Bottlenose dolphin survey in the Lower River Shannon SAC, 2018

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Cover image: A group of bottlenose dolphins in the outer Shannon Estuary © DCHG

EXECUTIVE SUMMARY

Standardised boat surveys and photo-identification of individual bottlenose dolphins (*Tursiops truncatus*) were used to estimate the abundance of bottlenose dolphins using the Lower River Shannon SAC during the summer and autumn of 2018. A total of 12 surveys were conducted between June and October resulting in 42 encounters with bottlenose dolphin schools.

Dorsal fin photographs were taken during surveys resulting in 327 identifications of a minimum of 108 uniquely marked dolphins. Of these, 59 individuals were matched with the catalogue created and maintained by UCC since 1996. In addition to animals identified during surveys conducted in previous years, 49 new individuals were added to the catalogue. Of all dolphins identified during 2018, 36 had permanent marks including fin nicks; 51 had superficial marks and 21 had temporary marks. School sizes ranged from 1 to 30 dolphins with a median school size of 6. Unusually, no dolphins were encountered during three surveys.

Photo-identification data from the nine surveys with dolphin encounters were used in a mark-recapture abundance estimation of dolphins using the SAC during the survey period using package 'RMark' in programme R. In order to compare the abundance to previous estimates, we applied the model Mth, which is suitable for closed populations when there is heterogeneity in capture probabilities between the capture events and between individuals. Only well marked animals and high quality photographs were used in the abundance estimation. Estimates of total abundance were calculated by increasing the estimates of the abundance of marked dolphins in accordance with the proportion of well-marked animals identified during surveys. We selected the best estimate by ranking CV values. Using this procedure, we estimated the total number of dolphins using the Shannon SAC during June to early October 2018 as 139 dolphins (CV: 0.109, 95% confidence interval: 121-160). This estimate lies within the range of previous estimates calculated since 1997 indicating a stable population size.

INTRODUCTION

Common bottlenose dolphins (*Tursiops truncatus*, Montagu, 1821) are widely distributed throughout tropical and temperate seas and found in pelagic oceanic environments, on the continental shelf, and in coastal inshore waters (Wells and Scott, 2009). It is estimated that approximately 600,000 individuals are found globally (Wells and Scott, 2009). Individuals are often found in very shallow, coastal habitats including inlets, bays, estuaries and rivers (Leatherwood & Reeves, 1983) and the Shannon Estuary represents a typical habitat for this species.

Within the wider Northeast (NE) Atlantic, several resident/semi-resident populations are known to occur in coastal areas around north-western Europe such as the Moray Firth, Scotland (Wilson *et al*., 1997), Cardigan Bay, Wales (Feingold & Evans, 2012), Sado Estuary, Portugal (Dos Santos & Lacerda, 1987) and the Shannon Estuary, Ireland (Ingram & Rogan, 2002). In addition to these coastal populations, sightings data from large-scale surveys in European waters such as SCANS 2, CODA and the ObSERVE aerial programme show that within the wider NE Atlantic, bottlenose dolphins are widespread, occurring coastally, over the continental shelf and in the deeper waters off the continental shelf (Hammond *et al*., 2009, 2013, Rogan *et al*., 2018). Using genetic markers combined with data on stable isotopes ratios and analysis of stomach contents, Louis *et al.* (2014) have suggested that two ecotypes may exist in the NE Atlantic waters of western Europe, represented by "coastal" and "pelagic" forms. In Irish waters this hypothesis is supported by findings indicating genetic (Mirimin *et al*., 2011) and social (Oudejans *et al*., 2015) segregation between animals using coastal and pelagic habitats.

In the waters off western Ireland, at least three genetically distinct populations occur: (i) the resident group from the Shannon Estuary plus a small group of individuals (n = 8) utilising outer Cork Harbour; (ii) a more mobile population, moving along the west coast of Ireland, referred to here as the Connemara-Mayo-Donegal population (west coast group), with an abundance for part of the range estimated as 171 (± 48) (Ingram *et al*., 2009); and (iii) a less defined population primarily represented by stranded animals that may represent a more oceanic population (Mirimin *et al*., 2011, Oudejans *et al*., 2015). The fine scale genetic structure of the two coastal populations is consistent with results from photo-identification studies, which suggests that there is limited gene flow and possibly little spatial overlap between these two populations (Ingram *et al*., 2009, O'Brien *et al*., 2009). Additional work by Nykänen *et al*. (2018) confirms that the Shannon dolphins likely have a low estimated effective population size and are not just genetically but also demographically isolated from the other populations in Irish waters.

Within Irish coastal waters, summer abundance estimates for the lower Shannon Estuary SAC suggest that it is used by between 107 (±12SE) and 140 (±12SE) individuals (Berrow *et al*., 2012), with smaller numbers using the estuary in the winter time (Englund *et al*., 2008). In addition, two core habitats within the lower Shannon Estuary have been identified (Ingram & Rogan 2002, Englund *et al*., 2008). Within the framework of the species' range, current population definition and its ecology, the Shannon Estuary is therefore a critical habitat for bottlenose dolphins (Ingram & Rogan, 2002) in both a national and a European context.

