in recognising individuals although these markings are likely to be more ephemeral (Lockyer and Morris, 1990) and subject to change during healing. Wursig and Wursig (1977) found that small scratches and bite marks may heal within a few months and Bigg (1982) considered marks visible for over 2 years to be permanent. Whilst these less obvious marks are useful for identification of individuals, they should be excluded from data sets used for population estimates, since they may introduce errors into the identification of members of the population (Hammond, 1986).

2.4.1 Photograph Analysis

The success of photo-id studies relies on effective analysis of the data. In order to standardise the time consuming process of sorting, storing and matching photographs the methods used in this study were closely based on those described by Wilson (1995) in the study of bottlenose dolphins in the Moray Firth (Scotland). Photographic film was developed without mounting and was stored in sheet mounts. Data relating to each survey were entered into a relational database (Access 2.1).

The positives were examined on a lightbox with the aid of an 8x loupe magnifier. Photographs from each encounter were analysed separately, with no reference to the photo-id catalogue until the best photos of each of the individuals from a group were selected.

Matching of individuals identified from an encounter with the catalogue was made with the aid of traced pencil outlines of the dorsal fin of every animal in the catalogue. The tracings were stored according to the types of mark, and age class (i.e. newborn calf, juvenile, adult). Once the most likely matches were selected using the tracings, the slides of these individuals were compared with the unmatched photographs using a slide projector. If a match was made with the catalogue, the slide was marked with the catalogue number and added to the catalogue. The details relating to this sighting (e.g. encounter code, time, date etc.) were then recorded in the database. Care was taken throughout the photo-matching to record every step of the process to enable (if necessary) the re-matching of any sighting. Details of every frame were recorded onto written sheets.

If a match was not found from the catalogue, the individual was given a unique identification number and added to the catalogue. The individuals were numbered using sequential integers. In the event of matching two identified animals during subsequent analyses the lowest identification number of the two was given to both sightings and a permanent gap was left in the catalogue for the higher identification number.

2.4.2 Data analysis

Using the methods of photo-identification as described above; the photographs obtained during the surveys were used for comparison with the catalogue of individually recognisable individuals. The results of such comparisons over repeated surveys provided data for the analysis of the associations between individuals. Population estimates were derived mathematically using the capture-recapture programme CAPTURE (Rexstad and Burnham, 1991).

Position data of each encounter were collected during the surveys and used in the distribution and habitat use analyses.

2.5 Minimum population estimate methodology

Minimum estimates of dolphin populations inhabiting an inshore area of water, can be made by combining the results of synchronised multiple observer ground counts (Hammond and Thompson, 1991). This technique is inexpensive and provides an indication of the size of the population and its distribution. Estimates derived in this way only give a rough indication of the population size however, and do not take into account seasonal and temporal variations in abundance. The accuracy of estimates made in this way may be better known after repeated surveys at different times of year.

This technique was used to obtain four minimum population estimates throughout the study period. Sites were selected according to the same criteria as the shore watch sites and covered an area of the river from Loop Head in the West (grid ref. Q 680 475) to Beagh Castle in the East (grid ref. R 355 557)

Counts were made with binoculars by scan sampling for ten minutes every half-hour of the watch. Minimum estimate watches were made in sea states of two or less and the scan period lasted for six hours, approximately three hours before and after high-water. The estimated positions of all dolphins seen during a scan were recorded on a map allowing for correction of errors due to double counting of the same animals by different observers.

After a watch was completed, the maps were collected from all the observers and the total number of animals sighted for each scan was calculated. The highest combined count for a single scan was taken as the minimum population estimate.

2.6 Tour boat interactions

Observers accompanied tour operators on a number of consecutive days on dolphin watching trips. A questionnaire was compiled to assess the degree of knowledge of the area and the dolphins. Exact locations of the tour boats were recorded using the boats GPS and where possible, photographs were taken to identify individual dolphins, to try and assess overlap between trips and between days.

3 RESULTS

3.1 RESIDENCY AND SEASONAL VARIATION

3.1.1 Seasonal variation

A high degree of seasonal variation in abundance was seen throughout the calendar year, with many more dolphins seen during shore watches and boat-based surveys during the summer months, May to September, than the winter months, October to April (Figure 3). Dolphin abundance increased sharply during the month of May and dropped off rapidly during September.

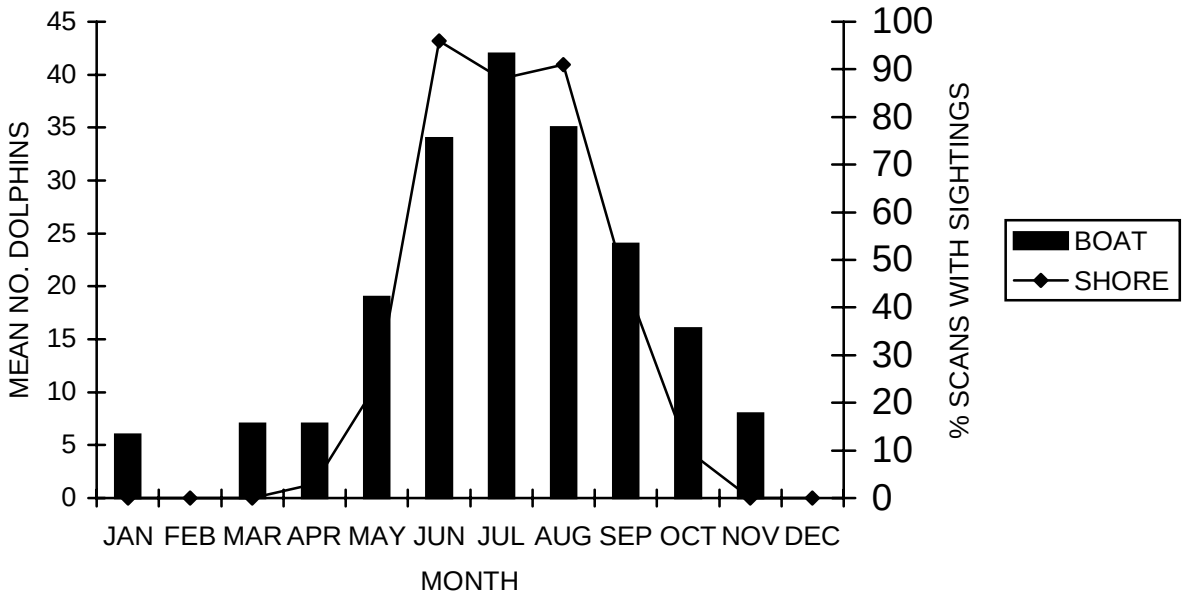


Figure 3 Seasonal change in abundance of dolphins using the Shannon Estuary (bars show numbers encountered on full boat surveys, points show frequency of sightings during shore watches at Kilcredaun, 1996 and 1997).

The frequency of dolphin sightings from the Tarbert/Killimer ferry also showed the same seasonal changes in abundance. To supplement the fieldwork carried out by the project fieldworkers, the operators of the Shannon Ferries were requested to record all sightings of dolphins from the ferry. Each ferry crosses the estuary between Killimer in Co. Clare and Tarbert in Co. Kerry, taking about half an hour to make the trip. During the summer, two ferries are in operation, each crossing half-hourly from 07:00hrs to 21:30hrs each weekday. During the winter, one ferry operates hourly from 07:00 hrs to 19:00 hrs each weekday, with a 09:00 hrs start on Sundays.

The skippers of the ferries were requested to fill out a form giving details of sightings, numbers seen etc. In all, 976 sightings were recorded in 28 months. Dates on which no sightings were made were also noted on the form. Out of a possible 859 days in the period April 1996 to July 1998, animals were seen on 435 days. The months with the greatest number of sighting days in 1996 were April with 27 sighting days and May with 26 sighting days. In 1997, peak sightings were in July with 29 days and

June with 28 days, while the peak month in 1998 was June with 28 days. Figure 4 gives the number of sighting days for each of the 28 months in question. As can be seen, there is a clear pattern with sighting days peaking in late spring and summer, then dropping to much lower numbers in the winter months. As one would expect, this is echoed in the pattern of numbers of sightings (as distinct from days with sightings) with the peak period being from April to July of both years (see Figure 4).

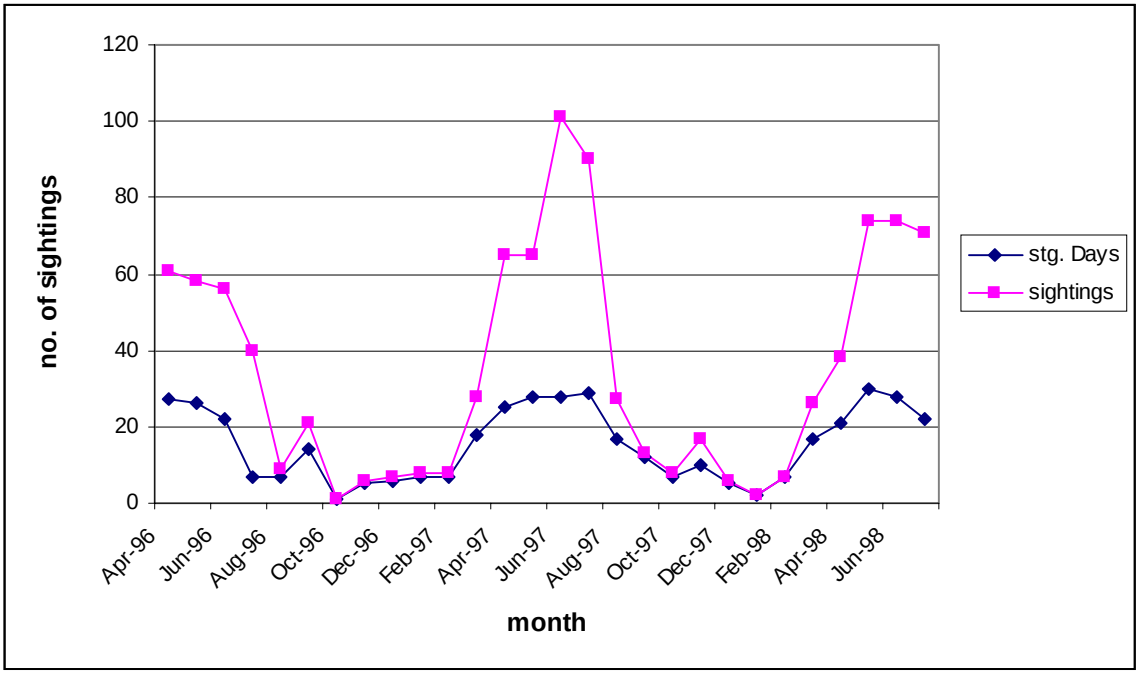


Figure 4 Frequency of sightings of dolphins and the number of sighting days for each month of the study.

The seasonal change, as shown in the outer estuary and in the Tarbert/Killimer area, suggests a habitat use pattern in this population, with an annual migration into the river during the summer months. Seasonal migrations of bottlenose dolphins are known to occur in other populations (Shane *et al.*, 1986; Wilson, 1998) and may be induced by a number of auto-ecological or environmental factors.

Little is known about the distribution of bottlenose dolphins on the West Coast during the winter months although unpublished casual sightings (Pollock *et al.*, 1997) indicate an increase in bottlenose dolphin abundance for this area in spring.

Maximum abundance of bottlenose dolphins in the Shannon occurs during the breeding (May-September) season and may be influenced by the breeding cycle of the species. The estuary may be a favoured calving area providing shelter from exposed Atlantic coasts for neonatal calves or may provide an opportunity for reproductively active animals to socialise and mate.

