BTO RESEARCH REPORT 800

Results of a tracking study of Wigeon to inform understanding of potential interactions with the National Grid Hinkley Connection Project.

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BTO Birds Science People

Results of a Tracking Study of Wigeon to Inform Understanding of Potential Interactions with the National Grid Hinkley Connection Project

Authors

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Report of work carried out by the British Trust for Ornithology
on behalf of the National Grid Hinkley Connection Project.

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EXECUTIVE SUMMARY

1. As part of the consenting process for The National Grid Hinkley Connection Project a S106 Agreement was signed in June 2015 to enable a bird tagging study. This study would have the principle aim of increasing current knowledge of waterbird movements between the Somerset Levels and Moors Special Protection Area (SPA)/Ramsar site and the Severn Estuary SPA/Ramsar Site.

2. In autumn 2020 a tracking study was commissioned to track the movements of 15 Wigeon *Anas penelope*, with specific objectives to provided data in order to understand:

   (i) The flight paths that birds might take between the Severn Estuary SPA and the Somerset Levels and Moors SPA, and how these relate to the route of the National Grid Hinkley Connection Project between Bridgwater and Seabank;
   (ii) The frequency of movements through the winter period; and
   (iii) As possible, the flight heights and speeds of birds.

3. On 3 November 2020, 15 Wigeon were caught and tagged under licence using OrniTrack-15 2G GPS-GSM devices at WWT Steart Marshes, adjacent to the Severn Estuary SPA. These tags remained attached for 17.88 ± 6.44 (sd) days (range: 11.85 – 27.81 days), and collected data on date, time, GPS location, speed, altitude, accelerometry, magnetometry and temperature.

4. Fourteen of the tags provided data of sufficient quality for further analysis. Details of all 14 birds' movements, area usage and time budgets during the tracking period are presented.

5. Four (28%) of the 14 birds were recorded making movements between the two SPAs, resulting in five recorded movements across the proposed route of the National Grid Hinkley Connection Project. Only 0.21% of the data points collected in total were associated with flight, suggesting that time spent in the air is a very small proportion of a Wigeon's activity budget. This suggests the proportional likelihood of collision risk with the powerline is small, although results should be interpreted with caution, given the relatively small sample size and short tracking duration.

6. From the 21 data points associated with flight, the mean flight speed was 68.5 ± 11.5 (sd) km/h (range: 54 – 96 km/h) and the mean flight altitude was 67.6 ± 70.2 (sd) m above mean sea level (range: -80 – 212 m).

7. In total, 10 (71.4%) of the birds spent the entire tracking period west of the National Grid Hinkley Connection Project proposed route, mainly using the WWT Steart Marshes and Severn Estuary SPA areas. Four (28.6%) birds crossed the proposed route of the National Grid Hinkley Connection Project. Birds spent a mean of 31.7% of their time in the Severn Estuary SPA and 1.1% of their time in the Somerset Levels and Moors SPA.

8. Conclusions on the data analysis are presented and recommendations are provided on how to take this research on Wigeon movements between the Severn Estuary SPA and the Somerset Levels and Moors SPA forward in future.

1. INTRODUCTION

1.1. Background

The National Grid Hinkley Connection Project (https://hinkleyconnection.co.uk/map-and-timeline/) is a new high-voltage electricity connection between Bridgwater and Seabank near Avonmouth. It is a significant investment in the region's electricity network and will connect new sources of power to homes and businesses, including Hinkley Point C, EDF Energy's new nuclear power station in Somerset.

As part of the consenting process for the project, and through agreement with Natural England, a S106 Agreement was signed in June 2015 to enable a bird tagging study that would have the principle aim of increasing current knowledge of waterbird movements between the Somerset Levels and Moors Special Protection Area (SPA)/Ramsar site and the Severn Estuary SPA/Ramsar Site. The intended focus of the study was to be either on Wigeon *Anas penelope* and/or Teal *Anas crecca*, both features of the respective protected sites.

In autumn 2020 a tracking study was commissioned to be undertaken in winter 2020. The results of this tracking study on Wigeon are outlined within this report.

1.2. Project Objectives

The project's overarching aim is to increase current knowledge of the movements of Wigeon between the Somerset Levels and Moors SPA/Ramsar site and the Severn Estuary SPA/Ramsar Site. Within this overall aim, the project has a number of more specific objectives, to understand:

(i) The flight paths that birds might take between these sites and how these relate to the route of the National Grid Hinkley Connection Project between Bridgwater and Seabank;
(ii) The frequency of movements through the winter period; and
(iii) As possible, the flight heights and speeds of birds.

Collecting more robust, qualitative data on parameters such as flight heights and bird activity levels will be key to improving assessments of vulnerability to collisions with powerlines.

2. METHODS

2.1. Field Methods

2.1.1. Study site

In order to maximise the likelihood of achieving the aims of this project it was identified that Wigeon should be caught from a site within, or immediately adjacent to, one of the two target SPAs (Figure 2.1). WWT Steart Marshes was identified as a suitable site, adjacent to the Severn Estuary SPA, where WWT site staff monitor the reserve daily, and thus had a very good knowledge of Wigeon numbers and possible catching opportunities.

Figure 2.1 Map of the area of Somerset relevant to this project, with the Severn Estuary SPA, Somerset Levels and Moors SPA, WWT Steart Marshes catch site (red dot) and the proposed high-voltage powerline highlighted.

WWT Steart Marshes was visited by BTO staff on 15 October 2020, and with WWT staff expertise and site knowledge, a cannon-netting catch site was identified on Otterhampton Marsh (Figure 2). Wigeon had been seen in this area of the marsh regularly, and could be easily observed from Quantock Hides. It was also easily accessible from the site office, which made bait storage and transport more manageable, and provided a private area for processing the catch after it was made.

Figure 2.2 The catching site within Otterhampton Marsh of WWT Steart Marshes. Filled red rectangle represents the catching site; circles are viewing positions for taking the catch, and open red square is the site office.

Bait (wheat grain) was laid within the catching area on the 15 October, the site was monitored using camera traps, and regular visits were made by WWT staff thereafter to see if/when Wigeon began eating the bait. Once all the initial bait had been eaten (26 October), WWT staff scattered additional bait in the area every other day at dusk, to ensure the Wigeon became habituated to the area and visited it daily. WWT staff laid a dummy cannon-net on 29 October to enable Wigeon to habituate to its presence.

WWT staff provided regular updates on the Wigeon numbers and movements within Otterhampton Marsh, their response to the bait, and the ground conditions between 15 October and the end of the month. It became apparent during this time that the Wigeon had responded well to the bait and the dummy net, and a catch attempt was planned for 3 November. By this date, all appropriate site, SPA, and licensing permissions and permits were in place. All appropriate steps were taken to adhere to government guidance on Covid-19.

2.1.2. Tag selection and licensing

Tag selection was informed by the data needs of the project and licensing criteria.

Licensing of the deployment of tags on birds in the UK is overseen by the independent Special Methods Technical Panel (SMTP) of the BTO Ringing Committee. Previous tracking studies of ducks have shown that they may not respond well to having tags fitted using a harness (Pietz, Krapu, Greenwood, & Lokemoen, 1993; Bergmann, Flake, & Tucker, 1994; Rogers, Petrie, & Baloyi, 1996; Lameris & Kleyheeg, 2017). Due to these reported problems, the SMTP will not currently licence deployments of back-mounted devices using harnesses on wild ducks, as they do not feel this method meets Home Office welfare standards. There are devices that can be attached to birds permanently using leg rings or neck collars, but none of these are capable of collecting data at the resolution required to fulfil the objectives of this project. Therefore, the only suitable attachment method for this project was glue-mounting a tag to the mantle of the Wigeon.

Glue-mounted tags only remain attached to the bird for as long as it takes for new feathers to grow underneath and displace the tag. It is reported within moult guides (Baker, 1993; Demongin, 2016) that adult Wigeon undergo body moult between August and November, and occasionally throughout the winter. It was therefore hoped that deployments made in November would be after the main body moulting period, and could therefore remain attached for up to three months, covering the majority of the winter period.

Given the assumption of this project was that birds may move between the two SPAs, and perhaps to other places also, it was assumed that manual retrieval of the tags in order to download data directly would not be possible. Therefore tags with remote downloading capabilities were required. Placing base stations in areas close enough to birds in order to remotely download data via VHF/UFH would be very difficult, given little was known about their winter movement patterns. Therefore, a tag capable of transmitting data remotely from any location within the UK (and Europe) was advisable. GPS-GSM devices are the most widely available method for achieving this, whilst still collecting data at a suitable resolution to achieve the objectives of this project. Other remote downloading systems are available (satellite/PTTs/Argos) but these are more expensive, and energy intensive and so require a large battery, which increases the tag weight beyond the licensable threshold. The SMTP generally only approve applications that have a device deployment weight that is less than 3% of the bird's body weight.

