Foraging ranges of northern gannets *Morus bassanus* in relation to proposed offshore wind farms in the UK: 2011

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Gannets at Bempton Cliffs, note antenna of tagged adult, top centre

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ABSTRACT

In 2011, thirteen adult northern gannets (*Morus bassanus*) from Bempton Cliffs, on the northeast coast of England, were fitted with satellite tags to investigate their foraging ranges during chick-rearing and early post-breeding periods. This was the second year such a study had been undertaken on gannets from the Bempton Cliffs nesting colony, which is a technically challenging site to work at. In particular, we were interested in finding out the likelihood of overlap with potential development zones for offshore wind energy generation in the North Sea. Locations of tagged birds during chick-rearing coincided with the Hornsea offshore wind energy zone in particular, with some birds recorded on Dogger Bank and one in the East Anglia zone, and a few recorded locations within the Greater Wash strategic area for wind energy generation. Post-breeding locations overlapped in particular with the Hornsea and East Anglia zones before dispersal out of the southern North Sea or cessation of recording. The two seasons of study, in 2010 (n=14) and 2011, have increased our understanding of the locations of Bempton gannets at sea. This report presents preliminary result for 2011 chick-rearing and early post-breeding periods, together with an initial comparison of results from 2010 and 2011 chick-rearing periods, which show a marked similarity in the sea area used. Relatively small samples mean that we remain unsure just how representative the data are of foraging activity by breeding gannets from year to year, in particular in less favourable conditions. A third season of data collection is underway in 2012.

Keywords: gannet, wind energy, satellite telemetry, chick-rearing, post-breeding

BACKGROUND

The European Union Renewable Energy Directive target requires the UK to meet 15% of its energy supply from renewable sources by 2020 (Directive 2009/28/EC). This is equivalent to 35–45% of electricity and places heavy reliance on wind energy for its delivery, requiring a substantial increase over the current 6.8 GW installed capacity (RenewableUK, www.bwea.com, accessed 30 August 2012). Estimates vary as to the exact scale of expansion needed, but it is generally thought that onshore wind generation will need to increase to 13–15 GW by 2020, and offshore wind generation to 25–30 GW installed capacity during the same period (DECC 2011). In response to these ambitious targets, there has been an order-of-magnitude increase in potential offshore wind energy projects, in particular the large proposed Round 3 development zones (Figure 1), initiated by The Crown Estate (2012, http://www.thecrownestate.co.uk/ accessed 21 June 2012).

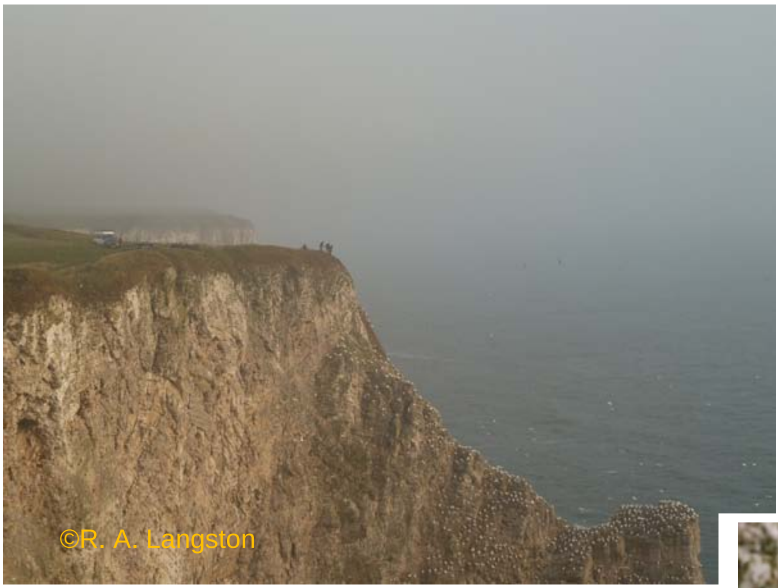
Britain and Ireland are of outstanding international importance for their breeding seabirds and migratory waterbirds, for which they host a high proportion of the biogeographical populations of several species, especially breeding Manx shearwater *Puffinus puffinus*, northern gannet *Morus bassanus* (hereafter, gannet), great skua *Catharacta skua* and lesser black-backed gull *Larus fuscus* (Mitchell *et al.* 2004). Several proposed offshore wind energy development zones lie within the expected foraging range of breeding seabirds from the Flamborough Head and Bempton Cliffs Special Protection Area (SPA), notably for gannets, for which studies from the Bass Rock indicate regular foraging ranges in excess of 100 km (eg Hamer *et al.*, 2007). The foraging areas used by gannets from Bempton Cliffs were unknown prior to 2010 (Langston & Boggio 2011). Breeding gannets are central place foragers (Grémillet *et al.* 2006). Consequently, their foraging ranges are likely to be most constrained when provisioning growing chicks, although they can still cover large distances during this period.

There were estimated to be approximately 261,000 Apparently Occupied Nests (AON) of gannets in Britain and Ireland (218,500 in the UK) when the last complete census was carried out in 2003/04 (Wanless *et al.* 2005). The gannet is amber-listed on the Birds of Conservation Concern (BoCC, Eaton *et al.* 2009). There has been a consistent rise in world population of northern gannets throughout the period since regular censuses began in 1900, of 2% *per annum*. Head and Bempton Cliffs SPA (hereafter, Bempton/ Bempton Cliffs) is the only breeding colony in England for gannets, with 7,859 nests in 2009 (http://www.jncc.gov.uk/page-2875, accessed 29 May 2012). The steady rate of increase at Bempton Cliffs, since its colonisation in the 1960s, has become more rapid since 2000. The potential for further growth of this colony is considerable in view of the large number of non-breeding immatures associated with the colony; 1,479 in 2009. This contrasts with the situation across Britain and Ireland as a whole, where the rate of population growth dropped to 1.33% *pa* during 1995-2005, from the previously recorded 2% *pa*, consistent with the expectation that the rate of increase would plateau (WWT Consulting 2012, Project report SOSS-04 to The Crown Estate).

An essential part of environmental impact assessment (EIA) for offshore wind farms is to determine the bird populations that may be affected, and in particular to assess the risk of adverse impact on relevant SPAs and their interest features (EU Birds Directive 79/409/EEC, as amended in Directive 2009/147/EC). Gannets may be vulnerable to collision with offshore wind turbines (Langston 2010). They have poor manoeuvrability, and their long, narrow wings and high wing-loading are adaptations to using the wind to assist fast flight (Nelson 1978). The risk is unclear, depending on levels of flight activity within the wind farm footprints and within the rotor swept area. It is known that gannets fly at and plunge-dive from elevations within rotor swept height (Nelson 1978, Krijgsveld *et al.* 2011). Flight activity, within a given area, may increase either as a result of feeding aggregations e.g. in response to fish shoals or discards from fishing vessels, or individuals commuting to the same foraging locations. It is anticipated that any risk is likely to be increased during chick-rearing, a higher-pressure time when adult birds are constrained by the need to return to the nest, albeit gannets would appear to be less energetically constrained than several other seabird species.