Conservation status

Bottlenose dolphins are listed in Annex II of the EU's Habitats Directive and the Lower River Shannon is one of two Special Areas of Conservation (SAC) designated for this species in Irish waters. Bottlenose dolphins have a widespread but somewhat patchy distribution throughout European Atlantic coasts. The best documented adjacent populations are found in the Moray Firth, Scotland (Wilson *et al.*, 1999; Cheney *et al*., 2014); Cardigan Bay, Wales (Baines *et al*., 2002; Pesante *et al*., 2008); Cornwall, England (Wood, 1998; Pikesley *et al*, 2011); Brittany and Normandy, France (Liret *et al*., 1998; Liret, 2001; Kiszka *et al*., 2004, Louis *et al*., 2014) and the Sado Estuary, Portugal (Dos Santos and Lacerda, 1987).

It is important for effective species conservation and management to obtain up-to-date and robust knowledge of population size and ranging patterns. This type of information is vital in detecting trends in numbers or changes in distribution or the use of habitat, or in quantifying the possible effects of human activities on the population. Accurate information on spatial and temporal variation in abundance is also necessary in determining whether management actions are needed and to evaluate the effectiveness of any actions that are implemented (Evans & Hammond, 2004).

Bottlenose dolphins using industrially developed coastal waters such as the Shannon Estuary are particularly vulnerable to anthropogenic disturbance and to habitat degradation. Threats may include industrial and agricultural pollutant contamination (Jepson *et al*., 1999, 2016; Pierce *et al*., 2008), disturbance from marine industrial activities (Richardson *et al*., 1985; Evans and Nice, 1997), harmful algal blooms, by-catch mortality (accidental entanglement in fishing gear) (Read *et al*., 2006), physical and acoustic disturbance from shipping (Au & Perryman, 1981; Acevedo, 1991) and disturbance from dolphin-watching boat traffic (Berrow & Holmes, 1999; Lusseau, 2005; Tyne *et al*., 2015). 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 extensive river Shannon catchment includes large areas of farmland, hundreds of towns and villages, and several tributary rivers providing potential sources of contamination of the estuary. It has also a very large amount of shipping traffic, using the ports at Foynes and Limerick, with an increasing likelihood that this traffic volume will increase with the proposed development of the port at Foynes.

Long term residency and site fidelity

Studies over the last 20 years show long-term site fidelity and seasonal residency of dolphins using the Shannon Estuary (Ingram, 2000; Ingram & Rogan, 2002; Englund *et al.*, 2007, 2008, Berrow *et al*., 2010). The animals appear to be loosely connected, with a fission-fusion society (Ingram, 2000, Foley *et al*., 2012, Baker *et al*., 2018a).

Abundance of the Shannon dolphin population

The abundance of dolphins using the Lower River Shannon SAC has been calculated using mark-recapture photo-identification techniques in a number of years since 1997 (Ingram, 2000; Ingram & Rogan, 2003, Englund *et al*., 2007, 2008, Berrow *et al*., 2010, Rogan *et al*., 2015). The work presented here includes an updated summer-autumn abundance estimate for the bottlenose dolphins inhabiting the Lower River Shannon using the same photo-id and mark-recapture methods.

Seasonal and temporal variation in habitat use

Year-round survey effort in previous years shows a repeated seasonal reduction in the number of dolphins using the outer estuary during the winter months (Ingram 2000; Englund *et al.*, 2007). The apparent seasonal migration out of the estuary during the winter indicates that the Shannon SAC does not cover the entire home range of this population (Ingram *et al.,* 2001). Despite this seasonal movement no differences in the spatial distribution of encounters within the SAC were found between winter and summer months (Englund *et al*., 2007). Two critical habitat areas within the Shannon Estuary were first identified in 2002 (Ingram & Rogan, 2002), and in subsequent years the data have consistently shown that these areas are important to dolphins year-round. The larger of these two areas is located at the estuary mouth near Kilcredaun and a smaller one off Money Point (Figure 1). These two areas were used differently by individually identified dolphins with known ranges, with a small minority of individuals extending their range into the upriver part of the study area (*i.e*., upstream of Tarbert).

Project aims

The main scientific objectives of this work were to:

(1) derive a robust and precise updated population estimate for bottlenose dolphins in the Lower River Shannon SAC using mark-recapture techniques based on photo-identification,

(2) determine the associated coefficient of variation (CV) and 95% confidence interval (CI) around the updated estimate, and

(3) deliver a population estimate with a CV equal to or less than a target threshold value of 0.12.

METHODS

Boat based photo-identification surveys

Dedicated photo-identification surveys were conducted using a 6.5m rigid hull inflatable boat (RIB) between June 25th and October 18th 2018. A minimum of twelve full surveys were contracted during the study period. A standardised 80km route (Figure 1) used by UCC for dolphin surveys in the Shannon Estuary since 1996 was followed at approximately 20kmh^{-1}. Surveys were conducted in a Beaufort sea-state 3 or less, with suitable light and swell conditions in order to minimise the effect of weather or sea conditions on the probability of sighting and photographing dolphins.

Survey methods and the photographic analysis used have been thoroughly described in previous reports to the NPWS (e.g. Ingram *et al.,* 2003; Englund *et al.,* 2007) but for clarity the details are also reproduced here.