For the purposes of this project it was thus agreed that the OrniTrack-15 2G GPS-GSM tags manufactured by Ornitela (Ornithology and Telemetry Applications)[1] were the most suitable option available. This is a GPS-GSM device that is capable of collecting up to 800 GPS positions on a fully charged battery, and has solar panels to aid additional charging after deployment. These tags are capable of maintaining one minute GPS fixes continuously under excellent solar charging conditions (mid-summer), but were expected to be capable of maintaining 10-15 minute fixes during a standard British winter. The tags also collect data on instantaneous speed, GPS altitude, temperature, acceleration and magnetometry. The GPS fix rate can be controlled by geofences, such that the tag collects data at a variable rate depending on whether the animal is within or outside a pre-defined geographic area. This functionality would enable battery power to be saved when the bird was outside the proposed route of the National Grid Hinkley Connection Project, thus ensuring enough battery power was available to collect the highest resolution data possible when moving between the Severn Estuary SPA and Somerset Levels and Moors SPA.

[1] Ornitela - https://www.ornitela.com/15g-transmitter

The 15 OrniTrack-15 2G GPS-GSM tags deployed weighed 16.1 ± 0.2 g on average (± sd) which was less than 3% of the birds average body mass (695 ± 50.1 g, range 605-765 g), as required by licensing. The tags were affixed using glue to the mantle following methods in Green *et al.* (2019), as recommended by the SMTP. The mantle positioning minimised the risk of the additional weight affecting the flight dynamics (Vandenabeele *et al.*, 2014; Lameris & Kleyheeg, 2017).

2.1.3. Catching and tagging

By the beginning of November, Wigeon were reliably responding to the bait. One full standard-mesh cannon-net (11.5 x 25 m) was set on the evening of 2 November. It was noted that the ground was muddy in the baiting area, due to waterfowl churning the ground through repeatedly walking over it. Therefore the net was set slightly further north-northeast (20 m) of the original area planned for the catch (Figure 2.2).

The catching team consisted of five people, all with extensive experience of cannon-netting and handling wildfowl. All adhered to strict coronavirus protocols throughout. All were in position to manage the catch before dawn on the 3 November, with the expectation that Wigeon would arrive to eat the bait in the catching area at first light.

The net and catching area were monitored by two cannon-net licence holders from a hide continuously. Wigeon numbers in the vicinity did not begin to build until ~08:50, well after first light. A flock of Canada Geese *Branta canadensis* entered the catch area first and made it impossible to fire when Wigeon did eventually start arriving. As soon as the geese moved away from the net, the catch was taken.

In total, 57 Wigeon, six Teal, three Canada Geese and a Bar-headed Goose *Anser indicus* were caught. Two team members (cannon-net license holders) were at the net within 20 seconds. The other three team members arrived within a further minute. Almost all of the birds became muddy under the net, as the substrate was in a worse condition than anticipated. All birds were transported back to the site office yard, where they could be washed clean, dried, processed (ringing and biometric measures) and then either tagged or immediately released. The net was fired at 09:20, and all non-tagged birds were released by 12:30. The final tagged bird was released at 15:30.

Of the 57 Wigeon caught, 15 were tagged, comprising 11 adults (six male, six female) and four juveniles (two male, two female).

2.2. Data Analysis

2.2.1. Data quality

All tags were programmed to enable the highest quality of data collection possible, whilst balancing the aims of the project with the battery voltage capabilities of the tag. GPS data collection and GSM transmission are both energy intensive processes. In optimum solar charging conditions (mid-summer) the solar panel on the OrniTrack-15 2G GPS-GSM tags is capable of recharging the battery such that the device can collect one minute continuous fixes during the day. In mid-winter, the solar charging conditions are very sub-optimal.

When deployed, all tags were thus programmed to collect data at a 15 minute rate when the battery capacity was between 75-100%, at a 30 minute rate when the capacity was between 50-75%, at a 90 minute rate between 25-50%, and at a 180 minute rate below 25%. They were set to transmit these data once a day (every 24 hours). Further, the tags also had a geofence programmed into them (Figure 2.3). If a GPS position occurred within this geofence, then the tag would switch to another set of programmed settings (Table 2.1). The intention of this geofence was to enable more intensive data collection whilst Wigeon flew between the two target SPAs, or when they were in the vicinity of the proposed high voltage electricity cables, thus giving high resolution data on flight paths, heights and speeds.

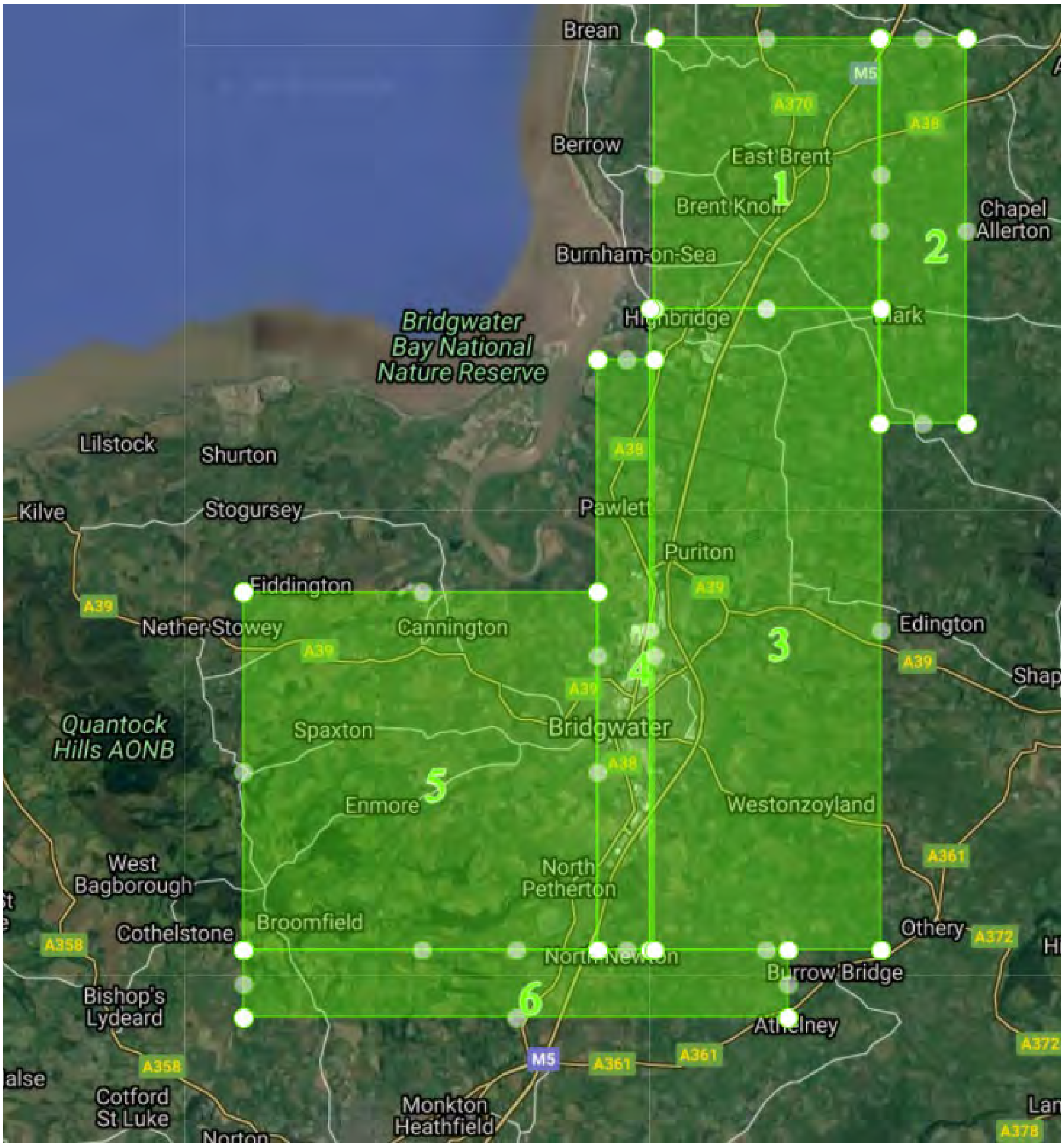

Figure 2.3 The geofence programmed into each tag. If a GPS fix was taken whilst the tag was inside the area highlighted in green (made up of six different rectangles), then a more intense data collection regime would be enabled. Image from © 2021 Google.

Table 2.1 Summary of the data rate settings programmed into each tag when they were deployed on Wigeon at WWT Steart Marshes on 3 November 2020.

