Discrete or not so discrete: long distance movements by coastal bottlenose dolphins in UK and Irish waters

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ABSTRACT

The potential for long distance movements in common bottlenose dolphins (*Tursiops truncatus*) from six UK and Irish study sites was examined using photographs of natural markings. Here we provide the first evidence for long-term re-sightings between the Moray Firth, Inner Hebrides and across international borders to the Republic of Ireland as determined for eight individuals over a ten year period from 2001 to 2010. Minimum dispersal distances of up to 1,277km were resolved providing a new distance record for the species in European waters. Although none of the sightings were made within protected areas, several were made in waters used by animals from a Special Area of Conservation (SAC) revealing some evidence for connectivity between areas previously regarded as discrete. Our findings highlight the need to mitigate broader-scale anthropogenic impacts affecting these dolphins across multiple sites throughout their coastal range. Accordingly, we underline the importance of developing wider conservation measures for this species in UK and Irish waters, but particularly in prospective corridor areas potentially linking designated SACs in the Moray Firth, Cardigan Bay and Shannon Estuary.

KEYWORDS: COMMON BOTTLENOSE DOLPHIN; MOVEMENTS; PHOTO-ID; MONITORING; MANAGEMENT PROCEDURE; CONSERVATION

INTRODUCTION

The analysis of ranging patterns in cetaceans is central to our understanding of their ecology, dynamics, social structure and the evolutionary trajectory of populations. Knowledge of an individual's use of space and habitat may be used, for example, to identify residency and territoriality (Stevick *et al.*, 2002), but can also provide important insights on the spatio-temporal distribution of available resources (Frantzis *et al.*, 2011; Silva *et al.*, 2008; Stevick *et al.*, 2006) and the sensitivity of a species to impending threats. Whilst animals living in sheltered coastal locations often display a high degree of fidelity for selected areas, seasonal fluctuations in numbers nonetheless occur (Berrow *et al.*, 1996; Martin *et al.*, 1984; Wilson *et al.*, 1997) and individuals classified as 'resident' in dedicated local-scale studies may in fact range over much wider geographical areas than previously recognised (e.g. Bearzi *et al.*, 2010; Pesante *et al.*, 2008; Ryan and Berrow, 2011; Stevick *et al.*, 2010), with subsequent implications for their welfare and management.

Examination of the spatial distribution of genetic diversity has proved invaluable for identifying population subdivisions indicative of geographically-isolated, demographically-independent communities (Moritz, 1994). For fragmented coastal concentrations of common bottlenose dolphins (*Tursiops truncatus*) in the United Kingdom (UK) and the Republic of Ireland, this has contributed to the creation of Special Areas of Conservation (SACs) for the species under the European Habitats Directive (92/43/EEC) in the Moray Firth in northeast Scotland, Cardigan Bay in Wales and the Shannon Estuary in Ireland. With over two decades of research, the Moray Firth represents the longest studied of these populations, yet our current knowledge of the broad-scale distribution, abundance and structure of these North Sea dolphins is still poorly understood (Thompson *et al.*, 2011). No individual matches of known, photo-identified animals have previously been reported between the Moray Firth and other established populations in the UK or Ireland (Grellier and Wilson, 2003; Mandleberg, 2006; O'Brien *et al.*, 2010; Pesante *et al.*, 2008) and the degree of individual and genetic mixing is thought to be low for this population (Parsons *et al.*, 2002). Nevertheless, excursions of up to 650km have been documented for the species in both UK and Irish waters (O'Brien *et al.*, 2010; Pesante *et al.*, 2008; Wood, 1998) and Ryan *et al.* (2011) identified a re-sighting between Cork Harbour in southern Ireland and Cornwall in southwest England. Individuals from the Moray Firth also range far beyond the boundaries of their designated SAC (Wilson *et al.*, 2004): throughout the larger, outer firth region (Armstrong, 2010; Culloch and Robinson, 2008; Robinson *et al.*, 2007), along the Aberdeenshire coastline to St Andrews Bay in Fifeshire (Stockin *et al.*, 2006; Wilson *et al.*, 2004) and even further south to Northumberland in northern England (Thompson *et al.*, 2011). Given these observations, it is likely that longer distance movements also

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occur. However, isolated, localised studies inherently overestimate site fidelity (e.g Koenig *et al.*, 1996) and have thus-far provided a poor basis for detecting individual ranging patterns over extended distances and time.