During surveys, the route was followed until a school of dolphins was sighted. Here, a dolphin school was defined as all dolphins within a 100m radius of each other (Irvine *et al*., 1981) and hereafter "encounters" refer to periods of data collection with dolphin schools. Following a sighting, dolphins were approached slowly and attempts were made to photograph all school members. Waypoints were recorded at the start and the end of each encounter using an onboard Global Positioning System (GPS). During each encounter, the number of animals present was estimated and the presence of juveniles, calves or neonates was also noted. Boat movements and changes in speed were minimised in order to reduce any negative effects on the behaviour of nearby dolphins. The behaviour of dolphins towards the survey vessel was monitored and any signs of distress or evasive behaviours from the animals was recorded. The survey protocol

required that if strong avoidance behaviours (*e.g.* aggressive approaches or rapid avoidance) were observed the survey team avoided approaching the animals within 50m for 5 minutes and subsequently terminated the encounter if such behaviours were repeated when the encounter was resumed.

Dolphin identification photographs were taken perpendicular to the dorsal fin, preferably from within a distance of <20m, using an auto-focus DSLR camera (Canon EOS 1D mark II) with a 70-200mm telephoto zoom lens. Each encounter continued until all animals had been photographed, preferably from both sides or until the school was lost (or when strong avoidance behaviours were noted as described above). Following an encounter, the survey was resumed at the location of first sighting of the animals, until the standard survey route was completed.

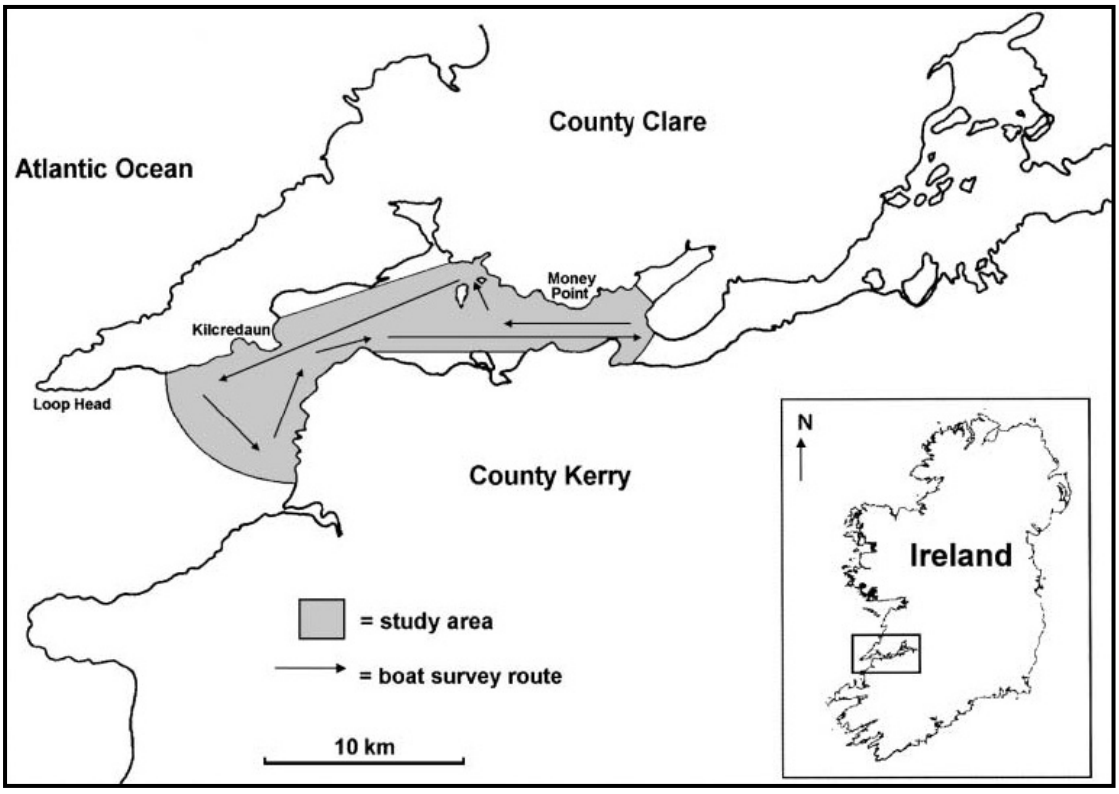

Figure 1. Map showing the Shannon Estuary study area and the standardised survey route.

Photograph analysis

The best photographs of each side of every dolphin identified from each encounter were selected. The quality of these photographs was scored from 1 to 4 (Table 1) with no consideration to the degree of marking of the individual. Selected photographs were then matched with the archive catalogue of known dolphins maintained by UCC since 1996. When a match was made, the selected photographs were renamed with the appropriate catalogue number and added to the archive. If a match could not be found in the archive, the animal was given a new catalogue number and subsequently added to the catalogue. Since it was not always possible to match left-side with right-side identifications, and since photographs were frequently only obtained from one side, there were effectively two separate catalogues of "right-side" and "left-side" identifications.

Table 1. The criteria used to score the quality of photographs taken of dolphin dorsal fins (independent of the degree of marking of individuals).

Grade	***Criteria***
1	Well lit and focused photo taken perpendicular to the dorsal fin at close range
2	More distant and less well lit or slightly angled photograph of the fin
3	Poorly lit or somewhat out of focus photograph, or photo taken at acute angles to the fin
4	Poorly focused, backlit or angled photographs taken at long distance to dolphins

Severity of identifying marks

A wide variety of identification marks are useful for identifying individual dolphins. These include permanent marks such as deep nicks on the trailing edge of the dorsal fin as well as other types of marks which may or may not be permanent, such as fin shape, scratches or skin lesions on the dorsal fin or the flank of the dolphin. Some marks may last for several years and thus remain useful for long-term identification of an individual. Animals acquire marks with time and younger animals are added to the catalogue of known individuals as they gain distinguishing scars or nicks. Long-term dedicated survey effort is thus required to ensure that individuals' changing marks are recorded correctly.

