Abundance, distribution and habitat use of Bottlenose dolphins in the west and north-west of Ireland

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Executive Summary

Boat-based surveys for bottlenose dolphins (*Tursiops truncatus*) consisting of 320 hours of survey effort were conducted in coastal waters of north-west Connemara (Co. Galway and Co. Mayo) Mullet peninsula (Co. Mayo) and in Donegal Bay (Co. Donegal and Co. Sligo) during the summer months of 2013-2014. This resulted in twelve photo-identification encounters of bottlenose dolphins by in 2013 and fourteen encounters in 2014. Data were combined with other photo-id catalogues and the best quality photographs were used to derive local abundance estimates for north-west Connemara for 2013 and 2014 and for Donegal Bay for 2014, as well as multi-site estimates for the wider Connemara-Mullet peninsula-Donegal area for 2013 and 2014 using mark-recapture methods. The identification photographs were also used in social structure analysis and to calculate average sighting rates for each study site and for individuals with varying mark severity. The encounter locations where bottlenose dolphin schools were observed and followed were investigated within the context of substrate type and depth. Passive acoustic monitoring (C-PODs) was used to investigate the occurrence and occupancy of dolphin schools in two strategic locations: at the mouth of Killary Harbour, Co. Galway and McSwyne's Bay, Co. Donegal.

The local abundance estimates of bottlenose dolphins in north-west Connemara was 56 (CV=0.25, 95% CI: 34-90) for May-July 2013 and 83 (CV=0.27, 95% CI: 49-140) for June-July 2014, using the M_{th} "closed population" model. The local estimate for Donegal Bay for August-September 2014 was 143 (CV=0.12, 95% CI: 113-181). The model averaged Bayesian multi-site abundance median estimate for the whole study area (i.e. Connemara – Mullet peninsula – Donegal) in 2013 was 145 (CV=0.30, 95% CI: 111-239) and in 2014 it was 189 (CV=0.11, 95% CI: 162-232). Bottlenose dolphins used the entire study area during the two years of survey effort, with nearly half (43%) of all well-marked identified animals sighted in more than one of the three survey blocks. The majority of the encounters occurred in water depths <25m, and at least in Donegal Bay, on sandy substrate.

Social structure analysis revealed a large number of small subgroups consisting of only a few individuals with a higher degree of association. The mean association index (AI) of 0.2 suggests very little social clustering within this coastal community and is indicative of a fission-fusion society, typical to the species. However, the coefficient of variation of true AIs was 0.510 indicating a well-differentiated social structure with preferred and/or avoided associations so it seems that dolphins within these small groups prefer to associate with certain individuals.

From the C-POD data, it seems that detections in McSwynes's Bay, Donegal, may show a decreasing trend during the winter months contrasting with a peak in detection positive days per month from August through November 2014. This coincides with more detections being logged in Killary Harbour during January, February and March 2015. The final retrieval of the data in September 2015 will show if this trend persists. Nevertheless, dolphins were detected in both locations during each month of deployment.

The multi-site estimates derived in this study are similar to the previous estimate for north-west Connemara and are likely to better reflect the true abundance of these coastal bottlenose dolphins than the local site-based estimates due to the wider-scale sampling over a larger coastal area.

We suggest continued use of the Bayesian multi-site method to monitor the abundance of bottlenose dolphins along the west coast of Ireland. The model produced estimates that have less

variability around the point estimation. In addition, multiple discrete locations can be sampled simultaneously and sampling can be done opportunistically using a sightings network. Based on the findings of this research, until there is a greater understanding of the movements, ranging behaviour and occupancy patterns of these dolphins we do not recommend solely relying on monitoring surveys within the boundary of the West Connacht Coast SAC (i.e., in Connemara and Mullet peninsula) in order to provide measures of conservation status of this population. We suggest that the work reported here is continued using a combined and comprehensive methodological approach around the entire Irish coast. Such an approach should use a combination of methods such as static acoustic monitoring, photo-id boat surveys and possibly coastal aerial surveys. Photo-id boat surveys should preferably use more than one mobile field-team based in different parts of the country to maximise the likelihood of encountering dolphins following sightings reports. Comparison of catalogues held in adjacent countries may better inform habitat use and individual movement and would likely aid in trans-boundary reporting for this species. Capturing and better understanding the entire range of this mobile bottlenose dolphin population will be important not only for monitoring the numbers and movements of these dolphins but also for identifying areas in which they may be threatened by specific anthropogenic activities.

Introduction

Bottlenose dolphins (*Tursiops truncatus,* Montagu) are a cosmopolitan species found throughout the world's tropical and temperate waters up to about 45° to 55° of latitude (depending on location) (Leatherwood and Reeves, 1990) and they are found in coastal inshore waters, in continental shelf regions and in open ocean environments (Wells and Scott, 2002). A minimum worldwide estimate for bottlenose dolphin abundance numbers 600,000 individuals (Hammond *et al.*, 2012). The mean reported bottlenose dolphin group size varies from 5 to 140 individuals and, in general, the dolphins live in fission-fusion societies (Connor *et al.*, 2000) with the composition of groups or subgroups changing on a scale of hours or days.

Bottlenose dolphin populations using coastal environments are at particular risk of exposure to a number of anthropogenic threats which may directly impact on individuals, for example through disturbance or damage to the health and functioning of the coastal ecosystems upon which they depend. The sensitivity of bottlenose dolphins to these threats is compounded by their position as an apex predator and as a highly K-selected species with low reproductive rates. The main threats in coastal environments include pollutants such as xenobiotic chemicals, PCBs and DDT (the latter two are linked to deterioration in immune system function), reduced prey availability (e.g., caused by overfishing), habitat degradation (e.g., physical and acoustic), disturbance from boat traffic, entanglement and incidental bycatch in fishing gear, direct hunting, marine construction and anthropogenic noise including shipping noise (now classed as a marine pollutant under the EU Marine Strategy Framework Directive or MSFD) (Hammond *et al.*, 2012). The determination of impacts from anthropogenic habitat degradation on coastal populations requires detailed understanding of the population structure and size of the communities/populations affected, and the ranging behaviour and site fidelity of individuals within these populations. Coastal bottlenose dolphin populations often display fine-scale genetic structuring (e.g. Mirimin *et al*., 2011, Fernandéz *et al*., 2011, Ansmann *et al*., 2012) presenting an added challenge to effective conservation and management.

Bottlenose dolphins in Irish waters

In Irish waters, evidence suggests that bottlenose dolphins using coastal habitats along the west coast belong to two small, genetically and socially distinct (Mirimin *et al*., 2011, Oudejans *et al*., 2015) populations which are separate from a larger offshore population estimated to comprise about 12,000 animals (Hammond *et al*., 2013). This distinction between coastal and offshore populations has recently been reflected in a proposed classification for MSFD purposes of dolphins using the waters of the west coast of Ireland as a discrete assessment/management unit (IAMMWG, 2015) with a key population of dolphins using the Shannon estuary proposed as a second coastal assessment/management unit.

Most research effort on bottlenose dolphins in Ireland has concentrated on dolphins inhabiting and resident within the large open outer estuary of the River Shannon. These animals belong to a discrete population of approximately 140 individuals (Ingram and Rogan, 2003, Berrow *et al.*, 1996, 2012, Ingram and Rogan, 2002, Englund *et al*. 2007, 2008). Dolphins using the Shannon appear to have a high degree of site fidelity and although the Special Area of Conservation (SAC) designated for these animals does not include the population's entire range it protects animals in what is considered to be their core feeding and breeding habitat. However, in addition to the Shannon

population, bottlenose dolphins occupy and range throughout a large part of the west coast of Ireland. Photo-identification (photo-id) surveys targeting these 'west coast' animals commenced in 2001 when Ingram *et al.* (2001) completed surveys in Brandon Bay, (Co. Kerry), Connemara (Co. Galway), Broadhaven Bay (Co. Mayo) and McSwyne's Bay (Co. Donegal). This preliminary study showed rematches of individuals over a period of months and concluded that because of the high numbers of individuals identified during the surveys, a significant number of bottlenose dolphins were likely to inhabit the waters off the west coast of Ireland (Ingram *et al.*, 2001). Further work around Connemara in 2003 and 2009 confirmed the importance of this particular region for this putative west coast population (Ingram *et al*., 2003, Ingram *et al*., 2009).

An analysis of photo-id matches at a wider geographic scale led O'Brien *et al.* (2009) to state that bottlenose dolphins occurring along the Irish west and south coasts seem to be highly mobile and occupy extensive coastal ranges. More recently, genetic work linked to photo-identification surveys has provided evidence that there may be different "ecotypes" using the North-east Atlantic Ocean, with ecological distinctions being driven by differences in habitat use between populations (Louis *et al*., 2014a). Genetic analysis of samples from stranded bottlenose dolphins of unknown provenance indicates that these animals belong to a large and distinct offshore population (Mirimin *et al*., 2011) while, according to Louis *et al*. (2014a), these putative ecotypes include a distinct coastal ecotype. The genetic evidence is also consistent with the results from photo-identification surveys conducted in Irish coastal waters since 2001; indeed the dolphins using the coastal waters of western Ireland do appear to be socially distinct from dolphins using offshore waters (Oudejans *et al*., 2015).

Legal status and protection

The major legislative instruments underpinning the protection and conservation of bottlenose dolphins in Irish waters are the Irish Wildlife Act (1976 plus amendments to 2012) and the European Communities (Birds and Natural Habitats) Regulations (2011). Among other conservation-oriented actions, the latter regulations transpose into national law the provisions of the EC Habitats Directive (Council Directive 92/43/EEC). All cetaceans are listed in Annex IV of Habitats Directive necessitating a system of 'strict protection' for such species. In addition, bottlenose dolphins are listed in Annex II of the Habitats Directive and Member States are thereby required to designate Special Areas of Conservation (SACs) as part of an overall European strategy to maintain or restore the favourable conservation status of key listed species and habitats. In Ireland, Special Areas of Conservation for bottlenose dolphin have been designated in the Shannon estuary (Lower River Shannon SAC) and in Connemara and western County Mayo (West Connacht Coast SAC).

While bottlenose dolphins as a species is not considered to be endangered, some populations such as those inhabiting the Moray Firth in North-east Scotland and the Shannon estuary appear to be demographically and geographically distinct (Parsons *et al.*, 2002, Mirimin *et al*., 2011), making them potentially vulnerable to stochastic environmental and demographic (e.g. changes in rates of reproduction and mortality as well as permanent migration) events. The Shannon-based population of bottlenose dolphins has been monitored since the mid 1990's and summer abundance estimates have been calculated for several years (e.g. Berrow *et al*., 2012). However, there has not been an attempt to calculate a robust abundance estimate for the recently designated West Connacht Coast SAC. Given the known ranging behaviour of bottlenose dolphins in Irish coastal waters, particularly along the north, west and south coasts, it is important to obtain precise estimates of the number of

bottlenose dolphins occupying the wider Irish west coast and the West Connacht Coast SAC, to continue monitoring their numbers, and also to establish whether distinct genetic groups exist among these dolphins in order to contribute to an effective management strategy for the species.