3.1.2 Degree of residency

Resightings of individually known animals provide information on the degree of residency of the population. Many of the identified individuals were resighted throughout the study indicating a high degree of residency of the population. However, the seasonal changes in abundance (Figures 3, 4) and the high number of

animals only identified on single occasions (Figure 5) shows that the Shannon only represents part of the home range for many members of the population.

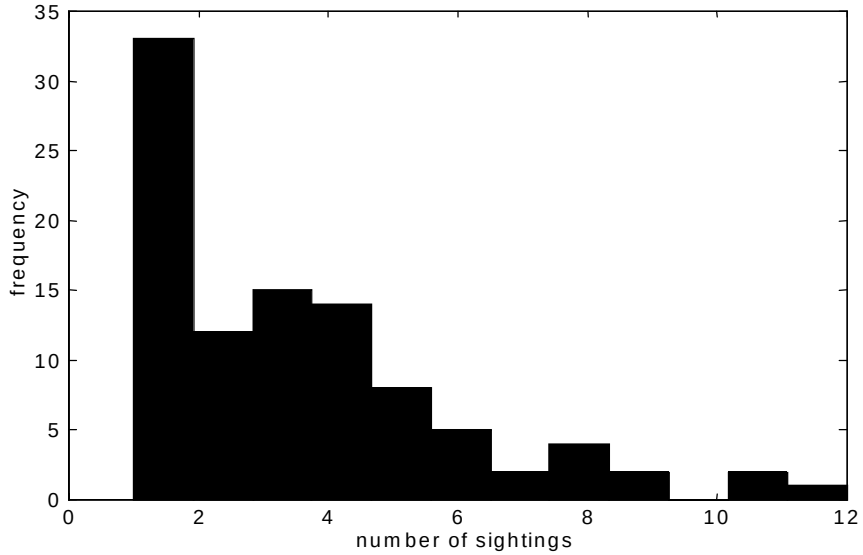


Figure 5 Frequency distribution of resightings of well-marked identifiable animals.

The movements of the animals beyond the Shannon Estuary are as yet unknown and must be considered when planning further research and the implementation of conservation plans.

3.2 POPULATION SIZE AND STRUCTURE

3.2.1 Shore-based minimum population estimate

In order to arrive at an estimate of the number of dolphins in the estuary four minimum population estimates were undertaken during the project. The original intention was to hold these estimates in April, August and November of 1996 and April 1997 to allow for seasonal variations in numbers of animals in the estuary. This schedule was frustrated by repeatedly unfavourable weather and sea conditions, causing numerous last-minute postponements of planned estimates. Consequently, the estimates were held in April and September of 1996 and May 1997 and May 1998.

As described previously, each estimate involved placing observers at up to 15 vantage points along both shores of the estuary, from Loop and Kerry Heads in the west to Beagh Castle (across the estuary from Shannon Airport) in the east. Each observer made a 10 minute scan, using binoculars, every 30 minutes, on the hour and on the half hour, over a period of 6 hours and 10 minutes, thereby making 13 scans on each occasion. During each scan observers recorded the location and number of dolphins seen in their watch area, as well as other details such as behaviour, direction of movement etc. The individual counts from each observer were combined to give a total number of dolphins seen throughout the estuary for each scan. The highest combined total of the day was taken to be the minimum population estimate (Hammond and Thompson, 1991).

The results of the estimates are given in Table 1. The maximum number of dolphins seen within the estuary using this method was 30. These animals were recorded in September 1996.

Table 1 Results from minimum population estimates

Date of estimate	Minimum number
13 April '96	14
7 September '96	30
17 May '97	10
August '97	*
April '98	*
17 May '98	11

The results of these estimates indicate that there are, at a minimum, 30 animals using the estuary, as recorded in the September 1996 estimate. This number is substantially higher than those recorded in any of the April/May estimates and may indicate greater usage of the estuary by the dolphins in the autumn. In addition, the total of 30 falls short of the 56-68 recorded by Berrow *et al.* (1996) in October 1993. This estimate (and the previous estimate of Berrow *et al.*, loc. cit.) is also considerably smaller than that estimated using the technique of photo-identification (see below). Compared to the minimum estimate from the photo-identification results the shore based minimum population estimate can be seen to be a poor technique for gaining accurate population estimate, and only provides a 'snapshot' estimate.

3.2.2 Population size using photo-identification and mark-recapture techniques

As previously described, individually recognisable animals are recruited into the photo-identification catalogue with on-going surveys. The recruitment of individuals to the catalogue is shown in Figure 6. The rate at which well-marked animals were recruited to the catalogue decreased throughout the study, but the continuing recruitment at the end of the study shows that unknown animals were still being encountered up to the end of the fieldwork. This implies that the population is larger than the photo-id catalogue and undoubtedly, larger than the minimum population estimates.

In order to reduce the errors associated with missing true matches, each animal in the catalogue was scored according to the extent and strength of its markings. This process resulted in a subset of animals containing 98 dolphins (see Table 2) with sufficient marks to ensure rematches between surveys and between years.

Table 2 Number of individually recognisable dolphins in the catalogue from the Shannon.

Catalogue	All animals	Well-marked animals (see section 3.4)
total	287	98
known from left and right	63	58
known only from left	109	19
known only from right	115	21

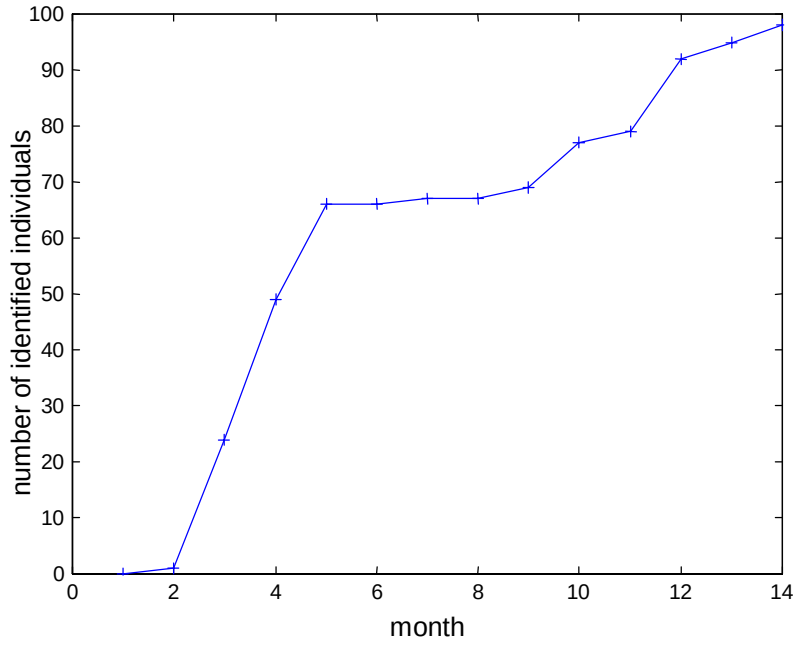


Figure 6 Recruitment rate of individually identified dolphins into the photo-identification catalogue

Many of these animals however, may only be known from one side of their dorsal fin and many animals lack sufficient notches to establish a link between photographs from both sides of their body. Therefore, a degree of redundancy exists in the photo-id catalogue with the same individuals inevitably having two numbers in the catalogue, one for the right side and one for the left side. Although many animals are individually distinct from other animals photographed within one survey their marks may not be sufficient to re-recognise them from future survey data. Thus, the number of animals in the photo archive can only be treated as a 'minimum number estimate'.

The estimates from the mathematically derived CAPTURE model were corrected according to the estimated proportion of unmarked animals in the population and combined using an inverse variance weighted average to give a total population estimate of 113 dolphins (C.V. 0.14, 95% C.I. 94 - 161) (Ingram and Rogan, in review (a)).

3.2.3 Population structure using photo-identification techniques

A total of 33 full- and 8 part-surveys were conducted throughout the study. Surveys were made in every month of the year although no full surveys were completed during the months of December or February of either year due to weather constraints. By completion of the study a catalogue containing photographs of 287 identified individuals had been established. This catalogue contained 63 animals known from both left and right sides, 109 known only from the left and 115 known only from the right (see Table 2).

It is very difficult to obtain information relating to gender of cetaceans in the field due to the ventral position of the genital slit. In bottlenose dolphins, there is only a small degree of sexual dimorphism, with males reaching a slightly larger size (Read *et al.*,

1993). Differences have been found between the degree of rakes and marks on adult male and female dorsal fins (Tolley *et al.*, 1995), but this trend is not reliable as a sole determinant of gender.

The catalogue established for the Shannon population contained 18 probable breeding females (adults closely associated with calves as defined by Wilson (1995)), and 48 sub-adults.

3.2.4 Calving season

The calving season for bottlenose dolphins is highly variable between populations (Leatherwood and Reeves, 1983). Research in the Moray Firth, for example, has shown a calving period between July and November (Wilson, 1995).

The distribution of neonatal calves sighted from boat surveys (Figure 7) was seasonally biased with sightings restricted to the months July to September, indicating a marked breeding season for the population during these months. This is the typical breeding season for the species (Leatherwood and Reeves, 1983). The presence of neonatal calves in the estuary indicates that the Shannon is used as a nursery area for mother calf pairs, an important conservation consideration.

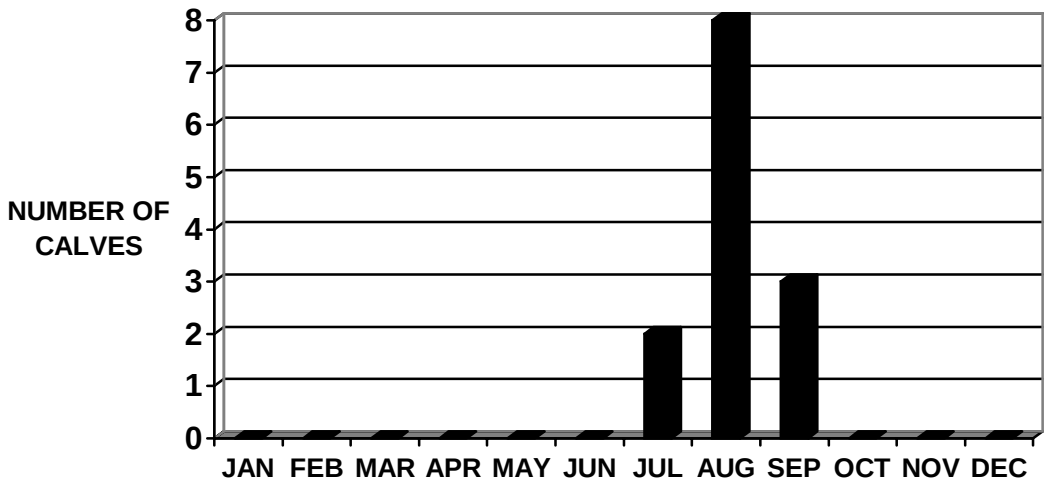


Figure 7 Timing of sightings of neonatal calves in the Shannon Estuary.

3.3 SOCIAL STRUCTURE

Previous studies of bottlenose dolphin populations have shown the species to have a fluid and dynamic social structure known as a fission-fusion society (Wursig and Wursig, 1979, Ballance, 1990, Smolker *et al.*, 1992, Williams *et al.*, 1993, Wilson, 1995). Typically, the only strong associations found have been between females and their dependent calves, and alliances between pairs of sexually reproductive males (Scott *et al.*, 1990, Wells, 1991, Conner *et al.*, 1992). Outside of these bonds members of bottlenose dolphin populations form temporary associations within groups or schools with no apparent long term pattern of allegiance.