In this study, each catalogued dolphin was scored from 1 to 3 according to the severity of its natural markings (Figure 2). Dolphins with deep wounds and significant fin damage were considered permanently marked and assigned grade 1 (Figure 2a). Dolphins with minor fin damage and/or deep tooth rakes were assigned grade 2 (Figure 2b). Dolphins with superficial scratches and skin lesions were assigned grade 3 (Figure 2c).

Figure 2. Examples of dolphin fins photographed in 2018 showing the three grades of mark severity used in the analysis. Each dolphin was graded from 1 to 3 as follows: a) grade 1 marks, consisting of significant fin damage or deep scarring that were considered permanent; b) temporary, grade 2 marking that consist of deep tooth rakes and lesions, with only minor cuts present; c) fin with grade 3 marks, having superficial rakes and lesions.

Capture-recapture abundance estimation

The procedures and assumptions made when estimating the abundance of dolphins in the Shannon are reproduced from previous reports (e.g. Ingram *et al*., 2003; Englund *et al*., 2007). However, in contrast to previous reports using program CAPTURE, abundance was estimated using program MARK (White and Burnham, 2009). In summary, the photo-identification data were used to estimate dolphin abundance using the model Mth for closed populations in the package RMark (Laake, 2013), which runs software MARK through R (version 3.5.0; R Core Team 2018). Closed models with repeated capture occasions rely on the following assumptions (Otis *et al*., 1978; Seber, 1982):

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

The first assumption refers to the demographic closure (the lower Shannon Estuary) in which there is no immigration or emigration into or out of the area, or changes due to birth or death, or changes in markings during the period of sampling. The short duration of the sampling period (June to October) included in the analysis effectively ensured that the assumption of closure was not violated during sampling.

Using identifications based on animals' natural markings risks violating assumptions 2 and 3 because of the 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 photographic quality or the comparison of insufficiently marked individuals. In order to reduce the likelihood of such matching errors, photographs of insufficient quality, or poorly marked grade 3 animals (see Table 1, Figure 2) were excluded from the abundance analysis.

We calculated the bottlenose dolphin abundance estimates for the SAC in 2018 based on sightings of marked animals identifiable from both the left and right sides. Consequently, the dolphins included in the analyses represent a 'well-marked' subset of the animals using the SAC. Each individual included in the subset is considered sufficiently marked to enable identification from all the selected photographs of either side of the dorsal fin.

Proportion of marked dolphins

Since the data set used for the estimate is restricted to well-marked animals and does not include poorly marked/unmarked individuals, the abundance estimates and associated measures of variability were adjusted according to the proportion of marked animals in the population. 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 across all capture occasions (days) (after Wilson *et al*., 1999). The following formula was used to inflate the estimates according the proportion of marked animals in the population:

$$N = \frac{Nhat}{\theta}$$

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

The variances of the total estimates (varN) were obtained using the delta method as follows:

$$varN = N^2 \times \frac{var(Nhat)}{Nhat^2} + \frac{1-\theta}{n \times \theta}$$

RESULTS

Survey effort

Of the twelve surveys completed between June and October 2018 (Figure 3), nine surveys had dolphin encounters and three surveys were carried out without encountering any dolphins.