Abundance of bottlenose dolphins off the west coast of Ireland

Accurate abundance estimates have yet to be obtained for bottlenose dolphins using the coastal waters of western Ireland but according to data gathered in the 2005 SCANS-II survey (Hammond *et al*. 2013) the total abundance of bottlenose dolphins off the north, west and south coasts of Ireland numbered 313 individuals (CV=0.81). This number seems low considering that mark-recapture population estimates for the Shannon estuary alone vary between 114 (Englund *et al.* 2008) and 140 (Englund *et al*. 2007). Ingram and colleagues (2009) surveyed the coastal waters of north-western Connemara in June – September 2009 and estimated the abundance of bottlenose dolphins using the area to be 171 ± 48 (CV= 0.28, 95% Confidence Intervals=100-294). This estimate represented the first attempt to assess the number of animals using a site outside of the Lower River Shannon SAC but surveys were restricted to Connemara (north of Slyne Head) and it was apparent from this work that the animals ranged well beyond this survey area, with matches of individuals as far apart as Youghal (Co. Cork) and County Donegal (Ingram and Rogan, 2003). The relatively wide confidence intervals around this estimate and repeated sightings of dolphins around the entire west coast called for an integrated approach combining survey data at a number of sites to produce a more precise estimate of abundance and the ranging behaviour of such animals.

Ingram *et al*. (2009) applied a routinely used closed population model M_{th} by Chao *et al*. (1992) to derive the abundance estimate for bottlenose dolphins around Connemara. Although this model is designed to accommodate differences in 'capture' probability between individual animals and between different surveys, the design of this estimate is generally applicable to sites where animals are all available for capture during the entire sampling period and within the sampled area (Ingram, 2000). However, when animals are encountered in multiple discrete sites during a field season, this method is less suitable as it may be impossible to sample throughout the whole geographic range of the population and also during a single season. This can lead to increased heterogeneity between individual sighting probabilities and thus underestimation of abundance (Durban *et al*., 2005) and greater uncertainty around the estimate. A multi-site model developed by Durban *et al*. (2005), which uses Bayesian inference instead of a traditional 'frequentist' statistics, is well-suited for sparse data sets such as those from cetacean mark-recapture sampling. This model, for which the data has been collected opportunistically from multiple study sites, also takes into account the geographical dependencies between the different sites. Another advantage of using Bayesian inference in abundance estimation compared to traditional statistics is that it incorporates *a priori* knowledge of the distribution of the parameters that we want to study into producing joint *posteriori* distribution of the parameters in question. An example of this would be setting a realistic maximum value, an upper limit, to the prior for the abundance of all well-marked animals in an area. This prior knowledge of the maximum number of well-marked animals is then incorporated into the model and more realistic estimates are produced. This Bayesian multi-site approach was previously used by Cheney *et al*. (2013) to estimate the abundance of bottlenose dolphins around the entire Scottish coast where animals moved between different sampling sites.

Project aims

The aims of this project were:

i) to derive an estimate of abundance for bottlenose dolphins using the north and west coast of Ireland, using a multi-site approach;
ii) to estimate bottlenose dolphin abundance on a smaller local scale;
iii) to examine site fidelity, ranging patterns and occupancy rates by individual dolphins;
iv) to investigate the social structure demonstrated by dolphin groups and individuals within the study population.

Methods

Survey areas

Three regional survey areas around the west and north-west coasts of Ireland, where bottlenose dolphins had frequently been reported, were selected as the focus of this study. These areas broadly represent the coastal waters of Counties Galway, Mayo, Sligo, Leitrim and southern Co. Donegal (Figure 1). In addition, one opportunistic survey that led to an encounter was carried out in Killala Bay as a response to a sighting by the Irish Whale and Dolphin Group (IWDG).

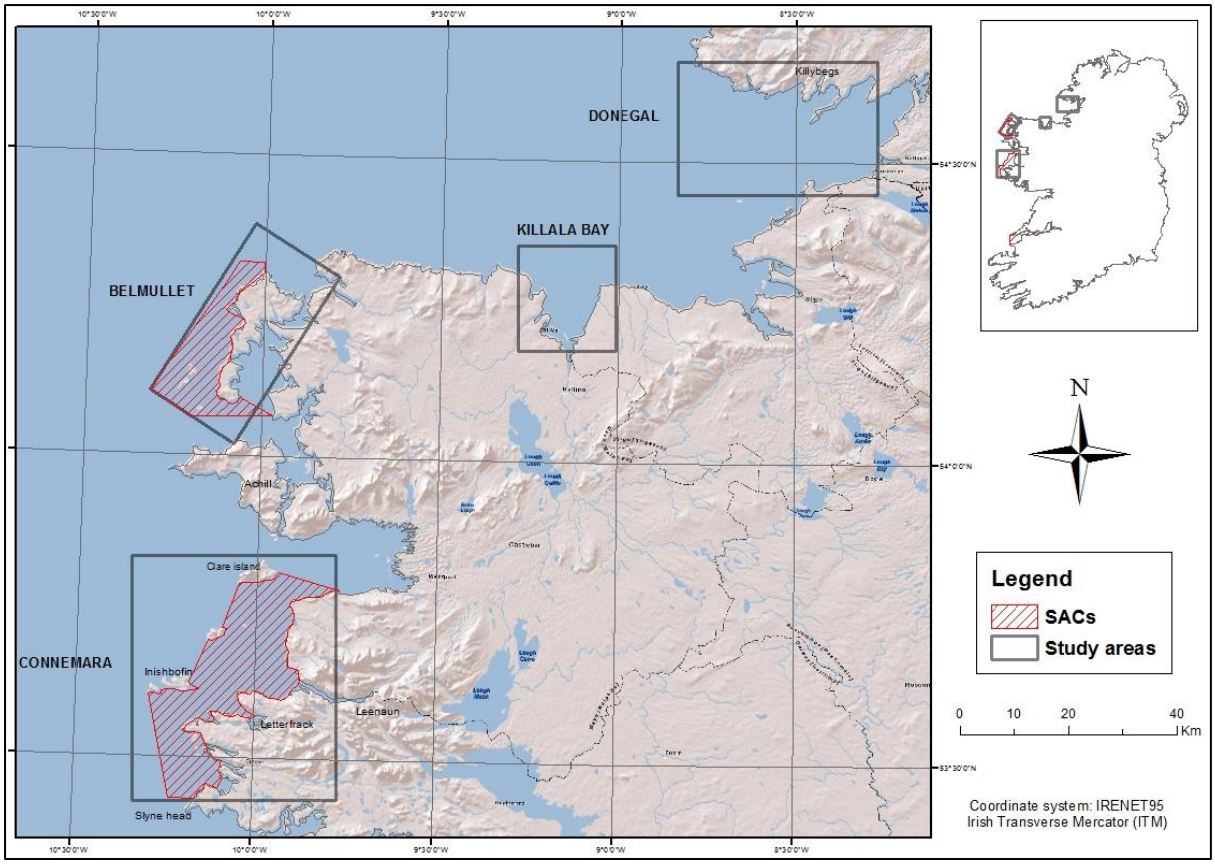

Figure 1. Special Areas of Conservation (SACs) and selected regional survey areas for coastal bottlenose dolphin surveys in 2013 and 2014.

Boat-based photo-identification surveys

Boat-based surveys were conducted within these coastal blocks during the summers of 2013 and 2014. Surveys were conducted using a 6.5m rigid hull inflatable boat (RIB) with a crew of 2-3 people. Survey speed was maintained at approximately 18-20 km/h for the duration of the surveys, with a reduction in speed during encounters with dolphins.

During dedicated surveys the observers would scan 180° in front of the vessel, 90° from bow to port and 90° from bow to starboard. Vessel position, speed, direction and water depth (m) were recorded automatically every minute using a Garmin 551S chart plotter mounted on the console of the boat. For each sighting, the time, GPS location and water depth were also recorded. Dedicated surveys were conducted in Beaufort sea-states 3 or less with suitable ambient light and swell conditions, in

order to minimise the effect of weather and sea conditions on the probability of sighting dolphins and obtaining high quality photographs. If weather conditions deteriorated during a survey, the survey was cut short.

A bottlenose dolphin group 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 whilst with dolphin schools. When sighted, dolphins were approached slowly and carefully, minimising changes in vessel speed and direction in order to reduce disturbance to the animals. Schools of dolphins were approached from a course that was parallel and convergent to the heading of the dolphin school. Best efforts were made to photograph the dorsal fins of all members of the school during each encounter without introducing bias due to mark severity. Identification photos were taken using a digital SLR camera (Canon EOS 1DS mark II and 70-200mm telephoto lens) as close to perpendicular to the animals' dorsal fin as possible and within a distance of 20m.

GPS coordinates were recorded at the beginning and at the end of each encounter. The number of animals present was estimated in the field and the presence of juveniles, calves and neonates was also recorded. The behaviour of dolphins around the survey vessel, including any signs of stress or evasive behaviour, was monitored and recorded. If strong avoidance behaviours were observed the survey protocol was suspended and approaches within 50m of dolphins were avoided for 5 minutes. If such avoidance behaviours were repeated on resuming the approach, the encounter was terminated. Each encounter continued until all animals had been photographed, preferably from both sides, or until contact with the school was lost. Following the end of an encounter the survey route was resumed, time and daylight permitting.

Photograph analysis

Individual bottlenose dolphins can be identified using their natural markings. These marks mostly consist of scars and nicks from interactions with conspecifics and they 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, flank or peduncle (Plate 1). 'Permanent' marks by definition are likely to last many years, enabling long-term identification of these dolphins. In contrast, 'temporary' markings, such as superficial tooth rakes and small nicks may fade and heal within a relatively short period of time and inter-annual re-sighting probabilities of these animals are likely to be reduced.

Digital photographs of dolphins were processed following methods described by Englund and colleagues (2007). For each encounter, the best picture was chosen of each individual identifiable dolphin and the quality of the photograph was graded from 1 to 4 with no consideration concerning the degree of marking of the individual (Table 1). Each photographed individual was then assigned one of three grades of mark-severity (Plate 1). Selected "best photographs" were then matched against the full UCC catalogue/archive of dolphins photographed during previous encounters. If a definitive match could not be found within the archive, the animal was given a new catalogue number and subsequently added to the catalogue as a new identification provided the best photograph was of sufficient quality (grade 1-2) or the animal had clearly identifiable marks.

The identified dolphins were categorised into three "age-classes": calves, adults or juveniles. Young calves (<1 year old) were identified by their size, the presence of foetal folds on their flanks and their

close association with a larger animal which was classified as the probable mother. Juveniles (older calves and sub adults >1 year) were identified due to their smaller size, the absence of significant markings and their close association with a larger animal assumed to be their mother. Adult animals were identified based on their body size. Because calves and neonates (and even juveniles) usually lack permanent markings, the potential for their identification depends on their association with a particular female (i.e., probable mother) and/or very minor tooth-rakes or skin lesions. This reduces the chance of individual re-sightings between years, especially post-weaning when the young animals begin to dissociate from their mother.

Table 1. Scoring criteria for the identification photographs (independent of the degree of marking of individual dolphins) (from Englund *et al*., 2007).

Grade	Criteria
1.	Well lit & focused photo taken perpendicular to the dorsal fin at close range
2.	More distant & less well lit or slightly angled photo of the fin
3.	Poorly lit or to some extent out of focus photo, or photo taken at an acute angle to the fin
4.	Poorly focused, backlit or angled photo taken at long distances to the dolphin

Plate 1. Examples of bottlenose dolphin fins showing the three grades of mark severity following Ingram *et al*., (2009). Left image: Grade 1 – significant fin damage or deep scarring that is considered permanent; Middle image: Grade 2 – marking that consist of deep tooth rakes and lesions, with only minor cuts present; Right image: Grade 3 – superficial rakes and lesions.

Urian *et al*. (2015) examined the influences of bias in photo-identification techniques on mark-recapture abundance estimates and made a number of recommendations, including that "researchers should: (1) determine the degree of marking, or level of distinctiveness, and use images of sufficient quality to recognize animals of that level of distinctiveness; (2) ensure that markings are sufficiently distinct to eliminate the potential for "twins" to occur; (3) stratify data sets by distinctiveness and generate a series of abundance estimates to investigate the influence of

including animals with varying degrees of marking; and (4) strive to examine and incorporate individual variability between research analysts into capture-recapture estimation". In this analysis we have striven to adhere to these recommendations and will present abundance estimates for 2013 and 2014 separately. The best identification photograph of each individual that was identified in each encounter was selected from all photographs taken during encounters throughout the study and quality graded according to methods previously described (after Englund *et al*. 2007).