	Battery capacity (%) and data rate [min (sec)]			
Programmed settings	**75 – 100**	**50 – 75**	**25 – 50**	**<25**
Outside geofence	15 (900)	30 (1800)	90 (5400)	180 (10800)
Inside geofence	0.3 (16)	1 (60)	15 (900)	180 (10800)

2.2.2. Data on movements

A summary of all recorded movements is given, with a focus on movements between the two target SPAs and thus across the proposed route of the National Grid Hinkley Connection Project. Maps of these movements are displayed. All maps were produced using a local R package 'BTOTrackingTools' (Thaxter, 2021). These were created using the raw dataset, with only data points where fewer than three satellites were used to estimate the location excluded.

2.2.3. Area use and time budgets

In order to assess the area usage of the Wigeon, Kernel Density Estimate (KDE) analysis was used (Worton, 1989), within the 'BTOTrackingTools' package (Thaxter, 2021) in R 4.0.3 (R Core Team, 2021). Core areas (50% Utilisation Distribution (UD) contour) and home ranges representing total area usage (95% UD contour) were calculated, along with an intermediate contour presented for graphical purposes (75% UD contour). Analysis was conducted on the data for all birds combined, and for each individual separately. Results presented in the main text are produced using data filtered to a 90 minute rate (n = 3376 for all birds). Additional analyses considered data filtered to a 30 minute rate (n = 6084 for all birds). These two rates are displayed to help reflect the different data sampling rates achieved during the tag deployment period. However, the data filtered to a 30 minute rate cover a shorter overall temporal period, as most tags had reduced to a 90 minute data rate by 16 November 2020. KDEs represent activity for both day and night time.

The percentage spatial overlap of KDEs with the areas of the Severn Estuary SPA and with the Somerset Levels and Moors SPA were quantified by overlaying shapefiles available through the Joint Nature Conservation Committee[2] .

2.2.4. Speed data

Data on instantaneous ground speed were reported directly by the tags, and are calculated based on the time interval between sending and receiving the location information from the GPS-satellites. The mean error of similar devices that collect speed data in this way is generally between 0.01-0.82 m/s, and thus are a more representative speed estimate than those calculated from the time and distance between consecutive GPS fixes (Fijn & Gyimesi, 2018). Given the low fix rate of the tags in this study, any speed estimates calculated from the time and distance between consecutive fixes would have been highly inaccurate.

In order to assess all data points associated with flight, a manual data extraction process was conducted. All points with a speed greater than 30 km/h (n = 50) were initially considered as representing flight. The GPS locations of these data points were then compared to the data points immediately before and after them. If a reasonable movement had occurred (>200m), then the point was considered likely to have been associated with flight. The number of satellites, estimated

[2] SPA shapefiles retrieved from: https://hub.jncc.gov.uk/assets/20dbc9b4-ceac-4bf2-8763-4ae387fa88c4

altitude and accelerometry data collected at the time of the fix was also considered in order assess the likely accuracy of the reported speed data. By this method, 21 fixes associated with flight were identified.

2.2.5. Altitude data

Data on GPS altitude were collected by the tag, which is calculated via GPS satellite triangulation. All data points where fewer than three satellites were used to estimate the altitude have been excluded from analysis. All reported altitudes represent the height in metres above mean sea level. As there were very few data points taken whilst birds were in flight, and the majority of the data collection area was <10m above sea level, no geoid calibration has been conducted.

The estimation of altitude from GPS triangulation can be relatively inaccurate when the bird is stationary and/or at ground level. Therefore, some of the altitude estimates are from below sea level. Negative altitude estimates represent part of the error distribution in estimates around the 'true' altitude. The data presented should be interpreted with this error distribution in mind, and in the knowledge that the vast majority of data points represent the bird at ground level.

3. RESULTS

3.1. Field Study and Tag Evaluation

3.1.1. Tag deployments

In total, 15 Wigeon (out of 57 caught) were fitted with OrniTrack-15 2G GPS-GSM devices using a glue-mounting method. Of these 15, 11 were adults (six male, six female) and four were juveniles (two male, two female). See Table 3.1 for details on all the birds tagged, and the biometric measures for each.

Table 3.1 Ring and biometric data from the 15 Wigeon tagged at WWT Steart Marshes on 3 November 2020.

Tag ID	Ring number	Age	Sex	Weight (g)	Wing (mm)	Total head length (mm)
OW-12	FJ51132	Juvenile	Female	760	260	89
OW-13	FJ51134	Adult	Female	720	253	81
OW-14	FJ51130	Adult	Female	710	245	81
OW-15	FJ51127	Adult	Female	660	256	81
OW-16	FJ51252	Adult	Male	765	262	86
OW-17	FJ51257	Adult	Male	605	261	-
OW-18	FJ51129	Adult	Female	730	253	-
OW-19	FJ51125	Juvenile	Female	660	247	80
OW-20	FJ51139	Juvenile	Male	630	251	82
OW-21	FJ51138	Adult	Male	720	273	84
OW-22	FJ51128	Juvenile	Male	690	265	84
OW-23	FJ51135	Adult	Male	620	258	83
OW-24	FJ51131	Adult	Female	710	253	80
OW-25	FJ51251	Adult	Male	765	266	85
OW-26	FJ51136	Adult	Male	680	266	80

A few of the tagged birds had a small amount of active body moult on the mantle (1-3 pin feathers in the trimmed area). Mantle feathers were trimmed cautiously to ensure that active pin feathers (with strong blood supply) were not cut, and the tags were glued to the trimmed site ensuring no pin feathers were glued. Tags were checked for a firm and unrestrictive fit before the birds were released (Figure 3.1).

Figure 3.1 Images showing a Wigeon with a glue-mounted tag.

On release all birds (except OW-25) flew strongly, and appeared behaviourally unaffected by the tags. Bird OW-25 initially refused to fly, and instead hopped around in circles with its neck arched backwards. These symptoms were discussed with all team members, and the bird was placed back in a holding crate for observation. After 30 minutes it seemed comfortable, and on closer inspection a couple of neck feathers had been glued under the front edge of the tag. These were released, and the bird then flew off ok, though not strongly. The data from OW-25 over the next two days showed the bird remained within the nearby freshwater marsh area. On 6 November the tag checked in again from the same area at 10:40, so at 14:00 a WWT staff member checked the area thoroughly, but could find no sign of the bird, the tag, or predation (i.e. fox prints). The tag never connected to the network again thereafter. It is possible that the neck arching and moving in circles were symptoms of avian influenza. It is also possible that the tag malfunctioned and the bird moved away from the area of its own accord. Either way, the data from this tag have not been included for further analysis, as they are not representative of 'normal' behaviour.

The other 14 tags remained attached for an average of 17.88 ± 6.44 (sd) days (range: 11.85 – 27.81 days). This was not as long as anticipated, though it had been identified ahead of the tagging that birds may have been in active body moult during the deployment period. Although a few birds had some pin feathers on the mantle during tagging, none were in heavy moult, and very few Wigeon feathers were evident around Otterhampton Marsh, suggesting the main body moult period (August – November, see section 2.1.2) was over. It is suspected that the extended period of poor weather after tagging (overcast, rainy and cold for two weeks), coupled with the presence of moulting hormones in the birds, may have induced more active moult on the mantle, which had been thermally compromised by trimming feathers off this area. This may then have caused the tags to be shed sooner than expected.

Despite this earlier than anticipated end to the deployment period, the tag deployments provided sufficient data to fulfil the main objectives of the study on movements between the Severn Estuary SPA and Somerset Levels and Moors SPA, and area usage.

3.1.2. Tag performance

Due to the extended period of poor weather post-deployment (continuous heavy cloud for two weeks), the tags were unable to fully recharge their batteries using solar energy to maintain the intended 15 minutes continuous data collection rate. They maintained the 15 minute rate on average for 3.5 ± 2.2 (sd) days, followed by an average period at a 30 minute rate of 5.5 ± 2.0 (sd) days. Thereafter they could only sustain a 1.5 hour (90 minute) rate on the battery voltage they were able to maintain with the available solar charging conditions. Tag OW-15 failed to sustain even the 1.5 hour rate beyond 22 November and so only transmitted a location every 24 hours, when data transmission occurred. The lack of ability to solar recharge effectively is the main cause for the tags being unable to collect the proposed quantity of data. Figure 3.2 displays the data rates achieved by each tag throughout their deployment periods.