3.3.1 Associations between individuals

Data were taken during encounters from photo-id surveys and any animals identified from a group were considered to be associated with every other member of the same group. The social structure analysis used a subset of 39 individuals which were 'well-marked' and had been encountered and photographed on four or more occasions.

The strength of pairwise associations is derived using the 'simple-ratio index' and is calculated as follows:

$$= \frac{X}{X + Yab + Ya + Yb}$$

where **X** is the number of groups in which **a** and **b** were both identified, **Ya** is the number of groups in which **a** was identified but not **b**, **Yb** is the number of groups in which **b** was identified but not **a** and **Yab** is the number of times both **a** and **b** were identified but in different groups.

An association index of '1' indicates that a pair has always been seen together whereas a value of '0' indicates that the two animals have never been seen together. The distribution of frequencies of association indices (Figure 8) shows that weak associations are more highly represented than strong associations.

These 39 animals are well-marked (minimising the number of matches which are 'false positives'), and were seen four or more times (giving a precision of +/- 1/4 or better in the association indices). The distribution of frequencies of association indices (Figure 8) shows that there are few 'strong' associations (above 0.5). In contrast, about 20% are non-associations (zeros). The modal value is 0.1. This distribution supports the notion of a fluid and gregarious social structure, with numerous weak alliances between individuals.

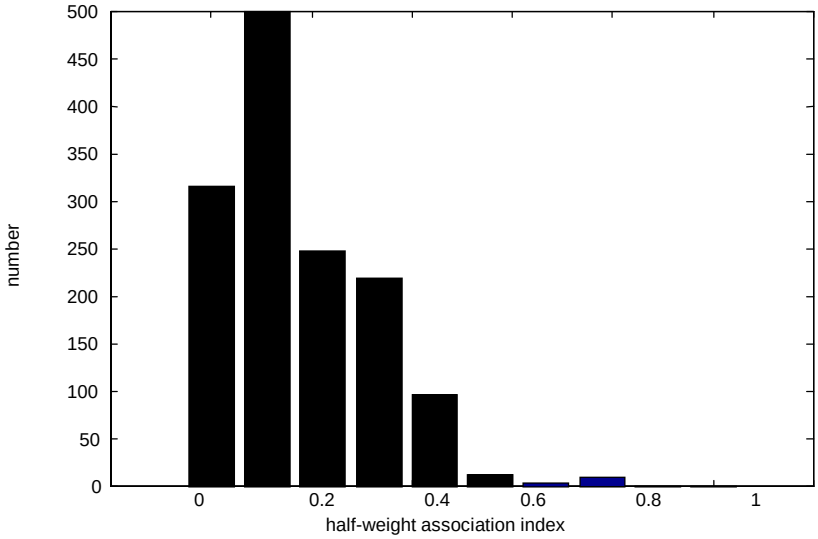


Figure 8 Frequency distribution of pairwise associations using simple ratio association index.

Figure 9 shows a plot of associations between the 98 well-marked individuals, where a dot indicates non-zero association. Again, this figure illustrates that the population shows a high degree of mixing with many of all possible pairwise associations represented. The fluidity of the society is aptly demonstrated, with most individuals associating with many other animals.

Figure 9 Distribution of associations between well marked individuals.

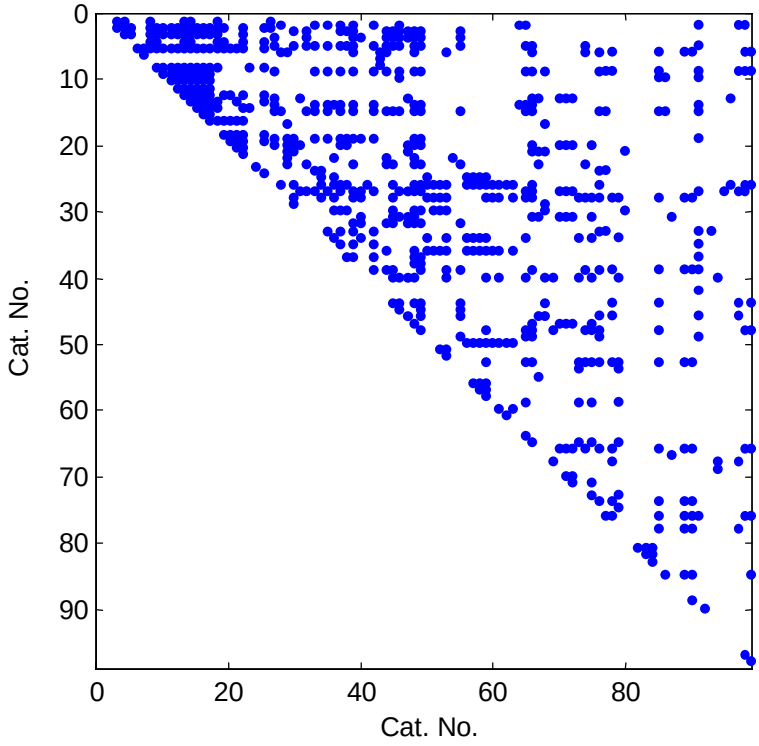
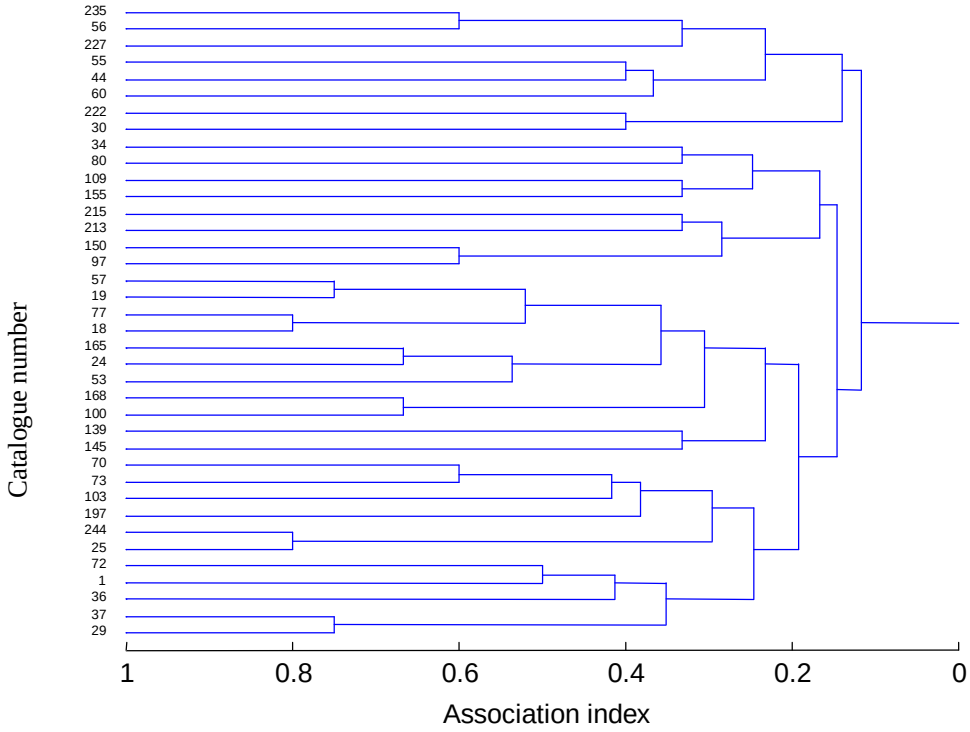


Figure 10 is a dendrogram showing the results of cluster analysis between well-marked animals identified on four or more occasions. In this diagram, individuals are aggregated into hierarchical groups, depending on their average association. Initially all animals are separate; as the average association decreases (left to right), groups are formed and agglomerated. In the subset of the Shannon dolphins examined here, there is a rapid agglomeration of groups when the average association falls to about 0.4. The high mixing in this population is evident in that no distinctive groups form in this analysis, although a cursory interpretation of Figure 10 might suggest four to five loose social groups.

Figure 10 Cluster analysis of pair wise associations



3.4 HABITAT USE AND DISTRIBUTION

Many animal species occupy limited territories, with movements restricted to a 'home range' (Jewell, 1966). The movements and ranges of bottlenose dolphins vary between locations, with some populations confined to very small areas (Liret *et al.*, 1994) and some populations showing wide ranging habitat use. A study of bottlenose dolphin habitat use in the Moray Firth, Scotland showed a marked stratification of habitat use, with more commonly sighted dolphins found consistently further upriver than rarely seen individuals (Wilson *et al.*, 1998).

During this study, 81 watches were made from Kilcredaun Head totalling 400 hours of fieldwork. In this time, 645 dolphin groups were observed. In addition, 13 watches (52 hours of fieldwork) were made from Moneypoint during which 9 dolphin groups were observed (Table 3).

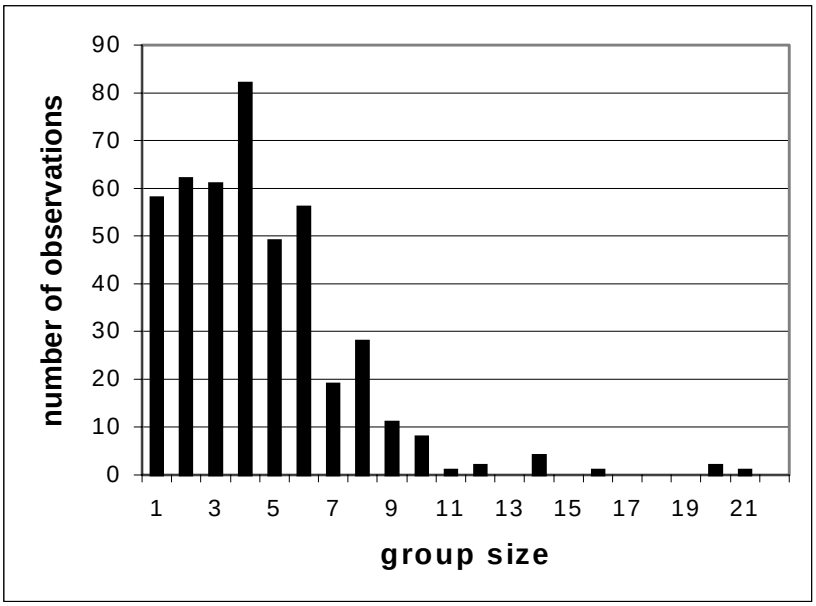
Table 3 Sightings rate for shore based surveys.

Year	Site	% Scans with dolphins	Median group size	% With calves
1996	Kilcredaun Head	94	4	41.5
	Money Point	8	6	50
1997	Kilcredaun Head	69	4.5	29.6

The data from land watch surveys showed a median group size of 4.5 dolphins. The frequency distribution of group sizes from shore based estimates are shown in Figure 11. The majority of groups sighted were of < 7 animals but ranged from single animals to groups of 21 animals.

In the boat based surveys, group sizes ranged from singletons to groups of 32, with groups between 2 and 10 dolphins being most common. This group size distribution (2-10 animals) is typical for the species (Shane, 1990, Wilson, 1995).