Photographs were also compared to catalogues held by the Broadhaven marine mammal group (MaREI (Marine Renewable Energy Ireland), Environmental Research Institute, UCC, formally known as CMRC) and by M. Oudejans (Dúlra Research), increasing the sampling effort in this area.

Data handling and analyses

To minimise capture probability bias and errors in individual identifications, only high quality (grade 1-3) photographs were selected for the abundance and social structure analyses. In addition only dolphins identifiable or known in photographs from both the left and the right side were included in the abundance estimation process. Furthermore, to minimise any bias in capture probabilities, only the "well-marked" animals, i.e. mark grade 1, were included in the abundance analyses, and mark grades 1 and 2 in the analysis of social structure. This data selection process led to the exclusion of all identifications from one encounter in the 2013 dataset.

Photographs from different encounters were compared within and between the regional study sites (i.e., Connemara, Mullet peninsula and Donegal in 2013 and Connemara, Mullet peninsula, Killala and Donegal in 2014) to establish whether individuals were seen across the whole study area. In addition, a discovery curve was fitted in order to investigate the rate at which newly identified dolphins were added to the photo-id catalogue during the period of study. This discovery curve indicates whether all individuals using the west/north-west of Ireland study area have been identified. We calculated the re-sighting rate from good quality photographs (Q1-3) for each dolphin that was identified or known from both sides for both years across all sites and also for each site separately using the following formula:

$$\frac{Number\ of\ times\ encountered - 1}{Total\ number\ of\ encounters\ - 1}$$

Local abundance estimation for Connemara and Donegal

For the local single-season abundance estimates for Connemara (within the West Connacht Coast SAC) and Donegal, a closed population mark–recapture model M_{th} (Chao *et al*., 1992) was fitted to the data using the CAPTURE software program (Rexstad and Burnham, 1991) within the program MARK (White and Burnham, 1999). This method is widely used in abundance estimation of cetaceans due to its level of tolerance to heterogeneity in capture probabilities and time dependence. In each case this produced a single abundance estimate of bottlenose dolphins for the years 2013 and 2014 for Connemara, and for the year 2014 for Donegal. We were unable to produce an abundance estimate for Mullet peninsula due to the few number of bottlenose dolphin encounters by UCC in 2013 (three encounters) and 2014 (only one encounter).

Since the data set used to derive the estimate is restricted to well-marked animals recognisable from both sides only and does not include poorly marked individuals, the 'capture' estimates were subsequently inflated according to the proportional representation by this marked subset of animals within the whole population. For this purpose, all positive identifications were examined closely in order to derive the fraction of dolphins that belonged to the "well-marked" subset (mark severity grade 1). This proportion (between 0 and 1) was calculated by dividing the number of identifications of dolphins from the marked subset by the total number of identifications from good quality photographs (i.e., quality grade 1-3) (after Wilson *et al*., 1999). The following formula was used to inflate the population estimates according the proportion of well-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.

Multi-site abundance estimation

Bayesian inference and hierarchical log-linear likelihood for counts of identified dolphins were used to derive a multi-site abundance estimate for (a) the Connemara-Mullet peninsula-Donegal area in 2013 and (b) the Connemara-Mullet peninsula-Killala-Donegal area in 2014, following the methods of Durban *et al.* (2005) and Cheney *et al*. (2013). The photos from the encounter in Killala Bay on the 8th September 2014 were included in the Donegal block, as per the initial contract with the NPWS. The Bayesian multi-site method is well-suited for sparse recapture data gathered in a more opportunistic way instead of through systematic line-transect surveys. The method assumes a closed population across the entire study area during the data collection period (i.e., no births, deaths or permanent immigration or emigration), which in this case is a reasonable assumption given the width of the area and the short duration of the study (May-August in 2013 and May-September in 2014). Another benefit of this method is the ability to quantify movements between each of the study sites.

A contingency table of well-marked dolphins was created based on their occurrence/absence in each of the discrete study sites (see Tables 2 and 3). The missing value (NA) on the last row of the table represents the count of individuals that were not seen in any of the study areas (i.e., missed well-marked dolphins) and the purpose of the model is to predict a value for the missing cell and thus estimate the overall abundance of well-marked animals across all of the study sites. The model also incorporates the proportion of well-marked individuals as a binomial sample of the total number of animals seen (well-marked plus poorly marked and unmarked animals); therefore it predicts the number of all individuals in the study area (see Cheney *et al*. 2013). The output is then presented as a mean abundance estimate (or point estimate) with 95% Credibility Intervals (the Bayesian equivalent of 95% Confidence Intervals).

The model selection and prediction were performed using Markov Chain Monte Carlo (MCMC) methods with Gibbs sampling in WinBUGS software (Lunn *et al*., 2000) with 200,000 iterations (100,000 burn-in with a further 100,000 samples). Three chains were used in order to visually assess and ensure the convergence of the chains.

Analysis of social structure

The social structure of the individuals identified in 2013 and 2014 was analysed using the program SOCPROG (Whitehead, 2009) in order to see if any clustering or associative grouping occurred among the individuals. In the analysis each survey was treated as a sampling period and group membership was defined as individuals being photographed within the same encounter (i.e., gambit of the group). Only the individuals with mark severity grade of 1 or 2 and photograph quality of 1 or 2 were included in the analysis. Whitehead (2009) recommends including only data of individuals sighted five or more times in order to minimize the bias caused by rarely seen individuals in the calculation of association indices. For example, individuals encountered only once and seen together during this encounter would automatically have an AI of 1 (seen together in 100% of the encounters). However, due to the scarcity of the encounters, we had to limit the dataset to individuals seen three or more times in order to keep a sufficient amount of individuals in the analysis. Half-weight Association Indices (AIs) were calculated for all validated individuals, and the data were visually inspected using NetDraw (Borgatti, 2002). We also obtained an estimate of the "social differentiation", which is the coefficient of variation of the true association indices. According to Whitehead (2009), values of social differentiation of <0.3 indicate fairly homogeneous societies, >0.5 well differentiated societies, and >2.0 extremely differentiated societies.

Occupancy analysis using passive acoustic monitoring

The continuous presence/absence of bottlenose dolphins within the Connemara and Donegal sites was monitored by deploying single acoustic data loggers (C-PODs, Chelonia Ltd.) in the mouth of Killary Harbour, Co. Galway/Mayo and in McSwyne's Bay, Co. Donegal. C-PODs are self-contained battery-powered acoustic monitors that detect echolocation clicks produced underwater by toothed whales such as dolphins and harbour porpoises. These autonomous devices, which are capable of continuous data collection for several months at a time, record the time, duration, inter-click interval, the dominant frequency and other features of each click or 'click train' with up to a 5 millisecond resolution. Click events detected and logged by the CPODs are saved onto an SD card, from which the data can easily be downloaded and analysed. However, they are not able to identify individual animals and the effective discrimination of clicks from different dolphin species is not possible, thus care needs to be taken in their positioning in inshore/coastal waters where species may coincide.

The C-PODs used in this study were deployed at 6-12m depth (at low tide) with a suitable mooring weight so that they remained at least 4m under the water surface in all tide heights. We deployed the C-PODs in sheltered locations where bottlenose dolphins were commonly seen. These deployment locations were also chosen in order to reduce the likelihood of recording other dolphin species (e.g., common dolphins *Delphinus delphis*). The C-POD in McSwyne's Bay, Co. Donegal was deployed on the 19th of October 2013 and a second C-POD was deployed in Killary Harbour on the 15th of September 2014 following the theft of a C-POD previously deployed in early June 2014. The C-PODs were retrieved every 4-5 months for data download and battery replacement and re-deployed as soon as possible after maintenance.

After each retrieval, the C-POD data were analysed in C-POD.exe software (Chelonia Ltd.) using the GENENC click classifier and 'other cet' setting which maximises the capture of echolocation click events for dolphins and discriminates them from harbour porpoise (*Phocoena phocoena*) clicks and

background environmental noise such as sounds caused by the moving sediment. Detection positive hours per day (DPH/day) and detection positive days per month (DPD/month) were then imported into MS Excel to investigate the presence of dolphins in each deployment location.

Results

Survey effort

In 2013, in Connemara, seven day-long dedicated surveys were conducted in June, July and August following either a southward or northward route between Clare Island and Mannin Bay (Fig. 2, see also Ingram *et al*., 2009) leading to 118 hours of survey effort. In addition, 15 shorter (in distance) surveys were carried out around the mouth of Killary Harbour in the area between Frehill Island, Crump Island and Inishdegil Mór. Six of these short surveys were in response to local sighting reports, but we also found the tactic of waiting around the fjord mouth to be quite successful since this narrow fjord and its entrance seem to be an important foraging site for the dolphins.

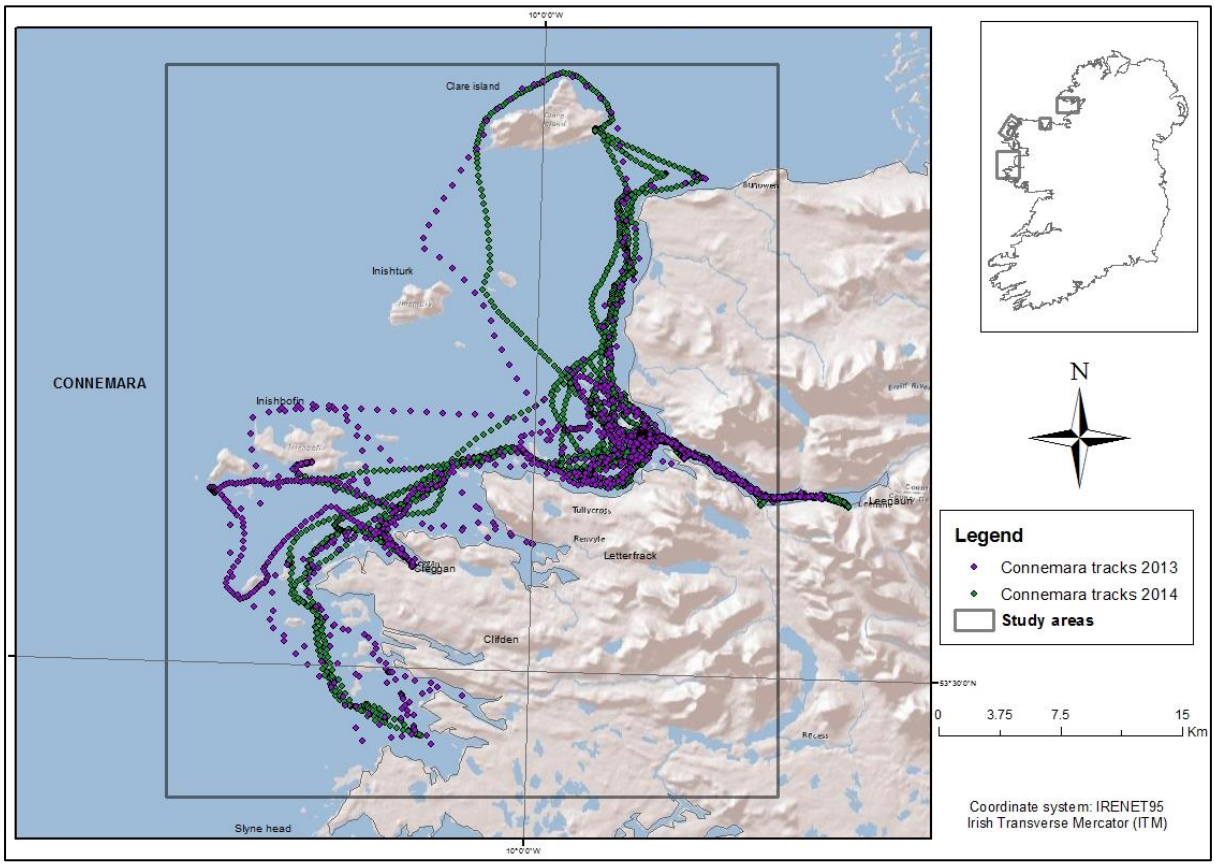

Figure 2. GPS tracks of all surveys conducted in the Connemara survey block in 2013 (n=7) and 2014 (n=6).