Aerial or boat-based surveys provide information about the overall distribution and abundance, including feeding aggregations, but do not enable colony origins of birds seen at sea to be determined, nor provide information on the frequency of foraging trips by individuals. Satellite tracking is a reliable method for tracking gannets from their breeding colonies (Hamer *et al*., 2000, 2001, 2007). Satellite tags can be deployed without the need for recapture of the bird, which reduces disturbance to the colony and reduces the risk of data loss. The chalk cliffs at Bempton present particularly challenging conditions, requiring skilled climbers to minimise risks both to climbers and breeding birds. A single visit to the Staple Newk section of the colony was the preferred approach in each year, hence the choice of satellite telemetry rather than the use of GPS data loggers which would have required recapture or close approach, with clear line of sight to remotely download data.

The study had the following objectives: to determine foraging ranges, flight directions, and foraging destinations of gannets from the breeding colony at Bempton; to determine whether gannets from Bempton forage within or pass through, on their way to foraging locations, areas of the North Sea proposed for wind energy development, notably the Round 3 zones of Dogger Bank, Hornsea and East Anglia; and to seek to obtain a measure of relative importance of the foraging areas identified, bearing in mind that the data presented here apply mainly to the latter half of two chick-rearing seasons, together with early post-breeding records for a reduced sample of birds. In reality, owing to the staggered breeding season for gannets, a range of chick ages is present during the study windows, but a small proportion are younger age chicks. Preliminary results for 2010 are presented in Langston & Boggio (2011).



Above: Staple Newk, Bempton Cliffs RSPB Reserve – for scale, note gannets to lower right and members of catching team at cliff top.

Right: climbers from JSMTW in action.

METHODS

SATELLITE TELEMETRY

The tags used in 2010 were Microwave Telemetry Inc (MTI) Platform Terminal Transmitters (PTTs) weighing 45g (approximately 1.5% of gannet body weight), with a duty cycle of continuous transmission. These tags lasted 13 to 84 days overall, considerably longer than the 30g tags originally recommended but no longer manufactured (Hamer *et al.* 2000). On 20 July 2011, four of these same 45g tags were deployed on continuous transmission throughout, and a further five tags were programmed on a variable duty cycle, using a multi-season nano timer. These tags were programmed to be on for six hours and off for 24 hours for 2 cycles, followed by continuous transmission for five cycles, then six hours on/24 hours off for the next 64 cycles, followed by 6 hours on/48 hours off for the remainder of the battery life. The variable duty cycle was utilised to extend battery life and so obtain information post-breeding, when gannets are no longer constrained to return to Bempton, as well as for the chick-rearing period. In addition, four gannets were fitted with MTI LC4 GPS PTT-100 tags, each weighing 40g, programmed to provide hourly positional information (Votier *et al.* 2010), to provide higher spatial resolution data on the adult bird's position during chick-rearing.

The tags were attached by means of Tesa© tape and two cable ties to the underside of the central three or four tail feathers, close to the base of the tail, with the antenna pointing upwards through the tail feathers, following Hamer *et al.* (2007). This arrangement was found to minimise drag when the birds were in flight and prevented displacement of tags when birds plunge-dive (Hamer *et al.* 2007).

Birds were caught at or near the nest, using a pole with a brass noose, by climbers roped securely to the cliff top. Each bird was transferred to the cliff top for fitting of the PTT, individually numbered metal ring (BTO ringing scheme), and collection of biometrics (age, wing length, mass), before release from the cliff top, within 15 minutes of capture and delivery to the cliff top. The fitting of PTTs was done sitting down with the gannet held by a second, experienced seabird handler so that it had a secure foothold on the tag-fitter's knees, facing outwards. A large cloth bag or similar draped over the head and eyes of the bird was used to calm the bird during handling (this follows the standard practice of placing birds in cloth bird bags/sacks preparatory to ringing and taking measurements).

Adult gannets were tracked during the chick-rearing period and during the early post-breeding period until early to late October. Regular observations were made at several monitoring plots at Bempton Cliffs, including Staple Newk at which several of the tagged birds could be seen from the cliff top, when they were at the nest. This provided observations of a small sample of tagged birds, and timing of fledging of their chicks, compared with untagged birds. The peak fledging period at Bempton in 2010 was between 20 August and 7 September, compared with the first three weeks of August in 2011, approximately 2 weeks earlier (L. McKenzie pers. comm.).

DATA PROCESSING AND ANALYSIS

Satellite data were processed by ARGOS (CLS, France). Regular downloads were made from the ARGOS online system and the resulting data compiled into a seamless dataset. GPS locations were obtained by running the data through MTI's parsing software, which includes an error filtering mechanism. In 2011, one tag failed after just six days, presumed lost. Excluding this tag, the overall operational duration, including the GPS LC4 tags, ranged from 20 to 92 days (mean = 65.85 days, Table 1). As expected, the non-GPS tags generally lasted longer than the LC4 tags. All tags had ceased to function, or been lost, by 19 October. In 2010, one tag failed after just 13 days, whilst three tags continued to function for more than 80 days (range 13 to 84 days; mean = 49 days) (Langston & Boggio 2011).

To account for positional error, only locations with ARGOS quality codes 3, 2, 1, 0, A were used. According to Hamer *et al.* (2007), working at Bass Rock, adopting this protocol of using only Class A or better gave a maximum SD of 7 km on each location, which is small in comparison to the distances travelled. The ARGOS quality codes 3, 2, and 1 are associated with an accuracy up to 1 km (ARGOS 1989 & 1996, cited in BLI 2004). Additional points were removed, as unrealistic, in instances where the calculated bird flight speed between adjacent registrations exceeded 90 kmh (Nelson 1978, Hamer *et al.* 2007); usually the first point in the sequence was retained, unless this was unlikely in relation to the previous location. All locations recorded within 5 km of the central location of Staple Newk were considered to be at the breeding colony. In 2011, data for chick-rearing and post-breeding were separated taking the approximate departure date from Bempton for each individual, based on the last recorded date at Bempton. The resulting data were plotted in ArcGIS (ArcGIS Desktop 10 ©ESRI), on a backdrop showing the indicative offshore wind energy project boundaries. Radial distance bands were added showing 50 km, 100 km, 150 km, and 200 km.

Some GIS analysis was also undertaken using MapInfo (MapInfo Professional 9.0 Release Build 36 ©Pitney Bowes).

For the chick-rearing period only, mean and maximum foraging range, trip length and trip duration were calculated from ARGOS data, as these provided more frequent positions, mainly from the tags on continuous transmission or the continuous transmission cycles of the tags on variable duty cycle. ARGOS data enabled comparison with data collected in 2010, when no GPS data were collected. The GPS data had large gaps in the data record, extending to several days, the reason for which has not been resolved. For the purpose of this analysis, we excluded records separated by more than one day. Maximum foraging range was calculated as the maximum straight-line distance from Bempton, whilst trip length was the combined distance between locations for each trip, from the first location away from the colony to the first record back at Bempton for each trip. Only complete foraging trips at sea were included, i.e. those that started and finished at the colony; inland data points were excluded. Data from 2010 were reanalysed, using all the available data, in the same way for comparison with data for 2011; hence values differ from those presented in Langston & Boggio 2011.

Fixed Kernel Density 50, 75 and 95% isopleths were calculated using the Hawths Analysis Tools (version 3.27) extension for ArcGIS (version 9.2, ©ESRI), using a default 8000 smoothing factor, a cell size of 1000 m, using just the locations at sea. The 50% and 95% kernel density estimates were considered to represent the core area of activity (50% of locations) and area of active use (95% of locations), respectively (Hamer *et al.* 2007). Sea areas under the contour lines were calculated separately for 2011 and 2010. These areas of activity encompass foraging areas which were distributed across the whole area used. End points of trips out to sea were taken to be foraging destinations, but birds also feed during foraging flights. Satellite data provide limited discrimination of bird activity, so it is more difficult to define foraging areas used in transit, although sometimes several locations occur close together in space and time indicating other diurnal foraging areas and these occur widely within the range of detected locations.