Figure 11 Frequency distribution of different group sizes (data from shore watches)



During boat surveys, dolphins were found throughout the survey area. Areas east of Tarbert were not surveyed and little information is available for dolphin abundance in the 30 miles between Tarbert and Limerick city, although casual sightings have been reported of dolphins as far up-river as Limerick docks. Data collected during 'minimum population estimates' show few sightings of dolphins in this stretch of the river suggesting that dolphins use areas upriver of Tarbert much less frequently than the outer estuary. A plot of the positions of all dolphin groups encountered during standardised boat surveys (Figure 12) shows a concentration of sightings near the mouth of the estuary. The largest groups encountered were also in this outer area.

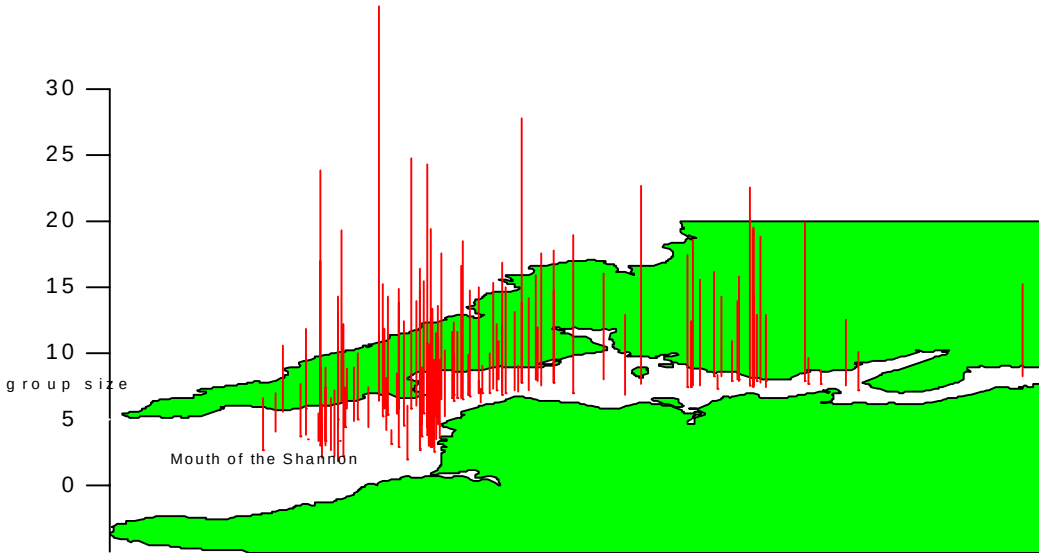


Figure 12 Locations of sightings of all dolphin groups encountered during boat surveys (length of line denotes group size).

Habitat use of the estuary was also analysed by dividing the survey area into four equally sized areas each about 35km^2 (Figure 13). These 'zones' were numbered 1-4 from east to west and data relating to groups encountered in each zone were compared statistically.

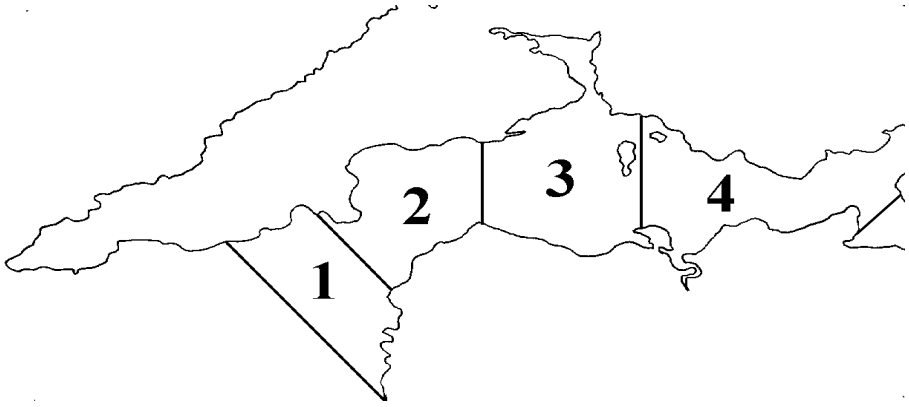


Figure 13 Area of the estuary covered by boat surveys divided into four equally sized zones.

Significantly more dolphin groups were encountered in the outer zones 1 and 2 (Figure 14) than the inner zones (Kruskal-Wallis, df=3, $p<0.05$). Whilst dolphin groups were more frequently encountered at the seaward end of the survey area, the furthest east zone 4 had a higher frequency of dolphin encounters than zone 3. Zone 1 (Kilcredaun area) and zone 4 (Tarbert area) are areas of the river with strong tidal currents and it is likely that these currents influence habitat use by dolphins as also found in the Moray Firth (Wilson *et al.*, 1998).

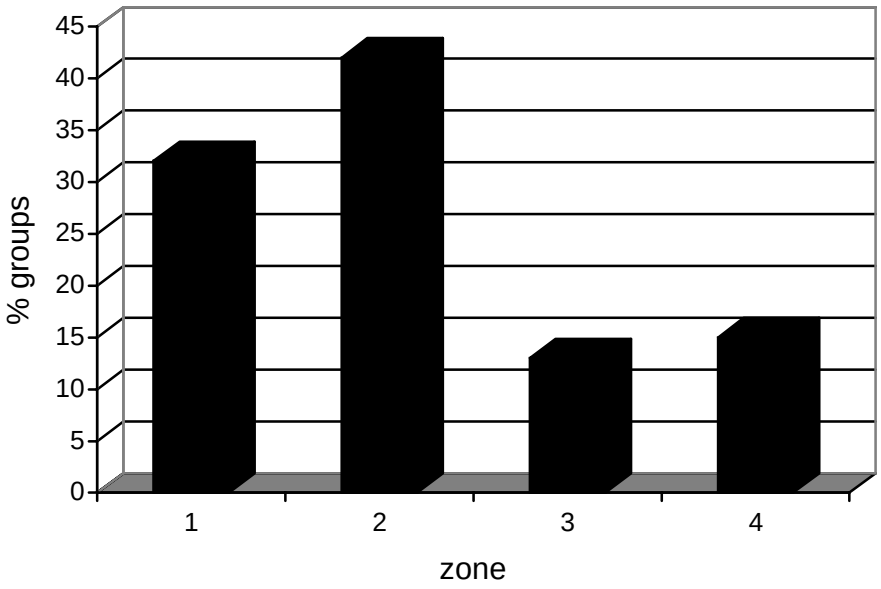


Figure 14 Distribution of groups between different zones of the survey route

Although the largest groups were found in the mouth of the estuary the mean group size was larger in the less frequently used zone 3. This may indicate that animals use different parts of the estuary for different activities.

A plot of the furthest east against furthest west sightings, of every individual sighted more than once (Figure 15), indicates a stratification of habitat use by individual dolphins in the Shannon. Although most animals were seen in the outer estuary (min. distance <18nm east of Loop Head) only a subset of the dolphins were encountered in the inner estuary (min. distance >18nm east of Loop Head).

The use of the outer parts of the estuary by many of the identifiable individuals would suggest that dolphin watching in this area is spreading any potential impact of the operation over many animals. With dolphin watching in upriver areas, however, the impact may be concentrated on fewer animals, raising the need of further monitoring of habitat use of the population.

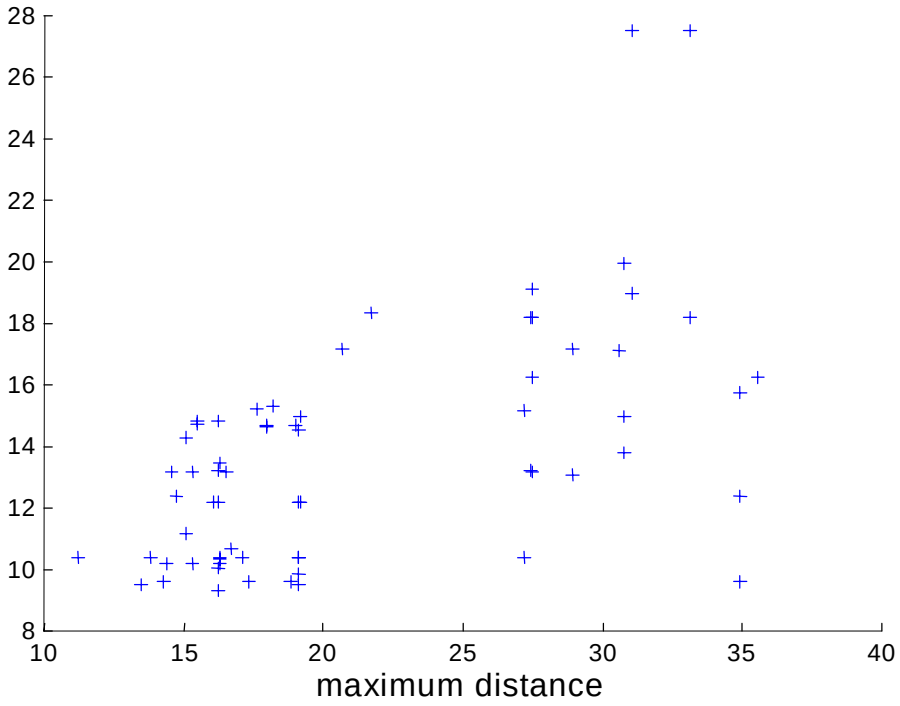


Figure 15 Extremes of habitat use for resighted, identifiable individuals.

Further survey work would also increase knowledge of the home ranges of recognisable individuals and provide more information on the partitioning of habitat use within the population. Such work would be a valuable contribution to the conservation management of the population.

In addition to habitat stratification, many factors may influence the distribution of dolphins within the estuary, e.g. tidal state, time of day. The tidal currents are very strong within the shore based study areas at Moneypoint and Kilcredaun with currents exceeding 8km/h during the spring phase, and a spring tidal range exceeding 5m.

Records from the Shannon ferry operators suggest that there is a pronounced pattern of sightings over the tidal cycle in the area between Moneypoint and Tarbert. Animals have been sighted at every stage of the tidal cycle but there is a distinct peak in sightings in the three - four hours after high water, with fewer sightings occurring in the two hours before high tide. Figure 16 shows the number of sightings at each stage of the tidal cycle.

Generally group size was between 5 and 8 animals and there was no discernible pattern in the group size over the seasonal or tidal cycle in this region.

The breakdown of the animals' locations, where given, showed a marked preference for the southern part of the ferry route, i.e. from midstream to Tarbert, which may be related to the particularly strong tidal currents experienced off Tarbert. 47% of located sightings were of animals off Tarbert, 46% were midstream and only 7% were placed on the north side.