In Mayo, three long surveys were conducted in July 2013 (Fig. 3) leading to a total of 29h of survey effort. In Donegal, one long survey was conducted in June 2013 along with two long surveys and a short one in August 2013, totalling 27h of survey effort (Fig. 4).

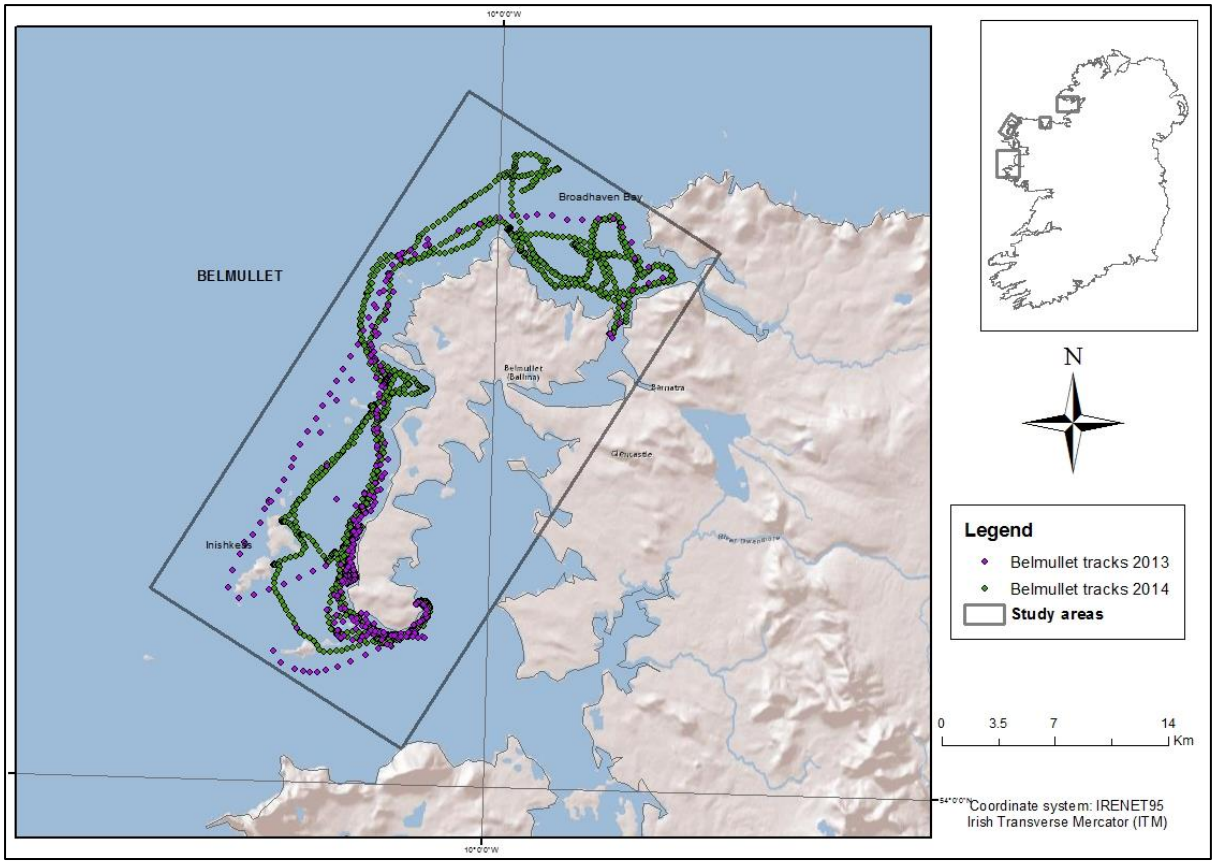

Figure 3. GPS tracks of all surveys conducted around the Mullet peninsula survey block in 2013 (n=3) and 2014 (n=5).

In 2014 sampling effort was concentrated more evenly throughout the wider west/north-west study area with the first part of the summer (June-July) spent surveying the waters off north-west Connemara (a total of 68h of survey effort) and the latter part of the summer (August-September) spent in south Donegal (a total of 50h of survey effort). In addition, a total of 28h were spent surveying the waters around Mullet peninsula, Co. Mayo in 2014.

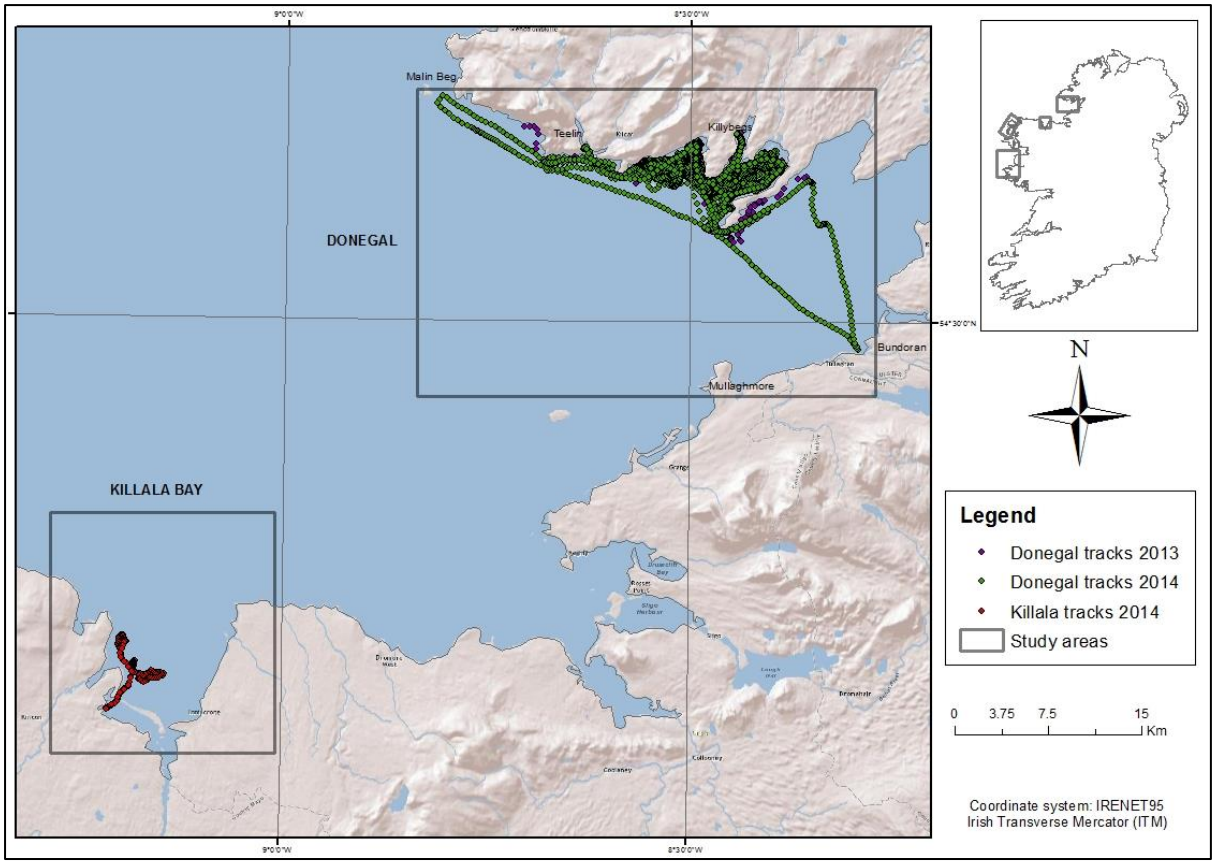

Figure 4. GPS tracks of all surveys conducted in the Donegal survey block in 2013 (n=3) and 2014 (n=7). A GPS track from Killala Bay on the 8th of September, 2014, is also marked on the map.

As outlined above, survey effort varied between years and between sites and this is summarised in Table 2. During surveys in 2013, eight bottlenose dolphin schools were encountered in Connemara, two in the waters around Mullet peninsula and two in Donegal (Fig. 5). In 2014, six dolphin schools were encountered in Connemara, one around the Mullet peninsula site, one in Killala Bay and six in south Donegal (Fig. 5). As mentioned previously, for the Bayesian multi-site abundance estimates, our data sets were supplemented by identification photographs of dolphins that were obtained by the monitoring team based in Broadhaven Bay, Co. Mayo (MaREI) and by M. Oudejans who conducted opportunistic surveys in the waters around the Mullet peninsula and Donegal during 2014.

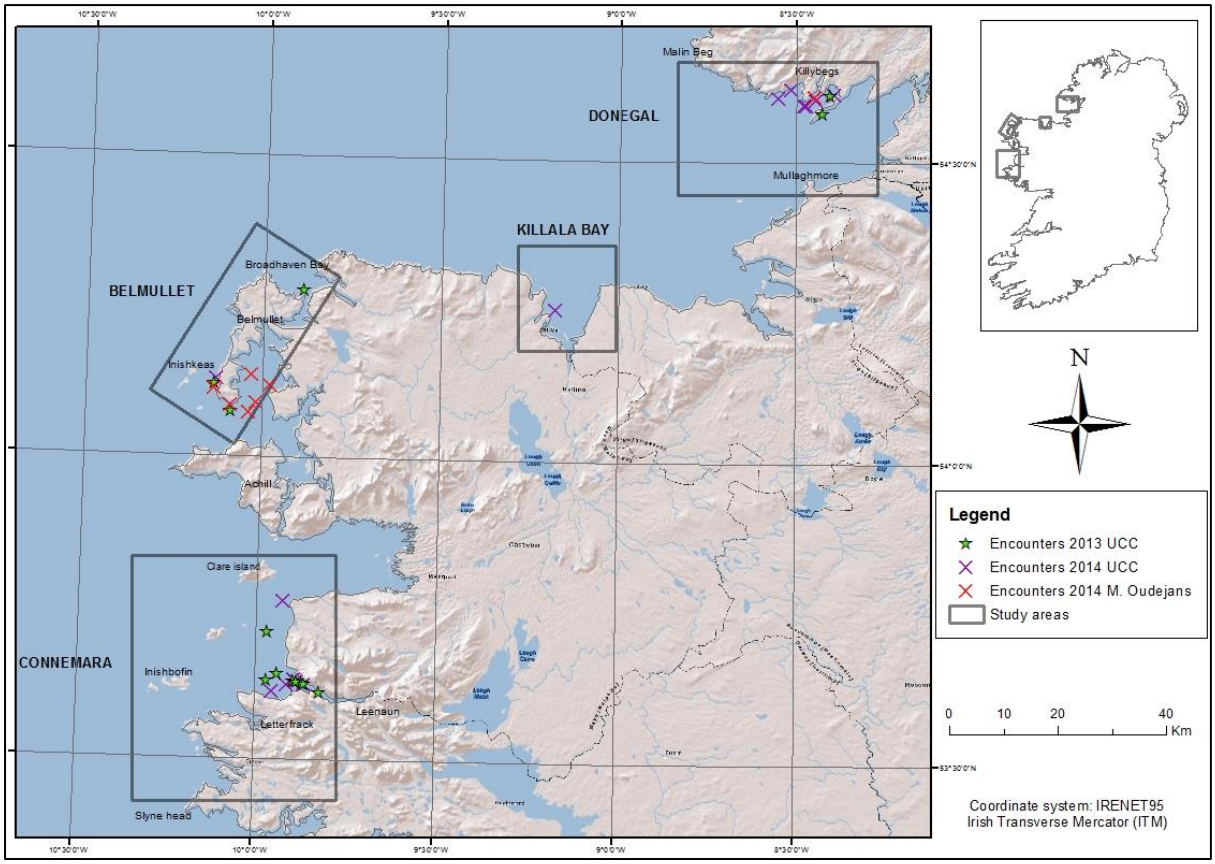

Figure 5. The locations of all bottlenose dolphin schools encountered by by all three research groups during surveys conducted in 2013-2014.