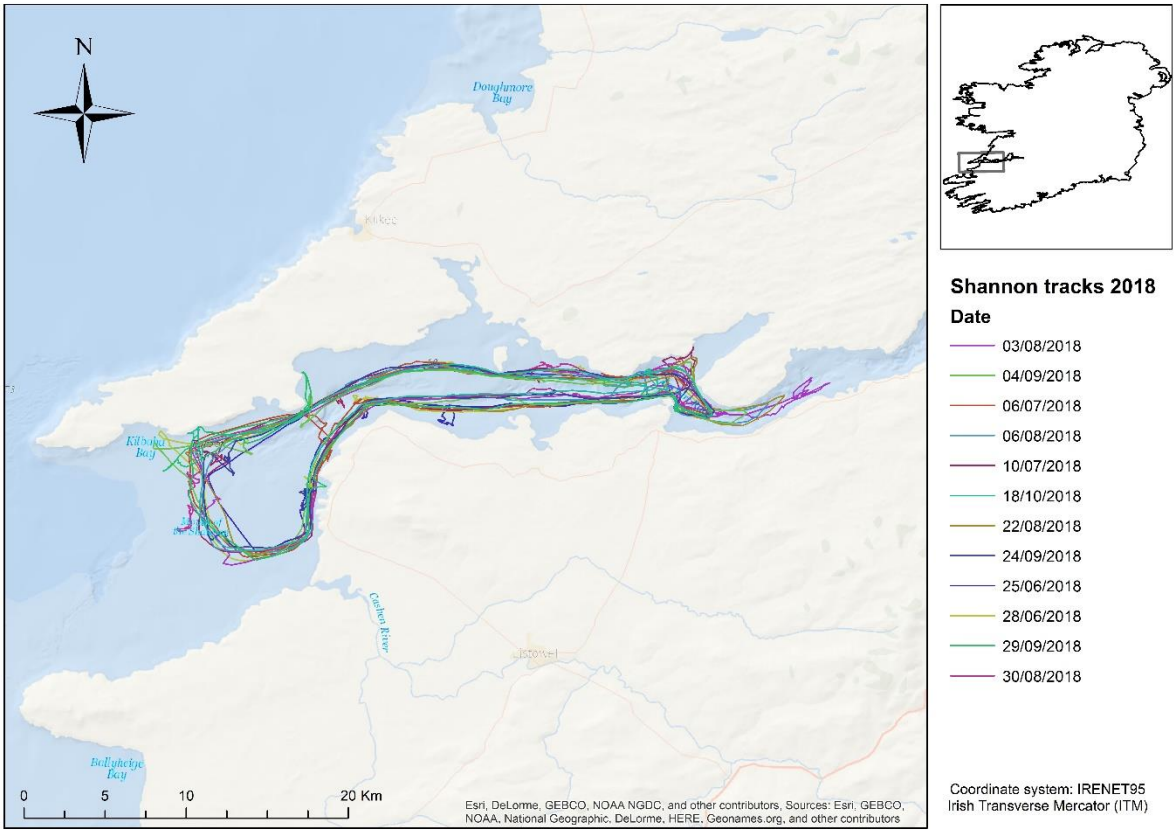

Figure 3. Map showing all survey tracks completed during the survey period in 2018.

Dolphin encounters

A total of 42 bottlenose dolphin encounters were recorded on nine survey days (Table 2). School size ranged from one to 30 individuals with a median school size of six. Three encounters were of single individuals. In some instances, encounters comprised a smaller group that subsequently were joined by other sub-groups, and *vice versa*. The number of dolphin schools encountered varied between survey days, with a median of four encounters per survey.

The only other marine mammal species encountered were grey seals (*Halichoerus grypus*), which were recorded on four occasions including two sightings of a pup hauled out on a small beach.

Table 2. A summary of dolphin encounters during surveys of the outer Shannon Estuary in 2018, showing the best field estimate of the number of dolphins compared to the number of animals identifiable from photos.

Survey	Number of groups encountered	Number of animals	
		Best	Identifiable
1: 25th June	4	25	21
2: 28th June	5	25	10
3: 6th July	6	48	37
4: 10th July	4	12	12
5: 3rd August	10	69	55
6: 6th August	0	0	0
7: 22nd August	0	0	0
8: 30th August	4	66	84
9: 4th September	0	0	0
10: 24th September	3	32	38
11: 29th September	1	6	10
12: 18th October	5	46	60
Total	42	329	327

Results of photo-identification analysis

Analysis of the photographs taken during surveys in the summer-autumn of 2018 yielded 288 identifications of 108 uniquely marked dolphins (Table 3). Thirty six new individuals, excluding neonates and calves were added to the catalogue. Out of the 108 dolphins matched with, or added to the catalogue, 36 had permanent marks, 21 had temporary marks and 51 had superficial marks. A much smaller number of individuals were known only from their left or right sides; therefore, we did not calculate separate abundance estimates using this approach.

Table 3. The number of dolphins known from the right, left and both sides in the outer Shannon Estuary in 2018.

Sides	Number of animals	Number of identifications	Number of animals not previously in catalogue (of which calves/neonates)
Left	14	19	12 (4)
Right	6	14	5 (1)
Both	88	255	32 (8)
Total	**108**	**288**	**49 (13)**

Level of disturbance

Indications of a negative impact on the dolphins during an encounter were monitored by the logging of any evasive behaviour such as aggressive approaches or rapid avoidance. No evidence of stronger evasive behaviour was noted during the surveys in 2018. If weak avoidance behaviours were noted, the survey team distanced itself from the encountered group. If such behaviours were not observed after five minutes, the encounter was resumed.

Sightings of juveniles, calves and neonates

Sightings of juveniles, calves and neonates were noted during surveys. Juveniles were defined as subadults <two-thirds the size of adults; calves (<1 year) and neonates (<1 month old) were recognised due to their smaller size, the presence of foetal folds or lines, and their close association with a larger animal assumed to be the mother.

The presence of neonates in a group was noted in 12 separate encounters, while the presence of older calves was noted in nine encounters (Table 4). Subadults were observed in 29 encountered groups. The number of neonates identified in total was nine, with seven definitively assigned to presumed mothers. All but two of those mothers (#2013 and #3023) could be matched to the existing catalogue.

Table 4. Calves (< 1 year old) and neonates (likely <1 month old) first encountered during 2018, including their escorting adult ID number (assumed to be the mother) and the marking degree of this escort. On two occasions, indicated by *, the identification of the escorting adult was uncertain.

Date of first sighting	Calf or neonate	Escorting adult ID	Degree of marking of escort
3rd August	Neonate	180	1
3rd August	Neonate	674	3
30th August	Neonate	286	1
30th August	Neonate	414	1
30th August	Neonate	606	3
30th August	Calf	2001	3
30th August	Neonate	2013	3
30th August	Neonate	3023	3
24th September	Neonate	700*	2
24th September	Calf	706	3
18th October	Neonate	685*	3
18th October	Calf	2009	3

The calf with the deformed spine that was sighted in 2015 (and assigned #6640, see Figure 4) was observed again as a juvenile, accompanied by the same adult as before (#664).

Figure 4. Individual #6640 with deformed spine sighted on August 30th 2018.