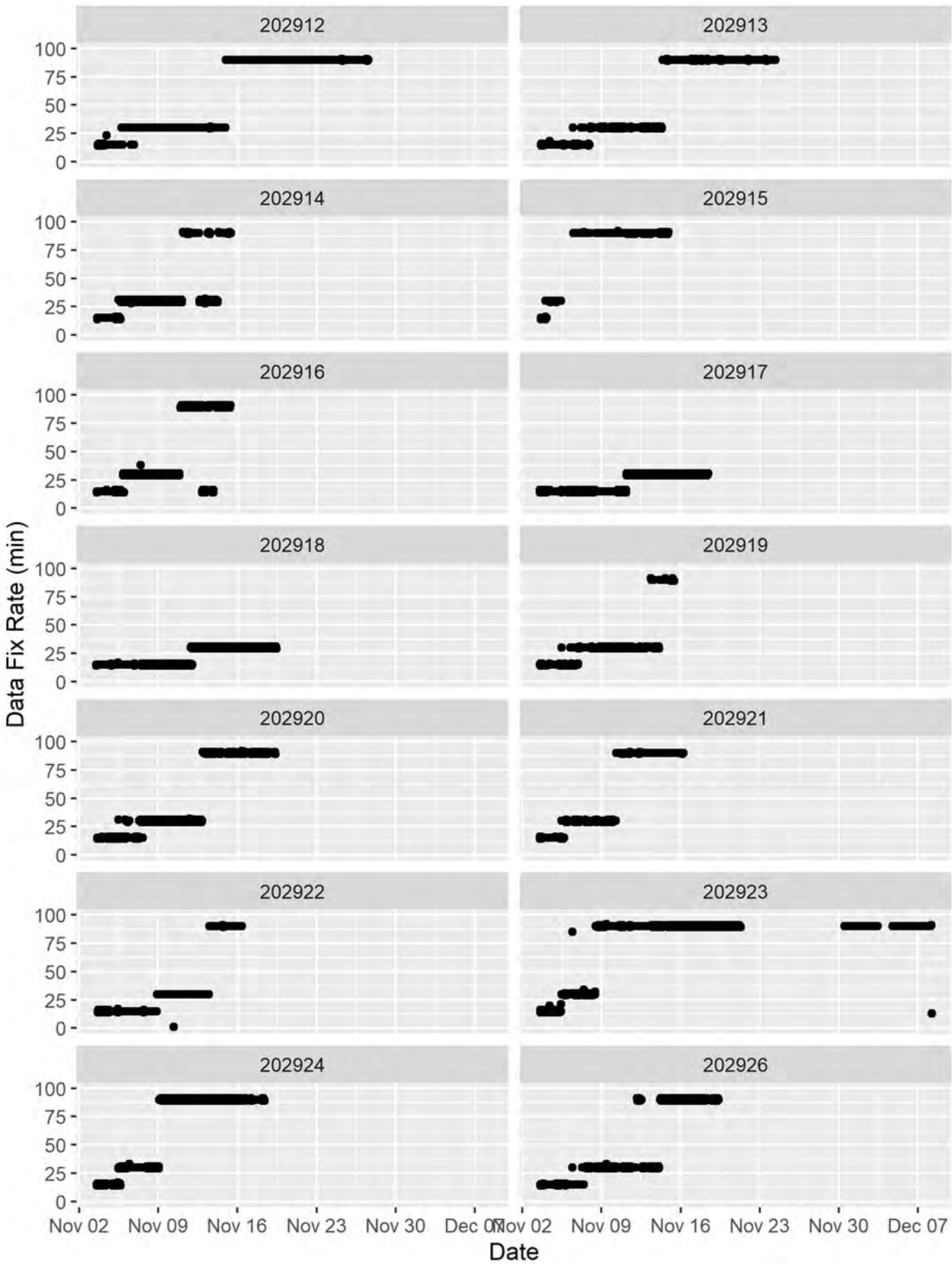

Figure 3.2 Data fix rates (interval between GPS fixes) achieved by each tag during their deployment on Wigeon. The final two digits of each graph title indicated the individual i.e. 202912 is OW-12. Note, OW-15 reduced to a 24 hr fix rate after 22 November, but for ease of graphical representation this has not been displayed.

3.2. Data Analysis

3.2.1. Data summary

A summary of the data collected by each tag during the deployment period is displayed in Table 3.2. Each data fix contained data on time and date, latitude and longitude, number of satellites used to calculate the position, instantaneous speed, altitude from GPS triangulation, instantaneous accelerometry and magnetometry data, external temperature, and battery voltage.

Table 3.2 Summary of the quantity of data collected by 14 tags deployed on Wigeon at WWT Steart Marshes on 3 November 2020.

Tag ID	End of deployment	Deployment period (days)	Total data fixes	Total analysable GPS fixes
OW-12	27/11/2020 13:28:35	23.9	858	858
OW-13	24/11/2020 09:39:59	20.8	869	869
OW-14	20/11/2020 09:09:35	16.8	578	574
OW-15	01/12/2020 10:37:05	27.8	300	296
OW-16	15/11/2020 09:17:06	11.8	578	578
OW-17	18/11/2020 10:09:05	14.9	1081	1081
OW-18	19/11/2020 10:38:49	15.9	1168	1168
OW-19	15/11/2020 09:52:31	11.8	668	668
OW-20	19/11/2020 09:09:05	15.8	712	710
OW-21	16/11/2020 06:24:52	12.7	522	522
OW-22	16/11/2020 09:13:14	12.8	774	774
OW-23	08/12/2020 04:55:42	34.6	647	537
OW-24	18/11/2020 09:58:47	14.9	512	512
OW-26	19/11/2020 08:55:35	15.8	756	755
Average		**17.9 ± 6.4 (sd)**	**715.9 ± 221.0 (sd)**	**707.3 ± 225.9 (sd)**

3.2.2. Data on movements

Figure 3.3 displays all the tracking data collected. Maps of the movements for each individual can be found in Appendix 1. Note that all grey lines in Figure 3.3 are straight lines drawn between known location points, and may therefore not accurately represent the exact route taken between these.

Overall, most birds remained in the area of WWT Steart Marshes and the Severn Estuary SPA, to the west of the proposed powerline. Four birds were recorded making movements that would cause them to pass across the line of the proposed high-voltage cables, with one bird (OW-12) making a return journey (i.e. crossing the proposed route twice). One bird (OW-22) made a flight east from the Severn Estuary SPA that almost crossed the proposed route, but it turned around and returned to where it came from just before passing over the route (Figure 3.3, 202922; point near Puriton). Table 3.3 summarises the timing of movements across, or in the direction of, the proposed powerline route.

The movements away from the Severn Estuary SPA / WWT Steart Marshes area towards the Somerset Levels and Moors SPA were made by one juvenile female (OW-12), one juvenile male (OW-22), one adult female (OW-15) and two adult males (OW-16, OW-23). Though the sample sizes for this project are small, this suggests that any member of the local wintering Wigeon population has the potential to move between these SPA sites.

