Bottlenose dolphins (*Tursiops truncatus*) in the Shannon Estuary and selected areas of the west-coast of Ireland.

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Appendix A compact disc containing images of all animals identified during this project is included with this report.

Summary

Between July and September 2003 19 boat-based surveys of bottlenose dolphins (*Tursiops truncatus*) were conducted in the outer Shannon estuary, Cork Harbour and Connemara, Co. Galway. A total of 14 surveys were conducted in the Shannon estuary resulting in encounters with 66 bottlenose dolphin schools. One school of 20 dolphins was encountered in Connemara and a school of 15 dolphins was encountered in Cork Harbour.

Dolphin schools were encountered throughout the outer Shannon estuary but concentrated at the estuary mouth. The median school size in the Shannon was six and school sizes ranged from lone animals to schools of up to 39 dolphins. Photo-identification was used to identify 141 dolphins from their unique natural markings. A total of 388 identifications were made during surveys of the Shannon estuary. Photographs were scored according to image quality from grade 1 (best quality) to grade 3 (poorest quality) and 49% of all identifications of dolphins in the Shannon were from grade 1 photographs. Of a total of 36 permanently marked dolphins sighted in 2003, 20 were first identified in 1996, the first year of dedicated UCC surveys in the Shannon. Clearly, dolphins using the Shannon have a high degree of site fidelity and represent a discreet community. Plots of the encounter locations of eight dolphins sighted in at least 20 schools showed a degree of habitat partitioning with fewer dolphins using the upriver parts of the study area. Ten neonatal calves were sighted during surveys in the Shannon showing the importance of the estuary as a nursing and breeding area.

Photographic identification data relating to sightings of a subset of marked animals were used to calculate a capture-recapture estimate of the abundance of dolphins using the Shannon estuary. The capture-recapture model used to derive the estimate accounted for heterogeneity in capture probabilities between sampling events and between individuals. Estimates were corrected according to the proportion of unmarked animals in the population and separate estimates were derived for left side and right side identifications independently. These estimates were then combined using an inverse variance weighted average to give a total estimate of 121 ±14 (SE) dolphins (CV=0.12, 95% CI=103-163). In order to maintain information relating to population status, survivorship and calf production in the Shannon estuary a photo-identification based monitoring programme is recommended.

Photo-identification data from surveys conducted in the waters around Connemara show a degree of site fidelity with one dolphin sighted in 2003 first identified in 2001. The coast of Connemara may be a suitable site for future SAC designation. Of 15 dolphins identified in Cork harbour, nine were encountered in a single school in 2002 in Youghal Bay. The west-coast appears to be inhabited by a fragmented meta-population of bottlenose dolphins and further research is needed before recommendations can be made regarding the protection of animals using numerous coastal areas.

Introduction

Bottlenose dolphins are found throughout the world's tropical and temperate seas and are one of 21 species of cetacean found in Irish waters (Berrow and Rogan, 1997). Throughout its range the species is frequently found in shallow coastal habitats such as estuary mouths, bays and lagoons (Leatherwood & Reeves, 1983a). Resident, coastal bottlenose dolphin 'communities', which exist permanently within a specific location, have been studied in a variety of habitats and locations around the world including: Florida (Wells & Scott, 1990); Shark Bay, Australia (Smolker *et al*., 1992); Texas (Leatherwood & Reeves, 1983b); Costa Rica (Acevedo & Würsig, 1991); Scotland (Wilson, 1995); Wales (Arnold, 1993); New Zealand (Williams *et al.*, 1993); Portugal (dos Santos & Lacerda, 1987); Brittany (Liret *et al*., 1994) and Croatia (Bearzi *et al.*, 1995). Bottlenose dolphins can be distinguished from other dolphin species due to their large size (measuring up to 4m in length) and their robust body shape and short beak. Dorsally they are uniformly grey with a subtle pale blaze on their flanks and a pale underside. Bottlenose dolphins are long lived animals with a life expectancy of approximately 30 years (Leatherwood & Reeves, 1983a). After a 12 month gestation, calves are approximately 1m long at birth and suckle for 1.5 to 2 years (Wells and Scott, 1999).

Conservation status

Bottlenose dolphins are listed in Annex II of the EU Habitats Directive. At present, the Shannon estuary represents the only candidate Special Area of Conservation (cSAC) designated for the protection of this species in Irish waters. Effective conservation relies on the availability of accurate up-to-date scientific information. Specifically, an appropriate management strategy requires an accurate estimate of the abundance of the animals to be protected and an understanding of their ranging patterns and use of habitat. Only by estimating population parameters, can future changes in abundance be detected and appropriate measures taken.

Estimating bottlenose dolphin abundance

Abundance estimates for bottlenose dolphins have been derived using a variety of methods including; shore-based platforms of observation, aircraft surveys and boat-based studies. Minimum abundance estimates of inshore dolphin populations can be derived from shore-based observations using multiple observer synchronised counts (Hammond and Thompson, 1991; Berrow *et al*., 1996; Ingram 2000). This technique is inexpensive and provides an indication of the size of the population and its distribution. However, estimates derived in this way only give a 'snap-shot' indication of the population size and do not allow for seasonal and temporal variations in abundance. Line transect methods (Hammond, 1986a) have also been used to derive abundance estimates for bottlenose dolphins (Leatherwood, 1979; Leatherwood & Reeves, 1983b; Blaylock, 1988). However, line-transects may be susceptible to errors arising from spatial and temporal patchiness in animal distributions (Hammond, 1986a; Wilson *et al.*, 1999a) and do not provide information regarding individual animals. Multiple sample, 'capture-recapture' abundance estimates (Otis *et al*., 1978; Seber, 1982 and 1992, White *et al*., 1982; Hammond, 1986b and 1990) are becoming more frequently applied to cetacean populations. These surveys often use photographic recognition of the dolphins' naturally occurring marks rather than physical capture (Würsig and Würsig, 1977; DeFran *et al.*, 1990; Wells and Scott, 1990; Williams *et al*., 1993; Wilson *et al*.,

1999a, Chilvers and Corkeron, 2003; Read et al., 2003). Photo-identification of bottlenose dolphins relies on matching marks and nicks on their dorsal fins and flanks. Much of this marking and fin damage is due to conspecific tooth rakes and the trailing edge of the dorsal fin, in particular, is easily damaged, resulting in a unique dorsal fin profile (Würsig & Würsig, 1977; Würsig & Jefferson, 1990).

Dolphins using the Shannon estuary

Bottlenose dolphins have been reported in the Shannon estuary since at least 1835 (Knott, 1997) and regular photo-identification surveys of the dolphins using the outer estuary have been conducted by UCC since 1996 (Ingram 2000; Rogan *et al*., 2000). Throughout this period, a photo-identification catalogue of uniquely marked dolphins using the Shannon estuary has been maintained. The photo-identification data from these survey showed that the animals probably belong to a resident community of freely mixing individuals (Ingram, 2000). The numbers of dolphins using the estuary were found to increase during summer months, a pattern that was repeated between years (Ingram, loc. cit.). An abundance estimate of 113 ±16(1 se) dolphins using the estuary was calculated using 'mark-recapture' photo-identification data collected between May and September 1997 (Ingram, loc. cit.). A single abundance estimate however does not provide information regarding population change and is insufficient in terms of monitoring. This study aimed to conduct further surveys, in order to calculate a new estimate of the abundance of dolphins using the Shannon and by contributing to individual sighting histories, to examine the ranging patterns of identified animals.