Broad scale approaches are evidently required to better understand the ranging behaviour of UK and Irish bottlenose dolphins, and in the present study photo-identification records were examined from six UK and Irish regional study sites to investigate the extent at which individuals could be detected between areas. Here we document the first evidence for consistent, long distance movements by coastal bottlenose dolphins between the Moray Firth, Inner Hebrides and across international borders to the Republic of Ireland.

METHODS

Photographs of natural markings were used to identify individual bottlenose dolphins (Würsig and Würsig, 1977). Collections held by eight organisations in the UK and Ireland were compared from six regional study sites to identify re-sightings. In Scotland, photo-archives were examined from the Cetacean Research and Rescue Unit (CRRU), University of Aberdeen Lighthouse Field Station (AULFS) and the Hebridean Whale and Dolphin Trust (HWDT); with CRRU and AULFS catalogues being pooled to create a composite catalogue for the larger Moray Firth and northeast Scotland region, including the Grampian and Fifeshire coast. In Ireland, records from the Galway-Mayo Institute of Technology (GMIT), Irish Whale and Dolphin Group (IWDG) and the Shannon Dolphin and Wildlife Foundation (SDWF) were contributed in the form of a collective Irish Coastal Bottlenose Dolphin Catalogue (currently maintained by the National Biodiversity Data Centre), with additional catalogues being respectively provided by Dúlra Research and the Coastal and Marine Research Centre (CMRC), University College Cork. The locations of the respective study areas for each of these collaborating institutions are shown in Fig. 1.

For each of the selected archives, only individuals exhibiting prominent dorsal edge marks (distinctive pronounced nicks, notches and/or anomalies in the trailing edge of the dorsal fin allowing their recapture over appropriate spatial and temporal scales) were used in the