RESULTS

Chick-rearing

In 2011, of the 6,500 Argos locations of quality codes 3, 2, 1, 0 or A, 3,616 were at sea (Figures 1a & b), comprising 559 foraging trips from 13 adult gannets. Approximately 44% of locations (2,884) were recorded at the breeding colony in 2011 (compared with approximately 53% of locations (2,722) in 2010) . Most locations were within 50-150km of Bempton, with the highest density of locations within 50 km, influenced by activity close to the colony. Locations extended to the ESE of Bempton, in particular, across the Hornsea zone. Location density declined markedly beyond 150 km from Bempton. Summary statistics on foraging parameters for 2011 and 2010 are presented (Table 1). The maximum foraging range recorded in 2011, was 285.53 km (range 5.01 – 285.53 km), whilst the maximum trip length was 1200 km (range 6.65 – 1200.11 km). Foraging trip duration was highly variable, on average lasting 11.90 ± 1.37 hours (n = 427 trips, 13 birds, 95% CI). The average foraging range was 47.80 ± 4.96 km (n = 457, 95% CI), whilst the average foraging trip length was 172.25 ± 16.34 km (n = 457, 95% CI). Foraging trip duration appeared to be bimodal in 2011, with one distribution associated with activity around the colony, and one representing longer trips (Figure 2). Foraging parameters will be investigated further in the three-year analysis incorporating data for 2012, including further assessment of the effect of time elapsed between recorded locations.

The overall pattern of locations during chick-rearing was similar in 2010 and 2011 (Figure 1). In relation to the proposed offshore wind energy development zones, flights occurred through and to the Hornsea Round 3 proposal zone in particular (Figures 1 & 3). There were also flight end points, and likely flights through, the southern part of Dogger Bank, a few records within the East Anglia Round 3 zone, and a few within and close to Round 1, eg Westermost Rough, and Round 2 sites (see discussion) in the Greater Wash strategic area (Figure 3). The kernel density figures (Figure 4a & b) illustrate that a high proportion of locations extended further east within the Hornsea zone in 2011, utilising more of this zone, compared with 2010, based on the 75% density contour. The 95% density contours in 2010 and 2011 incorporated clusters of locations within the periphery of the Greater Wash, but do not show much penetration into this area. There were no recorded locations further south than the coast of north Norfolk during chick-rearing periods in 2010 or 2011. The core foraging range represented by the 50% kernel density contour extended to 3,862 km^2 in 2011, compared with 2,416 km^2 in 2010, and includes a mix of loafing, foraging and flight activity around the colony and out to approximately 50 km from Bempton. The areas of active use represented by the 95% density contour extended to 25,601 km^2 in 2011 and 22,850 km^2 in 2010.

Only approximately 12% of the GPS locations passed the MTI checksum test (Appendix I), so the data need to be used with caution, but all our GPS locations fell within the range of values produced by the Argos locations and so provide some validation of the overall distribution pattern of locations (Figure 5).

Post-breeding locations

Few data were obtained in 2010, but records were obtained from six birds in 2011. One headed north, around the Orkney islands and the coasts of northern and western Scotland, then down the west coast of Ireland before crossing the Bay of Biscay to western France whereupon further contact was lost (Figure 6). The other five birds remained in the North Sea for at least one to two weeks before either tags ceased to operate or, in the case of one individual, onward southerly movement to northwest Africa (Figure 6). These movements are comparable to those recorded by Kubetzki *et al.* (2009) and Fort *et al.* (2012), for gannets from Bass Rock. Time spent in the North Sea tended to be relatively clustered for each individual, and records overlapped especially with the Hornsea and East Anglia zones and, to a lesser degree, with Dogger Bank. They also overlapped several Round 2 and Round 1 wind farm footprints, notably Westermost Rough.

In 2010, four birds provided post-breeding locations for a few days to a few weeks (Figure 7). It was more difficult to pinpoint the probable departure date in 2010 as, from 15 September records were all at sea without further records at the breeding colony, so a cut-off date of 15 September was used. The last data were transmitted on 6 October 2010. Most records were close to Bempton; one bird appears to have started a northbound movement similar to that observed in 2011, but much further offshore into the central North Sea.

The recorded locations are available as GIS layers from the Conservation Data Management Unit (CDMU) at the RSPB and the BGS DECC SEA data portal. Long-term external storage is via Medin Marine Environmental Data & Information Network (http://www.oceannet.org/), and anticipated via the BirdLife extended "Procellariiform" database too (BLI 2004).

DISCUSSION

The main concerns relating to birds in association with wind farms are as follows (Drewitt & Langston 2006): (1) disturbance displacement, leading to effective habitat loss (2) collision mortality, (3) habitat loss/change influencing prey availability, and (4) barriers to movement potentially increasing flight energy demands for daily foraging flights or longer migratory flights. In particular, the cumulative and in combination effects are of greatest concern, whereby the multiplicative effect across wind farms, unchecked, may lead to significant risk of population reduction.

This study reflects gannet foraging tracks prior to placement of wind turbines in the Round 3 zones. Of the wind farm locations coinciding with the range of gannet locations recorded by this study during chick-rearing, only Lynn & Inner Dowsing are operational; Lincs, Sheringham Shoal and Teesside are under construction. These are all outside the main area of active use identified during 2010 and 2011 (Figures 1, 3 & 4). The rest are in planning or consented (www.bwea.com, accessed 23 June 2012). So, it is too early to determine flight responses to constructed wind farms by gannets from Bempton, based on the small number of locations in the vicinity of operational wind farms. During post-breeding dispersal and migration, gannets may encounter several wind farms, as indicated here by the locations of the tagged individuals.

Recent studies of gannets, during spring and autumn migration, at Egmond aan Zee offshore wind farm in the Netherlands, indicate strong avoidance of wind turbines (Krijgsveld *et al.* 2011), which may suggest that flight avoidance of wind turbines is likely, although it is not known whether this response will apply to breeding gannets, especially during chick-rearing. Avoidance *per se* may, or may not, be detrimental, even if applicable to breeding gannets, unless it leads to a reduction in available foraging habitat, ie displacement, birds cannot compensate by feeding elsewhere, and do not habituate to the presence of wind turbines. Cumulative effects arising from multiple wind farms may lead to adverse effects if access to high quality habitat is restricted or prevented. Collision and displacement may have differential effects, depending on the season, age, sex, breeding status, and behaviour of individual gannets. Gannets are considered to be at risk of collision with wind turbines, owing to their flight elevation and plunge dive height, from 10-50 m, which coincide with the rotor swept area (Krijgsveld *et al.* 2011). Risky flights were identified to be those during foraging and searching, when individuals were observed up to 50m height, but direct flight was often observed to be below 10m, except in high winds when gannets used dynamic soaring to gain lift (Krijgsveld *et al.* 2011). There is considerable uncertainty at present about likely cumulative effects of the proposed scale of offshore wind farm development on gannets. Collision hazard could become significant, given the substantial scale of proposed wind energy development across the North Sea, not just in UK waters. A Population Viability Analysis (PVA) has been produced for gannets from the UK breeding population (WWT Consulting 2012, report to The Crown Estate, Project SOSS-04, part of the SOSS[1] programme). For the Bempton colony, based on the estimate of 3,940 Apparently Occupied Nests (AONs) in 2004, this model indicates that additional mortality in excess of 150 gannets per year would be expected to lead to a decline in colony size, with the probability of decline increasing rapidly with increasing mortality. It is not clear whether there is a proportional increase in additional mortality that the increased colony size may be able to withstand (7,859 AONs in 2009, see page 3); this requires testing by re-running the model.