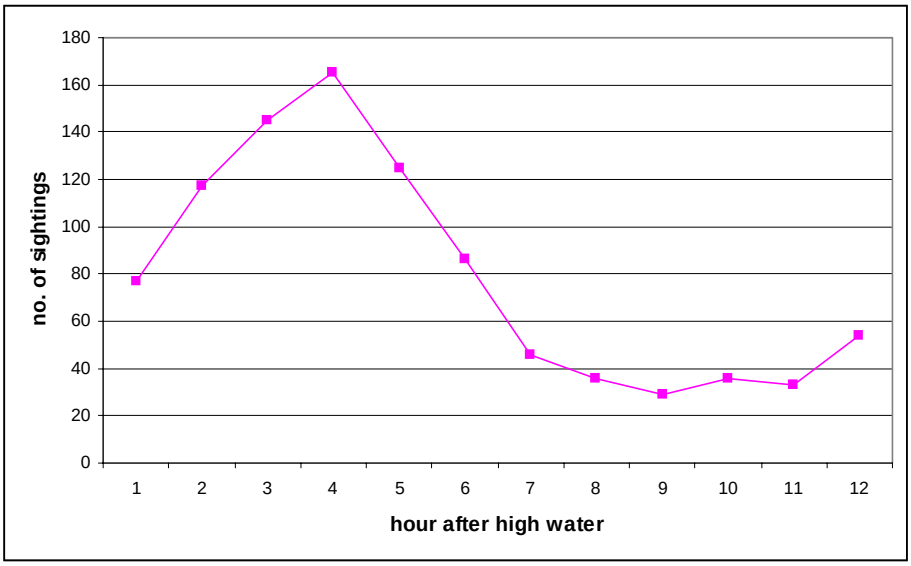


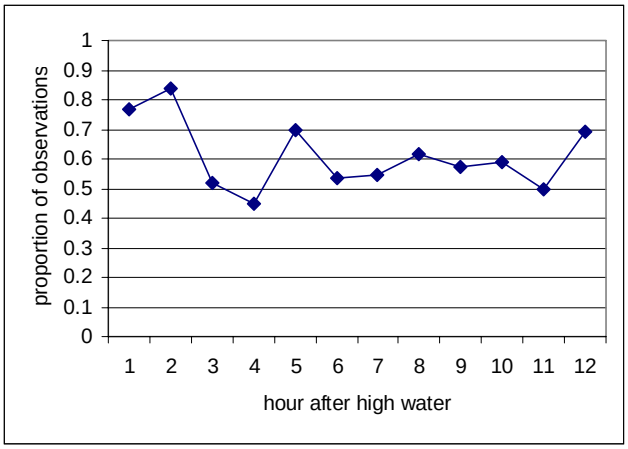
Figure 16 Frequency of sightings from the Tarbert ferry over the tidal cycle

From the data provided by the ferry operators, a distinct pattern of dolphin usage of this part of the estuary emerges, with clear peak and nadir periods over the tidal cycle and a marked preference for the southern part of the ferry route.

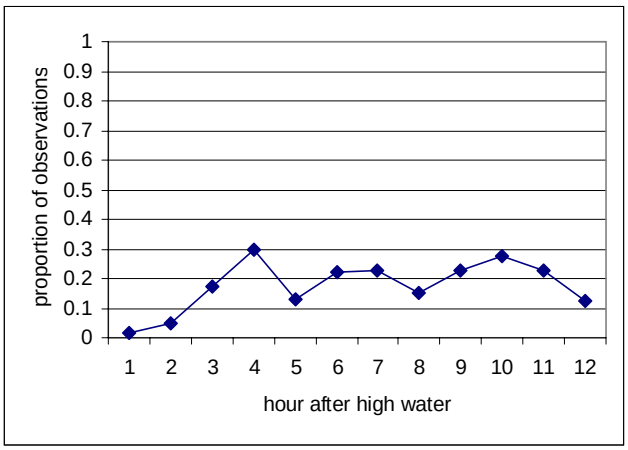
At Kilcredaun, groups engaged in socialising, feeding and milling were more frequently observed during the flood and ebb phases of the current than during the high and low water slack periods, whilst resting behaviour was observed most frequently during the slack waters (Figure 17a-e).

Figure 17 Proportion of observed dolphin groups engaged in different activities over the tidal cycle.

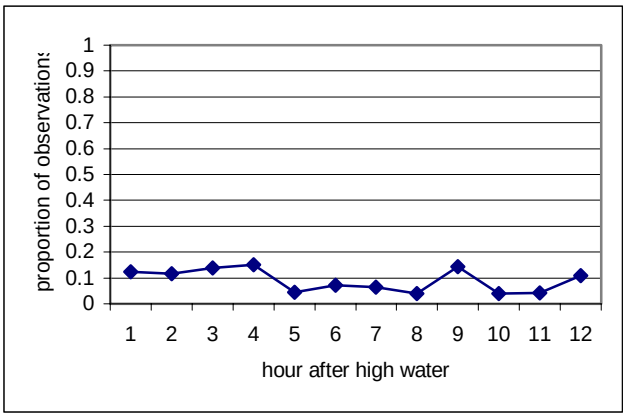
a) travel

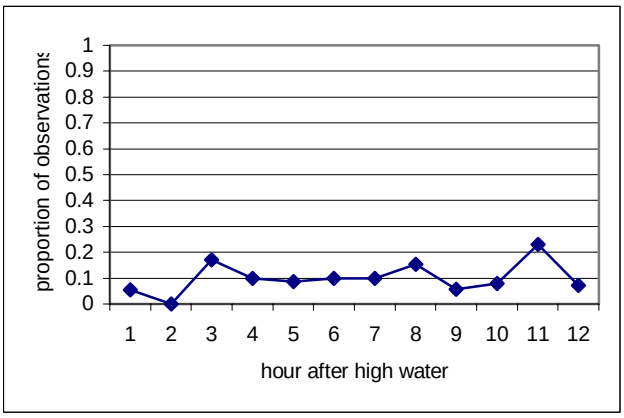


b) milling

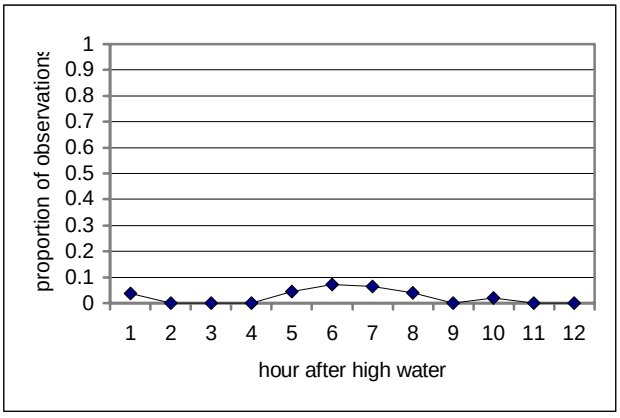


c) socialising





d) feeding



e) resting

Travelling occurred in the Kilcredaun area most frequently around the high water slack period of the tide cycle (Figure 17a), this may represent dolphins using the time of least current to transit through the study area, to enter or leave the Estuary. However, travelling was not confined to the periods of slack water, and groups were frequently observed travelling during the mid ebb and flood periods of the tide when the currents are at their strongest. During these periods of strong currents, rather than swimming with the tide, dolphin groups were more frequently seen travelling against the current. During the flood phase, this effect was very highly significant (χ^2, $p<0.001$) with groups only rarely observed travelling with the current. During several scan samples, dolphin groups were observed travelling into the current but actually being swept down-stream by the tide. Moving against the current is a common behaviour for this species (Shane 1980, 1990) although some studies have shown dolphins preferring to move with tidal current (Irvine *et al.*, 1981).

3.5 INTERACTIONS BETWEEN BOATS AND DOLPHINS

3.5.1 Effects of boats and shipping on cetaceans

Shipping represents a major component of man-made marine disturbance (Moscrop, 1993). Responses to boat disturbance are difficult to measure and may occur at distances of several miles (Au and Perryman, 1981). Despite this, various studies have examined the effects of boat disturbance on cetaceans (Au and Perryman, 1982, Richardson *et al*., 1985, Polacheck and Thorpe, 1990, Kruse, 1991, Acevedo, 1991, Gordon *et al.*, 1992, Lutkebohl, 1995, Janick, 1996). Kruse (1991) found that killer whales swim faster in the presence of whale watching vessels with no evidence of habituation through the whale-watching season. Janick (1996) found that the presence of dolphin watching vessels reduced the surfacing rates of bottlenose dolphins in the Moray Firth, Scotland. Similarly, Lutkebohl (1995) showed that bottlenose dolphins were more likely to alter their swimming direction in the presence of dolphin watching boats. Gordon *et al.* (1992) showed a level of habituation in resident sperm whales to whale watching vessels, with behavioural responses in dive length and breathing rate by unhabituated whales.

Data on boat traffic were recorded during each scan sample in shore watches. Information on the size, direction of travel, activity and engine type were included in data categories. Boats were classed and recorded according to size and engine type (Table 4).

Table 4 Categories of boat type with examples. (Categories were based on the size and engine type of vessels)

Boat type	**Examples**
planing boats with inboard diesel engine	sea angling boats
planing boats with outboard engines	speed boats, zodiac type inflatables, RIBs
displacement boats with diesel engines <15m	lobster pot fishing boats
displacement boats with diesel engines >15m	trawlers, pilot boats
ships	cargo vessels, oil rig supply boats
yachts under sail	
yachts motoring or motor sailing	

Boats were present in 65% of all scan samples and the maximum number of boats present within the study was five (Figure 18). Most boats recorded during scans were transiting the study area either leaving or entering the estuary (Figure 19). A small number of boats were anchored (usually engaged in sea angling) or working lobster pots, but by far the majority of boats remaining in the study area rather than passing through were engaged in dolphin watching tourism (Figure 19). Dolphin watching boats accounted for 38.6% of all vessels recorded.

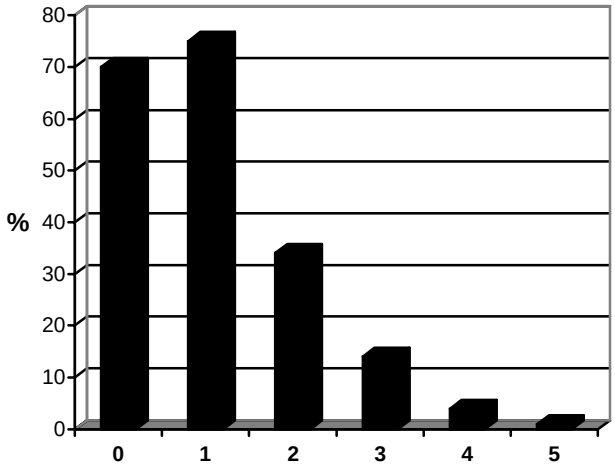


Figure 18 Number of vessels in the Kilcredaun study area during scans samples.

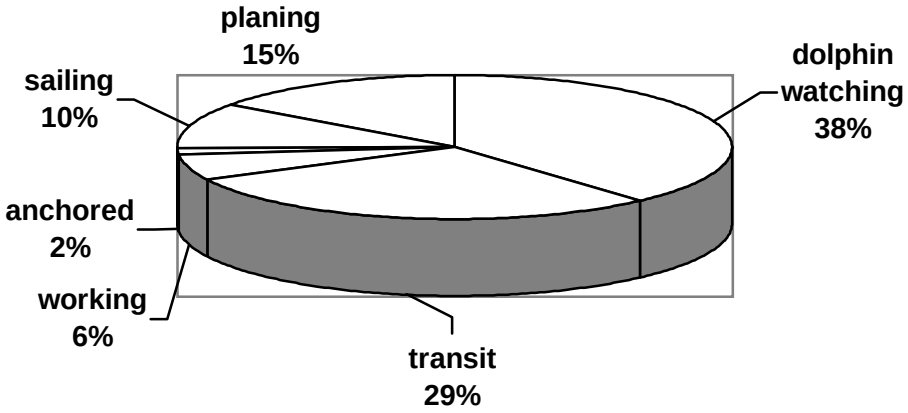


Figure 19 Frequency of observed boat activities in the Kilcredaun area of the Shannon (data from scan samples n = 206)

3.5.2 Interactions of vessels with dolphins

An interaction was recorded when vessels were judged to be within ten metres of dolphin groups. Dolphin-watching vessels were involved in 61.8% of interactions with dolphin groups, far higher than any other category of boat (Figure 20). Interactions also occurred frequently with large transiting ships (23.5%) and yachts under sail (8.7%). No judgement was made concerning the disturbance level of these interactions. Many interactions are initiated by the dolphins themselves such as bow-riding of transiting ships and yachts. However, every interaction involves some level of disturbance by altering the behavioural state of the dolphin group. Bow-riding, for example, whilst not appearing to have a detrimental effect on the behaviour of dolphins may have subtle influences on group composition, communication and activity (such as, ending a feeding or socialising period).