Distribution of dolphin sightings within the outer Shannon Estuary

The distribution of encountered dolphin groups was similar to previous years but with more groups encountered in the inner estuary and further upriver (Figure 5). The inner estuary where the estuary constricts near Tarbert/Killimer was used frequently by the dolphins with groups seen as far upriver as Glin. Dolphins were also encountered in the outer parts of the estuary and off Ballybunnion beach.

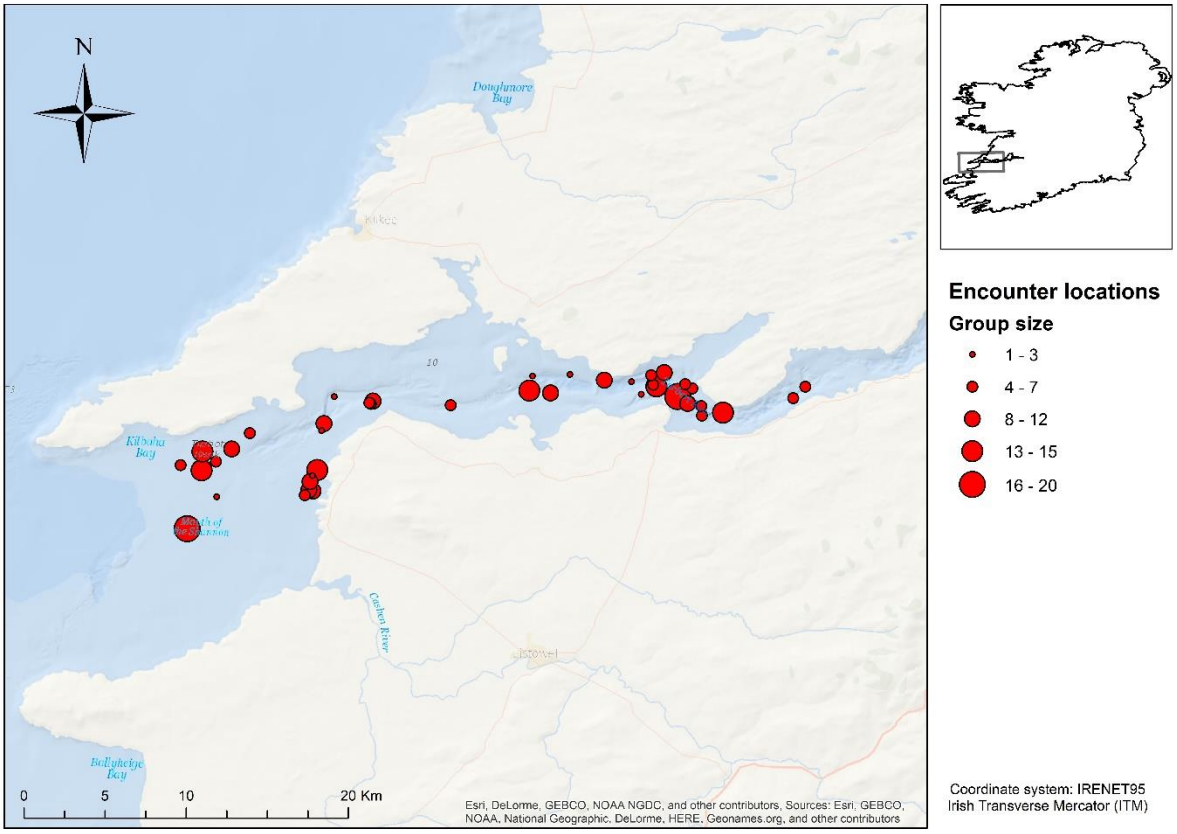

Figure 5. Locations of bottlenose dolphin schools encountered during surveys of the lower Shannon Estuary, 2018. Estimated group sizes are denoted by symbol diameters.

Mark-recapture abundance estimate

The rate at which well-marked individuals were recruited into the marked subset (or 'discovered') steadily decreased throughout the 2018 study and this is shown in the 'discovery curve' (Figure 6). The progressive levelling of the "well marked" population curve indicates that the population was likely closed during the mark-recapture sampling period.

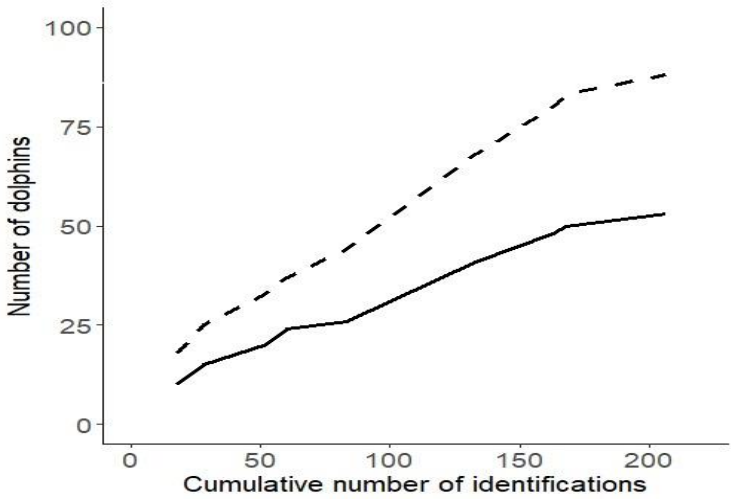

Figure 6. The 'discovery curve' showing the cumulative number of dolphins identified throughout the sampling period (June to October 2018). The dashed line shows the discovery of all identifiable dolphins and the solid line shows the discovery of the marked dolphins (mark grades 1 and 2) used to estimate abundance.