Bottlenose dolphin school size varied between encounters, locations and years (Table 3). The average school sizes (i.e., the number of photo-identified dolphins) ranged from 11.3 to 39, with groups comprising 4 to 48 individuals in 2013. In 2014 mean school sizes were larger, ranging from 18.5 – 44.5 individuals, with group sizes ranging from 8 to 95 individuals. The largest groups were encountered in Donegal with mean sizes of 39 and 44.5 in 2013 and 2014, respectively. Overall, the average bottlenose dolphin group size was larger in 2014 than in 2013.

Calves were also recorded during most encounters, with the largest number of calves recorded at any one time (n = 6) encountered in Donegal in 2014. Details regarding the group composition and the location of encounters are given in Appendix I.

Table 2. The total number of day-long surveys conducted in the different regional study sites in 2013-2014, the number of bottlenose dolphin encounters per site, and the number of dolphins (excluding calves) with different mark severity grading (M1-3) identified from photographs taken during the encounters per site. The data includes dolphins identifiable from both sides (M1 and M2), and only from right or left side (M3).

2013					
Site	**Surveys (UCC)**	**Encounters**	**IDs**		
			M1	M2	M3
Connemara	7	8	27	10	17
Mullet peninsula	3	2(+1)*	22	16	24
Donegal	3	2	27	8	22

2014					
Site	**Surveys (UCC)**	**Encounters**	**IDs**		
			M1	M2	M3
Connemara	6	6	28	17	25
Mullet peninsula	5	1(+6)*	50	18	33
Donegal	7	6(+1)*	79	29	73
Killala Bay	1	1	7	1	-

*Number given in brackets is the number of bottlenose dolphin encounters by UCC/ERI (1 encounter in 2013) and by M. Oudejans (7 encounters in 2014) from which the identification photographs were used in the analyses for this report.

Table 3. Mean bottlenose dolphin school size by location and year (with the number of encounters in parenthesis). N.B. Only the encounters by UCC are included in this dataset.

Location	**2013**	**2014**	**All years**
Connemara	11.3 (8)	19.5 (6)	14.8 (14)
Mullet peninsula	19.3 (3)	29 (1)	21.8 (4)
Donegal	39 (2)	44.5 (6)	43.1 (8)
	17.4	30.1	

Habitat use

It is noteworthy that some individual dolphins have been known within the photo-ID archive since 2001, showing that these individuals regularly and repeatedly visit these (and other) coastal sites. Examples of encounter data from 20 repeatedly-sighted individuals are given in Appendix II, and the range of 75 most sighted individuals is presented in Figure 6. Many individuals frequent more than one location in the west/north-west of Ireland, moving between two or three sites within and between years. This may possibly reflect prey distribution, the foraging strategy of these dolphins or other habitat-related preferences (e.g., preferences linked to calving or breeding in the summer months). There is no obvious direction of travel or occupancy (e.g., migration) evident from the data collected in the study area so far; animals appear to move up and down along the coast, remaining within kilometres from the shore and often staying in the same general area for a period of a few days to weeks.

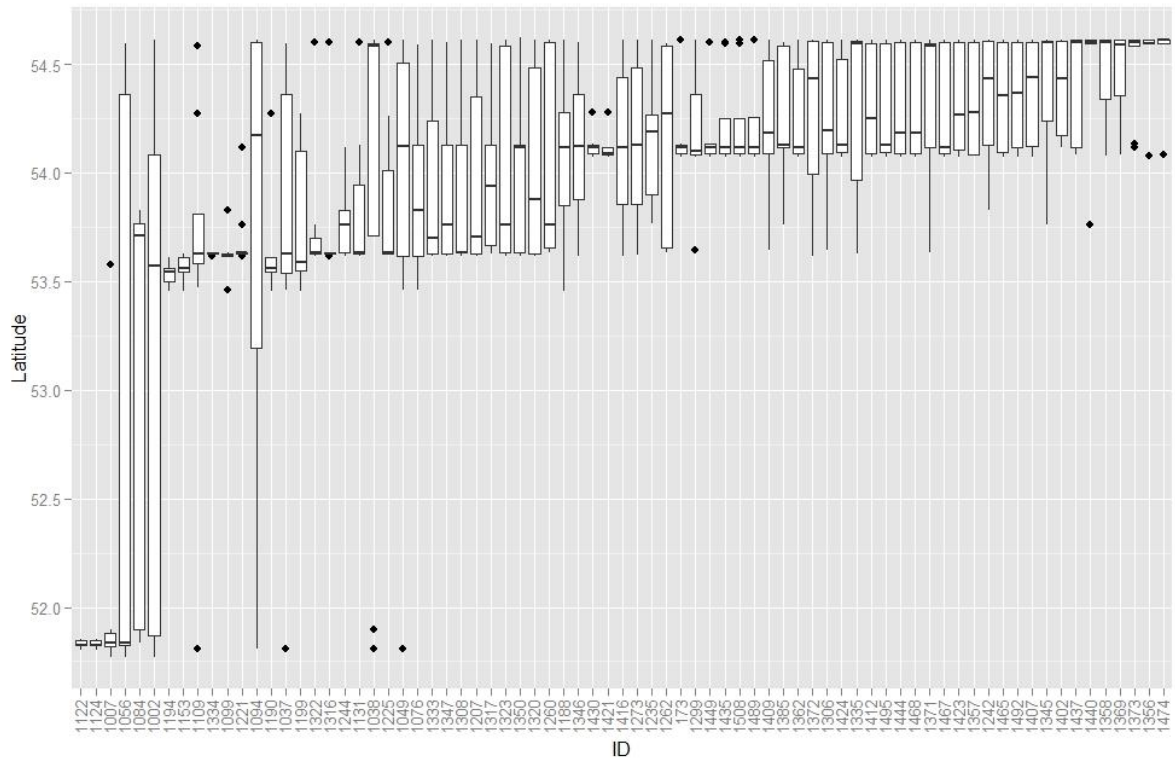

Figure 6. The range of 75 most sighted individually identified bottlenose dolphins. For reference, latitudes below N52° correspond to Co. Cork, around N53.5° to Connemara and around N54.5° to Donegal Bay. Data were collected between 2001-2014, and only individuals sighted at least five times have been included in the figure. The center line and the bottom and top of the box represent the 50th, 25th and 75th percentile, respectively, and the whiskers the 5th and 95th percentile. The dots represent "outliers" in the data. The data are arranged in order of increasing median latitude.

Looking at finer-scale bathymetric/habitat maps, it is clear that the dolphins use relatively shallow waters at all sites, frequently being recorded in waters <25m deep (Fig. 7). To date, the benthic sediment type has been mapped in only a few coastal locations around the west coast of Ireland but at least in the Donegal survey area it would appear that the animals are found in areas with a predominantly sandy seabed substrate.

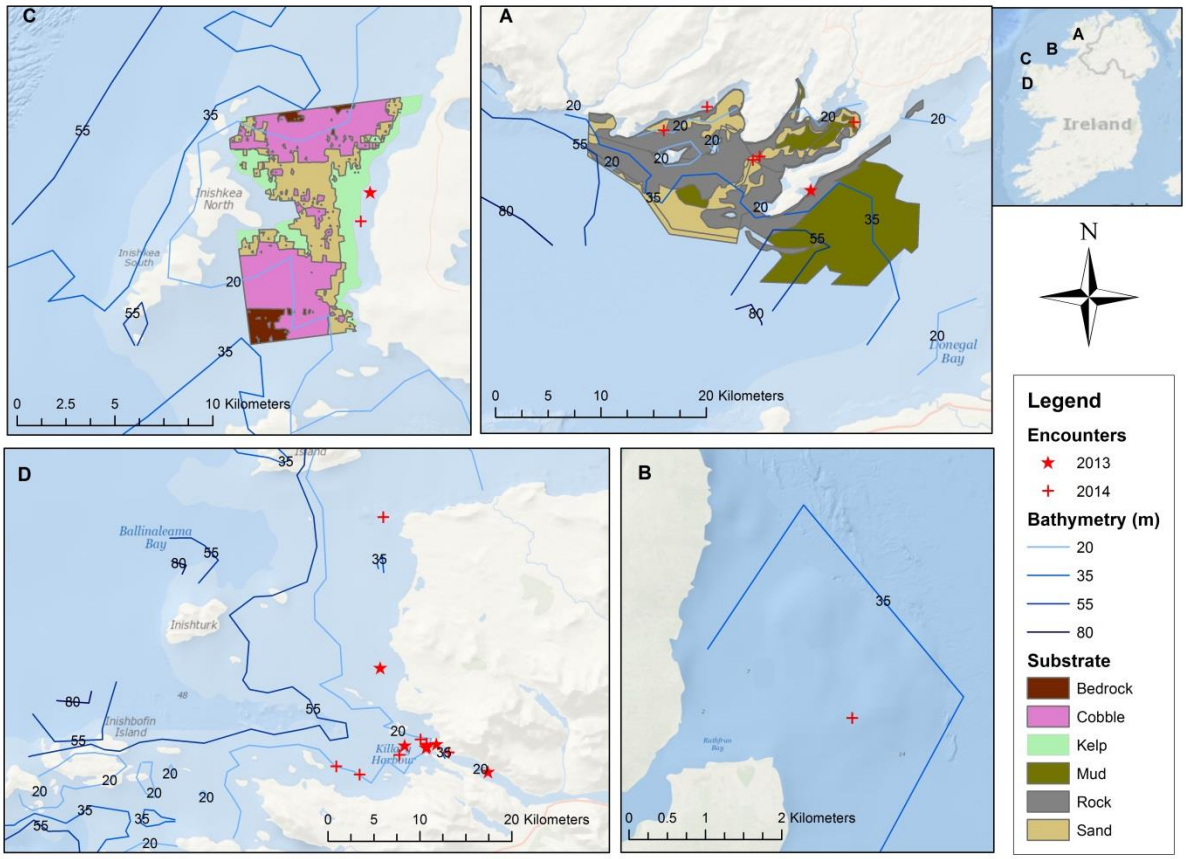

Figure 7. Locations of bottlenose dolphin encounters in 2013 and 2014 in relation to bathymetry and substrate type.

Abundance and movements

In 2013, a total of 101 new identifications (all mark severity grades and all quality grade photos) that could not be matched to the existing photographs in the UCC archive were added in the catalogue; 40 of these identifications were from both sides, 26 from the left side and 35 from the right side only. Twenty five dolphins were definite matches to the archive so these dolphins had been encountered during UCC surveys before 2013, and nine were possible matches to the catalogue. In 2014, 109 new identifications were added in the catalogue, 43 of these being identifications from both sides, 35 from the left side and 31 from the right side only. Of these, 71 identifications were definite matches and seven possible matches to the existing catalogue.