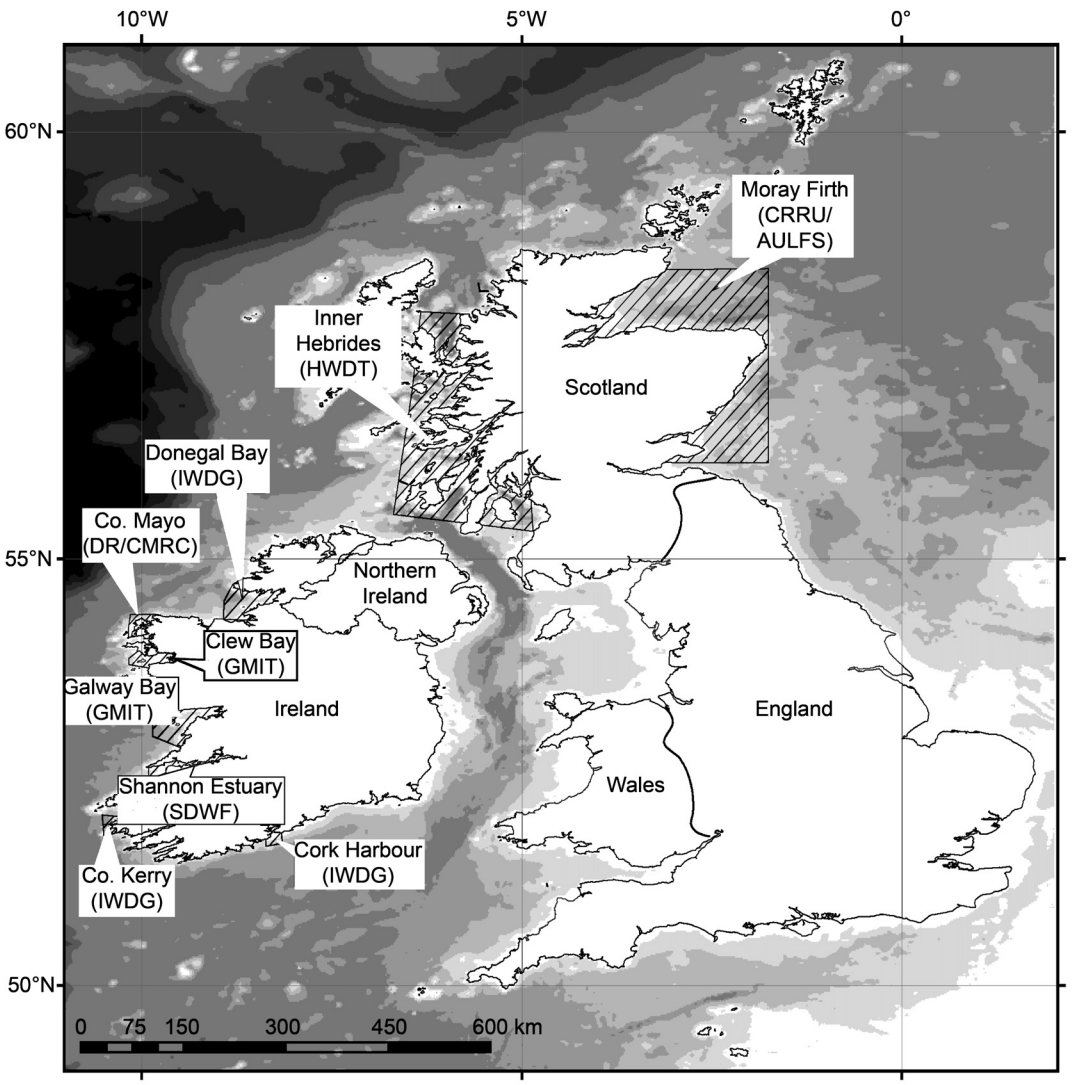

Fig. 1. Map of the UK and Ireland showing the locations of the respective study areas and collaborating research groups from whom photo-identification data and images were contributed. CRRU = Cetacean Research and Rescue Unit; AULFS = University of Aberdeen Lighthouse Field Station; HWDT = Hebridean Whale and Dolphin Trust; GMIT = Galway-Mayo Institute of Technology; IWDG = Irish Whale and Dolphin Group; DR = Dúlra Research; CMRC = Coastal and Marine Research Centre; and SDWF = Shannon Dolphin and Wildlife Foundation.

subsequent qualitative analysis. In total, 118 'marked' individuals were selected from the combined Moray Firth dataset (from 1989 to 2010) for cross-comparison, 23 from the Hebrides (2001 to 2010) and 138 animals from Ireland (1993 to 2010). The best (and most recent) right and left dorsal images for each individual were subsequently extracted for automated comparison using the fin-matching programs *FinEx* and *FinMatch*™ (developed for Europhlukes by CWI, Amsterdam) according to the method outlined by Culloch *et al.* (2005). *FinEx* allows single or multiple combinations of dorsal edge mark extractions to be queried from the catalogues, permitting the user to search for animals that may have acquired new marks over time. Although time consuming, once all extractions had been made, the software provided a useful tool for the organisation, ranking and retrieval of the selected animals thereafter. However, user discretion, experience and an in-depth knowledge of the study animals remained of utmost importance in the confirmation of each computer-made match. Accordingly, positive matches were subsequently only agreed upon for individuals exhibiting definitive multiple dorsal edge marks which could be confirmed by at least two lead researchers from their respective datasets. Those animals displaying only subtle or single edge marks, which could potentially be misinterpreted as a false-positive match, were therefore dismissed.