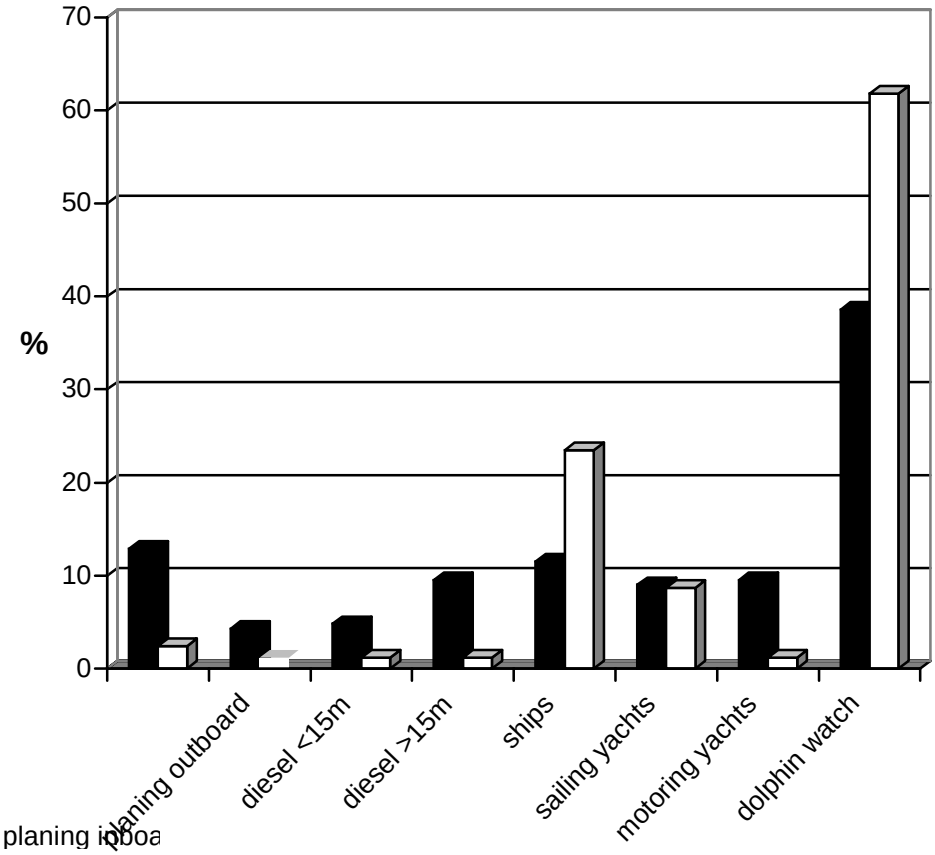


Figure 20 The frequency that different boat types were observed in the Kilcredaun area (solid bars) of the Shannon from shore watches and frequencies of observed associations with dolphin groups (striped bars).
(association scored when distance between vessel and dolphin group <10m)

The level of interaction of dolphin watching boats is not surprising since this is the only category of boats (with the occasional exception of planing outboard pleasure craft) which actively seeks out dolphin interactions. This high level of interaction has important implications when considering the disturbance levels to dolphins.

3.5.3 Dolphin watching in the Shannon estuary

As stated previously, commercial dolphin watching commenced in the Shannon in 1993, with one operator offering trips from Carrigaholt. Since then, the industry has grown and there are currently two operators offering trips from the north shore of the Shannon in Co. Clare. *Dolphinwatch* has one sailing out of the harbour at Carrigaholt whilst *Scattery Islands Ferries* moor three boats in the new Creek Marina at Kilrush. Although trips are run from May to September, most trips are carried out in August and September. A total of 2,431 passengers went whalewatching in 1997 at a mean rate of 6.3 passengers per trip (note: *MV St Senan II* is licensed to carry 32 passengers, all other vessels are licensed to carry 12). The number of trips carried out in the Shannon estuary from 1993 to 1998 are given in Table 5 (from Berrow and Holmes, 1999). In 1998, a smaller number of trips operated due to inclement weather conditions.

Table 5 Number of commercial dolphin watching trips conducted from 1993 -1998. (NA = not available).

	1993	1994	1995	1996	1997	1998	Total
MV Fiona David	NA	NA	162	145	118	63	488
MV Dena	-	8	28	33	36	18	123
MV St Senan II	-	-	-	36	38	28	102
MV Caraid	-	-	-	5	8	8	21
MV Karen Ann	-	-	2	6	-	-	8
Others	c10	-	-	-	-	-	c10
TOTAL	**10+**	**8+**	**192**	**225**	**200**	**117**	**C752**

3.5.4 Interactions of tour boats with dolphins

Observers accompanied tour boats on trips in an attempt to quantify the practices of dolphin watching vessels, where they searched and located dolphins, which dolphins were visited from each port and the degree of overlap. Dolphin/tour boat interactions were also recorded.

Eighteen trips were sampled in 1997 and 11 in 1998. The mean length of each dolphin-watching trip from Carrigaholt was 129 minutes in 1997 and 131 minutes in 1998. Trips were longer from Kilrush with an average of 141 minutes in 1997 and 179 minutes in 1998, but it took approximately 39 minutes to navigate in and out of the marina through the lock gates. If the trip length from and to the seaward lock gates is used, the mean length was 109 minutes and this is not significantly different to the mean trip duration from Carrigaholt ($t = 2.08$, $P = 0.06$). Bottlenose dolphins were seen during every trip sampled from both locations. They were found on average 19 minutes (range: 10 – 30 minutes) after leaving Carrigaholt in 1998 and 25 minutes (range 10 – 60 minutes) in 1998 and from Kilrush 39 minutes (range: 19 – 60 minutes) in 1997 and 45 minutes (range 19 – 60 minutes) in 1998. This is the most appropriate measure of effort required to locate dolphins and it was significantly longer from Kilrush than from Carrigaholt in 1997 ($t = 2.81$, $P < 0.05$). However, in 1998, no significant difference was found between ports.

Vessels from the two ports tended to operate in different areas. Tour boats from Carrigaholt generally searched an area between Kilcredaun Head, Beal bar and west to Ballybunion while boats from Kilrush searched mainly between Carrig Island and

Moneypoint, occasionally travelling as far up river as the Tarbert lighthouse and down river to Letterpoint buoy and Beal bar.

In 1997, the number of groups encountered by tour boats ranged from 1 – 4 per trip. Single groups were observed on eight trips (44%) and two groups on seven trips (39%). The number of dolphins per group encountered ranged from 5 – 26, although these values are considered minimum numbers. Juvenile dolphins were recorded in these groups, suggesting that the boats were interacting with breeding groups. Fewer dolphins or groups of dolphins were encountered in 1998, with the number of groups per trip ranging from 0 – 3, and numbers of dolphins encountered ranging from 0 – 40.

The technique of photo-identification, as described previously, was used to examine whether the same individual dolphins were being encountered on subsequent trips or by different operators on the same day. During 1997, 24 individual dolphins had distinctive marks on their dorsal fins to allow recognition. Of these dolphins, seven (24%) were only recognised on a single trip, a further seven were identified on two trips and a third group of seven (29%) on more than four occasions. One dolphin was identified on seven (35%) of the 20 trips carried out during the season.

Twenty-one individual dolphins were recorded from the boat from Carrigaholt, at a rate of 3.2 identifiable dolphins per trip and eight from Kilrush at a rate of 2.8 dolphins per trip. Of the 21 dolphins identified from Carrigaholt, five (21%) were also recorded from vessels operating from Kilrush. The other 16 dolphins were only recorded from Carrigaholt and a further three individuals only from Kilrush. Of the five recurring dolphins, three were seen by vessels operating out of Kilrush the day after being seen from Carrigaholt one two days later and only one individual (# 9) on the same day.

On four occasions, the same dolphins were seen on consecutive trips on the same day from the same port suggesting this was the same group of dolphins targeted by the tour boat on each trip. Twice, the same group of dolphins was targeted on consecutive days.

In 1998 a similar pattern was recorded, although sample size is small. Of the 19 dolphins identified, 13 were recorded only on one trip and three on three trips (11%). Six animals were recognised between years, and five dolphins identified in 1998 and an additional one in 1997 were also identified by Berrow *et al*., (1996) in 1993 – 1994. This suggests that these animals have been using the Shannon estuary in the summer since at least 1993.

3.6 SHORE BASED DOLPHIN WATCHING

In addition to producing a minimum population estimate, the four simultaneous counting exercises provided an opportunity to assess the land based dolphin-watching potential of the various sites. The dolphin watching potential of a particular site depends on a number of factors, including the obvious requirement that there must be a reasonable chance of seeing dolphins from the site, and they must be in sufficient numbers to be of interest to the layperson. The table below gives an analysis of the sightings made from each location during the four minimum population estimates.

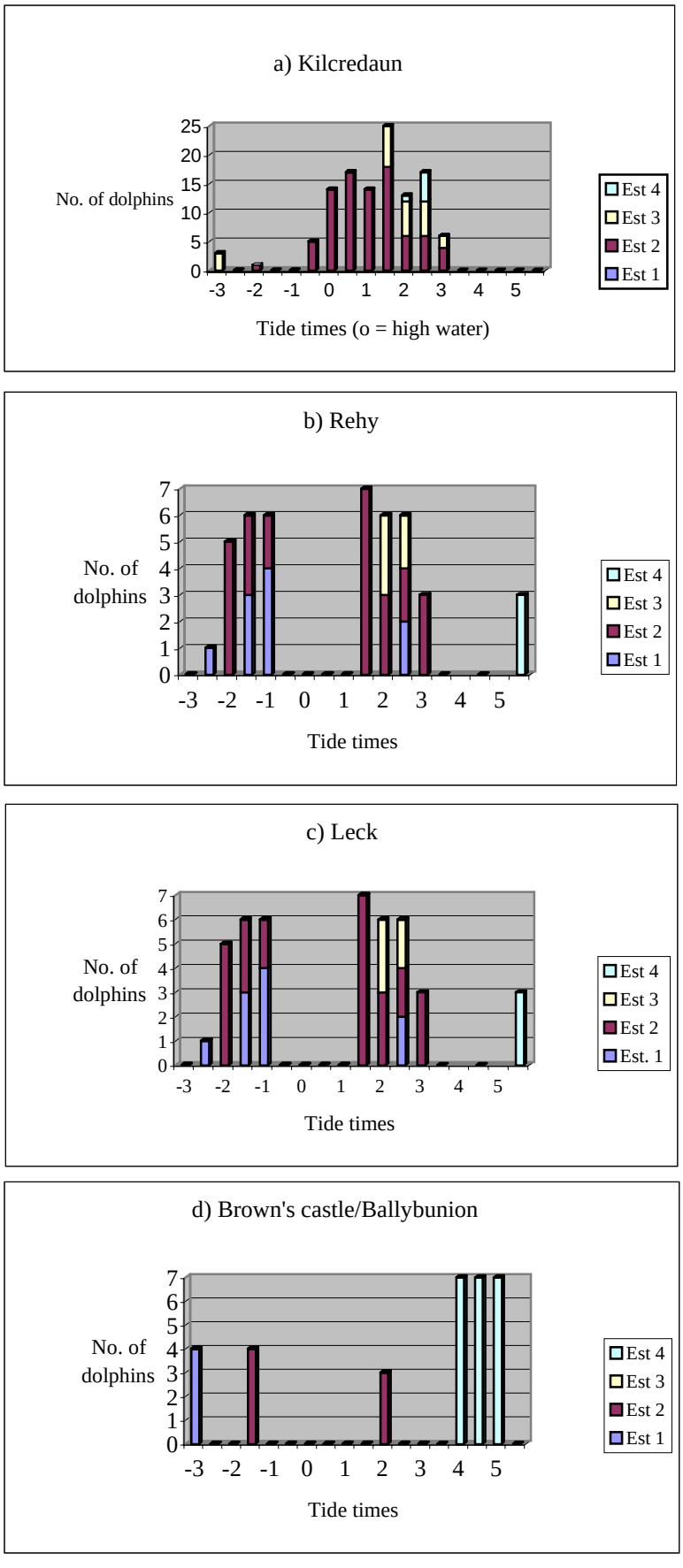
Table 6 Number of dolphins seen at various locations during the minimum population estimates (MPEs).