Abundance estimates were calculated on an annual basis. A total of 59 well-marked bottlenose dolphins were selected for the analysis as identified from the high-quality photographs taken in May-August 2013 (Table 4). Unfortunately, our dataset from 2013-2014 was too scarce to formally investigate annual transition probabilities. Nevertheless, fifteen of these 59 individuals (25%) were recorded in more than one of the study areas, with similar numerical overlap between Connemara and Mullet peninsula (i.e., six dolphins), Mullet peninsula and Donegal (i.e., two dolphins) and Connemara and Donegal (i.e., four dolphins). Three out of the 59 well-marked dolphins (5%) were seen in all of the study sites (Table 4). The model averaged Bayesian multi-site abundance median

estimate for the whole study area in 2013 was 145 (CV=0.30; Table 6). This estimate includes both the well-marked, less marked and unmarked individuals.

Table 4. Contingency table showing the count of well-marked bottlenose dolphins present (Y) or absent (N) in each of the study sites Connemara, Mullet peninsula and Donegal in 2013.

Count	Connemara	Mullet peninsula	Donegal
3	Y	Y	Y
6	Y	Y	N
11	N	Y	N
11	Y	N	N
2	N	Y	Y
4	Y	N	Y
22	N	N	Y
NA	N	N	N

From the photo-identifications from May-September 2014, a total of 91 well-marked dolphins were included in the analysis (Table 5). Eight dolphins (9%) were encountered in all of the study areas. The highest overlap in site use was between Mullet peninsula and Donegal with 28 dolphins (31%) sighted in both these areas. Donegal also had the highest number (i.e., 23 individuals) of animals seen in only one of the three study sites. The Bayesian multi-site abundance median estimate of dolphins for the whole study area for 2014 was 189 (CV=0.11; Table 6).

Table 5. Contingency table showing the count of well-marked bottlenose dolphins present (Y) or absent (N) in each of the study sites Connemara, Mullet peninsula and Donegal in 2014.

Count	Connemara	Mullet peninsula	Donegal
8	Y	Y	Y
2	Y	Y	N
13	N	Y	N
6	Y	N	N
28	N	Y	Y
11	Y	N	Y
23	N	N	Y
NA	N	N	N

The average local abundance estimates (derived using the M_{th} method for closed populations) of bottlenose dolphins in Connemara were 56 (CV=0.25) and 83 (CV=0.27) for May-July 2013 and June-July 2014, respectively (Table 6). The average M_{th} estimate for Donegal for August-September 2014 was 143 (CV=0.12). Due to the scarcity of encounters by UCC in the Mullet peninsula, we were unable to derive a local estimate for this area.

Table 6. Model averaged Bayesian multi-site estimates (after Durban *et al*. 2005) and maximum likelihood -based local M_{th} estimates (after Chao *et al*. 1994) of bottlenose dolphin abundance for the summer months of 2013 and 2014.

Method	Area	Year	Total abundance	95% CI	CV	θ
Multi-site	Connemara-Mullet peninsula-Donegal	2013	145*	111-239	0.30	0.55
Multi-site	Connemara-Mullet peninsula-Donegal†	2014	189*	162-232	0.11	0.57
M_{th}	Connemara	2013	56	34-90	0.25	0.63
M_{th}	Connemara	2014	83	49-140	0.27	0.56
M_{th}	Donegal	2014	143	113-181	0.12	0.63

*Median given in the Bayesian multi-site estimates, local M_{th} estimates are averages.
†One encounter in Killala Bay has been included with the encounters in Donegal.

Re-sighting rates of identified dolphins

The re-sighting rate of identified individual dolphins across the whole study area in 2013 varied from 0 to 0.36 with the average rate being 0.06 (where a value of 1 is the theoretical maximum). In 2014 the re-sighting rate was twice as high, averaging at 0.12 and ranging from 0 to 0.45.

The average site-specific re-sighting rate for dolphins identified or identifiable from both sides in 2013 was highest in Donegal (0.44), followed by Connemara (0.09) and it was lowest in the Mullet peninsula (0.01). The average re-sighting rates for 2014 were 0.20 in the Mullet peninsula, 0.15 in Donegal Bay and 0.16 in Connemara (Fig. 8).

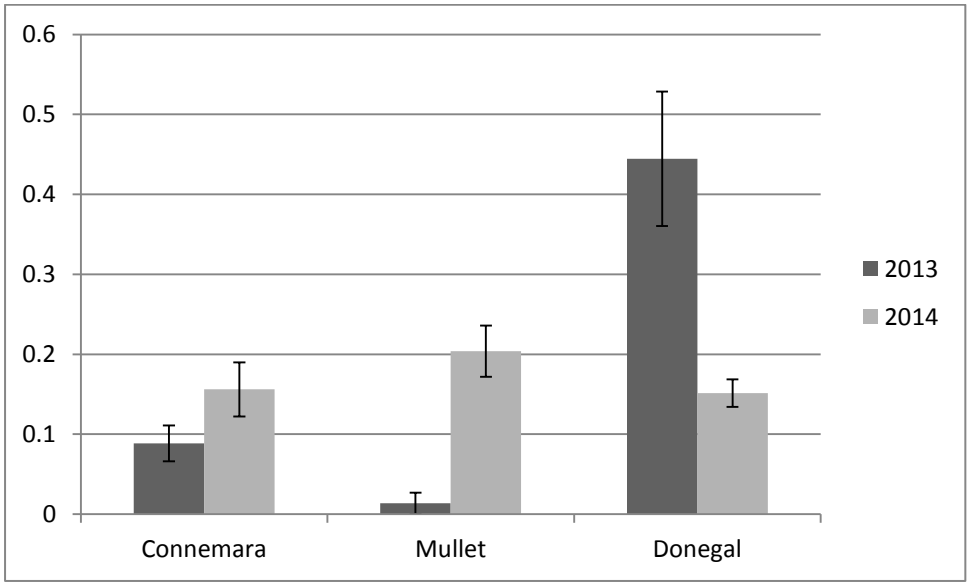

Figure 8. Average re-sighting rate (with S.E.) of dolphins identified/identifiable from both sides from high quality photographs (quality grade 1-3) per site for 2013 and 2014.

The number of individuals photographed in the study area between 2001 and 2014 is presented as a discovery curve in Figure 9. The flattening off of the rate of discovery of previously un-catalogued animals indicates that most individuals occurring within the area have been photographed and archived, with very small numbers of new individuals being added towards the end of the sampling period.

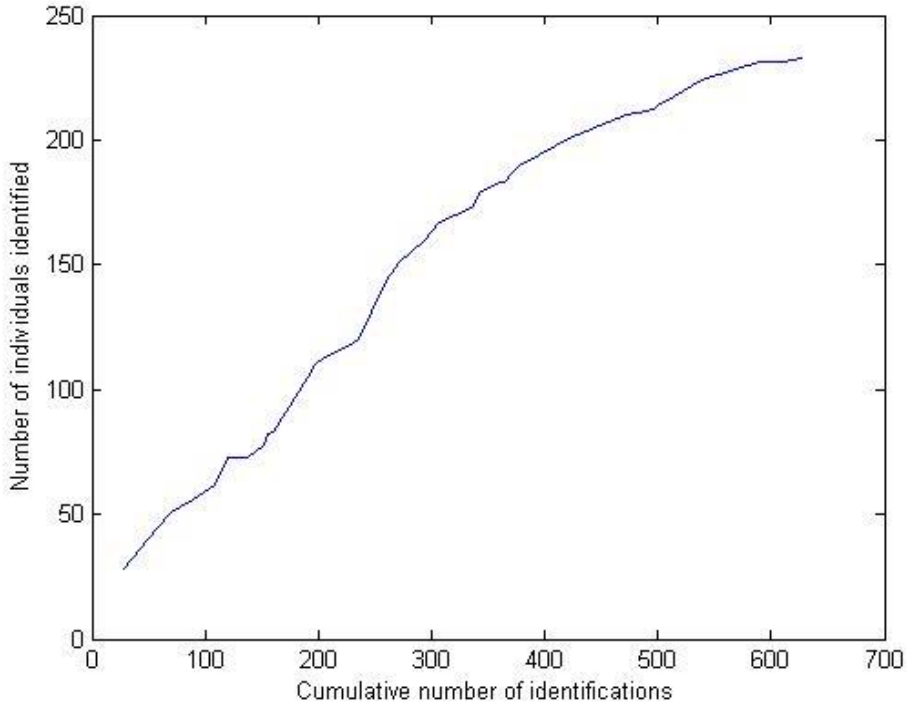

Figure 9. Discovery curve for bottlenose dolphin identifications made in 2001-2014 by UCC researchers. Only well-marked dolphins identifiable from both sides are included in the data.

Social structure

Social analysis using a subset of the combined dataset (i.e., only the well-marked animals that were recorded in three or more encounters) shows a network of mostly loosely associated individuals (Fig. 10) with a large number of small subgroups consisting of only a few individuals with a higher degree of association. The mean association index (AI) of 0.2 (two individuals always seen together would have a mean association index of 1, and two individuals never seen together would have an association index of 0) suggests very little social clustering.

The mean number of associations per individual is 73.5, and this gives further support to the evidence that these mobile individual bottlenose dolphins have a very large number of associates. However, the coefficient of variation of true AIs was 0.510 indicating a well-differentiated social structure with preferred and/or avoided associations so it seems that dolphins within these small groups prefer to associate with certain individuals. No site-specific associations were found for any of these small “clusters” suggesting that there is no strong individual/cluster site fidelity.

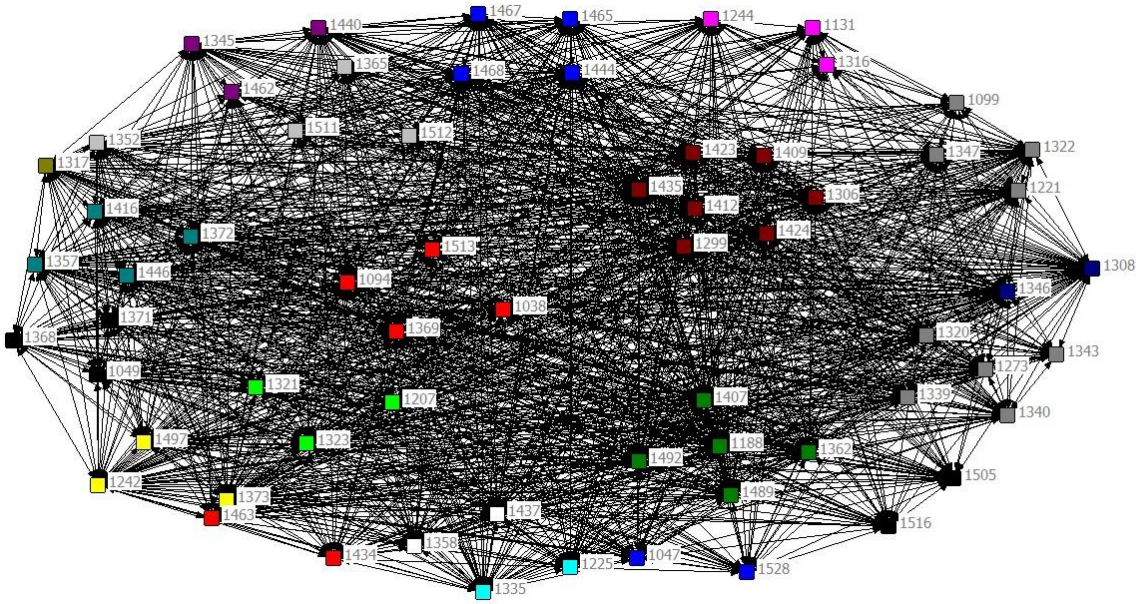

Figure 10. Social network diagram of a subset of well-marked bottlenose dolphins encountered off the west/north-west coast of Ireland in 2013 and 2014. Different colours represent social clusters obtained via analysis with the SOCPROG program. The numbers shown are UCC catalogue ID numbers for individual dolphins and line-length represents how distantly associated the linked individuals are with one another.