Bottlenose dolphins using the west-coast of Ireland

Whilst the Shannon represents a critical habitat for bottlenose dolphins in Irish waters (Ingram and Rogan, 2002), boat-surveys and casual sightings have identified several other locations on the west-coast regularly used by this species (Ingram *et al*., 2001). Specifically, boat-based surveys conducted by UCC in areas of the west-coast identified several sites used by bottlenose dolphins. Photographs taken during these surveys were used to identify 80 individuals from these sites (Ingram *et al*., 2001). Only 11 of these dolphins were known from surveys of the Shannon estuary suggesting that they belong to different coastal communities. Furthermore, individuals were resighted within coastal sites between years, indicating a degree of site fidelity and possible residency in specific areas. These results indicated that the west coast may support a dispersed metapopulation with several discreet subpopulations rather than a single intermixing population. However, limited information exists to date on the abundance and site fidelity of individuals using these coastal areas. This study provided the opportunity to continue survey effort in selected coastal areas and to respond to sightings of bottlenose dolphins around the coast.

Project aims

This project aimed to:

- Conduct repeated photo-identification boat surveys in the Shannon estuary.
- Calculate an estimate of abundance of dolphins using the Shannon estuary during the study period.
- Examine long-term residency and ranging patterns of permanently marked dolphins using the Shannon.
- To conduct photo-identification surveys at selected sites on the west-coast

Methods

Boat-based photo-identification surveys

Boat-based photo-identification surveys were conducted using a 5.8m rigid inflatable boat (RIB), powered by a 80hp four-stroke outboard engine. Surveys in the outer Shannon estuary followed a standard 70km survey route used during dolphin surveys conducted by UCC since 1996 (Figure 1). The study area included areas of known dolphin abundance (Ingram, 2000; Rogan *et al*., 2000; Ingram and Rogan 2002) and areas visited by commercial dolphin watching tours (Berrow & Holmes, 1999). Surveys in other coastal areas followed non-standard routes and were directed to maximise the probability of encountering dolphins based on local reports and existing knowledge of dolphin habitat use (Ingram *et al*., 2001).

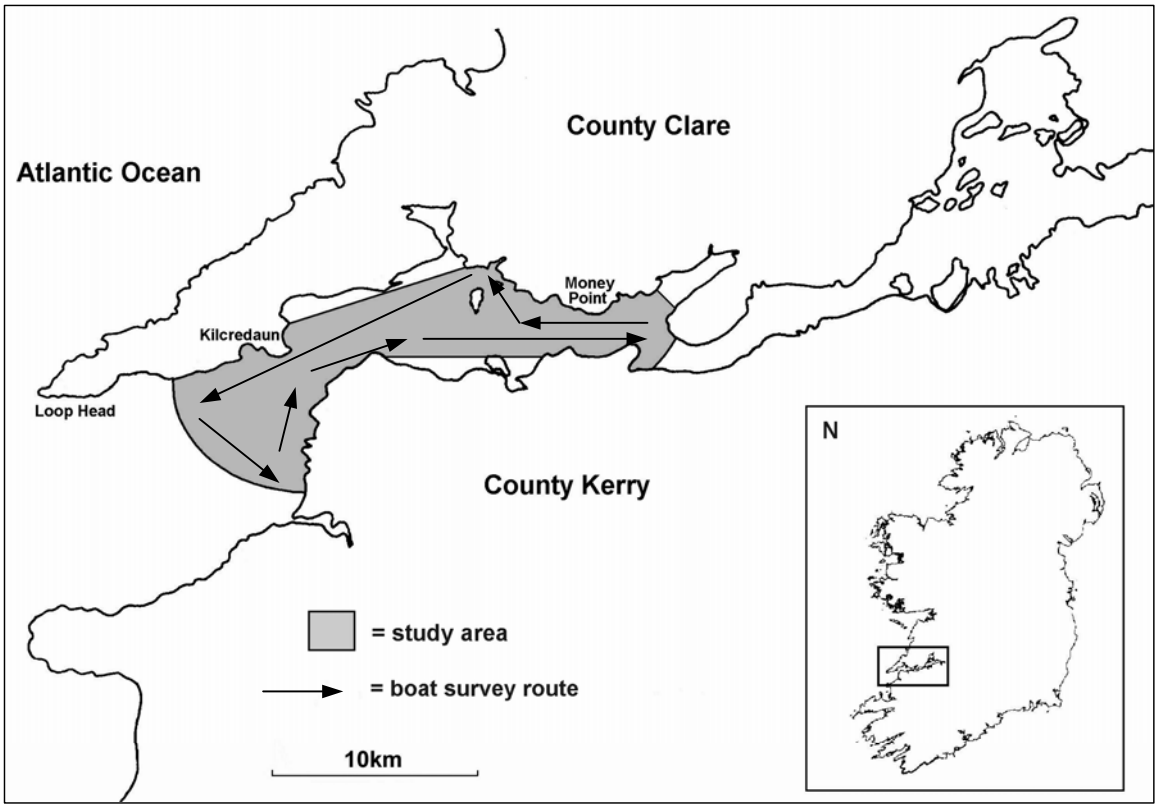

Figure 1. The outer Shannon estuary showing the study area and the boat survey route.

All surveys were conducted in Beaufort sea-states two or less in order to minimise the effects of sea-state on the probability of sighting and photographing dolphins. Surveys were conducted at a constant speed of approximately 20km.h^{-1} and a lookout for dolphins was maintained throughout. A dolphin school was defined in this study as all dolphins within a 100m radius of each other (Irvine *et al.*, 1981) and interactions with a dolphin school were termed an 'encounter.'

On sighting dolphins, the school was approached slowly in order to minimise disturbance and the school's position (± 3m) was recorded using an onboard GPS unit. During encounters attempts were made to photograph all members of the school without preference accorded to their marks. Photographs were taken perpendicular of the dolphins' dorsal fins, in well-lit conditions, from within a distance of

approximately 20m. Photographs were taken using an auto-focus SLR camera with a 100-300mm f4 telephoto zoom lens. The films used in this study were 100, 200 and 400 ISO Fuji Sensia slide film. In order to obtain well-exposed images of identifiable markings, the lens aperture was increased by one f-stop in sunshine and by two f-stops in overcast conditions. The film was then processed according to the stated ISO rating for the film. Each encounter continued until all the dolphins in the school had been photographed or the school was lost (a school was considered lost after 10 minutes without a sighting). Following an encounter the survey was resumed until the route was completed. Surveys on which the route was completed were classed as 'full', and incomplete surveys which were abandoned due to deteriorating weather were classed as 'part'.

Data analysis

Photograph analysis

The best photographs of each side of every dolphin encountered on each survey were selected and scored from 1-3 according to photograph quality (see Table 1) with no consideration of the degree of marking of the subject (Hammond, 1990; Wilson *et al*., 1999a, Ingram, 2000; Read *et al*., 2003).

Table 1. Criteria used to grade the quality of all photographs taken of dolphins (Decisions on photo quality were made independent of the degree of marking of individuals).