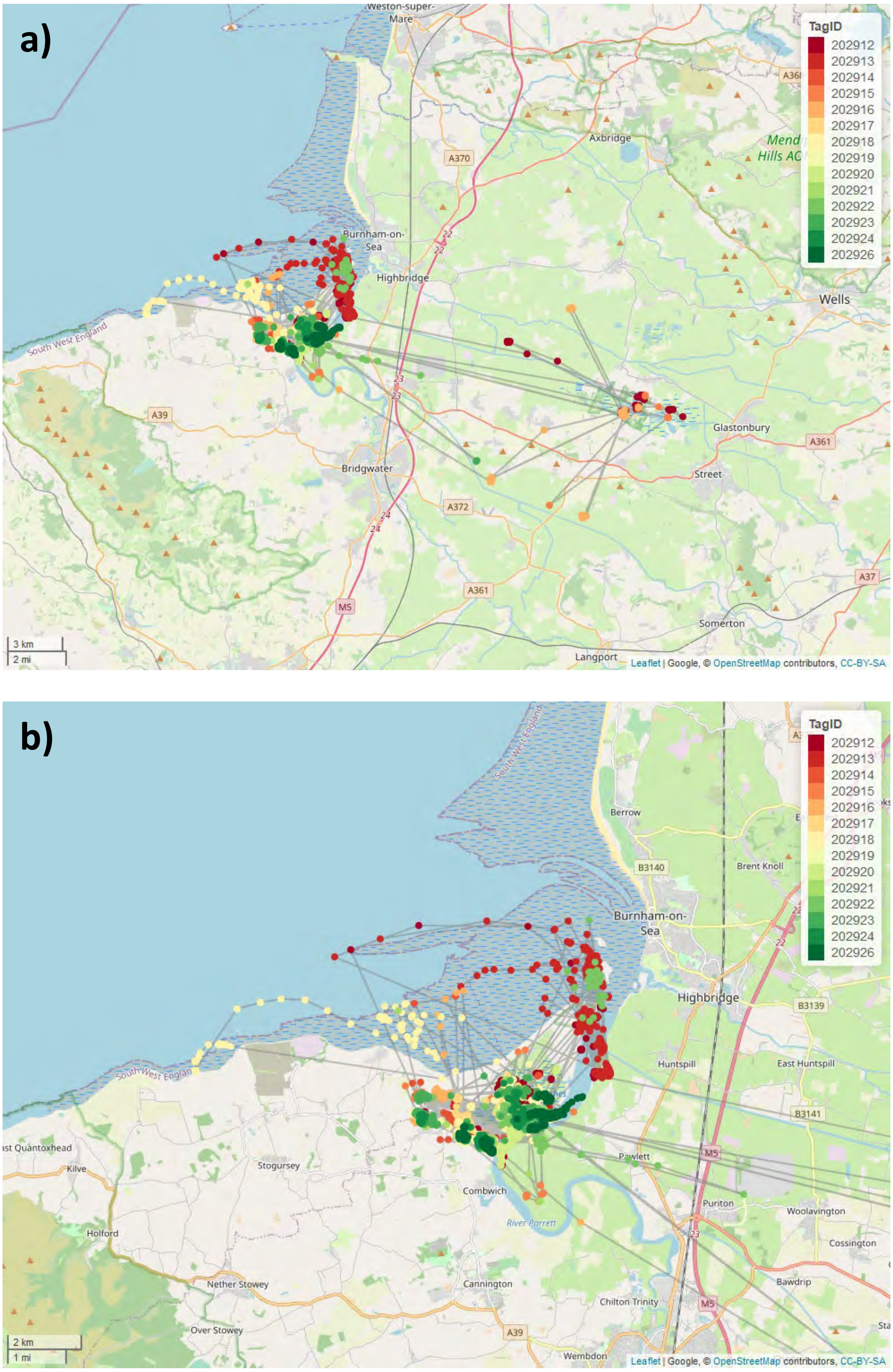

Figure 3.3 Overview of all the location data collected from tags deployed on Wigeon at WWT Steart Marshes on 3 November 2020, in: a) the entire data collection area; b) the areas around WWT Steart Marshes and Severn Estuary SPA and; c) the areas around the Somerset Levels and Moors SPA.

Figure 3.3 cont…

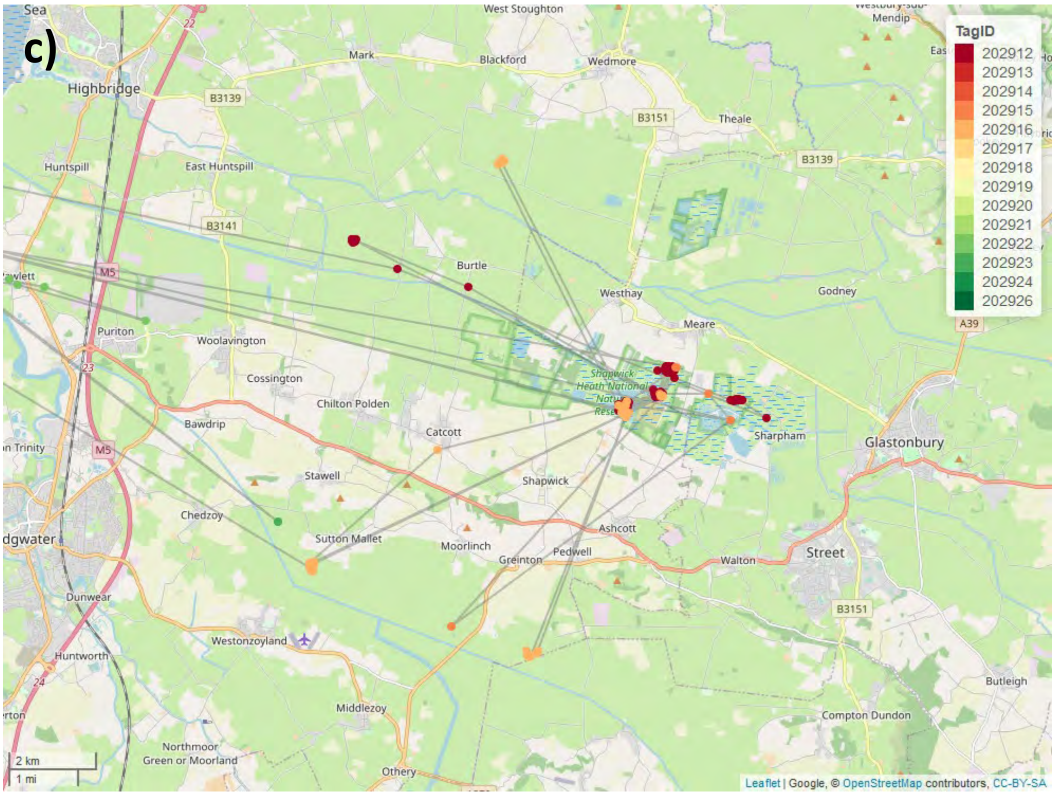

Table 3.3 Summary of data collected during movements of Wigeon across the proposed high-voltage powerline route.

Tag ID	Movement direction	Start	End	Data fix rate
OW-12	West to East	05/11/2020 04:13:08	05/11/2020 04:43:07	15 min
OW-12	East to West	08/11/2020 17:28:35	08/11/2020 17:58:05	30 min
OW-15	West to East	22/11/2020 10:37:13	23/11/2020 10:37:07	24 hr
OW-16	West to East	12/11/2020 19:31:43	12/11/2020 21:02:06	1.5 hr
OW-22	Partial (return to Puriton)	10/11/2020 09:09:27	10/11/2020 09:13:17	1 min
*OW-23	West to East	23/11/2020 10:39:06	08/12/2020 04:42:00	-

*OW-23 failed to transmit GPS data between 23/11/2020 and 08/12/2020. On 23/11/2020 it was within the Severn Estuary SPA. When it transmitted again, the tag was just east of the existing 132,000 volt powerline, near Sutton Mallet. The Wigeon must have carried the tag to this location, but no data were collected during the flight to this location, which likely took the bird over the proposed powerline route.

3.2.3. Area use and time budgets

Kernel Density Estimates (KDEs) were calculated using 90 minute regularised data for each bird, and their core area (50% Utilisation Distribution (UD) contour) and home range (95% UD contour) are presented in Table 3.4. The overlaps of these UD areas with each of the target SPAs is also presented.

Table 3.4 Summary of the KDE area usage of 14 Wigeon tagged at WWT Steart Marshes on 3 November 2020, and the overlaps of this KDE area with the two target SPAs for this study. The data used to calculate these KDEs were regularised to a 90 minute rate.

Bird ID	**50% KDE area**	**95% KDE area**	**% overlap between 50% KDE and Severn Estuary SPA**	**% overlap between 95% KDE and Severn Estuary SPA**	**% overlap between 50% KDE and Somerset Levels and Moors SPA**	**% overlap between 95% KDE and Somerset Levels and Moors SPA**
OW-12	6.4	41.4	25.1	33.9	0	7.2
OW-13	2.8	17.3	92.9	64.1	0	0
OW-14	0.4	2.1	0	8.0	0	0
OW-15	2.1	11.5	49.0	36.6	0	0
OW-16	20.3	183.3	37.7	15.5	0	12.4
OW-17	0.3	2.8	0	26.2	0	0
OW-18	1.4	11.0	57.5	36.0	0	0
OW-19	0.8	3.6	6.0	29.4	0	0
OW-20	0.5	2.3	68.4	63.0	0	0
OW-21	0.8	4.5	17.5	27.1	0	0
OW-22	0.8	3.7	73.0	52.3	0	0
OW-23	2.1	9.3	40.3	29.7	0	0
OW-24	0.8	3.9	12.5	28.2	0	0
OW-26	0.3	1.5	22.4	43.2	0	0
All birds	**2.4**	**31.6**	**40.4**	**46.3**	**0**	**3.0**

Figure 3.4 displays the overall KDE calculated using all tracking data regularised to a 90 minute rate with a 50 m grid. The key spatial areas around the Severn Estuary SPA / WWT Steart Marshes area and Somerset Levels and Moors SPA can be seen. Equivalent maps for each individual are shown in Appendix 2.1.

Results based on data regularised to 30 minutes on a 25 m grid are displayed in Appendix 2.2. The two analyses are presented in order to help capture some of the variation created when regularising datasets that were never on a consistent data collection rate (see section 3.1.2 and Figure 3.2). The data regularised to 30 minutes represent a shorter overall temporal period, as most tags had reduced to a 90 minute rate by 16 November 2020.