The ranges of recaptured animals, subsequently identified in the analysis were determined thereafter using *Garmin MapSource*® (after O'Brien *et al.*, 2010). The total dispersal distance was calculated as the shortest route by sea (avoiding land) between the two most distant sightings positions. Routes travelled were then plotted in a Geographic Information System using *ArcGIS v.10* (Environmental Systems Research Institute, USA).

RESULTS

A total of 21 recaptures representing eight adult bottlenose (seven females and one male) were identified from the Moray Firth, Hebridean and Irish catalogues (Fig. 2). Gender was determined from observations of the genital slits and/or, in the case of females, from repeated associations with dependent calves (after Grellier *et al.*, 2003). Seven matched adults (assigned identities *Tt*_01 to 07) were identified between the Moray Firth and the Hebrides, of which five were subsequently recaptured in Ireland (Table 1). An additional individual (*Tt*_08) was recorded in the Moray Firth in 2001 and Ireland in 2010.

Individuals *Tt*_01 to 08 were first recorded in the outer Moray Firth, outside the SAC on 10 July 2001, within a mixed-gender group of 21 animals. Additional sightings of the same core group were subsequently made in the area over the following two weeks, on 14, 17 and 23 July. Accordingly, ten marked adults (including seven identified females with calves), one unmarked adult (also with calf, taking the total number of calves to 8), an unmarked sub-adult and a juvenile were noted. No previous or subsequent records of these animals were found in the Moray Firth archive. However, animals *Tt*_01, 03, 06 and 07 were recaptured over 452 kilometres away in the Hebrides, near Mull on 2 August 2002. Further recaptures of *Tt*_01 to 07 were identified thereafter from Skye and Mull in May, June and August 2004 and September and October 2005 respectively (Table 1). During this period, no additional sightings of these individuals were recorded from any other site.

Just one individual (*Tt*_01), the only adult male, was recorded in the Hebrides post 2005, with sightings confirmed from Gairloch, Skye, Mull, Kintyre and the Small Isles in 2006, 2008 and 2009 (Fig. 3). No further sightings of female *Tt*_02 were detected post 2005, but individuals *Tt*_03 to 08 were subsequently recorded in Ireland from 2006 onwards. *Tt*_03 to 06 were first recorded on 26 March 2007 in Galway Bay, some 530km from the Hebrides by the shortest coastal route. Further sightings of *Tt*_03, 04 and 05 were respectively made in Cork Harbour, County Kerry and Donegal Bay in 2008. In addition, *Tt*_08 was resighted for the first time outside the Moray Firth in Broadhaven Bay, County Mayo in June 2009 in the company of *Tt*_03 and 04. Individuals *Tt*_04, 06, 07 and 08 were further recorded in County Mayo between March and July 2010, although *Tt*_04 was also identified in Galway Bay on 15 June 2010. *Tt*_05 was later sighted in Blacksod Bay and Broadhaven Bay, County Mayo in September 2010 in the company of *Tt*_03, 04 and 06 (Table 1). No matches were established from the Shannon Estuary SAC, despite its close proximity to Galway Bay and the consistently high survey effort maintained at this site over 16 years.

Table 1

Sightings and recapture records for the eight bottlenose dolphins (*Tt*_01 to 08) recorded from the Moray Firth, Inner Hebrides and/or the Irish coastline respectively. Numbers in the monthly columns indicate the total recaptures recorded.