Site	No. of Scans	No of scans with sightings	% of scans with sightings	Total of dolphins seen*	Average no. dolphins per scan
Dunmore	49	3	6%	21	7
Rehy	38	12	32%	46	4
Kilcredaun	48	17	35%	112	7
Querrin	37	1	3%	1	1
Scattery	23	2	15%	4	2
Brown's Cas.	39	3	8%	11	4
Ballybunion	12	3	25%	21	7
Leck	44	12	27%	40	3
Beal	48	6	8%	31	5
Carrig	26	2	8%	10	5
Tarbert	52	10	19%	51	5
Glin	51	7	14%	9	1

**This figure is the gross total of dolphins recorded from each site. Animals present at a site over a number of scans are counted for each scan in which they were recorded.*

From the above, two sites emerge as having the most potential for shore based dolphin watching in the estuary. They are the neighbouring sites of Kilcredaun and Rehy on the north shore of the estuary. Kilcredaun offers a slightly higher probability of a sighting, just greater than one in three, as well as a larger average group size than Rehy. The usefulness of Kilcredaun as a vantage point is further discussed in sections 3.1.1 and 3.4. On the southern shore, only Leck and Ballybunion approach the above sites, although the Ballybunion figure must be treated with caution as all scans and sightings relate to one day. However, the frequency of sightings from the boat-based surveys of dolphins in the area, combined with data from the nearby Browns castle, suggest that this would also be a good area for shore-watching operations. In addition, data from shore watches at Moneypoint and the Shannon ferry show that Tarbert/Killimer might also be a potential site for shore-based dolphin watching. As the scans undertaken during the minimum population estimates are not fully representative of all stages of the tidal cycle or of the calendar year, it is not possible, on the basis of the minimum population estimate data, to suggest a best time of the year or state of the tide for dolphin watching. However, examining the data obtained from these four sites (Kilcredaun, Rehy, Ballybunnion, Tarbert) shows some patterns associated with tidal cycle (see Figure 21a-d).

Figure 21 Sightings of dolphins at different sites during four MPEs



At Kilcredaun, most sightings were made immediately at high water and in the three hour period after that. This is consistent with the results from the scans survey, as described in section 3.4 and reported previously by Berrow *et al*. (1996). In the Rehy and Leck areas, most sightings were made in the two hour period before high tide and 2 – 3 hours after high water. The information in relation to the tidal cycle at Browns castle/Ballybunion is less obvious and more information is needed from this area.

Further study is clearly required at these and at the other sites to ascertain the best time of the year and the best state of the tide for dolphin watching. If this was done for the above sites, it might then be possible to arrive at a stage where a dolphin's presence could be forecast with some degree of certainty thereby enhancing the potential for dolphin watching.

4 DISCUSSION

Bottlenose dolphins are one of 21 species of Cetacea recorded from Irish waters (Berrow and Rogan, 1997) and are typically a coastal living species. Preliminary studies by Berrow *et al*. (1996) suggested that a population of bottlenose dolphins may be semi-resident in the Shannon Estuary, but little was known about the size of the population, distribution, seasonal changes, etc. There are five other resident groups of bottlenose dolphins in Europe, located in the Moray Firth, Scotland; Cardigan Bay, Wales; Brittany, France; the Sado estuary, Portugal and in Croatia.

Inhabiting inshore coastal areas bottlenose dolphins are an accessible and popular species to observe in the wild, and many countries have dolphin watching industries built up around them. In Ireland, the now famous Fungi, attracts up to 75,000 visitors to Dingle each year and it is estimated that Fungi is worth £2.9 million to the local exchequer (Hoyt, 1995).

Dolphin watching began in the Shannon Estuary in 1993. Initially, the trips were on an *ad-hoc* basis, but with a high degree of success in dolphin encounters and a growing number of interested tourists, the industry grew. To date, two operators, with four boats, operate out of Kilrush and Carrigaholt, offering regular trips during the summer months.

Any expansion of the dolphin watching industry needs careful consideration as bottlenose dolphins are a species afforded full protection under a number of national, European and international laws and treaties. This study aimed to examine a number of key questions, which could be used as a basis for future management decisions and provide advice for the future development of a dolphin watching industry.

4.1 Population size and structure

Two methods were used to examine the questions relating to abundance and distribution of the dolphins boat-based surveys and shore-based watches. Both are standard techniques in the study of wild cetaceans.

Resightings of recognisable dolphins from photo-identification work provide information on the degree of residency of the population. Many of the identified animals were resighted throughout the study period, indicating a high degree of residency of the population. However, the seasonal changes in abundance and the high number of animals only recorded on single occasions indicates that the Shannon represents only part of the home range of many of the members of this population.

Minimum population estimates (simultaneous counts by observers) indicated that the maximum number of dolphins in the estuary was 30 animals. However, the more rigorous technique of photo-identification suggests that the number is much higher than this and the mathematically derived estimate suggests that the population size is 113 (95% C.I. 95 - 161) Ingram and Rogan (in review (a)). While this study showed simultaneous shore-based counts to be inadequate in providing reliable population estimates, they are useful in providing ‘snapshots’ of dolphin distribution and abundance at a given point in time, and were also useful for examining the suitability of shore-based sites for watching dolphins.

Dolphins were recorded in the estuary in all months of the year, but in much greater numbers during the months May – September. Newly born calves and mother-calf pairs were commonly seen in the estuary during the months of July to September, suggesting that the breeding season for the animals is during this period and that the Shannon is an important nursery area for these animals. This trend of a peak in abundance in summer was found to be consistent in the outer estuary at Kilcredaun and at the Tarbert/Killimer area.

Seasonality in distribution of a species is not unique to cetaceans and many animal species undergo seasonal migrations. The increase in numbers in the estuary in the summer months is not fully understood but may be influenced by the movement and migration of prey species. Feeding preferences of bottlenose dolphins in the Shannon estuary are not known, although instances of fish tosses suggest that they eat a number of different species, including mackerel (*Scomber scombrus* L), garfish (*Belone belone* L) and salmon (*Salmo salar* L). The river Shannon is a major salmonid river (ESB Fish Conservation Report, 1996 – 1997). From studies in other areas, bottlenose dolphins are known to eat a wide variety of prey species, and while mostly piscivorous, cephalopods have been recorded in the diet in some areas (Barros and Wells, 1998). Without a more detailed survey of the Estuary, for fish species and distribution, it is not possible to relate seasonality with prey dynamics.

Alternatively, the seasonal increase in numbers of dolphins may be associated with breeding/mating cycles. Newly born calves are seen from July to September and so the Shannon may be an area suitable for giving birth, away from predators such as blue shark and killer whales. It may also provide an opportunity for reproductively active animals to socialise, mate and nurse their young.

Previous studies on bottlenose dolphins have shown that this species has a fluid and dynamic social structure, termed a fission-fusion society (Wursig and Wursig, 1979, Balance, 1990, Smolker *et al*., 1992, Williams *et al*., 1993, Wilson, 1995). Strong associations have been recorded only between mother-calf pairs and alliances have been recorded between pairs of sexually reproductive males (Scott *et al*., 1990, Wells, 1991, Conner *et al*., 1992).

Social structure was examined in this study, by looking at a sub-set of animals, which are well marked and that had been encountered four or more times during photo-identification surveys. The strength of pairwise associations between known animals was measured using a "simple-index ratio" and this analysis showed that most of the associations were weak, with an index of < 0.5. Using cluster analysis, where individuals are aggregated into hierarchical groups depending on their average association, again shows that most animals interact with each other with no distinct groups forming. Examining the distribution of all associations between well-marked individuals also showed that there is a high degree of mixing within the population. All these analyses support the notion of a fluid and gregarious social structure.

4.2 Habitat use

Sightings of dolphins as far upriver as Limerick docks suggests that they may use all 80km of the tidal estuary. During the shore-based minimum population estimates, dolphins were recorded as far upriver as Glin. However, the boat-based surveys

extended only as far east as Tarbert and west to Ballybunion, and limited data exists on the abundance and distribution beyond these limits

Dolphins have been recorded in all parts of the survey area, but in much higher numbers and more frequently, in the outer estuary. They were frequently seen in the area around Kilcredaun Head and further upriver, at Killimer/Tarbert. Both these areas are deep, narrow channels subject to strong tidal flows. Of the whole survey area, dolphins were less frequently recorded in the area from Scattery island to Beal beach.

An examination of the distribution and location of well-marked animals shows that the recognised animals were all encountered in the outer estuary, but only a small percentage of animals were encountered in the upper area, suggesting a possible stratification in the use of the habitat by some individuals. This is further described in Ingram and Rogan (in review (b)) where minimum convex polygons of known ranges were calculated for frequently sighted dolphins to examine habitat use at an individual level. Although many of these MCP areas overlapped, a degree of partitioning was found in the use of up-river parts of the study area. This finding has important implications for the development of boat-based dolphin watching upriver. If this area is an important area for a smaller number of dolphins, then the potential for disturbance from a large number of boats is greater than in the outer estuary, where more dolphins are present. However, from a conservation perspective, both these areas are important and Kilcredaun appears to be an important feeding area.

4.3 Behavioural activities

Behavioural activities are difficult to study in wild animals, and in particular in cetaceans, as observations are restricted to the waters surface. During this study, standardised shore based watches were carried out from Kilcredaun, over the annual and diurnal (daylight) cycle. Activities were classified as travelling, feeding, milling, resting, feeding, and socialising. Travelling (defined as regular surfacing and movement in uniform direction) was the most common activity, recorded in 65% of all scan samples. Resting was the least recorded of all the activities and suggests that this area is not used for resting. Feeding, socialising and milling were each recorded in approximately 12% of all scan samples.

Group sizes throughout the year ranged from singletons to groups of 32 animals, with groups between 2 and 10 dolphins being common. This group size distribution (2 – 10) is typical for the species (Shane, 1990, Wilson, 1995). Group size was influenced by activity, with larger groups engaged in socialising and feeding. This may reflect co-operative feeding effort and/or different groups involved in ‘greeting’ behaviour.

At Kilcredaun, groups engaged in socialising, feeding and milling were more frequently observed during flood and ebb phases of the tide than during high and low water slack periods, whereas resting was observed more frequently during slack water. Travelling was most frequently recorded at high water slack periods, a time corresponding to least current. However, travelling against the tide was recorded. This energy expensive behaviour may be associated with foraging and feeding. Milling was also recorded during periods of strong current.