Understanding the spatial and temporal coincidence of gannets with proposal areas for wind turbines is the first step in understanding any potential impact of offshore wind energy generation on gannets. The limitations of this study result primarily from the relatively small number of birds tracked during the chick-rearing periods in 2010 and 2011, and the small sample for early post-breeding dispersal. The results for 2010 and 2011 provide the first records of foraging ranges and destinations for breeding gannets from Bempton Cliffs. The majority of foraging trips were within 100 - 150 km of Bempton Cliffs, representing a smaller foraging range than recorded for breeding gannets from the Bass Rock (mean range 155.2 ± 65.3 km, range 68-276 km, Hamer *et al.* 2009). The 95% kernels for Bempton, also were considerably smaller in extent than those recorded for Bass Rock (45,890 – 211,120 km^2, Hamer *et al.* 2007). The similarity of results for the 2010 and 2011 chick-rearing periods may stem from the fact that both were good breeding seasons. Whilst it is not clear whether this pattern of foraging is typical for Bempton, the observations fit with the theories of intraspecific competition and colony size, whereby birds from larger colonies have to forage further afield because of intraspecific competition and prey depletion (Lewis *et al.* 2001). This is also likely to suppress foraging extent to the north of Bempton. There were an estimated 3,940 AONs (apparently occupied nests) of gannets at Bempton Cliffs, compared with 48,065 AONs at Bass Rock in 2003/04 (Wanless *et al.* 2005).

[1]SOSS is the Strategic Ornithological Support Services to the Crown Estate, www.bto.org/soss

Some overlap of foraging areas used by birds from Bempton Cliffs and Bass Rock was apparent in the sea area north of Bempton (Figure 1, Hamer *et al.* 2007). GPS loggers from Bass Rock indicate that, during foraging trips, gannets tend to intersperse rapid direct flights with slower sinuous tracks over foraging areas associated with the tidal mixing front (Hamer *et al.* 2009).

Distinguishing foraging locations from in flight locations is more challenging using Argos PTTs, but foraging end points and diurnal clusters of closely spaced locations over short time periods are cues to likely foraging areas. Gannets also feed during foraging trips, so end points are not the only foraging locations.

Peak fledging at Staple Newk occurred during the first three weeks of August 2011, with most of the rest fledging by the end of September. The earliest fledging date was 29 July, considerably earlier than most gannets at Bempton; the last, really late chick, fledged in mid-November (L. McKenzie pers. comm.). The 2011 breeding season at Bempton was a good one, overall productivity being 0.83 chicks per apparently occupied nest (AON), compared with 0.82 in 2010 and 0.86 in 2009 (D. Aitken pers. comm.). There was no indication of a difference in behaviour or breeding performance by gannets with or without a PTT, although the sample for comparison was small, constrained by tagged birds observable from the cliff top observation point. Birds flew strongly when released with their PTT fitted, the weight ratio of which, at approximately 1.5% of body mass, was well within the recommended range (less than 3% of body mass, Phillips *et al*. 2003). Birds observed at the colony ignored the tag and antenna, even when preening. Four of the birds tagged in 2011 had eggs/chicks at different stages of development when the adults were tagged, ranging from an egg hatched on 20 July, to a well-grown chick due to fledge in early August. All these chicks fledged within the expected time for their stage of development at the time of capture of the adults, eg the chick hatched on 20 July fledged during the third week of October. Many adults remain at Bempton for a while after their chicks have fledged. The last adults were seen at Staple Newk in late September; all were gone by 4 October.

Cliff-top observations indicated that PTTs were eventually lost; three of the birds identified at the nest with tags in place were observed later in the season without tags. Mounting the PTTs on tail feathers, they were expected to shed tags at least when moulting if not sooner due to a reaction between the tape adhesive with seawater over time. Attempts to extend the recording period, using a variable duty cycle setting for 5 tags in 2011, was only partially successful as the last location was obtained on 19 October. It is unclear whether battery failure or tag loss was the cause of curtailment although the latter may be more likely as last dates were comparable for tags on continuous transmission or variable duty cycle, and given the observations at the breeding colony. Votier *et al.* (2010) also considered that tail-moult induced tag loss was likely. Tail moult is irregular (Nelson 1978) although it is thought to commence around egg-laying time, and in 2011 several adults were observed to be in the process of growing at least one or two new tail feathers at the time of fitting tags. Harnesses were ruled out for this study of gannets due to their plunge-diving and entry into the water at considerable speed, as well as the increased risk for the birds of entanglement with any underwater gear, fishing nets etc.

In view of the disappointing performance of the LC4 GPS tags, together with their generally shorter operational life and higher unit price, the decision was taken not to deploy further LC4 tags in 2012. The lower resolution data associated with locations from Argos PTTs, compared with GPS units is only likely to be a potentially significant limitation when determining gannet responses to wind farms under construction or operational wind turbines, so relevant to future tracking studies.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Right: fitting a PTT to a gannet.

Above: gannet flies away after PTT has been fitted.

©Steve Race

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Twenty seven breeding adult gannets, tracked via satellite Platform Transmitter Terminals, from Bempton Cliffs in 2010 and 2011, yielded information about their foraging ranges during chick-rearing, and the extent of overlap of their foraging trips with potential development zones for offshore wind energy generation in the North Sea. Most foraging trips were within 100-150 km of Bempton Cliffs, and considerable overlap was noted in particular with the Hornsea Round 3 development zone for offshore wind energy generation. Some information was obtained for the early post-breeding period in both 2010 and 2011, indicating variability in dispersal and migration away from Bempton, and the potential for interaction with several different wind farms at this stage of the gannet's annual cycle. In particular, increased numbers of locations were recorded in the East Anglia zone in the post-breeding period, contrasting with few locations during chick-rearing.

Further data collection at Bempton is highly recommended, to provide comparative data for a third season to investigate inter-annual variation in gannet foraging range and destinations during chick-rearing and the post-breeding period. There is a clear advantage in repeating the approach to provide comparable data for 2012. However, there appears to be limited scope for further extension of the study period using PTTs. At the present time, there does not appear to be an obviously suitable tagging method available to further extend the study period without back-mounting with a harness which is undesirable in a species that plunge-dives and enters the water at considerable speed. A harness may interfere with plunge-diving and increase the risk of entanglement with underwater fishing gear or other objects. Further developments of remote download capability together with additional on-site or boat-based recording might overcome the specific difficulties of obtaining the necessary clear line-of-sight at Bempton to facilitate the use of alternative tracking technology, such as GPS data loggers, to the PTT-100 tags used here for future studies in relation to operational wind farms.

Further analyses will be carried out, with the addition of the third year's tracking data. These analyses will include a comparative analysis of foraging trip data over three years, incorporating some oceanographic variables. Individual and temporal variation will be investigated further.

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Right: Major Tony Crease (retd.)

Above: QMSI Haslam & Andy Phillips from JSMTW

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TABLES

Table 1: Summary statistics describing foraging trip parameters for gannets during chick-rearing in 2010 (*n* = 682 trips, 14 birds) and 2011 (*n* = 427 trips, 13 birds). See text for details.