		2001			2002			2003			2004				2005			2006			2007			2008			2009							2010					
ID	Gender	J	J	A	J	A	S	J	A	S	M	J	J	A	A	S	O	J	A	S	M	A	M	M	J	J	A	J	F	M	J	S	O	M	A	J	J	A	S
*Tt*_01	M		4			1													1						1								1						
*Tt*_02	F		4									1		2		1																							
*Tt*_03	F		4			1					1	1		2		1					1‡			1†							5*	1*						1*
*Tt*_04	F		4								1	1		2		1	1				1‡					2#+	1+				4*	1*		1*		1+		1*	1*
*Tt*_05	F		4									1		2		1					1‡					1+						1*			1*				1*
*Tt*_06	F		4			1					1	1		2		1	1				1‡						1*											1*	1*	1*
*Tt*_07	F		2			1						1		1																								1*	
*Tt*_08	F		2																												2*			1*			1*		

Moray Firth (MF).
Inner Hebrides (HB).
Ireland (IRL) – ‡Galway Bay, †Cork Harbour, +Donegal Bay, #County Kerry, *County Mayo.

Total dispersal distances ranged from 487 to 1,277km with a mean distance (±SD) of 870 ±257km. The respective sightings positions for individuals *Tt*_01 to 08 and the routes travelled between sightings are shown in Fig. 3. Occurring over a 10-year interval, this figure illustrates the appreciable geographic range travelled by these individuals from the Moray Firth, to the west coast of Scotland, to the southwest and northwest of Ireland.

DISCUSSION

The long distance movements reported here demonstrate the wide-scale ranging behaviour and multiple area use of individual bottlenose dolphins in UK and Irish waters. The work further demonstrates the power of photo-identification as a monitoring tool for the long-term evaluation of ranging patterns in these animals. Residency within a population or community is typically defined by the repeated occurrence of a known individual in a given area over many years (Wells, 2003). Yet this description does not necessarily imply permanent or year-round presence, as seasonal migrations (e.g. Bearzi *et al.*, 2010; Wilson *et al.*, 1997) and intermittent range shifts evidently occur as documented herein. At just over 20 years, however, even the longest term study of bottlenose dolphins in UK and Irish waters is equivalent to less than one generation for the species, which inevitably limits the chances of detecting such movements over time. Furthermore, the detection of age groups most likely to disperse would be constricted by the lack of markings in