Grade	Criteria
1	Well lit and focused shots taken perpendicular to the dorsal fin at close range
2	More distant, less well lit or slightly angled shots of dorsal fins
3	Poorly lit or out of focus shots taken at acute angles to the dorsal fin

These photographs were then matched with the archive of photographs of identified individuals maintained by UCC since 1996. If a dolphin fin was matched with an individual in the catalogue, the slide was marked with the appropriate catalogue number and added to the archive. If a match was not found from the catalogue, the individual was given a new, unique identification number and subsequently added to the catalogue. Since photographs were frequently only obtained of one side of a dolphins dorsal fin there effectively existed two separate sets of 'right-side' and 'left-side' identifications.

Severity of identifying marks

Each catalogued dolphin was scored from 1-3 according to the severity of its natural markings (Plate 1), based on the scale published by Lockyer and Morris (1990). Dolphins with deep healed wounds and significant fin damage were considered to be permanently marked and assigned as 'Grade 1'. Dolphins with more minor fin damage and deep tooth-rakes were assigned as 'Grade 2'. Dolphins with superficial scratches and skin lesions were assigned as 'Grade 3'.

a)

b)

c)

Plate 1. Examples of the three grades of mark severity used in the capture-recapture analysis. Photo-identification relies on recognising individuals from the unique fin and flank markings caused by dermal infection and conspecific interaction. Each dolphin was graded from one to three according to the severity of its marks. **a**, an example of an animal with grade 1 marks, these marks consisted of significant fin damage or deep scarred marks which were considered permanent; **b**, shows an animal with grade 2 marks, these consist of deep tooth rakes and lesions **c**, shows an animal with grade 3 marks, these consisted of superficial rakes and lesions.

Capture-Recapture Analysis
The resulting photo-identifications of individuals obtained during all surveys of the Shannon were used to model the abundance using the 'mark-recapture' software CAPTURE (Rexstad and Burnham, 1991). Multiple sample capture-recapture abundance estimates of closed populations depend on the following basic assumptions (Otis *et al*., 1978; Seber, 1982):

1) the population is closed for the duration of sampling
2) animals do not lose their marks during the sampling period
3) all marks are correctly recorded in each 'capture' event
4) each animal has an equal and constant 'capture' probability

Assumption 1 refers to geographic and demographic closure in which there is no immigration or emigration in the population or changes due to birth or death or change of marking during the course of sampling. Identifications based on animals' natural marks risks violating assumptions 2 and 3 due to differences in the severity of markings between individuals, making some members of a population more easily recognised than others (Gunnlaugsson & Sigurjonsson, 1990). Additionally, incorrect matches may result from poor photograph quality and/or the comparison of insufficiently marked individuals. In order to reduce the probability of these matching errors poorly marked grade 3 (see Plate 1) animals were excluded from the capture-recapture analysis. In addition, poor quality photographs with a score of 3 were also excluded from the analysis.

Following this selection procedure the sample of dolphins included in the capture-recapture analysis represents a 'marked' subset of the dolphins using the estuary. Every dolphin within this subset was sufficiently marked to enable identification from all the selected photographs so reducing the probability of violating assumption (4).

Proportion of marked dolphins
In order to calculate the total number of dolphins the estimates derived using CAPTURE for this marked population was increased according to the proportion of dolphins included in the marked subset using the following formula:

$$N = \frac{N_{hat}}{\theta}$$

where; N= estimated total population size, Nhat = estimate of the subset of marked animals, θ *(theta)* = proportion of the population with identifiable markings.

The best quality (grade 1) photographs were examined in order to derive the proportion of dolphins that belonged to the marked subset used in the 'mark-recapture' analysis. This proportion was calculated by comparing the total number of identifications of all dolphins with the number of identifications of dolphins from the marked subset (after Wilson *et al*., 1999a).

The variances of the total estimates ($_{var}N$) were obtained using the delta method as follows:

$$_{var}N = N^2 \times \frac{_{var}N_{hat}}{N_{hat}^2} + \frac{1-\theta}{n\theta}$$

Separate estimates for right-side and left-side identifications were calculated and these were then combined using an inverse variance weighted average producing an overall population estimate (Wilson *et al*., 1999a).

Results

Survey effort

In total, 14 surveys were conducted in the outer Shannon estuary between July 5th and September 21st (Table 2). Eleven of these surveys were 'full' surveys in which the survey route was completed and the remaining three were incomplete or 'part' surveys, abandoned due to deteriorating light or weather conditions. In addition, three surveys were made in the coastal waters of Connemara and two surveys were made in Cork Harbour. All surveys conducted in the Shannon estuary resulted in encounters with bottlenose dolphin schools (Figure 2). In addition, one survey in Connemara (Figure 3) and two surveys in Cork harbour (Figure 4) were successful in locating dolphin schools (Table 2).

Table 2. The timing of surveys conducted between July and September 2003 including a summary of the number of schools encountered during each survey (incomplete surveys are indicated with an asterisk).

Date	Location	Number of schools encountered	Number of dolphins identified
5th July	Shannon estuary	11	38
4th August	Shannon estuary	3	22
5th August	Shannon estuary	12	53
6th August	Shannon estuary	2	26
7th August	Shannon estuary	5	61
8th August *	Shannon estuary	2	14
10th August	Shannon estuary	2	20
11th August	Shannon estuary	6	51
12th August	Shannon estuary	4	32
13th August *	Shannon estuary	4	30
15th August	Shannon estuary	5	26
16th August	Shannon estuary	3	41
19th August	Cork Harbour	1	15
20th August	Cork Harbour	1	15
24th August	Connemara	0	0
16th September	Shannon estuary	4	42
21st September *	Shannon estuary	3	44
27th September	Connemara	1	20
28th September	Connemara	0	0

Encounters with dolphin schools in the Shannon estuary

In total 66 dolphin schools were encountered during boat surveys of the outer Shannon estuary (Figure 2). Only 5 encounters were with lone animals and school sizes ranged from 1 to 39 dolphins with a median school size of 6 (Figure 5).