FIGURE LEGENDS

Figure 1: Combined tracking locations for adult gannets from Bempton Cliffs, based on a) 5,154 locations in 2010 (n = 14 birds) and b) 6,500 locations in 2011 (n = 13 birds), during the chick-rearing period. The blue circle is the 5km buffer around the central location of Bempton Cliffs, with added 50km, 100km, 150km and 200km buffers to aid interpretation of foraging distances. Inset shows the location of Bempton Cliffs.

Figure 2: Foraging trip duration for gannets from Bempton during chick-rearing in 2011 (*n* = 427 trips, 13 birds) and 2010 (*n* = 682 trips, 14 birds).

Figure 3: Flight end points indicating foraging destinations of gannets from Bempton: a) 2010 (5,154 at sea locations, *n* = 14 birds), and b) 2011 (6,500 locations, *n* = 13 birds). Different colours signify different individual birds.

Figure 4: Kernel Density Estimation (kernel density tool, ArcGIS Desktop 10): a) 2010 (n = 14) & b) 2011 (n = 13) chick-rearing period, showing the 50%, 75% and 95% density contours.

Figure 5: GPS locations of individual gannets during chick-rearing in 2011, from three LC4-PTTs, in comparison with ARGOS locations. See text and Appendix I for further information.

Figure 6: Post-breeding locations in 2011 of six individually tagged gannets from Bempton Cliffs breeding colony, fitted with 45g PTT-100 battery powered satellite tags, based on 1,262 locations.

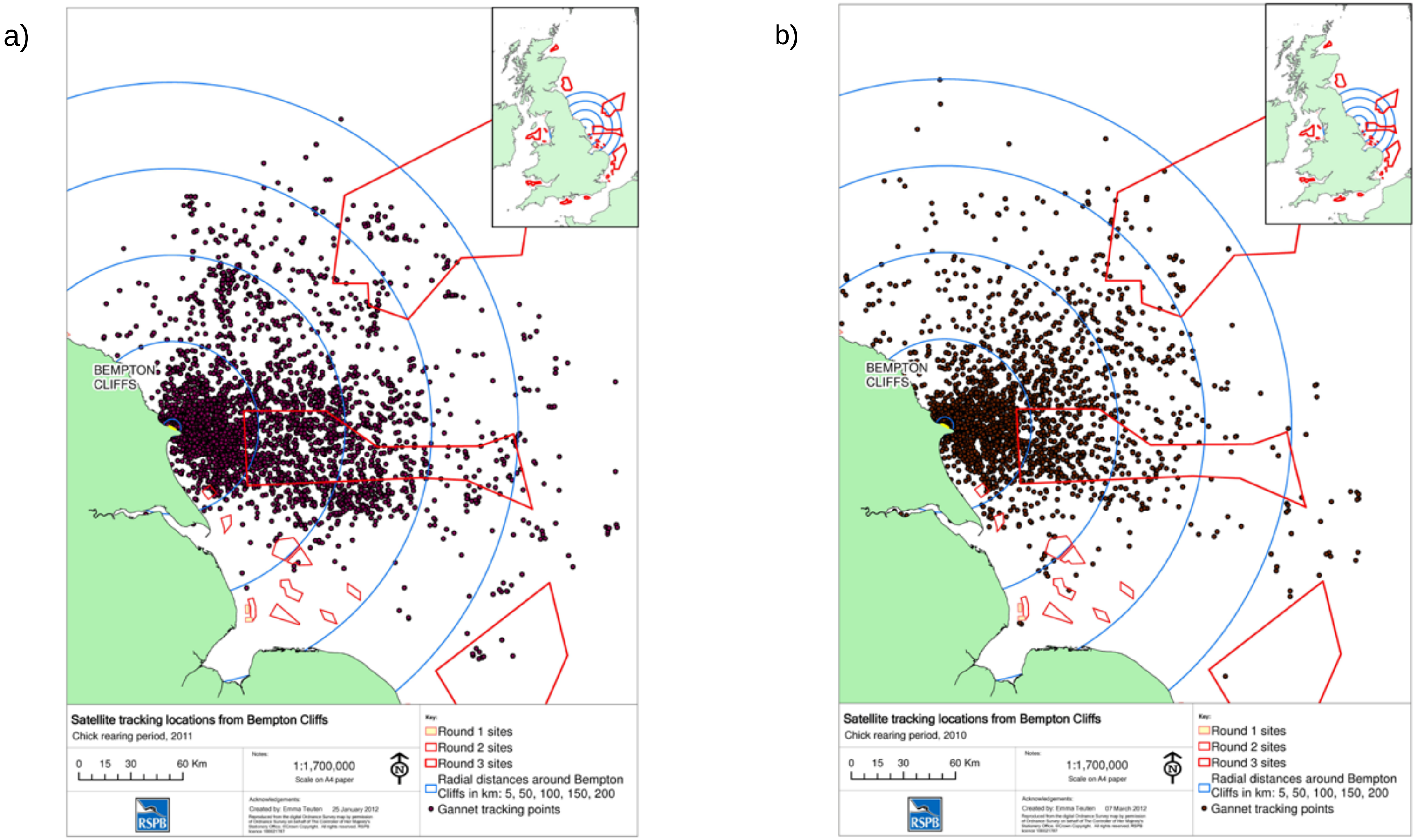
Figure 7: Post-breeding locations in 2010 of four individually tagged gannets from Bempton Cliffs breeding colony, fitted with 45g PTT-100 battery powered satellite tags, based on 2,341 locations.

APPENDICES

Appendix I: Summary information for each satellite tag and individual adult gannet in 2011

Table 1: Summary statistics describing foraging trip parameters for gannets during chick-rearing in 2010 (*n* = 682 trips, 14 birds) and 2011 (*n* = 427 trips, 13 birds). See text for details.

	2010	**2011**
%		
Maximum foraging range (km)	306.49 km (range 5.03 – 306.49 km)	285.53 km (range 5.01 – 285.53 km)
Mean foraging range (km)	54.36 ± 3.73 km (95% CI)	47.8 ± 4.96 km (95% CI)
Maximum trip length (km)	947.65 km (range 5.93 – 947.65 km)	1200.11 km (range 6.65 – 1200.11 km)
Mean trip length (km)	140.12 ± 10.58 km (95% CI)	172.25 ± 16.34 km (95% CI)
Min/Maximum trip duration (hours)	0.2/96 hrs	0.35/110 hrs
Mean trip duration (hours)	14.88 ± 0.99 hrs (95% CI)	11.90 ± 1.38 hrs (95% CI)