Occupancy rate

Detection positive days per month (DPD/month) from the C-POD deployments in Killary Harbour and McSwyne's Bay are presented in Figure 11. Acoustic detections were verified with simultaneous visual observations of bottlenose dolphin schools in the vicinity of the C-POD in McSwyne's Bay on five separate occasions. Two issues arose in relation to C-PODs. One of the C-PODs was stolen from Killary Harbour in June 2014 and so there was a gap in data recording from that period until September 2014. The C-POD in Donegal ran out of batteries on the 25th of December 2013, and due to bad weather we were unable to service it until the 15th of March 2014; hence no echolocation click data were recorded during January and February 2014. Nevertheless, dolphin detections in Donegal seemed to decrease during the winter months with a peak in DPD/month in August, September, October and November 2014. This contrasts with more detections logged in Killary Harbour during January, February and March 2015. It must be noted that the C-POD in Killary Harbour was only recording echolocation clicks for nine days in April 2015 before the retrieval of the data and redeployment of the device.

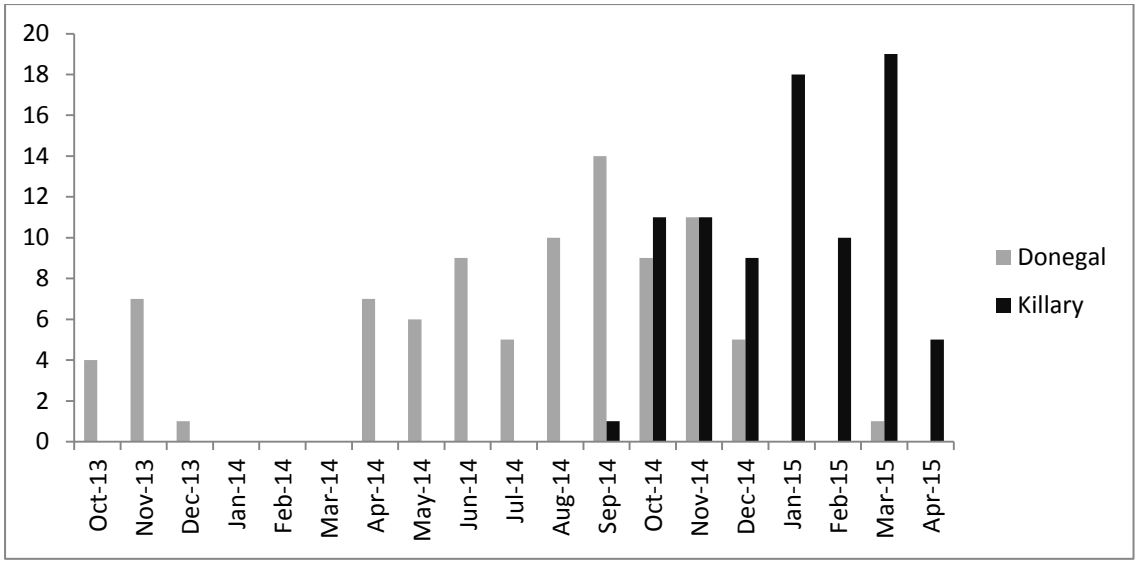

Figure 11. The number of days per month when dolphin echolocation clicks were detected by C-PODs in two sites, McSwyne's Bay, Co. Donegal and Killary Harbour, Co. Galway. N.B. The C-POD in Donegal ran out of battery power in January-February 2014.

Discussion and recommendations

During the two years in which photo-id surveys took place 83 new identifications with photographs obtained from both sides of the animal were added to the catalogue kept by UCC. However, 38 animals were matches to encounters from previous years with ten identifications dating back as far as 2001. Such long term re-identifications and the inter-annual re-sightings indicate that a degree of site fidelity occurs in the west/north-west of Ireland, at least at extended coastal scales. Bottlenose dolphins clearly used the entire study area covered during the two years of survey effort, with nearly half (43%) of all well-marked identified animals sighted in more than one of the three survey blocks during 2013-2014. In addition, the occupancy data from the static acoustic monitoring showed that animals appeared to be present in the monitored areas over periods of weeks or months separated by similarly lengthy absences. This apparently unpredictable habitat use produces patchy temporal site occupancy as individuals and dolphin schools range around the Irish coast and possibly further afield.

The interconnected sociogram derived from shared group membership (Figure 10) clearly shows that the dolphins (identified in three or more encounters) all belong to a single inter-connected social community of animals. This finding supports further the concept of social integration between coastal dolphins as shown by Oudejans *et al*. (2015). Furthermore, the social segregation between coastal and offshore dolphins found by Oudejans *et al*. (2015) together with the genetic findings of Mirimin *et al*. (2012) and Louis *et al*. (2014a) indicate that the areas surveyed are most likely used by a single free-ranging and genetically distinct coastal population.

Abundance of dolphins in NW coastal waters

Of the two years of the study, summer estimates of abundance were far more precise using data collected during 2014 than during 2013 with an overall median multi-site estimate of 189 (CV=0.11, 95% CI=162-232) compared to 145 (CV=0.30, 95% CI=111-239) dolphins. This difference, although not significant, may be due to a combination of environmental, sampling and/or behavioural factors. The total number of surveys, encounters and identifications were higher during 2014 leading to a more comprehensive dataset and the weather was notably better during that summer than in the previous year. However, the difference may also be attributable to differences in the natural ranging behaviour of many of the dolphins in the areas surveyed during the two years due to heterogeneous, patchy and unpredictable changes in seasonal site use or possibly also due to variation in the composition of the population occupying Irish coastal waters from one summer to the next.

The multi-site abundance estimates for the west coast of Ireland are similar to the ones for the East coast of Scotland obtained using the same multi-site method (195 with 95% CI:162–253 in 2006, and 227 with 95% CI: 175–384 in 2007) (Cheney *et al*. 2013), with our 2014 estimate having a slightly smaller confidence interval. Another adjacent community of bottlenose dolphins are found in the Sound of Barra, in the Outer Hebrides, Scotland, but this community is significantly smaller consisting of only 6-15 individuals (Grellier and Wilson, 2003). This group of dolphins is also thought to have high site fidelity with repeated identifications of the same individuals within and between years. Yet another neighbouring semi-resident group of bottlenose dolphins is found in Cardigan Bay, Wales, with mean summer abundance estimates of dolphins using the SAC varying between 70 and 214 in 2003-2007 (Ugarte and Evans, 2006, Pesante *et al*., 2008, Veneruso and Evans, 2012, Feingold and Evans, 2013). These dolphins are known to have a seasonal occupancy in Cardigan Bay during the summer months with the majority of the animals moving northwards in the Irish Sea during winter (Baines *et al*., 2002; Pesante *et al*., 2008). All of the mentioned dolphins (including the ones on the west/north west coast of Ireland) have recently been found to belong to a wider "coastal north" population thus retaining some gene flow between the communities (Louis *et al*. 2014a). This population differs genetically from the much larger but also somewhat nearby "coastal south" population occupying the Normano-Breton Gulf on the west coast of France whose abundance was estimated at 420 dolphins (95% CI: 331–521) in 2010 (Louis *et al*., 2015), making this the largest community of coastal bottlenose dolphins in north-central Europe.

Such patchy and changeable site use by groups of dolphins combined with a far wider spread of survey effort by the research team is likely to at least partly explain why local abundance estimates for Connemara in 2013 (N=56, CV=0.25, 95% CI=34-90) and 2014 (N=83, CV=0.27, 95% CI= 49-140) were much lower than the estimate of 171 (CV= 0.28, 95% CI=100-294) obtained for the same area in 2009 (Ingram *et al*., 2009). Also the large group sizes observed in Donegal, particularly in 2014, and the larger local abundance estimate of 143 (CV=0.12, 95% CI=113-181) might reflect differences in occupancy rates between the different study sites and long distance movements of the dolphins (Appendix I and II); it is certainly possible that whilst encountering smaller groups in Connemara, we may have missed a significant number of animals ranging elsewhere along the west coast of Ireland, hence delivering the lower abundance estimates for the Connemara site in each study year.

The multi-site estimates derived in this study are more similar to the previous estimate for north-west Connemara calculated by Ingram *et al*. (2009) and are likely to better reflect the true abundance of these coastal bottlenose dolphins than the local site-based estimates due to the wider-scale sampling over a larger coastal area. This broader sampling method minimises the repeated inclusion of individuals using multiple sites and also has a lower likelihood of bias due to individual animals spending extended periods within a single site (i.e., there are fewer violations of the 'closed population' assumption). The fact that the sighting rate of individuals was not significantly affected by mark severity coupled with the much higher precision (lower CV of the abundance estimate) gives the 2014 multi-site estimate greater scientific robustness compared to the 2013 estimate.

Ranging behaviour and site fidelity of bottlenose dolphins off the west/north-west

Despite being more precise, the summer estimate for 2013 is lower than that for 2014; this most likely indicates that the dolphins within this population are using an even wider geographic area than is covered by the three existing survey blocks and that some animals encountered during surveys in 2014 were missed or absent in 2013. In fact, we know that these animals range widely. Some of the dolphins that were encountered during surveys in 2013-2014 were previously recorded for example, in Youghal, Co. Cork and in Kenmare, Co. Kerry (see Fig. 6 and Appendix I). Furthermore, a dolphin encountered during a survey in Donegal in the summer of 2014 has also previously been photographed in the Moray Firth in 2001 and around the inner Hebrides in 2004 (Robinson *et al*., 2012). In addition, Cheney *et al*. (2013) found that a large percentage of dolphins (57%) were using more than one study site on the east coast of Scotland; this percentage is higher than in the present study (43%) but this could be a factor of shorter distances between the study sites in Moray Firth and St. Andrews. On the west coast of Ireland the distances are longer with shortest over water distance between Connemara and Mayo of approximately 90km and the longest distance between Connemara and Donegal over 300km.

The discovery curve (Figure 9) and sighting reports to the IWDG from areas well outside the study area indicate that it is likely that a larger number of dolphins may occupy the coastal waters around Ireland. Yet one needs to take into consideration that some of the marks on these animals may have changed considerably throughout the years since 2001, resulting in such animals being classified as 'new' identifications rather than re-sightings due to matching failure over a period of years between encounters. The latter possibility highlights the need for regular and consistent survey effort in the area so that an updated catalogue can be kept with a more precise record of changing marks.

The multi-site survey approach shows that many of these animals are wide ranging, with some inter-annual site fidelity, a feature borne out in previous, more localised work (e.g., Ingram *et al*., 2009; Oudejans *et al*., 2010). These movements may be regional or even trans-boundary. For example, at a regional scale we observed a reduction in the detection of dolphin echolocation clicks by the C-POD in McSwyne's Bay during the winter months with a simultaneous increase in detections by the C-POD in Killary Harbour (Fig. 11). These changes may indicate some degree of regional and/or seasonal movement between the different study areas or over a wider area, although more data are needed (especially from Killary Harbour) before any firm conclusions can be drawn about seasonal or regional patterns in occupancy rates and habitat use. Although the full extent of the ranges of individuals in this population are not known, previous research has shown that at least some of

these animals move over great distances (Ingram *et al*. 2001, 2003; O'Brien *et al*., 2009; Robinson *et al*., 2012, Cheney *et al*., 2013). If these animals comprise part of the "coastal" population defined by Louis *et al*. (2014a), then there is also likely to be trans-national movement of many more individual dolphins than has been reported up to now. As mentioned previously, a number of individuals from the west coast of Ireland have been matched on an *ad-hoc* basis to other existing catalogues but there is a need for a collaborative effort and consistent scientific approach to better compare photo-id catalogues from separate regions/countries (e.g., Wales, Scotland, France, Cornwall) and to better elucidate habitat use, ranging patterns and the numerical abundance of this population. This approach would also facilitate any trans-boundary reporting required under, for example, the EU Marine Strategy Framework Directive.