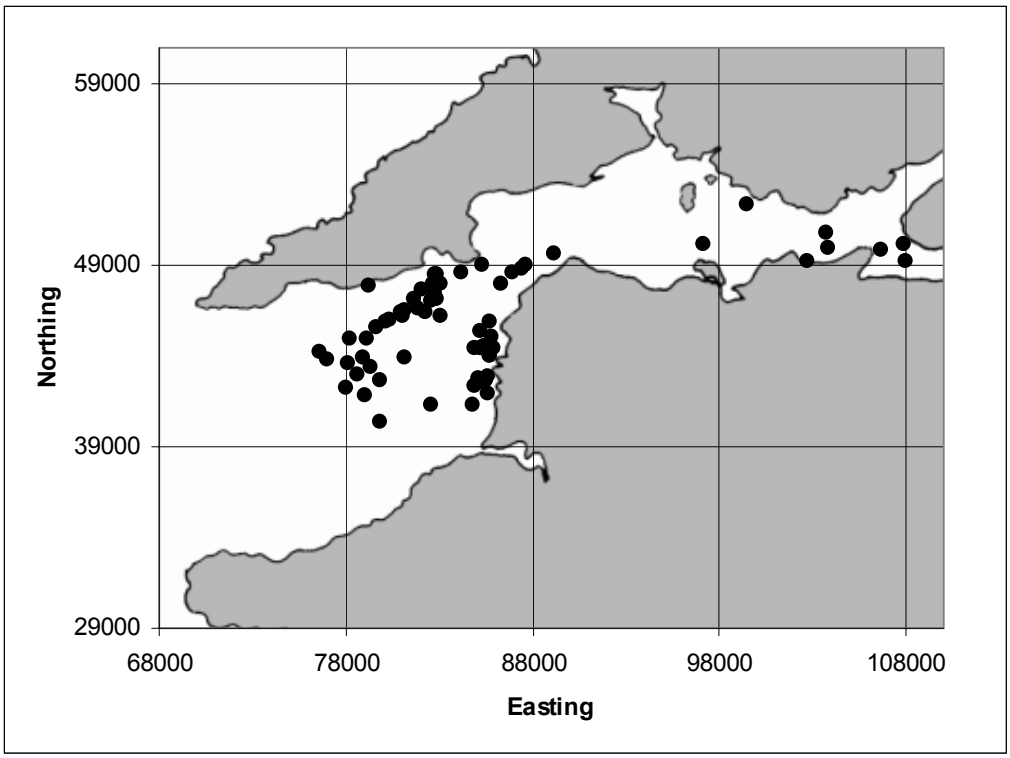

Figure 2. The locations of encounters with dolphins in the outer Shannon estuary. The black dots denote the encounter locations. The axes show metric OSI easting and northings in metres.

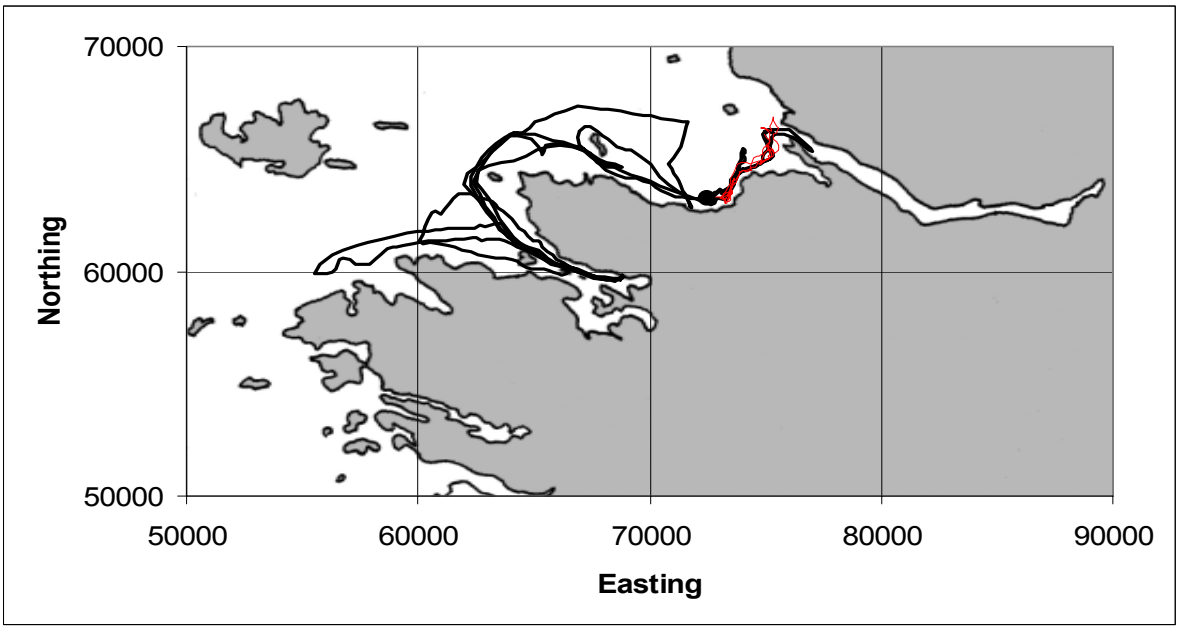

Figure 3. Survey tracks and locations of encounters with dolphins in Connemara. The black line shows the boat's track, the black circle indicates the encounter location and the red line shows the boat track during the encounter. The axes show metric OSI easting and northings in metres.

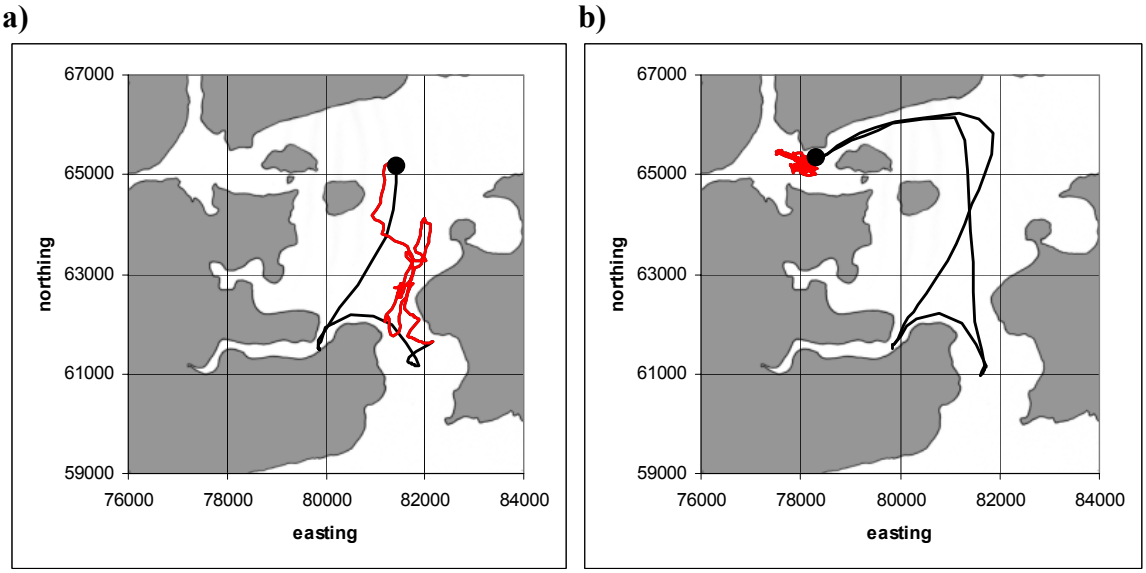

Figure 4. Survey tracks and locations of encounters with dolphins in Cork harbour on a) 19th August b) 20th August 2003. The black line shows the boats track, the black circle indicates the encounter location and the red line shows the boat track during the encounter. The axes show metric OSI easting and northings in metres.