The abundance of dolphins using the Shannon Estuary

Photo-identification data from all nine full surveys were used in mark-recapture abundance estimation. As previously mentioned, high quality images of well-marked individuals were selected and used to construct a sightings matrix of sighting histories of each marked dolphin. This matrix was used to estimate the abundance of marked dolphins in the lower Shannon Estuary in 2018 (Table 5) using model M_{th} (Chao *et al.,* 1992) within the dedicated software program MARK. The resulting estimate was inflated according to the proportion of all identifications represented by marked dolphins (Table 5) to give an estimate of the total abundance of dolphins using the Shannon in the summer-autumn of 2018.

Table 5. Summary of the results of the abundance estimates of bottlenose dolphin in the Shannon Estuary in summer-autumn 2018. Theta θ is the proportion and Nhat is the abundance of dolphins in the marked subset (grade 1 & 2 markings). N is the estimated total number of marked animals in the Shannon, SE = standard error associated with the estimates of the abundance of the marked subset. CV = coefficient of variation, 95% CI = 95% confidence interval.

Sides	n	ϑ	Nhat	N	SE	CV	95% CI
Both	88	0.56	69	**121**	15.49	**0.127**	95–156
Both + Left	102	0.54	77	**140**	18.17	**0.129**	109–180
Both + Right	94	0.55	74	**133**	17.27	**0.129**	103–171
Weighted Average				**139**	15.23	**0.109**	121–160

The most precise estimate of the abundance of bottlenose dolphins using the Shannon Estuary during the summer-autumn of 2018 is 139 ± 15.23 (SE), CV=0.11, 95% CI = 121 – 160.

This is the eighth abundance estimate for the species within this Special Area of Conservation (Figure 7), spanning a 20-year time series from 1997 to the present. Dedicated surveys to estimate bottlenose dolphin abundance in the estuary have been patchily distributed in terms of survey interval. As evident in Figure 7, the CVs and associated CIs around the point estimates vary between years with the best CV (0.08) obtained in 2006 (Englund *et al*., 2007). The CV for the 2018 estimate is 0.11 and the abundance estimate is within most of the 95% CI of all previous abundance estimates.

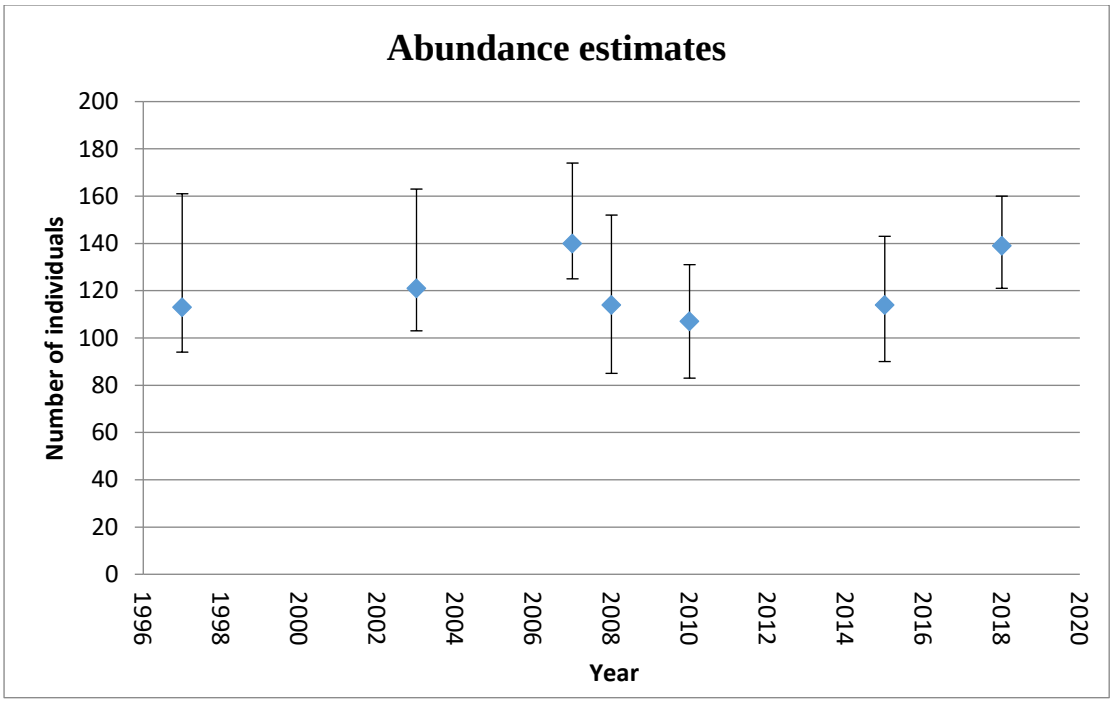

Figure 7. Estimates of abundance of bottlenose dolphins using the Shannon Estuary carried out to date (point estimate and 95% confidence intervals).