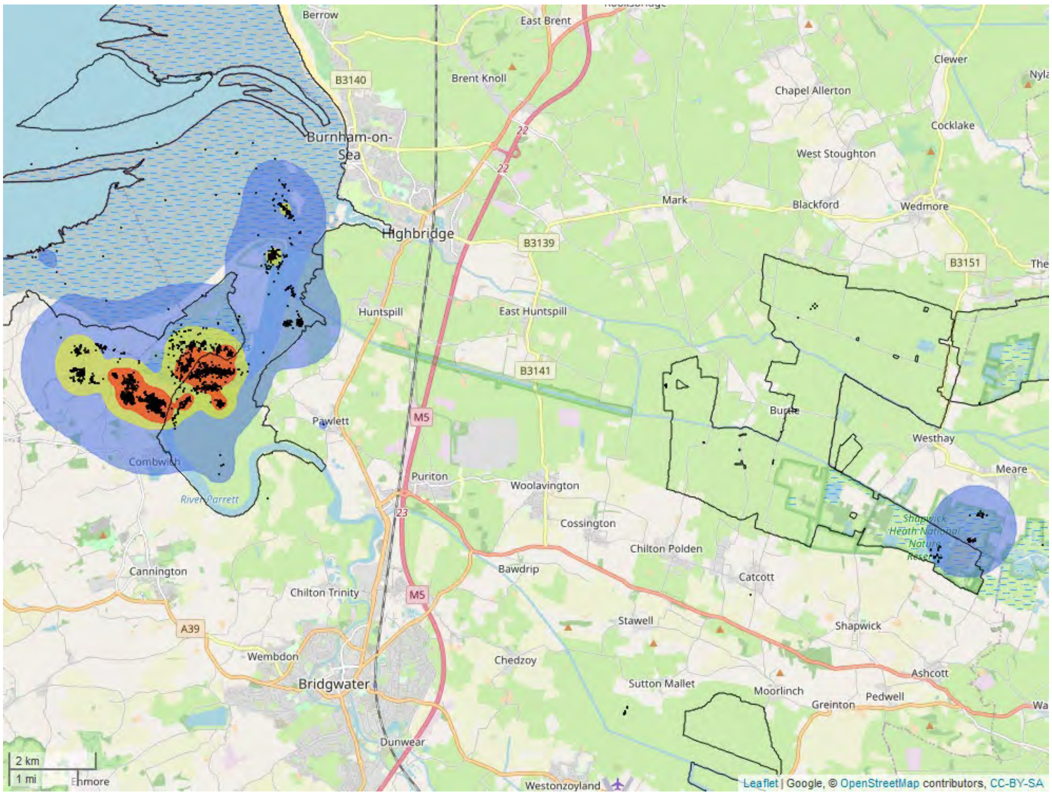

Figure 3.4 Kernel density estimates (KDEs) for the 14 Wigeon for which data were obtained. The 50% utilisation distribution (UD) (core area) is in red, with the 75% UD in yellow and the 95% UD (total home range) in blue. The raw tracking points used for this KDE are displayed as black dots (n = 3376; Href = 379.2978). The Severn Estuary SPA is outlined in black to the west, with the Somerset Levels and Moors SPA outlined to the east.

These KDEs provide a visual display of the spatial distribution of the Wigeon during the tracking period. They highlight that area use was greatest around WWT Steart Marshes and the Severn Estuary SPA, to the west of the proposed powerline, with more limited use of the Somerset Levels and Moors SPA.

When analysing the temporal distribution of the data also, this same pattern can be seen. On average, birds spent a far greater proportion of their time in the area around WWT Steart Marshes and the Severn Estuary SPA (94.7 ± 10.3 %), than on the Somerset Levels (5.0 ± 9.5 %) (Table 3.5).

Table 3.5 Summary of the proportion of time each Wigeon spent in different areas, including the Severn Estuary SPA and Somerset Levels and Moors SPA. 'Steart area' is defined as the area west of the proposed powerline; 'Levels' is defined as the area east of the proposed powerline*.

Bird ID	Total time tracked (days)	Time in Steart area (days [% of total time])	Time in Levels (days [% of total time])	Time in Severn Estuary SPA (days [% of total time])	Time in Somerset Levels and Moors SPA (days [% of total time])
OW-12	23.9	20.3 [85]	3.5 [15]	4.1 [17.2]	0.8 [3.3]
OW-13	20.8	20.8 [100]	0 [0]	19.3 [92.7]	0 [0]
OW-14	16.8	16.8 [100]	0 [0]	0.9 [5.2]	0 [0]
OW-15	27.8	18.8 [68]	8.0 [29]	8.7 [31.1]	1.0 [3.6]
OW-16	11.8	9.3 [78]	2.5 [21]	1.0 [8.4]	1.1 [9.1]
OW-17	14.9	14.9 [100]	0 [0]	1.1 [7.7]	0 [0]
OW-18	15.9	15.9 [100]	0 [0]	6.3 [39.6]	0 [0]
OW-19	11.8	11.8 [100]	0 [0]	2.3 [19.6]	0 [0]
OW-20	15.8	15.8 [100]	0 [0]	10.7 [67.8]	0 [0]
OW-21	12.7	12.7 [100]	0 [0]	2.3 [18.2]	0 [0]
OW-22	12.8	12.8 [100]	0 [0]	8.4 [65.9]	0 [0]
**OW-23	34.6	19.9	0	9.9	0
OW-24	14.9	14.9 [100]	0 [0]	2.9 [19.4]	0 [0]
OW-26	15.8	15.8 [100]	0 [0]	3.6 [23.0]	0 [0]
Average	**17.9 ± 6.4 (sd)**	**15.7 ± 3.3 (sd) [94.7 ± 10.3 (sd)]**	**1.1 ± 2.3 (sd) [5.0 ± 9.5 (sd)]**	**5.8 ± 5.2 (sd) [31.7 ± 26.1 (sd)]**	**0.2 ± 0.4 (sd) [1.1 ± 2.6 (sd)]**

*Where percentages do not add up to 100, the discrepancy reflects the time taken to move between the focal areas, which may have been as much as 24 hours between GPS data points (OW-15).
**OW-23 did not transmit a location between 23 November 2020 and 08 December 2020. The data provided represent a minimum estimate of the time spent within each area. The tag was recovered east of the proposed powerline, but due to the data quality after 23 November 2020 it was not possible to accurately assess the proportion of time spent in the 'Levels' area.

3.2.4. Speed data

The tags collected information on instantaneous ground speed at each fix (see section 2.2.4 for further detail). As this is not a speed calculated from the time and distance between two GPS points, it should be an accurate reflection of the speed of the Wigeon at the time of the fix, assuming the triangulated GPS position is accurate. With 15 to 90 minute intervals between fixes, a speed interpolated from the distance and time between fixes would not be accurate as the bird is very unlikely to have been travelling at a continuous velocity in one direction for the entire intervening period.

The speed data collected during the entire deployment period are displayed in Figure 3.3, with the frequency axis limited to ensure that those speed readings recorded less frequently are displayed. The majority of data collected occurred when the birds we either stationary (0 km/h), or performing ground level activities (grazing, swimming, walking etc.; see section 3.2.5). Of the 9,902 data points included in these analyses, only 15 (0.15%) represented speeds above 60 km/h. Studies on Wigeon have demonstrated that their flight speeds are usually around this speed, with mean speeds of 61.6

(n = 7), 66.6 (n = 86) and 74.2 km/h (n = 36) recorded by Pennycuick (2001), Pennycuick *et al.* (2013) and Alerstam *et al.* (2007) respectively.