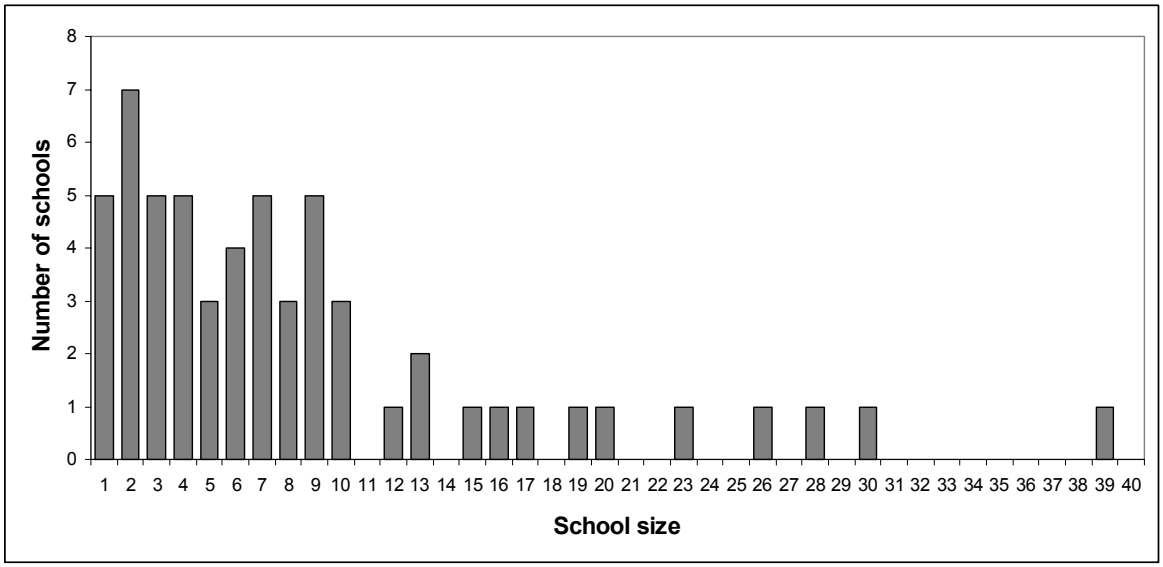

Figure 5. Frequency distribution of dolphin school sizes. School size is derived from the number of dolphins identified in each school.

Encounters with dolphin schools during west-coast surveys

One school of 20 bottlenose dolphins was encountered on the 27th September (Table 2) during a survey of the coast of Connemara (Figure 3). Acting on local reports of dolphins in Cork harbour two encounters with the same school were made on consecutive days on the 19th and 20th of August 2003 (Figure 4).

Results of photo-identification analysis
During a total of 19 boat surveys conducted during this study, approximately 2500 slide photographs were taken of bottlenose dolphins during 63 encounters with dolphin schools. These photographs were used to make a total of 388 identifications in the Shannon, 20 identifications in Connemara and 20 identifications in Cork harbour.

Summary of identified individuals from Connemara
Using photo-identification, 20 dolphins were identified from the encounter in Connemara. One juvenile was included in the encountered school with 19 adults. Two of the adults had spinal deformities, one of these animals had a severe hump behind the dorsal fin (id# 1099) and one had a slight deformity at the base of the tail stock (id#1001) which was noticeable as the animal dived. The total number of animals identified in the waters of Connemara since 2001 is 27.

Summary of identifications from Cork Harbour
A total of fifteen dolphins were photo-identified from two encounters with the same scool in Cork Harbour. The school included 12 adults two juveniles and one calf.

Resightings between years
A single dolphin (id number 1001) was resighted from surveys conducted in Connemara during 2001 (Ingram *et al*., 2001) and all other identified animals were previously unrecorded. Of the 20 dolphins identified in Cork Harbour, 9 were matches with animals previously identified from a single school of 16 bottlenose dolphins encountered in Youghal Bay on 29/08/02. One of the adults sighted in Cork Harbour and matched with the school in Youghal in 2002 (#1002) had also previously been identified in Connemara on 20/09/01.

Photo-identifications of bottlenose dolphins in the Shannon estuary
Using photographs of their natural markings a total of 68 individual dolphins were identifiable from both sides of their dorsal fins, 106 dolphins were identifiable from their right sides and 101 from their left (Table 3).

Table 3. The number of dolphins identified from photographs of their natural markings. Numbers of dolphins identified from the left-side, right-side and both sides are given. The table shows the degree of mark severity.

	Mark severity			
Side	**Permanent marks**	**Temporary marks**	**Superficial marks**	**Totals**
Left	36	41	24	101
Right	34	37	35	106
Both sides	31	25	12	68

The frequency of sightings of identified dolphins ranged from 51 animals sighted only once to one animal (# 18) which was sighted on nine occasions (Figure 6). However, resighting frequency is strongly influenced by the individual mark severity with the majority of dolphins sighted only once having only superficial marks (Figure 6).

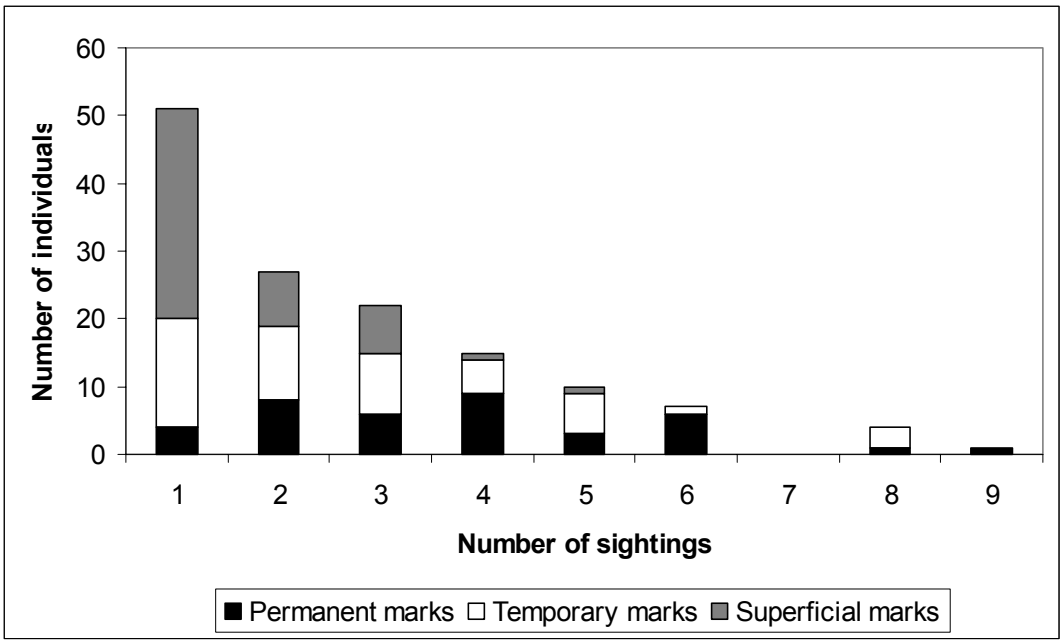

Figure 6. The sighting frequency of identified dolphins using the Shannon estuary. The different shades represent animals with three grades of mark severity.

Identification of individuals is dependent on the quality of the photographs taken during surveys. In particular, dolphins with more superficial markings are less easily recognised from poorer quality photographs as shown in Figure 7.

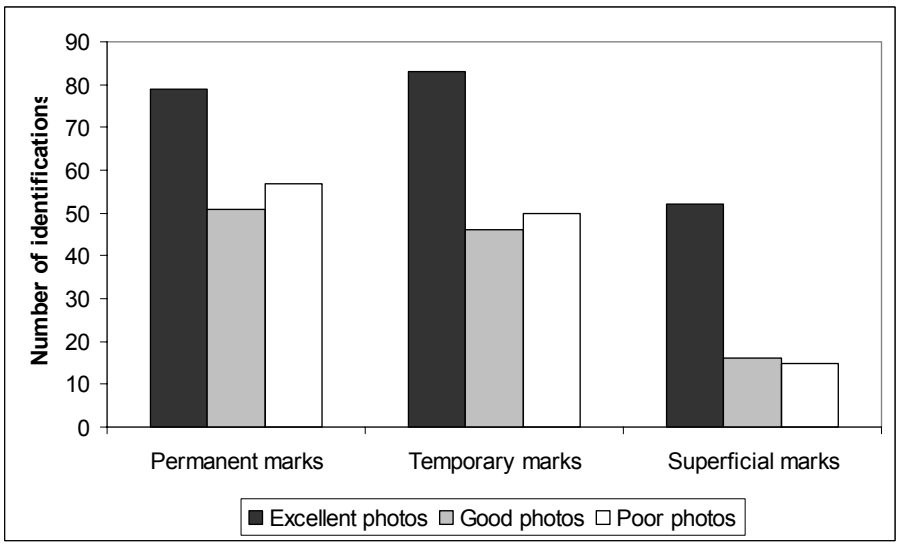

Figure 7. The sighing frequency of dolphins with different degrees of marking identified from three different classes of photograph quality.