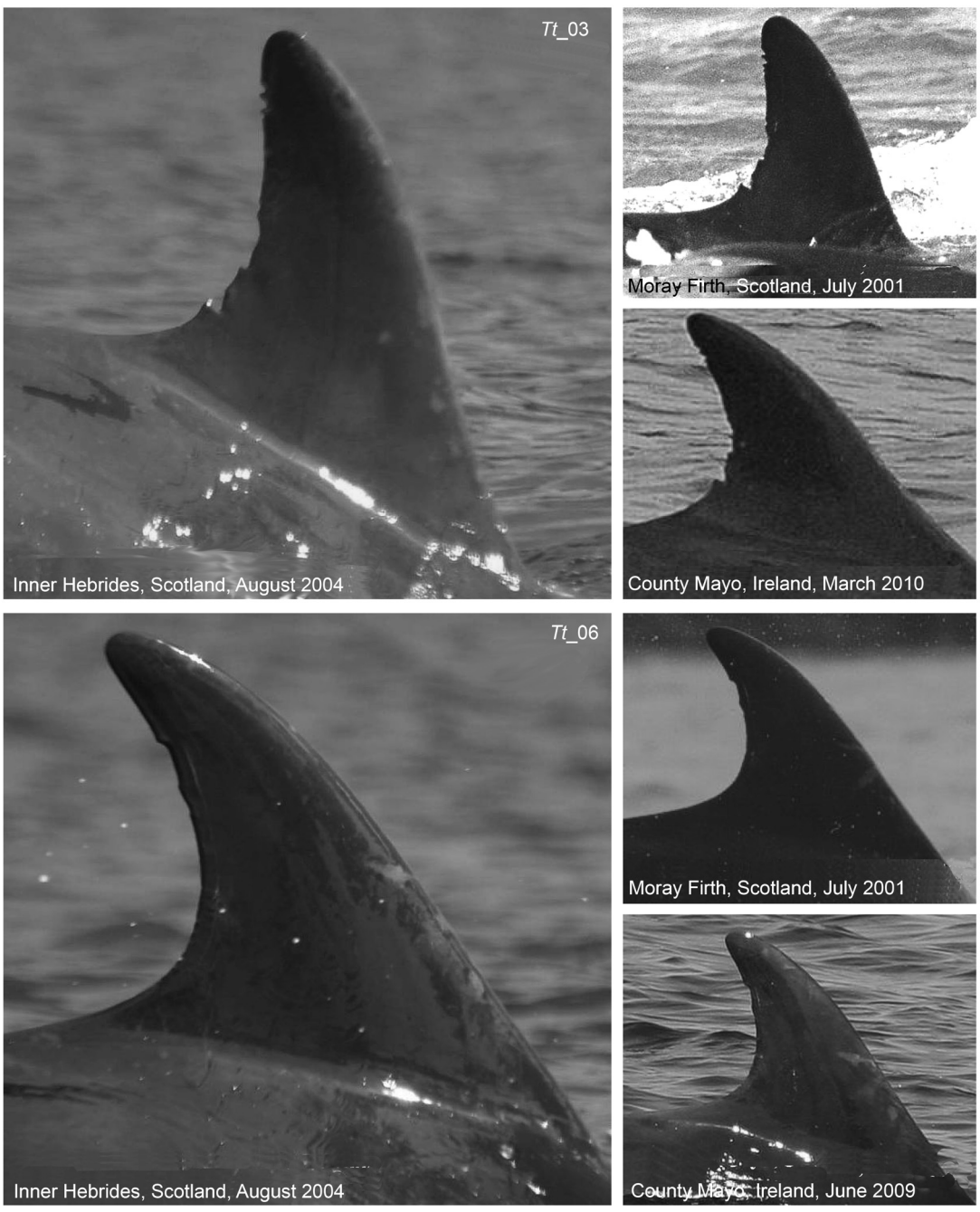

Fig. 2. Showing the dorsal profiles of two of the distinctively marked bottlenose dolphins recaptured in this study, from the Moray Firth, Inner Hebrides and coastline of Ireland respectively. Both individuals, referred to as *Tt*_02 and *Tt*_06 in Table 1, were photographed over a 10 year period between 2001 and 2010 inclusive. The unique dorsal edge features facilitating their recapture remained unchanged throughout this period. Photo credits: HWDT, CRRU, Dúlra Research, CMRC.