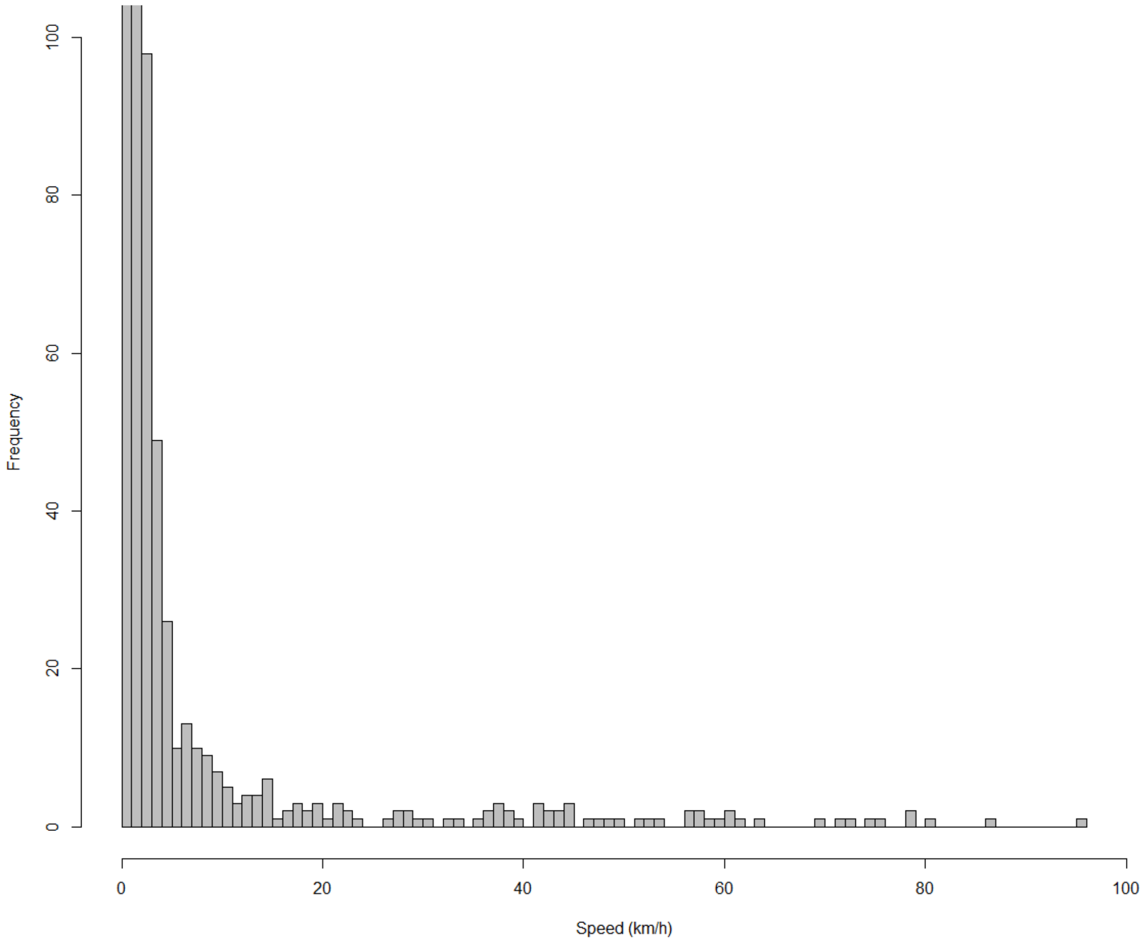

Figure 3.5 Speed data collected for 14 Wigeon tagged at WWT Steart Marshes on 3 November 2020. The frequency axis has been constrained for display purposes.

All the data points believed to be associated with flight in this study were extracted using the methods described in section 2.2.4. Of the 9,902 data points considered, only 21 (0.21%) were deemed likely to have been associated with flight. The mean flight speed was 68.5 ± 11.5 (sd) km/h (range: 54 – 96 km/h). These flight speed data are displayed as a boxplot in Figure 3.4; the median value was 64 km/h.

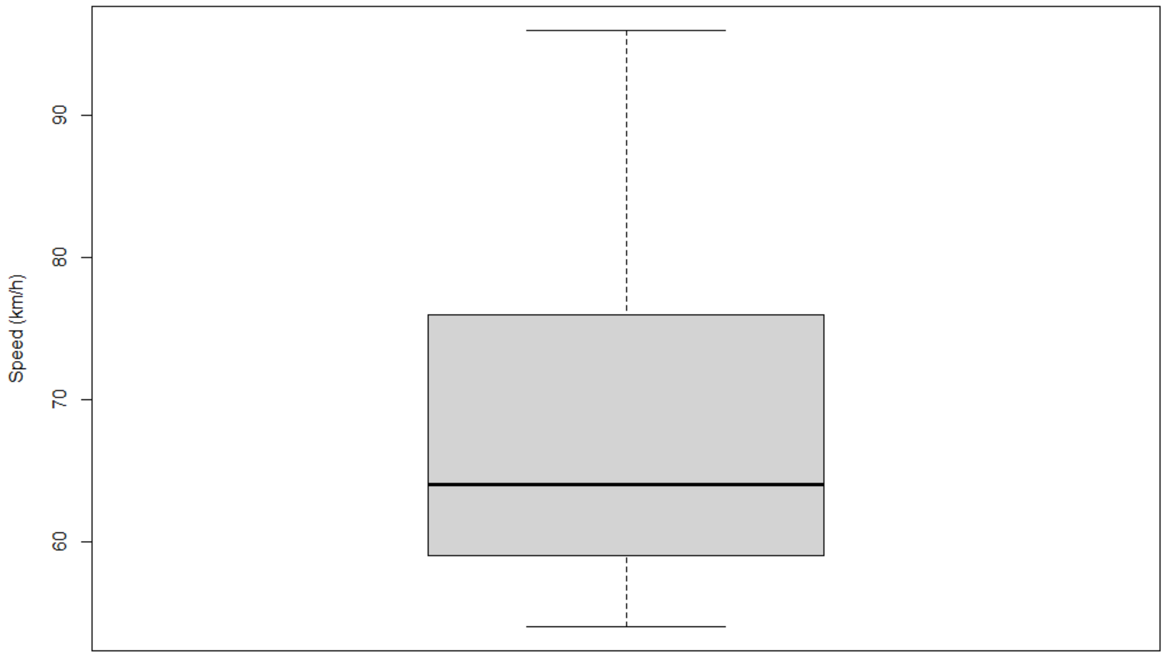

Figure 3.6 All flight speed data collected for 14 Wigeon tagged at WWT Steart Marshes on 3 November 2020 (n = 21 fixes).

3.2.5. Altitude data

Data on altitudes were calculated directly by the tag using GPS measurements. This method estimates altitude relatively accurately when a bird is moving, but is less accurate when a bird is stationary. The altitude distribution of the data reflects this, with many points occurring below sea level (0 m), reflecting the error distribution of the data.

The altitude data collected during the entire deployment period are displayed in Figure 3.5, with the frequency axis limited to ensure that altitude readings recorded less frequently are displayed. Half of the data (25 to 75% quartile) collected where between -5 and 15 m above sea level (asl), which most likely represents data collected whilst birds performed ground level activities (grazing, swimming, walking etc.). Wigeon were observed and tracked using the River Parrett estuary at low tide, and grazing on the top of sea wall banks; these locations would fall within the -5 to 15 m asl range.

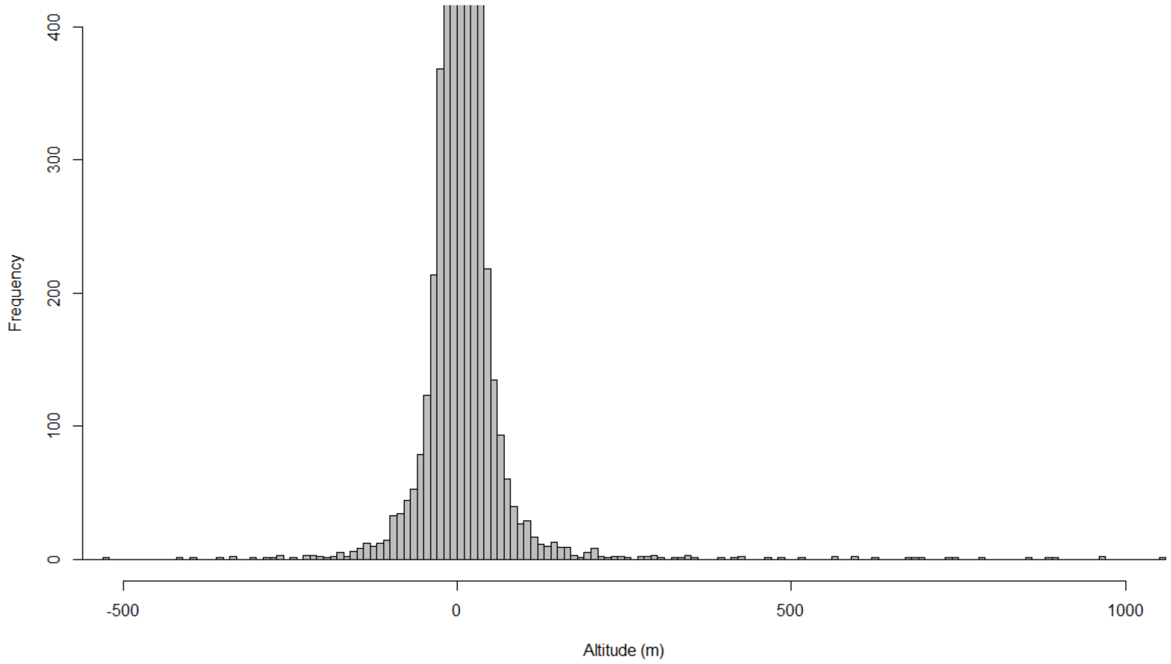

Figure 3.7 Altitude data collected for 14 Wigeon tagged at WWT Steart Marshes on 3 November 2020. The frequency axis has been constrained for display purposes, so that altitudes recorded less frequently can be seen.