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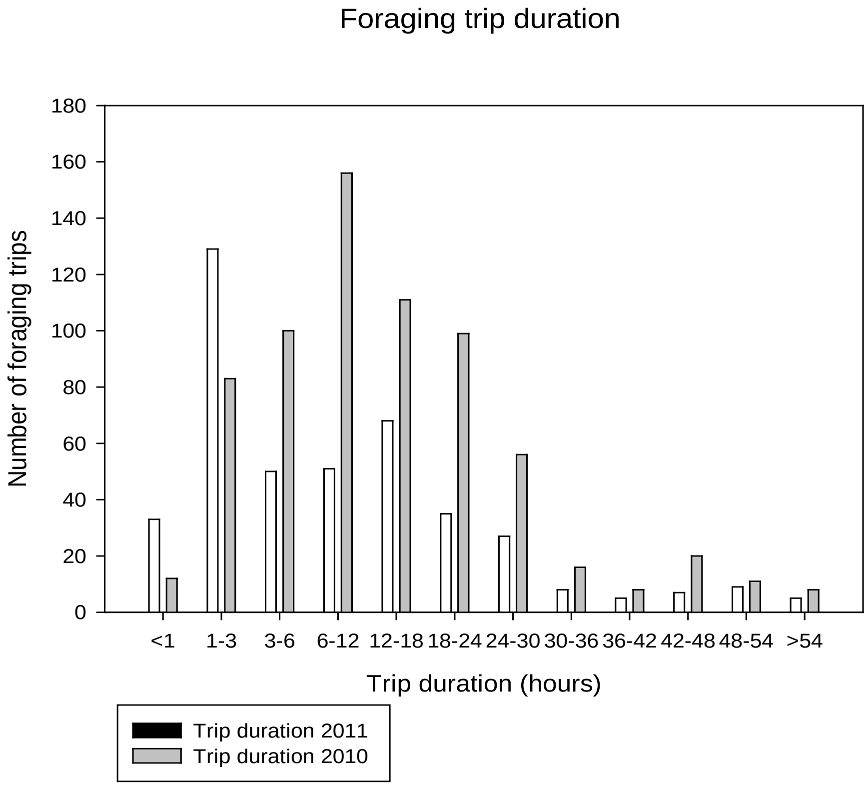

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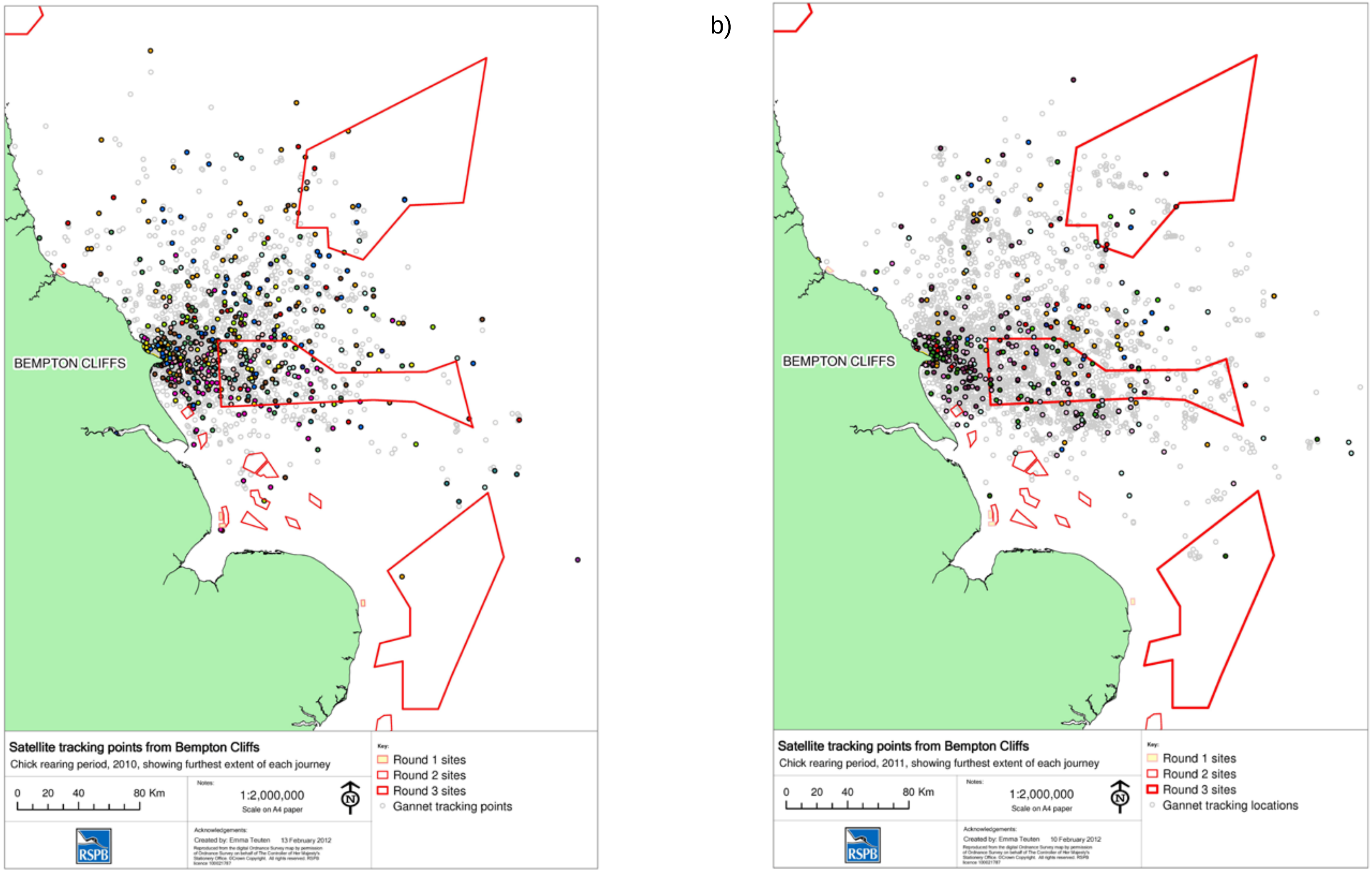
a) b)



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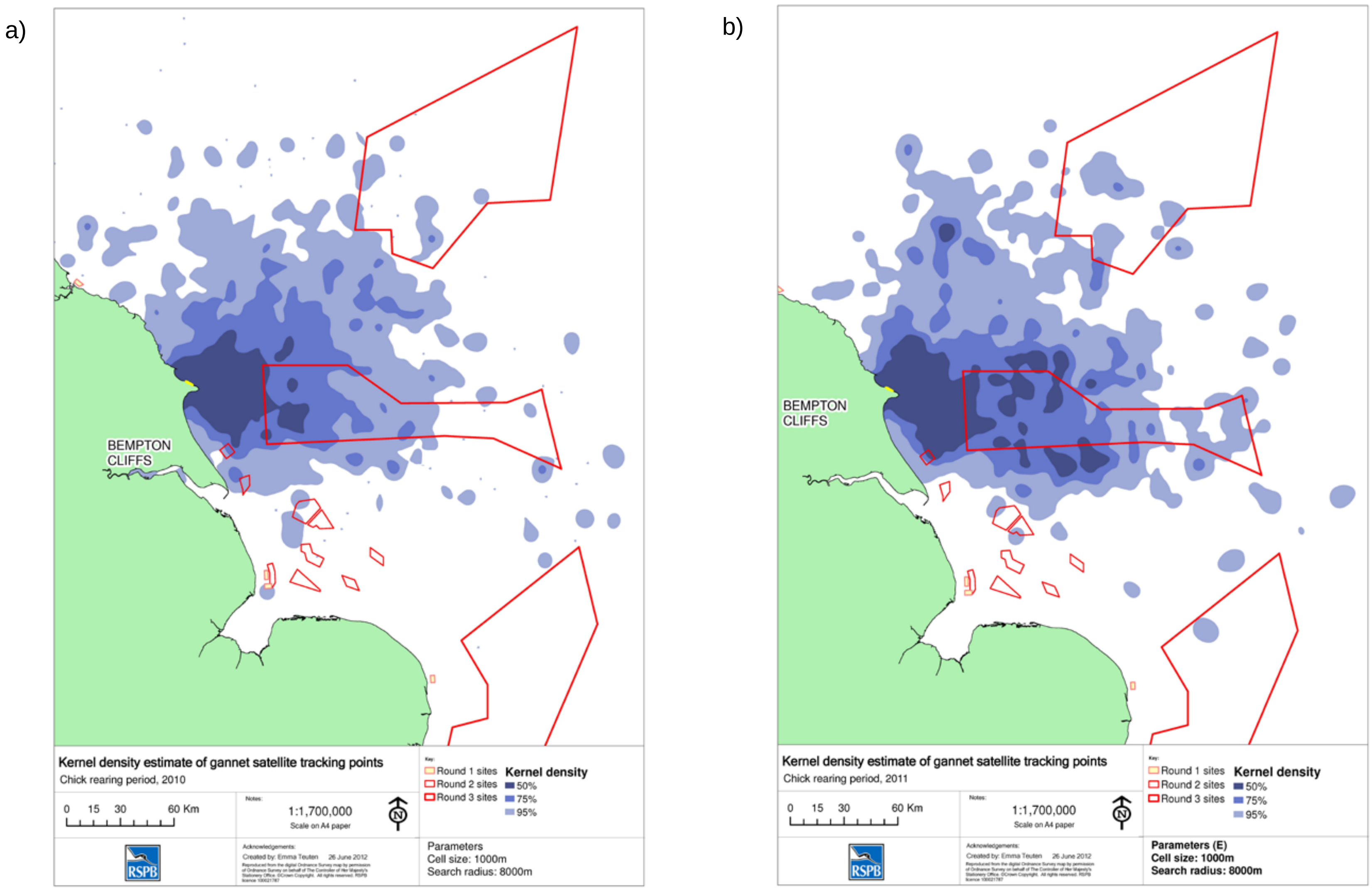