Habitat use and foraging preferences of bottlenose dolphins in coastal waters of the west/north-west

Very little is known about what drives bottlenose dolphin habitat use or habitat preferences in Irish waters or indeed European waters as a whole. The broad population structuring in the North-east Atlantic Ocean, whereby some individuals are "oceanic" using large areas overlying the continental shelf and slope whereas others appear to use more coastal environments, likely reflects an historical divergence in populations and possibly colonisation events into emerging/available inshore habitats by a more oceanic population after the Last Glacial Maximum (Louis *et al*., 2014b). What maintains the apparent current population "segregation" is unknown but it could reflect differing foraging strategies, feeding specialisations or social composition/structure and/or different cultural development between disparate non-breeding groups. Research is on-going internationally in relation to the feeding preferences and habitat use demonstrated by coastal dolphins. Possible explanatory variables being examined with regard to habitat use include bathymetry, sediment type, distance to river mouths, distance to aquaculture sites and various hydrographic features.

Variation observed in the occupancy rates and seasonal use of the different coastal areas may be related to foraging strategies and prey preferences shown by bottlenose dolphin schools and it would be useful to examine the habitat use by this coastal Irish population in finer detail, including looking at potential prey species and prey availability. At present information on the diet of bottlenose dolphins in the North-east Atlantic is scarce and patchy. A recent paper by Hernandez-Milian *et al*. (2015) examined the diet of bottlenose dolphins found stranded on the west coast of Ireland and showed that the diet comprised a wide range of teleost species including gadoids such as whiting, blue whiting, pollock, saithe and haddock. Flatfish such as plaice, dab and sole, made up a smaller amount of the diet followed by dogfish, conger eel, salmon and horse mackerel. It was not possible to determine the diet of the putative "coastal" and "pelagic" (i.e., offshore) populations separately but the authors noted (a) that the "pelagic" population had prey remains consistent with a wide scale habitat use, including coastal waters and continental shelf and slope areas, and (b) that some individuals appeared to be specialist feeders.

Monitoring Strategy and Recommendations

Monitoring abundance is central to the management of coastal SACs that have been designated for bottlenose dolphins. Whereas other SACs designated for the protection of this species around Ireland and the UK appear to describe a considerable degree of site fidelity in a single confined bay (e.g., Shannon estuary, Sound of Barra, Cardigan Bay, Moray Firth) this west/north-west coast

population clearly does not fit this model and so it represents a novel challenge in designing an effective and robust monitoring strategy. Such a strategy must provide accurate data that will contribute to knowledge of the species' population status and also enable the competent authority to detect, in a timely manner, changes in abundance, population viability and survival rates in order to assess conservation status. The Bayesian multi-site approach used in this study appears to provide the most precise and comprehensive estimate of the abundance of dolphins in the study area. According to Durban *et al*. (2005) the Bayesian multi-site model of abundance takes into account uncertainty from having a sparse data set and also the uncertainty in model selection by weighing the different model probabilities and thus producing a model-averaged estimate. It also accounts for much of the individual heterogeneity in capture probabilities due to movement (similar to the model M_{th} by Chao *et al*., 1992). But individuals are still likely to show different movement and capture probabilities that are not completely captured by the model (Durban *et al*., 2005) so some caution should be taken when interpreting the resulting estimates.

We suggest continued use of the Bayesian multi-site method to monitor the abundance of bottlenose dolphins in the west coast of Ireland. The model produces estimates that have less variability around the point estimation. In addition, multiple discrete locations can be sampled simultaneously and sampling can be done opportunistically using a sightings network. Clearly single site monitoring is liable to miss many animals if they are not using that site during the survey period and resulting estimates will vary and reduce precision as a consequence of animal movements and occupancy rather than due to actual changes in population size.

Based on the findings of this research, until there is a greater understanding of the movements, ranging behaviour and occupancy patterns of these dolphins we do not recommend solely relying on monitoring surveys within the boundary of the West Connacht Coast SAC (i.e., in Connemara and Mullet peninsula only) in order to provide measures of conservation status of this population. We suggest that the work reported here is continued with a more comprehensive combined methodological approach around the entire Irish coast similar to the work in Scotland reported by Cheney *et al*. (2013). Such an approach should use a combination of methods such as static acoustic monitoring, photo-id boat surveys and possibly coastal aerial surveys. Photo-id boat surveys should preferably use more than one mobile field-team based in different parts of the country to maximise the likelihood of encountering dolphins following sightings reports. Capturing and better understanding the entire range of this mobile bottlenose dolphin population will be important not only for monitoring the numbers and movements of these dolphins but also for identifying areas in which they may be threatened by specific anthropogenic activities.

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Go raibh maith agaibh go léir!

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Appendix I: Summary details of bottlenose dolphin encounters in 2013 and 2014.

A. Bottlenose dolphin encounters in 2013.

DATE	LOCATION	LAT	LONG	EST. GROUP SIZE*	MIN. GROUP SIZE*	# CALVES
21/05/2013	Connemara	53.643	-9.938	10-15	10	0
25/05/2013	Connemara	53.632	-9.969	4	4	0
02/06/2013	Connemara	53.713	-9.969	12-15	12	2
03/06/2013	Mullet peninsula	54.279	-9.889	NA	31	0
04/06/2013	Connemara	53.628	-9.869	5	5	0
06/06/2013	Connemara	53.631	-9.892	20	20	4
19/06/2013	Connemara	53.626	-9.862	8-10	7	0
26/06/2013	Connemara	53.614	-9.822	15-20	25	3
08/07/2013	Mullet peninsula	54.122	-10.136	12-15	17	3
09/07/2013	Mullet peninsula	54.077	-10.090	10-12	10	1
13/07/2013	Connemara	53.630	-9.884	7-8	7	1
07/08/2013	Donegal	54.614	-8.405	?	30	4
08/08/2013	Donegal	54.584	-8.425	50	48	6

*Est. group size – estimate of the bottlenose dolphin group size during the encounter. Minimum group size has been derived from identification photographs taking into consideration the likely inability to match the left side of a dolphin with only grade 3 markings (without any nicks) with the correct right side.

B. Bottlenose dolphin encounters in 2014.

DATE	LOCATION	LAT	LONG	EST. GROUP SIZE	MIN. GROUP SIZE*	# CALVES
19/06/2014	Connemara	53.626	-9.863	15-20	18	3
20/06/2014	Connemara	53.634	-9.891	~20	29	3
21/06/2014	Connemara	53.631	-9.885	15-20	20	2
29/06/2014	Connemara	53.613	-9.953	14-16	11	2
30/06/2014	Connemara	53.625	-9.912	~10	12	2
01/07/2014	Connemara	53.763	-9.928	20-25	27	4
27/07/2014	Mullet peninsula	54.129	-10.132	25-30	29	5
20/08/2014	Donegal	54.621	-8.516	~10	9	2
22/08/2014	Donegal	54.614	-8.393	30-40	46	2-3
24/08/2014	Donegal	54.596	-8.471	~80	95	4
26/08/2014	Donegal	54.595	-8.477	~10	10	0
08/09/2014	Killala Bay	54.252	-9.180	12	8	1
12/09/2014	Donegal	54.604	-8.445	~60	71	3
13/09/2014	Donegal	54.608	-8.552	40-50	36	2

*Est. group size – estimate of the bottlenose dolphin group size during the encounter. Minimum group size has been derived from identification photographs taking into consideration the likely inability to match the left side of a dolphin with only grade 3 markings (without any nicks) with the correct right side.

Appendix II: Sighting history for twenty of the most frequently encountered bottlenose dolphins during all years of study by UCC (2001-2014).

	ID #	1049	1188	1407	1424	1409	1495	1099	1299	1306	1323
Location	**Date**										
Connemara	19/09/2002	X									
Connemara	21/09/2002	X									
Cork	27/09/2003							X			
Cork	02/09/2005	X									
Connemara	01/06/2009		X								
Connemara	22/06/2009							X			
Connemara	12/08/2009		X								
Mayo	28/07/2010	X	X								
Mayo	14/10/2010	X									
Connemara	21/05/2013					X			X		
Connemara	02/06/2013	X									
Mullet peninsula	03/06/2013		X	X	X	X			X	X	
Connemara	06/06/2013							X			X
Connemara	26/06/2013	X						X			X
Mullet peninsula	08/07/2013	X									X
Donegal	07/08/2013										X
Donegal	08/08/2013	X									X
Mullet peninsula	27/05/2014			X	X	X	X		X	X	
Mullet peninsula	29/05/2014			X	X	X	X		X	X	
Mullet peninsula	14/06/2014		X		X	X	X		X	X	
Mullet peninsula	15/06/2014		X		X	X	X		X	X	
Mullet peninsula	17/06/2014	X	X	X	X		X				
Connemara	19/06/2014							X			
Connemara	20/06/2014							X			X
Mullet peninsula	21/06/2014		X	X	X		X				
Donegal	26/06/2014		X	X			X				
Connemara	29/06/2014							X			
Connemara	30/06/2014							X			
Connemara	01/07/2014										X
Donegal	22/08/2014		X	X	X	X	X			X	
Donegal	24/08/2014			X			X				X
Donegal	26/08/2014			X							
Killala Bay	08/09/2014					X					
Donegal	12/09/2014			X	X	X			X	X	
Donegal	13/09/2014				X				X	X	
	Total	**10**	**10**	**10**	**10**	**9**	**9**	**8**	**8**	**8**	**8**

	ID #	1347	1444	1489	1508	173	1038	1131	1207	1221	1308
Location	**Date**										
Donegal	10/08/2001						X				
Connemara	19/09/2002							X			
Cork	02/09/2005						X				
Connemara	22/06/2009								X		
Mayo	28/07/2010								X		
Connemara	21/05/2013								X		
Connemara	02/06/2013						X				
Connemara	06/06/2013							X	X	X	X
Connemara	26/06/2013	X							X	X	X
Mullet peninsula	08/07/2013	X									
Connemara	13/07/2013							X		X	
Donegal	07/08/2013						X		X		
Donegal	08/08/2013						X		X		
Mullet peninsula	27/05/2014		X	X	X	X					
Mullet peninsula	29/05/2014		X	X	X	X					
Mullet peninsula	14/06/2014		X	X	X	X					
Mullet peninsula	15/06/2014		X	X	X	X					
Mullet peninsula	17/06/2014	X		X	X	X		X		X	X
Connemara	19/06/2014	X						X		X	
Connemara	20/06/2014	X						X			X
Mullet peninsula	21/06/2014			X	X	X					
Connemara	22/06/2014	X								X	
Donegal	26/06/2014			X		X	X				
Connemara	01/07/2014									X	
Mullet peninsula	27/07/2014	X					X	X			X
Donegal	22/08/2014		X	X	X						
Donegal	24/08/2014		X		X						
Killala Bay	08/09/2014		X								
Donegal	12/09/2014	X	X								X
Donegal	13/09/2014										X
	Total	**8**	**8**	**8**	**8**	**7**	**7**	**7**	**7**	**7**	**7**