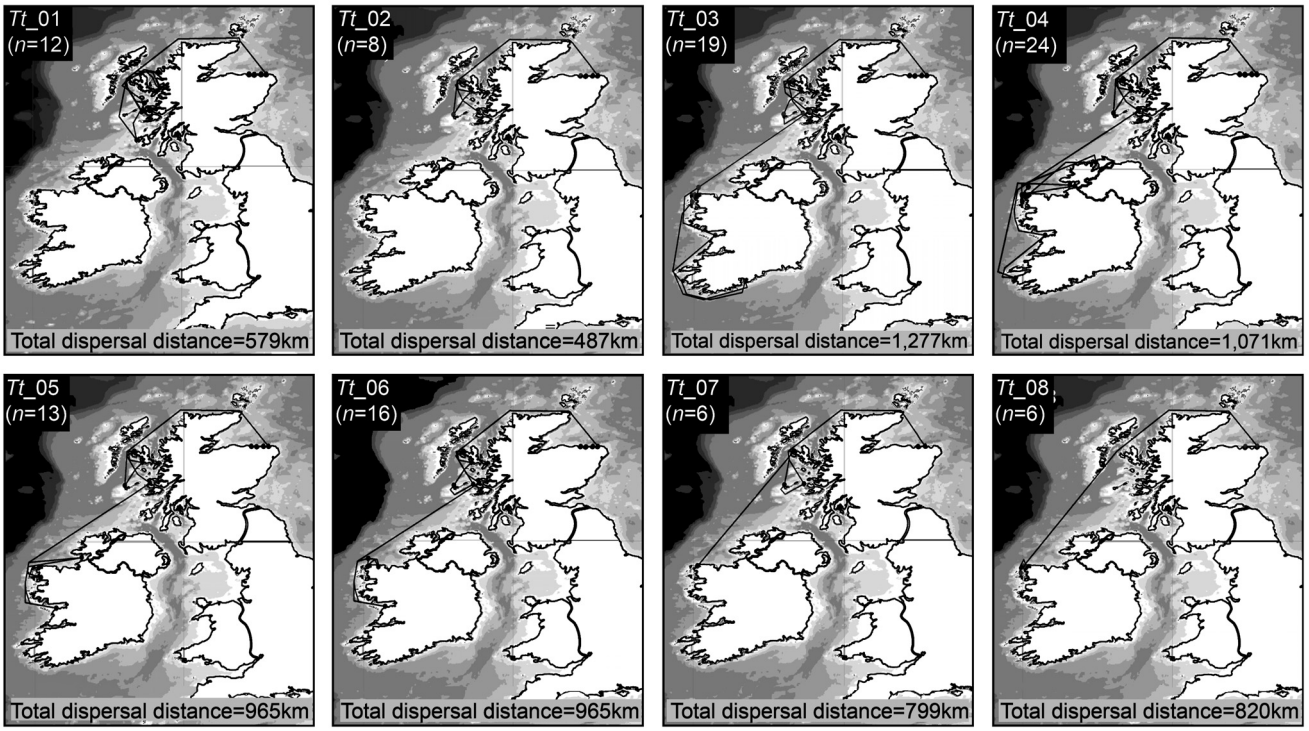

Fig. 3. Showing the re-sightings positions of the eight bottlenose dolphins (*Tt*_01 to 08) identified in the present study from the Moray Firth, Inner Hebrides and Irish coastline and the respective routes travelled between sightings. *n* = the total number of re-sightings for each individual. The total dispersal distances were calculated as the minimum distance by sea between the two furthermost sightings points.

younger animals for photo-identification (Grellier and Wilson, 2003). Nevertheless, the ranges of up to 1,277km documented in this study provide a new distance record for the species in European waters and the very first confirmation of individual exchange between previously considered discrete populations in the UK and Ireland.

Whether or not such movements signify social or genetic exchange between geographically-discrete populations using protected areas remains unclear in this evaluation. However, the eight animals first identified in the outer Moray Firth were only observed in this area for a period of weeks and, given the relatively high level of sampling effort in these waters, they were evidently not part of the core population as recorded during the last two decades (Culloch and Robinson, 2008; Lusseau *et al.*, 2006; Wilson, 1995). Moreover, photo-identification studies on the west coast of Scotland only began in 2001, so it was not possible to determine whether the individuals identified in this study had been present around the Hebrides prior to this time. Incidentally, none of these animals were detected from the collective Irish records from 1993 to 2006, but more limited research efforts outwith the Shannon Estuary in these years would have had restricted potential to detect these. O'Brien *et al*. (2010) also compared their Irish data with those from Cardigan Bay in Wales and found no matches between these areas. Though remarkably, one of the identified individuals from this study (female *Tt*_03) was verified off the southwest of England by Wood (1998; Fig. 2a) in the mid 1990s. This animal was also documented by O'Brien *et al.* (2010) in Galway Bay, Ireland in 2008 (ID GB20), although the link with Wood (1998) was not established in this report. Nevertheless, the successive identification of *Tt*_03 in the extreme northeast of Scotland in 2001 (some 1,218km by sea from southwest England via the Bristol Channel and Scottish west coast) and in Irish waters thereafter (as also reported by Ryan *et al.*, 2011) evidently illustrates the vast distances over which these delphinids may journey.