Sightings of neonatal calves

In total, 10 neonatal calves were sighted during surveys of the Shannon estuary. The first sightings of all these calves were made during surveys conducted in August and September. Four of the escorting adults sighted with these neonates had temporary, grade 2 markings and the remainder had only superficial grade 3 marks (Table 4).

Table 4. The dates of first sightings of neonatal calves. The catalogue numbers and degree of mark severity of escorting adults are given for each calf. Mark severity grades are as follows; grade 1 = permanent markings, grade 2= temporary markings, grade 3=superficial markings.

Date of first sighting	Escorting adult	Degree of marking of escort
04/08/03	484	3
04/08/03	452	3
05/08/03	425	2
05/08/03	101	2
06/08/03	511	3
11/08/03	512	3
15/08/03	74	2
16/08/03	510	3
16/08/03	514	3
21/09/03	286	2

Sighting of permanently marked dolphins

In total, 36 permanently marked dolphins were identified from their left sides, 34 from their right sides and 31 were identifiable from both sides. Only one permanently marked dolphin (animal #453) sighted during this study had not been identified in the Shannon in previous years. In fact, 20 of the permanently marked dolphins sighted in 2003 were first identified during surveys in 1996, the first year of UCC's survey programme (Figure 8).

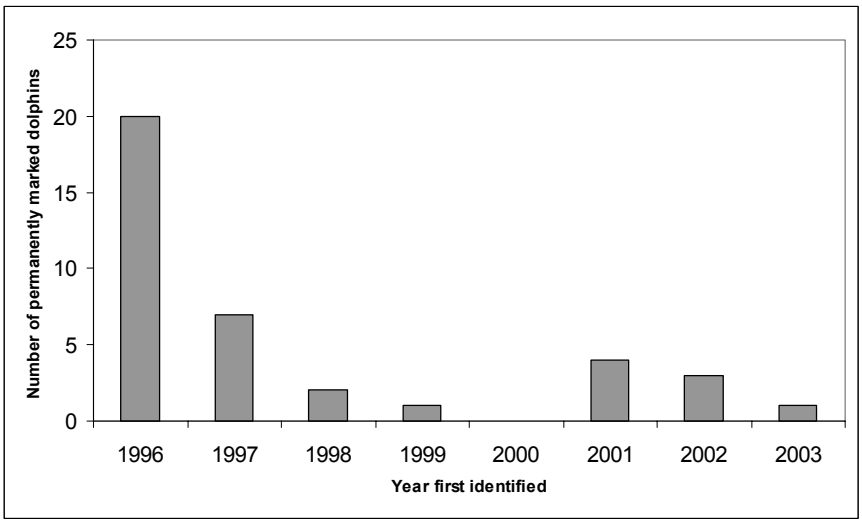

Figure 8. The number of permanently marked dolphins sighted during 2003 and the year of their first identification. Survey effort started in 1996.

Ranging patterns of permanently marked dolphins

The complete sighting histories of permanently marked dolphins identified during 2003 were examined and plots made of the encounter locations for all permanently marked dolphins sighted on 20 occasions or more throughout surveys since 1996 (Figure 9).

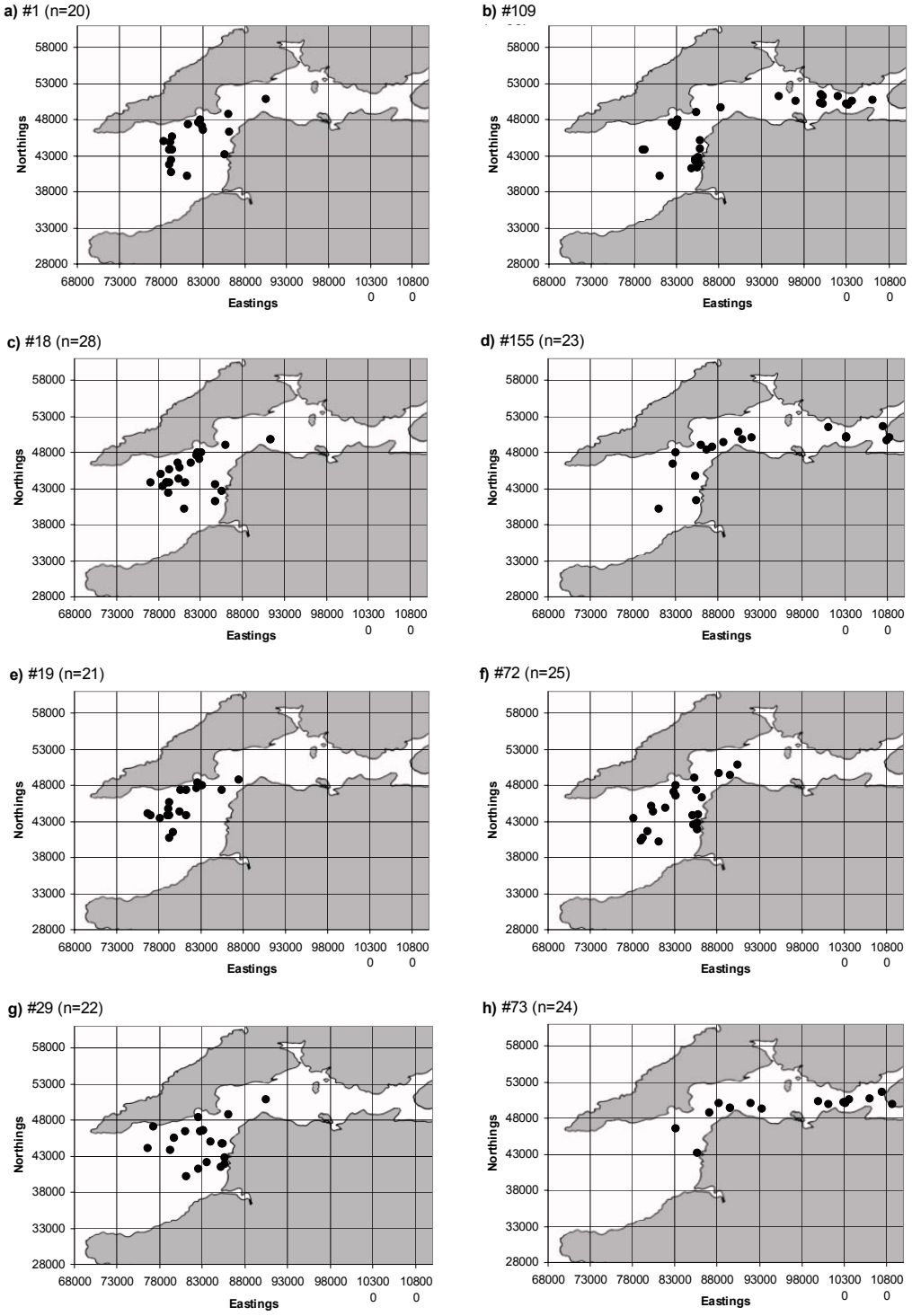

Figure 9. Plots showing the encounter locations of permanently marked dolphins sighted in at least 20 schools throughout surveys conducted since 1996. The identification number is given for each plot and the number of sightings is shown in brackets

Mark-recapture estimate of the abundance dolphins using the Shannon
All dolphins with permanent and temporary identifying marks (grades 1 and 2 marks) were included in the mark-recapture data set. Furthermore, poor quality grade 3 photographs were excluded from the sighting data. The mark-recapture data consisted of 239 identifications of marked animals. 157 of these were identifications from the left, 125 were of right-side identifications and 59 were identifications from both sides. These identifications were of 71 dolphins known from their left-sides and 59 dolphins known from their right-sides.