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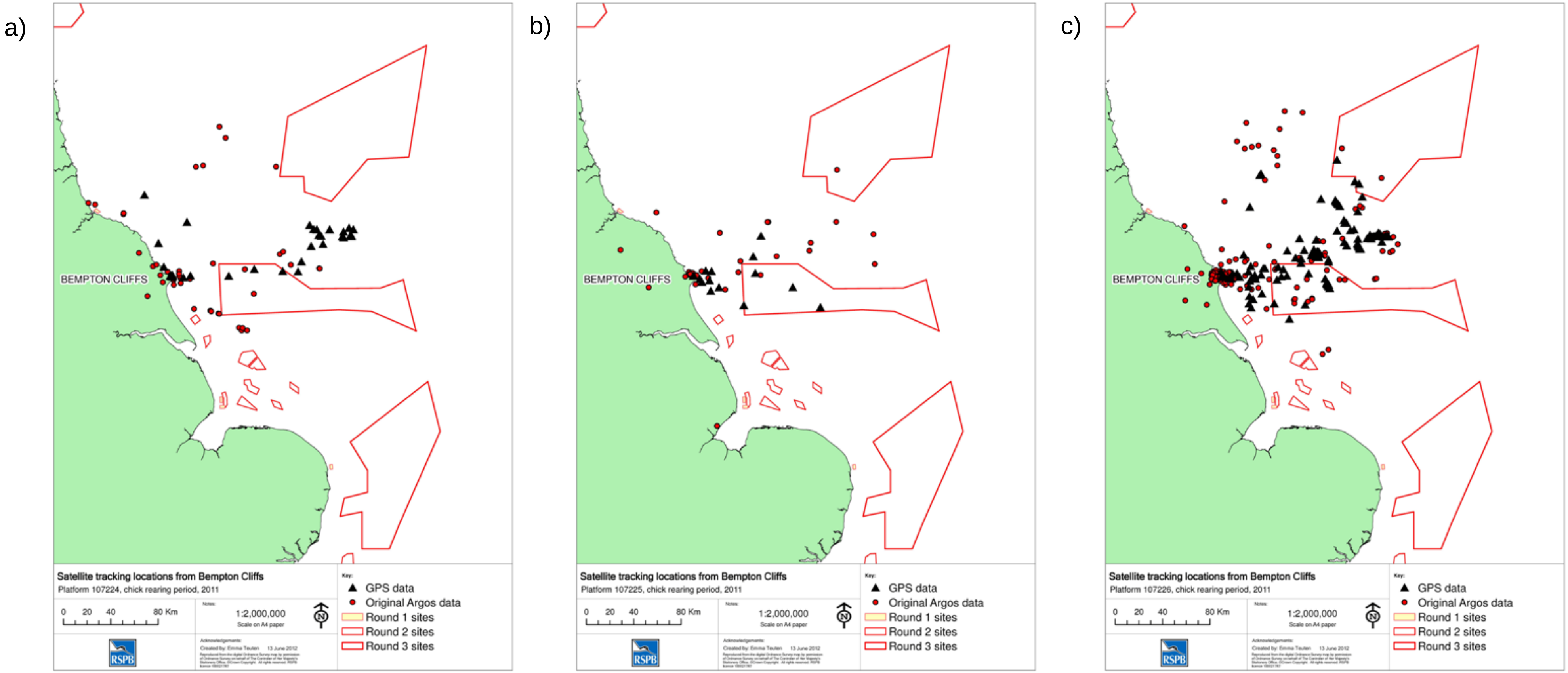

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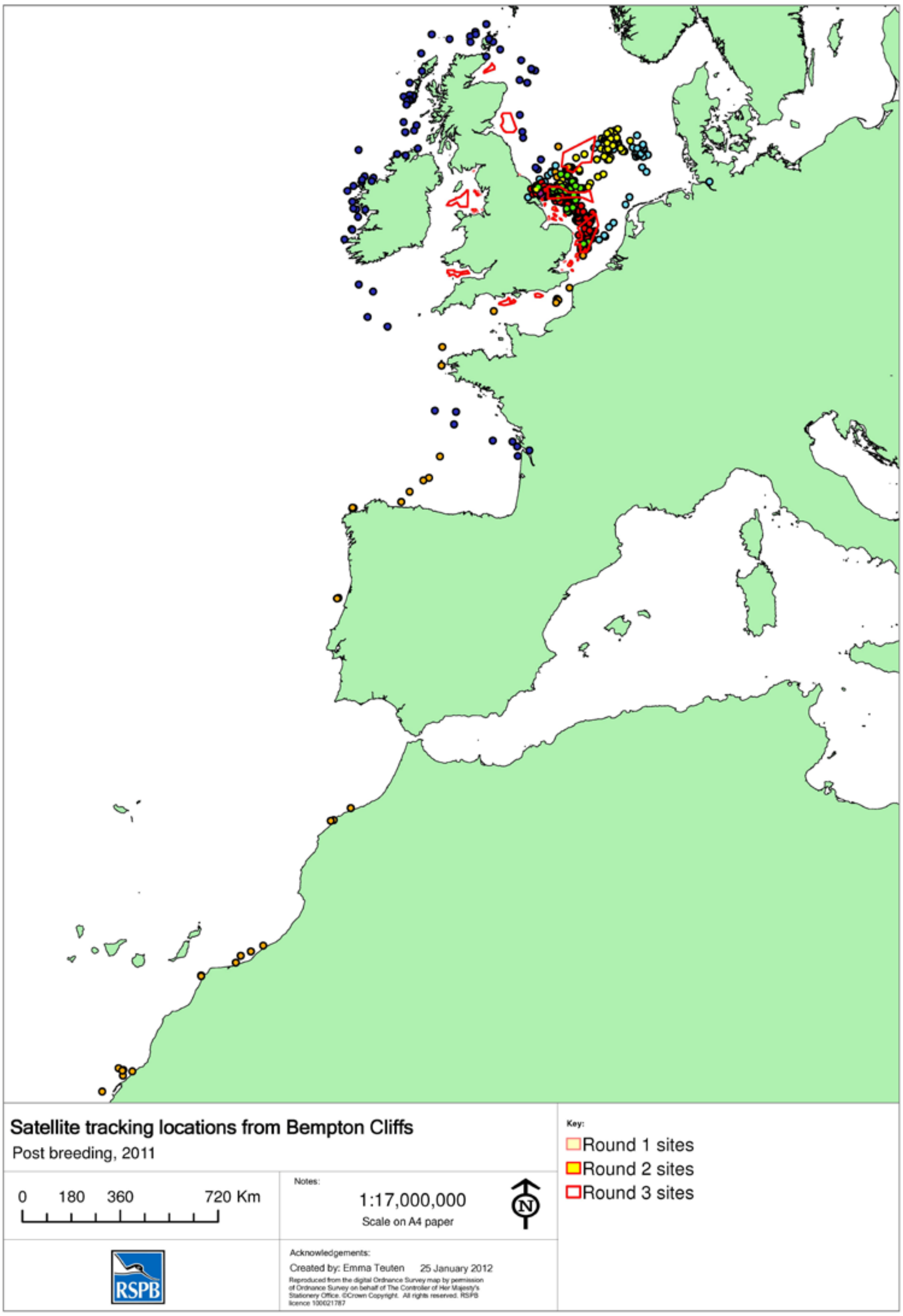