Group size was found to be larger during ebb and flood periods of the tides than during periods of slack water. This may be as a result of larger groups forming for co-operative feeding and/or socialising. In addition, groups shifted distribution towards the south side of the study area during the flood phase, concentrating around areas of steeply sloping areas and headlands, and during ebb phase, moved to the areas near the Clare shore. These differences in distribution are related to changes in the strong tide currents in the area.

Although patterns are apparent in the distribution of dolphin groups according to environmental variables such as the tide cycle, little evidence from this study suggests differential habitat use according to activity states, although it should be noted that only the Kilcredaun area was extensively studied. However, it appears that the Kilcredaun area of the Estuary is an important foraging area for the dolphins.

4.4 Boat based dolphin watching

The boat-based dolphin watching tourism in the Shannon estuary is at present small. The existing operators are keen to promote the implementation of codes of conduct and have contributed to the writing of the present voluntary code. Care is taken to minimise physical and acoustic disturbance and efforts are made to enhance the quality of the tours (e.g. via use of hydrophones and available scientific information).

The stratification in use of the Estuary, with a small number of the overall population using the upper river, suggests that dolphins that use this region may be subject to a higher 'impact' from tour operators, than the larger number of animals in the outer estuary. It is recommended that any increase in tour boats frequenting this area should be very carefully monitored and regulated.

While it was not possible in the present study to quantify a disruptive or negative impact from dolphin watching boats on the dolphins, a specific study on the reaction of dolphins to tour boats would be useful.

However, even at the present level, dolphin watching accounts for a high level of vessel activity around dolphin groups and this can only increase if the boat-based dolphin watching industry expands. Therefore, it is important to maintain the present standards as new operators start running dolphin watching trips. A model of 'best-practice' designed with the involvement of existing operators would help to secure high quality objectives and promote dolphin watching in the Shannon estuary as an exemplary tourism product both nationally and internationally.

Rather than assigning specially protected areas according to dolphin activity the disciplined use of codes of conduct around dolphins should minimise the level of disturbance in all areas of the Estuary and during all activity states of the dolphins. Suggested basic principles to be incorporated in the code of conduct are outlined in Appendix 1. The protection of dolphins in the Shannon should be reviewed in the future in order to take account of further research into habitat use.

4.5 Land based dolphin watching

Shore based dolphin watching has great potential in the Shannon estuary. Several locations have been highlighted which offer a good chance of seeing dolphins with good accessibility and elevation. For example, at Kilcredaun, dolphins were seen

>70% of the time during scan samples. In addition, the movement of the dolphins across the river in this region, shows that dolphins are more likely to be seen at the ebb phase of the tide at Kilcredaun, moving to the Kerry side during the flood phase. Dolphins here were seen more frequently 3 hours after high tide. Similarly, in the Killimer/Tarbert, animals were sighted at every stage of the tidal cycle but there is a distinct peak in sightings in the four hours before low tide.

No amount of research can guarantee that dolphins will turn up on cue as required and it would be useful to include in any dolphin watching tourism project other attractions as a fallback. This could take the form of a coastal zone or cliff walk package embracing bird-life, botany and geology etc. It should also be recognised that all the sightings during the minimum population estimate during the present study were made by experienced observers equipped with binoculars. Any assessment of a site must take into account access, public safety and the animals' usual behaviour and distance from shore as well as the basic "chance of seeing dolphins" factor.

In addition to the suitability of the Shannon region to outdoor holidays, there is also the potential for land-based facilities to be located at some of the identified sites. There are many areas that are good vantage points (e.g. high elevation, un-obstructed view) along the Shannon, but many are situated on private land, with difficult road access, e.g. Kilcredaun. Others areas, e.g. Ballybunion, have public walks, where an outdoor viewing area with educational facilities such as an information board could possibly be constructed.

A third possibility, to further improve the educational component and increase the 'value added' experience, would be the construction of a larger building, with a look-out post and equipment such as binoculars or telescope. Along with the possibility of seeing dolphins, additional educational facilities, for example, audio visual facilities, leaflets, posters, it would also be possible to allow people to 'hear' and listen' to dolphins and other forms of marine life. A very suitable area for this is the Tarbert/Killimer area.

The regular use of the stretch of water at Tarbert/Moneypoint lends itself to predictability and could make this a prime area for boat-based dolphin watching. However, this same regular usage of this area means that this stretch of water is of importance to the animals well-being and, that disturbance, already present from shipping and the ferry itself, must be kept to a minimum. In addition, the strong tidal flows and regular shipping traffic in this narrow stretch of the estuary might present a hazard to dolphin watching launches. Consequently, it would seem better to pursue shore-based dolphin watching as an option at this location.

The sightings recorded from Tarbert during the minimum population estimates show that dolphins could be seen regularly from the shore. This is particularly interesting since the minimum population estimates were organised around high tide rather than the peak pre-low tide period. A series of watches from Tarbert during peak sighting times could establish this area's potential for shore-based watching and perhaps enable Tarbert to complement the other likely dolphin watching sites on the north shore of the estuary. This would hopefully limit the demand for boat-based dolphin watching in the estuary and thereby keep disturbance to an acceptable level.

In this area, apart from the existing infrastructure, such as roads, and carpark facilities on the Tarbert side, there is a 'captive' audience in the people who are waiting to cross the river and who may see dolphins on the way over. Research should be carried out to examine the suitability of this site for the deployment of hydrophones or the use of sonar buoys as a possible method of enhancing shore-based dolphin watching.

SUMMARY AND CONCLUSIONS

The main results of the study can be summarised as follows:

- Bottlenose dolphins are present in the Shannon year round, but with seasonal fluctuations and a higher use of the estuary from May to September
- Dolphins were found throughout the study area, but were more frequently encountered at Kilcredaun and in the outer estuary. A second area where dolphins were frequently encountered was further up-river at Killimer/Tarbert. Based on photo-identification, the animals recorded here were often observed in this region, suggesting some habitat stratification of the estuary. This needs further investigation, and may have implications for the developing dolphin watching industry.
- Based on mark-recapture models and the existing photo-identification catalogue, the total population is estimated at 113 dolphins (CV 0.14, 95% C.I. 94 - 161).
- The presence of neonatal calves between July and September suggests that there is a very distinct breeding season for this species and that the estuary is an important breeding/nursing area.
- Association indices show that there are few "strong" associations and few "non" associations between individuals, supporting the theory of a fluid and gregarious social structure.
- There were strong associations with dolphin behaviour and the tidal cycle, with a distinct peak in sightings in the four-hour period before low tide.
- The Shannon estuary is a very busy port, with many different boat types and users. Boats were present in 65% of all scan samples with dolphin watching boats accounting for 38.6% of all vessels recorded. Dolphin watching boats were involved in 61.8% of interactions with dolphin groups, higher than any other category of boat.
- At present, two operators make approximately 200 dolphin watching trips annually, carrying a total of 2,400 passengers per year. The operators are highly successful in locating dolphins (97%) and tour boats rarely come into contact with each other on the water and search in different areas.
- A number of potential sites have been identified for use as land-based dolphin watching facilities, but further study is required to ascertain the best sites for dolphin watching.

While this study has provided an invaluable baseline data set relating to the dolphin population, the existing dolphin watching industry and the potential for land-based dolphin watching, it is important to maintain a scientific monitoring and research programme of the bottlenose dolphin population. Such a monitoring programme would continue to provide important information for the conservation management of the population and for management decisions relating to other coastal zone industries such as oil and gas exploration and shipping development within the Shannon estuary. Results from research and monitoring of the population will serve to equip the authorities to comply with environmental obligations under EU law, and contribute to developing an effective long-term conservation management strategy for cetaceans in Irish coastal waters.

The proposed designation of the Shannon as a Special Area of Conservation (SAC) will aid the active management of the dolphins' habitat. Assigning legal status to

codes of conduct together with the protection endowed by the 1976 Wildlife Act would lead to an effective management of boat based disturbance.

For boat based dolphin watching it is recommended that:

- the stratification of habitat use within the estuary and the degree of partitioning of the up-river area suggests that these "up-river" animals may be more vulnerable to dolphin watching operations. Any increase in the number of tour boats operating in this area, or increase in the number of trips would need to be carefully monitored and regulated.

- the impact of the tour boats on the dolphins should be assessed

- the high standards as currently exist in dolphin watching operations are maintained. The implementation of a model of best practice and investment in on-going training for existing and new dolphin watch operators would help secure high quality objectives.

- a public awareness scheme should be implemented to help industrial operators and members of the public understand the importance of the estuary to bottlenose dolphins. An increased profile will help reduce any unnecessary disturbance and allow effective regulation. Following the codes of conduct will help minimise any disturbance.

- consideration should be given to the acoustic properties of proposed engine types when advising and licensing dolphin-watching vessels. Generalised noise outputs are available for different engine types (Richardson *et al.,* 1995) or engine noise of specific vessels can be easily measured. Quieter vessels would be more appropriate and in addition, will facilitate the towing of hydrophones, thereby heightening the dolphin-watching experience.

With regard to shore-based development, it is recommended that:

- shore watching facilities be developed, to increase the accessibility of the Shannon dolphins to tourists. To increase public awareness and knowledge such sites could be supplemented with interpretative information about the species and the local population.

In order to ensure effective and precautionary conservation of the dolphin population it is important to identify all potential threats to dolphins within and around the Shannon estuary. Such information would be vital in advising industrial activity. Incorporation of these threats into pollution response models would aid the effectiveness of a clean-up operation following pollution events (such as oil or chemical spills).

Due to the seasonal trend in dolphin abundance in the area and the timing of the calving period of bottlenose dolphins, it is recommended that any potentially disturbing industrial activity should take place outside of the summer period, May-September.

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Appendix 1 Code of practice to protect small cetaceans in the Shannon Estuary

1. Any vessel shall not approach within 10m of any small cetacean except under licence from the Minister. Vessels, which are approached by small cetaceans, may remain within 10m of them.

2. Any vessel shall not, when less than 100m from the small cetaceans, exceed a speed of 5knots except under licence form the Minister.

3. Any vessel shall not alter speed or course suddenly when less that 100m from the small cetaceans.

4. Not more than 4 vessels may approach to less than 100m from the small cetaceans.

5. Any vessel with person/s engaged in dolphin watching may not remain with 100m of any small cetacean at any time for more than 30 minutes. Persons/boat operators who wish to remain longer than 30 minutes must obtain a licence from the Minister.

6. Any vessel shall not use underwater acoustic transmitters, except navigational echo sounders, when less than 100m from the small cetaceans. Sound, for example, tapes and radios etc., may not be broadcast from the boat.

7. No vessel shall permit any passenger to enter the water, swim or use SCUBA within 100m of small cetaceans, except under licence from the Minister.

8. No person shall feed, give drugs to or medication to, or throw objects near any small cetacean.

9. No person shall attach marks to any small cetacean except under licence from the Minister.

10. The use of water-ski/s, jetski/s or the discharge of any firearm shall be prohibited within 100m of any small cetacean.

11. No person shall detonate any explosive or operate a pile-driving machine except under licence from the Minister.

12. Nothing in these regulations shall operate to prohibit anything done for the preservation of life at sea or in the interest of public safety.

13. Nothing in these regulations shall operate to restrict the obligations on persons and vessels to obey rules for the prevention of collision at sea and the regulations enacted by statuary Harbour Authorities.