Estimates of the number of marked dolphins using the Shannon
Separate estimates were calculated of the number of marked using left-side and right-side identifications (Table 5). We used a model which is robust to sources of capture heterogeneity arising from differences in the approachability between individual animals and between survey occasions (Chao *et al*., 1992).

Table 5. Results of abundance estimates from left side and right side sightings. n is the number of identified dolphins, Nhat is the estimated total number of marked dolphins.

Side	n	Nhat	se	cv	95% confidence intervals
Left	71	97	10.7	0.11	83 to 127
Right	59	71	6.4	0.09	63 to 91

Proportion of dolphins using the Shannon with marks
Using excellent grade 1 photographs the proportion of the total number of identifications represented by dolphins included in the marked subset was calculated (Table 6).

Table 6. The proportion of dolphins with identifying marks. θ is the proportion of identifications of members of the marked subset made from grade 1 photographs.

side	Total number.of identifications from grade 1 photos	Number of identifications of marked animals from grade 1 photos	Proportion of animals with marks, θ_2
Left	139	99	0.7122
Right	126	80	0.6349

Estimate of the total number of dolphins using the estuary
The values of Nhat for left side and right side obtained from capture were increased according to the values calculated for theta (Table 6). This gave separate left-side and right-side estimates for the total number of marked and unmarked dolphins using the outer Shannon during the study period. These two values were combined using an inverse variance weighted average to give the final estimate of 121 ±14 (1SE) CV=0.12, 95% CI 103 to 163.

Discussion

Distribution of encounters

All 14 boat surveys conducted in the outer Shannon estuary during this project resulted in encounters with bottlenose dolphin schools. The locations of the resulting 66 encounters were distributed throughout the survey area but concentrated at the estuary mouth. This pattern is typical of dolphin surveys conducted in the estuary over the past seven years (Ingram and Rogan, 2002). Photo-identification work conducted during 2003 resulted in 388 identifications of 106 uniquely marked individuals. The quality of the images obtained during photo-identification was extremely high with nearly half (48%) of all identifications resulting from excellent (grade1) photographs. Photograph quality is fundamentally important to any photo-identification study since the ability of researchers to recognise individuals relies solely on the quality of the images at their disposal. Errors resulting from poor photo-identification analysis will introduce false matches and obscure genuine matches. Subsequently these errors will affect the bias of 'mark-recapture' models reliant on these data and introduce errors in any examination of individual sighting histories such as association patterns and ranging behaviour.

Long term residency of identified individuals using the Shannon

The results of photo-identification effort during this project clearly show that the dolphins using the Shannon have a high degree of site fidelity. Out of 36 permanently marked dolphins identified in 2003 only one was previously unrecorded. Furthermore, since 1997 only 11 permanently marked adults have been added to the catalogue, suggesting that one or two animals gain significant marks annually. Seasonal changes of abundance and resighting rates show that the Shannon is not the sole habitat for this community (Ingram, 2000), but information regarding movement patterns of these animals outside of the estuary is presently limited to a single encounter only a few kilometres from the estuary mouth in 2001 (Ingram *et al*., 2001)

Ranging patterns of individuals using the Shannon

Although bottlenose dolphins are capable of rapid movement and the outer Shannon represents only a small area (approx. 150km^2) the encounter locations for frequently sighted individuals clearly show differences in ranging patterns between individuals (Figure 9). Specifically, only three dolphins sighted on at least 20 occasions were encountered in the up-river portion of the study area. The sighting locations of the remaining five frequently sighted dolphins were restricted to the area around the mouth of the estuary (Figure 9). These findings support earlier examinations of habitat partitioning amongst members of the community (Ingram and Rogan, 2002).

Abundance of dolphins using the Shannon

The abundance of bottlenose dolphins using the outer Shannon estuary during the period of July to September 2003 is estimated at 121 ±14 (1SE) CV=0.12, 95% CI 103 to 163. This figure is higher than the minimum estimate of 106 derived from the number of dolphins identified during the study. However, the estimate is very close to this minimum estimate suggesting that nearly all of the dolphins using the Shannon during this period were identified. Furthermore, if the ten neonatal calves sighted during this study are included the minimum estimate is very close to the mark-recapture estimate. The advantage of the mark-recapture modelled estimate is the estimate of precision provided. The estimate has a high degree of precision with a

low standard error and a coefficient of variation of 0.12. Without these measures it would be difficult to estimate precision solely from photo-identification data. The removal of poor quality photographs and poorly marked individuals from the mark-recapture procedure reduced the likelihood of bias due to false identifications without affecting the final estimate of abundance as would be the case if only the absolute number of identified animals were considered. Additionally, the use of a model which is robust to sources of heterogeneity in capture probabilities and sampling events served to further limit the affects of bias from the estimate.

The estimate calculated for 2003 was very close to a previous estimate obtained in 1997 using the same methods which resulted in an abundance estimate of 113±16 (1SE) CV=0.14, 95% CI 94 to 161 (Ingram, 2000). This indicates that the community shows no evidence of significant change and the presence of ten neonatal calves suggests the breeding status of this population is healthy.

Bottlenose dolphins on the west-coast

Surveys conducted during 2003 at other coastal sites, namely Connemara and Cork Harbour resulted in encounters with two schools of bottlenose dolphins. Twenty dolphins were identified from Connemara, one of which had previously been encountered in 2001. Results of shore watches and acoustic surveillance in the waters around Connemara (Ingram *et al*., 2003) suggest that many more dolphins use this area than have so far been photo-identified. The rematching of an individual between years indicates that a degree of site-fidelity may be evident amongst dolphins using this coastal area. As yet however, insufficient data exist to examine the ranging patterns and long-term presence of dolphins in these waters.

Of the twenty dolphins identified in Cork harbour, nine were first sighted together in Youghal Bay in August 2002. Significantly, one of these animals (#1002) was first identified in Connemara in 2001 and subsequently sighted in Youghal Bay in 2002. Again, the complete ranging patterns of these animals is not known but further photo-identification surveys may provide future sightings of these dolphins.