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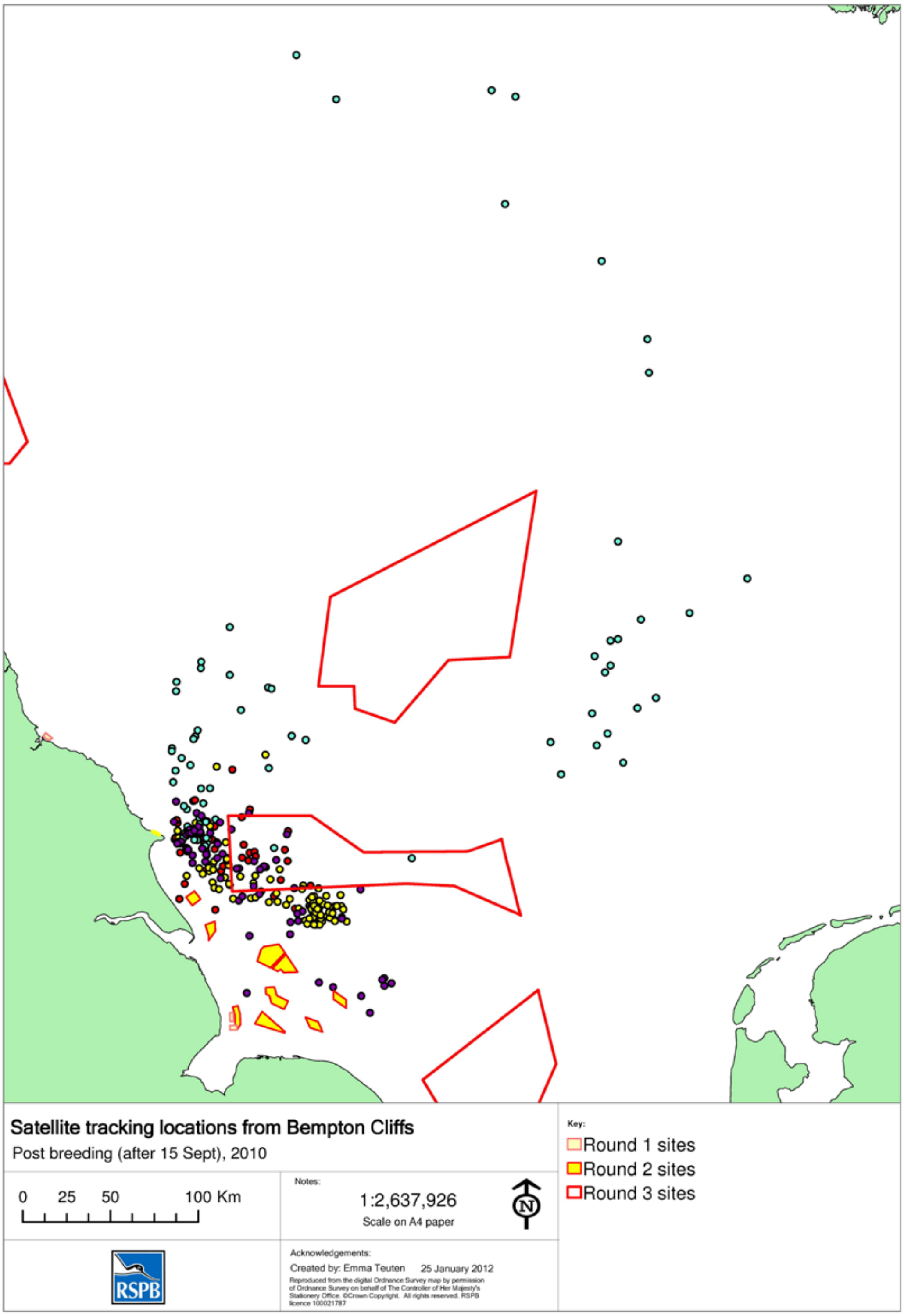

Figure 7: Post-breeding locations in 2010 of four individually tagged gannets from Bempton Cliffs breeding colony, fitted with 45g PTT-100 battery powered satellite tags, based on 2,341 locations.

APPENDIX I

Summary information for each satellite tag and individual adult gannet in 2011

Platform ID	224	225	226	227	467	468	469	470	472	473	474	475	476	
Tag type	LC4	LC4	LC4	LC4	PTT	PTT	PTT	PTT	PTT	PTT	PTT	PTT	PTT	
Duty cycle	hourly	hourly	hourly	hourly	contin	contin	contin	contin	var	var	var	var	var	
GPS total fixes (passed checksum)	118(18)	141(14)	408(48)	0										
Argos total fixes quality codes 3,2,1,0,A	64	54	164	154	1489	410	1906	1836	60	359	278	395	516	
LC 3	0	0	0	0	97	8	114	44	3	22	14	18	29	
LC 2	1	2	7	1	271	18	326	196	5	62	43	58	78	
LC 1	1	5	13	13	293	47	427	463	9	77	50	73	128	
LC 0	54	30	103	94	387	299	468	569	30	86	81	117	144	
LC A	8	17	41	46	441	38	571	564	13	112	90	129	137	
Total number of Argos fixes	64	54	164	154	1489	410	1906	1836	60	359	278	395	516	7685
Mean Argos fixes per day	2.78	2.70	3.28	2.85	16.73	4.82	22.69	20.40	10.00	5.13	6.95	4.39	5.61	
Days operational	23	20	50	54	89	85	84	90	6	70	40	90	92	
Last record date	08-Aug	08-Aug	07-Sep	11-Sep	16-Oct	12-Oct	11-Oct	17-Oct	26-Jul	27-Sep	28-Aug	17-Oct	19-Oct	
Inferred last date of chick-rearing period*	08-Aug	08-Aug	07-Sep	08-Sep	28-Sep	20-Sep	23-Sep	03-Oct	26-Jul	22-Sep	28-Aug	15-Sep	29-Sep	