The movements identified, between the Moray Firth, Inner Hebrides and Ireland between 2001 and 2010, suggest a progressive, directional passage from east to west coasts with detected short-term residency on the west coast of Scotland from 2002 to 2005 and along the Irish coastline from 2007 to 2010. However, photo-identification effort along the west coast of Scotland and in Irish coastal waters was relatively low during this period, and we cannot be certain these individuals did not also range into other areas as well. Nevertheless, in both regions the recaptured dolphins were exclusively recorded over several years and often in association with other individuals that were observed repeatedly in these areas over many years. With the exception of one individual that was recorded in the Hebrides post 2005, the latter incursion of coastal Irish waters resulted in an apparent desertion of the former Hebridean site by these same individuals. A similar abandonment of a coastal area commonly-used by bottlenose dolphins was noted by Tregenza (1992) in Cornish waters during the 1970s and 80s, although reoccupation of these waters was subsequently reported by Wood (1995) in the early 1990s.

Whether due to regime shifts, breeding access or as a consequence of changes in water temperature or food availability (Hansson, 1991; Wells *et al.*, 1990), the existence of long-range movement patterns by individual dolphins is consistent with recent genetic findings for UK and Irish bottlenose populations reporting a weak genetic structure eroded by occasional dispersal (Mirimin *et al.*, 2011; Thompson *et al.*, 2011). Although none of the determined

sightings were made within protected areas, several were made in waters known to be used by individuals also occupying the adjacent SAC (Thompson *et al.*, 2011). These data indicate that wide-ranging individuals may serve an important function by increasing gene flow between established populations for which SACs have been designated, thereby increasing the viability of biological coastal populations as a whole. That said, a recent report by Mirimin *et al*. (2011) suggests that bottlenose dolphins in the Shannon Estuary may be genetically distinct from other putative populations, and this evidently requires further investigation.

It is further possible that some of the movements observed in this study could have involved animals from alternative offshore populations. Whilst studies in the northwest Atlantic infer that nearshore versus offshore bottlenose dolphins are ecologically and genetically discrete (Hoelzel *et al.*, 1998), little is known of the relationship between these recognised populations in UK and Irish waters. Offshore surveys estimate approximately 5,700 bottlenoses (95% CI: 2,900 and 11,100) north of 53 degrees latitude in waters greater than 200 metres (CODA, 2009) compared to just four to five hundred in Scottish and Irish coastal regions combined (Berrow *et al.*, 2010; Thompson *et al.*, 2011). Thus, if exchanges between offshore and inshore populations predictably occur, as intimated by Thompson *et al*. (2011), then contemporary coastal populations from the UK and Ireland might be appreciably larger than currently recognised.

The European Habitats and Species Directive (92/43/EEC) requires that all cetacean species must be strictly protected and the primary means of achieving this for bottlenose dolphins has been to develop a network of SACs through which protected areas have been established around key habitats with relatively high densities of animals (Hoyt, 2005). However, at the same time it is recognised that site protection alone is largely inadequate for highly-mobile, wide-ranging animals (Parsons *et al.*, 2007) and hence the Directive affords further protection to individuals from core populations when outside current SAC boundaries. The long distance movements reported in this study consequently reinforce the importance of developing these wider conservation measures. Indeed, evidence for connectivity between previously considered discrete SACs for bottlenose dolphins is reassuring, as a key principle underlying the Habitats Directive is to develop a linked network of protected sites for the species.

Our findings highlight the need to mitigate broader-scale anthropogenic impacts potentially affecting these delphinids across multiple sites throughout their coastal range. Clearly not all individuals provide the same value or function to the structure of a population and wider conservation measures are undoubtedly required to inform appropriate management actions to protect identified transient animals behaving as reproductive units between established core communities. Indeed, the loss of individuals potentially linking UK and Irish SAC strongholds might have serious repercussions for the long-term viability of biological population(s) in these and adjacent European waters. Therefore, careful consideration needs to be given to the future conservation of these animals, including the determination of further research requirements and, perhaps, a wider examination of photo-archives from neighbouring European countries such as France, Portugal and Spain.

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