Conservation implications and recommendations for future research

Bottlenose dolphins using the Shannon are vulnerable to anthropogenic disturbance and to the degradation of their habitat. Threats may include industrial and agricultural pollutant contamination (Moscrop, 1993; O'Shea, 1999); disturbance from marine industrial activities (Richardson *et al*, 1985; Richardson *et al*., 1995; Evans & Nice, 1997); by-catch mortality (accidental entanglement in fishing gear); physical and acoustic disturbance from shipping (Au & Perryman, 1981; Acevedo, 1991; Wells & Scott, 1997) and disturbance from dolphin watching boat traffic (Kruse, 1991; Gordon *et al.,* 1992; Blane & Jaakson, 1994; Corkeron, 1995; Lutkebohl, 1995; Janik & Thompson, 1996). The Shannon region is a major centre of industry including aluminium extraction and electricity generation with coal fired and oil fired stations located at Money Point and Tarbert in the outer estuary. The Shannon catchment includes large areas of farmland and several tributary rivers providing many potential sources of contamination of the dolphin habitat areas in the estuary. In addition, the Shannon is one of the busiest waterways of the Irish Republic transporting more than ten million tonnes of shipping traffic per annum (Anon., 1997). Furthermore, since 1993 the dolphin population has been targeted by a growing dolphin-watching tourist industry in the estuary, and by 1997 an estimated annual total of 2500 tourists visited

dolphins in the estuary on approximately 200 boat trips (Berrow & Holmes, 1999). The activity of dolphin watching vessels has been shown to affect the behaviour of dolphins with short term reactions such as changes in dive duration (Janik & Thompson, 1996) and swimming direction (Lutkebohl, 1995).

The Shannon estuary is clearly a site of national and international importance to bottlenose dolphins. The identification of individuals over a number of years has shown that dolphins using the estuary belong to a discreet community. This information together with the abundance estimate provides baseline information useful in any future monitoring programme in the SAC. Consideration should be given to planning and executing a photo-identification monitoring programme in order to provide information regarding potential changes in the numbers of dolphins using the estuary and to provide data relating to individual sightings histories, ranging patterns and calf production. Photo-identification work can provide data useful in population viability analysis and can also contribute to monitoring aspects of the physical health of individuals, particularly the rates of infection and severity of dermal infections (Thompson and Hammond, 1992; Wilson *et al*., 1997; Wilson *et al*., 199b). A priority should be given to maintaining the photo-identification catalogue of dolphins using the Shannon estuary. The marks used to identify individuals change over time and without continued survey effort many dolphins will not be recognisable from future photographic data. The quality of information resulting from photo-identification is dependent on long-term data and any breaks in survey effort will degrade the long-term use of these data.

The evidence of habitat partitioning amongst members of the community should be considered in aspects of management of the estuary. Fewer dolphins appear to range upriver and any impacts in upriver locations such as a growth in dolphin watching traffic in these areas are likely to be borne by these few individuals. The mouth of the estuary appears to be the most frequently used part of the SAC visited by the majority of dolphins using the estuary. Any industrial development such as dredging, wind-turbine construction, blasting or destructive fishing activity should, if possible, be prevented in this area.

In addition to the Shannon estuary, other coastal areas also appear important to this species. The waters around Connemara Co. Galway may represent a suitable site for future SAC designation. Encounters with large schools of bottlenose dolphins have occurred in the waters off all western counties but more data are needed to provide accurate recommendations regarding further SAC designations in these coastal areas. It is probable that a meta-population of bottlenose dolphins use the waters of western Ireland. This meta-population may consist of a network of adjacent communites or sub-populations whose health and long-term status depend upon the movement of individuals and genetic transfer between these sites. In this scenario the health of any of these coastal communities is dependent on the status of others and local decline or extinction of any of these communities is likely to have a detrimental affect on the status of the whole population. Further research effort is needed in order to examine the extent of individual movements and genetic transfer between putative communities but the importance of such work should not be underestimated. Even with limited photo-identification data to date the movement of individuals can be traced between coastal locations. Specifically, one dolphin identified in Connemara in 2001 has subsequently been resighted in consecutive years (2002 and 2003) in the

waters of County Cork. Efforts should be made to compare photo-identification data with those held by researchers working in different areas. Dolphin movement patterns may well extend beyond Irish waters and collaborative matching effort would extend the geographic range of available photo-identification data. Similarly photo-identification effort should be incorporated into the protocols of future off-shore cetacean surveys to provide information relating to individuals ranging beyond the reach of small boat inshore surveys. Furthermore, future studies in coastal areas would benefit from a multi-disciplinary approach. For example, acoustic monitoring in Connemara has yielded useful information regarding the presence of dolphins in specific areas over periods of months (Ingram *et al*., 2003). Additionally, genetic analysis of tissue samples from dolphins using different coastal areas would provide important information regarding genetic transfer between different communities. Photo-identification, which depends on resighting identifiable individuals will not provide information regarding mating behaviour or genetic transfer.

Additional recommended monitoring schemes for the Shannon estuary:

1. water quality monitoring for the presence of contaminants;
2. fish stock surveys in order to monitor the status of dolphin prey resources;
3. necropsy analysis of stranded animals to determine diet, cause of fatality and contaminant burden and to provide samples for genetic analysis;
4. monitoring the growth and activity of the dolphin watching industry;
5. monitoring of fishing effort and by-catch within the estuary.

1. Efforts should be made to identify and quantify the present threats to this population including an examination of contaminant levels in the estuary. There is a paucity of recently published literature on the contaminant levels in the Shannon although work in the eighties showed the estuary to be generally unpolluted with all tested contaminants meeting OSPARCOM (Oslo and Paris Commissions) required levels (O'Sullivan *et al.,* 1991). A regular water sampling and analysis programme would serve to identify rising contaminant levels and ensure that water quality standards are maintained.

2. Similarly, little work has been done to survey the fish species present in the Shannon estuary (see O'Sullivan, 1984) other than salmon and eel migration studies (Moriarty, 1974; Anon, 1998). The use of the Shannon estuary by bottlenose dolphin population is likely to depend on the availability of various prey species. A comprehensive survey of fish species present in the estuary and regular repeated sampling would provide valuable information on the changes in abundance of prey over time and help identify possible causes in changes in the use of the estuary by dolphins.

3. Necropsy studies of stranded dolphins found in the estuary would provide important information regarding, cause of death and diet and would provide indications of the contaminant burden in dolphins using the estuary. In addition, necropsy samples can be used to determine stock structure through genetic analysis. Such work would help to determine the reproductive isolation of this population from adjacent ones and provide data on paternity and genealogy.

4. The growth of the dolphin watching industry in the Shannon should be monitored and efforts made to ensure that disturbance to dolphins is minimised. The adherence

to the existing precautionary codes of conduct should be maintained and a training programme for new operators established. In addition to physical disturbance, boat traffic can cause acoustic pollution and disrupt co-operative behaviour and communication between individuals. Important consideration should be given to the acoustic quality of the dolphins' environment in order to minimise the degradation of their habitat .

5. Fishing activity within the estuary could affect dolphins directly through by-catch fatalities or indirectly through prey depletion. By monitoring fishing effort and by-catch incidents the level of these affects could be measured and mitigated.

Scientific research should be an integral component of bottlenose dolphin conservation in Irish waters. Research provides fundamentally important information necessary for planning and implementing conservation management programmes. For example, in Cardigan Bay, Wales (Grellier *et al*., 1995; Arnold, 1997), the Moray Firth, Scotland (Curran *et al.,* 1996) and in New Zealand (Constantine and Baker, 1997) research has provided the basis for conservation recommendations. These examples should be followed in Ireland to ensure the success of integrated conservation management of bottlenose dolphins.

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