DISCUSSION

As in previous years, the same standard survey route was followed in the Lower River Shannon SAC. This route has been used since the start of dedicated dolphin surveys in 1996 (Ingram, 2000) and it covers areas of the outer estuary that are most intensively used by bottlenose dolphins (Ingram & Rogan, 2002). The Shannon does not represent this population's entire geographic range and although during 2018 surveys dolphins were encountered throughout the survey area, schools were only encountered on nine of the 12 days surveyed. The lack of sightings of dolphins during surveys is highly unusual (occurring in summer surveys only once before) suggesting that in the summer of 2018 dolphins may have been spending extended periods outside of the survey area. In addition, there were three encounters with only one individual. The summer of 2018 was exceptionally warm and dry, with below average rainfall amounts reported for the months of June and July at Shannon airport and significantly higher temperatures than the long-term (1981 – 2010) moving average in June and July (source: Met Eireann website). To what extent the dry weather influenced the river flow and level, and

subsequently the prey availability/behaviour leading to changes in dolphin distribution, is difficult to quantify in the absence of data on prey. The dolphins were also found in the inner estuary and further upriver more frequently than in previous years. Again, whether this relates to prey availability or prey distribution is difficult to assess in the absence of data on movement of likely prey species, including Atlantic salmon (*Salmo salar*).

The survey team took great care to minimise any disturbance effects during data collection and no excessive reactions to the survey boat were observed during the course of the study. The surveys resulted in 42 encounters with dolphin schools. The photographs were carefully matched within and between encounters and surveys to minimise any mistakes in identification. It is important that this is done thoroughly since any estimates of population size or changes in distribution depend on the quality of the photographic analysis.

Long term residency and site fidelity

Data collected during 2018 confirm previous findings showing a high degree of site fidelity of dolphins using the estuary (Ingram & Rogan, 2001, Englund *et al*., 2007), with 55% of the dolphins being re-sighted in previous years. This includes the re-sighting of an individual with a spinal deformity, known as a calf in 2015 and re-sighted with the same adult 3 years later. However, a high percentage (45%) of well-marked individuals were new to the catalogue, highlighting the need to keep the photo-identification catalogues up to date and demonstrating that even within a short period of three years, individuals' marks can change to the extent that it is impossible to match them with certainty.

While it is known that bottlenose dolphins use the Shannon Estuary throughout the year (e.g. Englund *et al*., 2008), numbers have been shown to decrease during the winter (Ingram, 2000, Englund *et al*., 2008). The ranging behaviour and habitat use by 'Shannon' animals whilst outside of the estuary remains largely unknown, however, due to a lack of photo-id matches from other sites. Despite this, it must be remembered that much of the associated survey effort so far has concentrated on the summer and early autumn months and comparatively little is known of the species' winter-spring occurrence and ecology. Dolphins biopsy sampled in Cork Harbour belonged to a small group of largely unmarked individuals (Ryan *et al*., 2010) and genetic analysis clustered these animals with Shannon Estuary dolphins. It is therefore likely that these animals had relocated from the Shannon Estuary at some point prior to being biopsied.

Calves and neonates

Neonates were recorded in 12 encountered schools in 2018, all of these were first sighted between August and October. Due to low degree of markings on neonates and calves they can generally only be reliably identified from their association with a marked adult assumed to be the mother. This makes the estimation of survival rates very difficult, especially when breeding females are poorly marked. During 2018 nine neonates were identified. In some seven occasions, their mothers were identified during the encounter, whereas on two occasions the accompanying adults were poorly marked and thus only tentatively assigned an ID number. Calves (n = 3) were also recorded during the survey period. As with previous years, calving appears to be concentrated during the late summer and autumn.

Baker *et al*. (2018b) estimated the mean inter-birth interval in the Shannon population to be 2.7 ± 0.6 and 3.5 ± 1.3 years, depending on the method used and reported that the number of neonates per year varied between 3 and 10, with a mean of seven. The number of neonates recorded during the current study are therefore slightly higher than the average but within the range reported by Baker *et al*. (2018b). These authors also estimated a peak in parturition in

July, which is slightly earlier than estimated here; neonates were only reported from early August onwards.

Abundance of dolphins using the Shannon

The individual recognition of dolphins from photographs of their natural markings provides a powerful tool in estimating abundance using traditional mark-recapture models. As in previous years, we reduced potential matching errors by screening the data for poor quality photographs and poorly marked animals. Following a quality control protocol, a second researcher independently assigned photo-quality and mark severity to the photos and confirmed the identification of the individuals matched to a sub-set of the photographs. The discovery curve shown in Figure 6 indicates a steady decline in the rate at which marked animals were recruited into the sampled population. We can be confident therefore that the majority of marked animals had been sighted during these surveys and that the 'population' was closed during the sampling period.

As a result of previous work we recommended that estimate precision (i.e., low CV values) should be a priority when designing future reporting strategies (Englund *et al*., 2008). In light of the importance of maintaining low estimate CV values we recommended that regardless of reporting frequency, monitoring for this population should include at least 12 surveys within each sampling period in order to derive a robust and precise estimate. Our calculations indicated that 12 surveys should be sufficient to derive an estimate with a CV below 0.12 and would incorporate approximately 2 sightings of each sampled dolphin. Sampling effort throughout the summer of 2018 was consistent, however, three full surveys resulted in no sightings of dolphins. The number of daily encounters also varied considerably throughout the 2018 sampling period, but by using the weighted average approach we were able to derive an estimate with a CV < 0.12.

We estimated the total number of dolphins using the estuary between June and October 2018 to be 139 ±15 (CV=0.11, 95% CI= 121 – 160). The latest estimate for the site has similar precision as the previous estimates and the 95% Confidence Interval falls within most of the previous estimate values, thus it shows that the point estimate of abundance is similar to all previous estimates and it indicates that this population's status appears to be stable.

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