All data points believed to be associated with flight in this study were extracted using the methods described in section 2.2.4. Of the 9,902 data points considered, only 21 (0.21%) were deemed likely to have been associated with flight. The mean flight altitude was 67.6 ± 70.2 (sd) m asl (range: -80 – 212 m). These flight height data are displayed as a boxplot in Figure 3.6; the median value is 44 m.

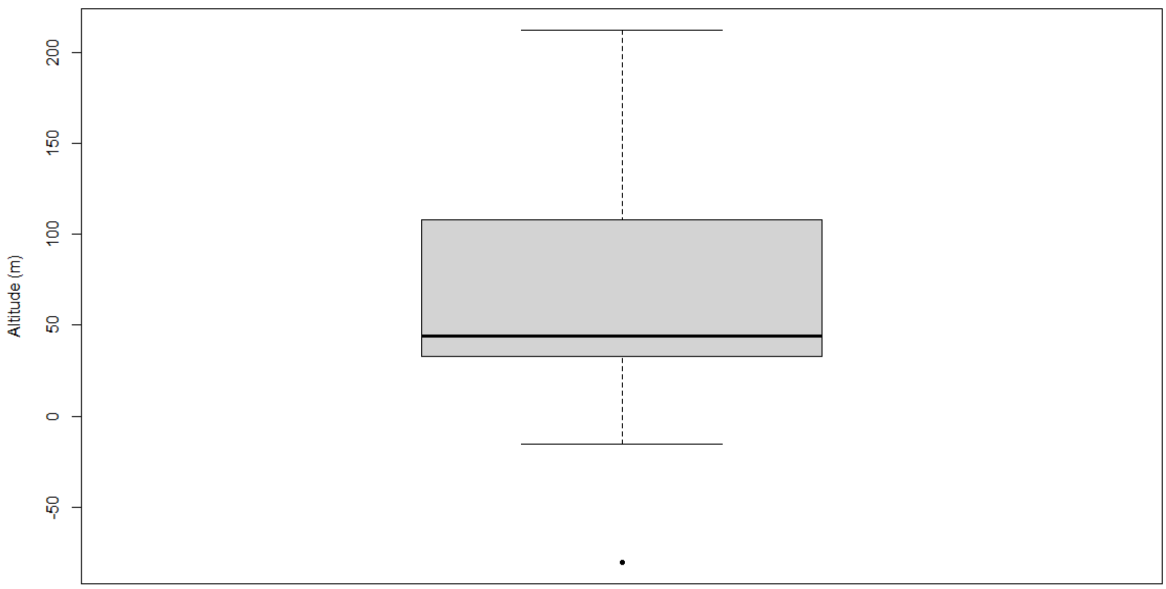

Figure 3.8 All flight height data collected for 14 Wigeon tagged at WWT Steart Marshes on 3 November 2020 (n = 21 fixes).

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Evaluation of the tracking study

All 15 tags were successfully deployed on Wigeon at the WWT Steart Marshes reserve adjacent to the Severn Estuary SPA, and across a representative sample of the population (including adult males, females, and juveniles). The highest resolution of data possible was collected, given the limitations of available tag models, attachment methods, and study expectations (movement outside a small area). However, solar recharging capabilities were effected by an extended period of poor weather after the deployment, meaning that it was only possible to maintain a fix rate of 1.5 hrs for most tags after the first few days of deployment. Deployment periods averaged 18 days, providing a mean of 707 data points per bird.

4.2. Summary of movements between the Severn Estuary SPA and Somerset Levels and Moors SPA and the potential interaction with the National Grid Hinkley Connection Project

The Wigeon tracking data proved that there is connectivity between the Severn Estuary SPA and the Somerset Levels and Moors SPA, with indicative evidence that birds from all parts of the demographic structure of the population may move between these SPAs.

The data suggest that birds do not regularly commute between the Severn Estuary SPA and the Somerset Levels and Moors SPA. Birds that did move to the Somerset Levels and Moors SPA tended to spend an extended period (several days) at the new location. Only one bird made a return journey during the tracking period, though it should be noted that the tracking period only represented a small portion of the time these birds spend within the UK each year.

Of the 14 birds providing sufficient data, only four (28.6%) made a movement that would have caused them to cross the proposed route of the high-voltage powerline. However, these results should again be interpreted with caution, given the relatively small sample size and short tracking duration.

Where the timing of the movement between these SPAs is known with relative accuracy (within 1.5 hrs; Table 3.3), they occurred in the dark, either shortly before or shortly after astronomical twilight. Only the partial movement of OW-22, which flew from WWT Steart Marshes to Puriton and back, occurred during daylight hours (09:09 – 09:13).

Only five movements across the route of the National Grid Hinkley Connection Project were recorded in total (from four individuals), whilst just 0.21% of the data points collected were associated with flight, suggesting that time spent in the air is a very small proportion of a Wigeon's activity budget. This suggests the proportional likelihood of collision risk with the powerline is small.

4.3. Summary of flight speeds and altitude

The data associated with flight suggest that the mean flight speed of Wigeon in this study was 68.5 ± 11.5 (sd) km/h (range: 54 – 96 km/h), which is comparable to previously reported flight speeds of Wigeon (Pennycuick, 2001; Alerstam et al., 2007; Pennycuick et al., 2013).

The flight altitude data were similarly limited, but suggest the birds fly at heights of 67.6 ± 70.2 (sd) m (range: -80 – 212 m) above sea level (asl). Negative altitude estimates represent part of the error distribution in estimates around the 'true' altitude. Some negative estimates would coincide with birds flying below mean sea level, in the estuary of the River Parrett at low tide.

The majority of the flight altitude data were between 33 m and 108 m asl. This means that for the majority of the time Wigeon may be flying above the height of the proposed T-pylons (35 m), but may fly at a height that could cause interactions with traditional 400kV lattice pylons and the cables between them.

Most of the flights passing the proposed powerline route occurred in the dark. This means that any observational studies trying to assess the rate of Wigeon passage over the powerline route would be unlikely to survey the key transition periods (at night).

4.4. Summary of use of the Severn Estuary SPA and Somerset Levels and Moors SPA

In total, 10 (71.4%) of the 14 birds tracked spent the entire tracking period west of The National Grid Hinkley Connection Project proposed route, mainly using the WWT Steart Marshes and Severn Estuary SPA areas. Of the four (28.6%) birds that crossed the proposed route of the National Grid Hinkley Connection Project, three were recorded utilising the Somerset Levels and Moors SPA. The tag on the fourth bird (OW-23) malfunctioned before it travelled east from the Severn Estuary SPA, so we cannot say whether it did or did not utilise the Somerset Level and Moors SPA.

Overall, the Wigeon spent a mean of 31.7% of their time in the Severn Estuary SPA, but just 1.1% of their time in the Somerset Levels and Moors SPA. This temporal distribution is likely biased by the original catching and tagging location of the sample, but may also be reflective of the extent of movements of the local population. It should be noted that the time OW-15 spent within the 'Levels' area to the east of the proposed powerline was excluded from these analyses, due to the data regularisation process (Figure 3.2 and A1.3). This bird did spend eight days within the 'Levels' area before the tag ceased collecting data.

The spatial distribution of these tracking data are also likely to be somewhat biased as the entire sample comprised birds caught within the WWT Steart Marshes site. The period of the tracking data was also quite limited, when viewed in the context of the entire Wigeon wintering period. Both of these elements should be considered when interpreting the results of this study.

Those Wigeon that did fly to the east of the powerline and provided reasonable tracking data from within the Somerset Levels and Moors SPA, appear to have used the SPA as a centre point and then made foraging trips to areas outside of the SPA. OW-12, 15 and 16 used the Shapwick Heath National Nature Reserve as a central place, and then travelled up to 8 km from here to apparently utilise grassy agricultural fields. Each of the four birds that provided data from the 'Levels' area (OW-12, 15, 16, 23; see A1.3) utilised different fields, suggesting there is a range of suitable grazing opportunities available within commuting distance from the Somerset Levels and Moors SPA.

4.5. Recommendations

This project has proven that it is possible to catch and tag wintering Wigeon to assess their local winter movements, in this study between the Severn Estuary SPA and Somerset Levels and Moors SPA. However, due the current limitations in the UK licensing of tag attachment methods and the available tracking technologies, it was not possible to collect data over the entire wintering period, or at a high enough resolution to characterise in detail the exact flight paths between the two SPAs.

Given the results of this tracking demonstrate that there is connectivity between the SPAs, we would recommend conducting further tracking work in future. However, we would recommend waiting for further developments in both winter tracking devices and tag attachment methods before doing so.

Tracking technologies are developing at a fast pace currently. The devices used in this project were not available two years ago, and so it can be assumed that in a further few years even more advanced technologies will become available, that may be capable of collecting higher resolution data in the winter. There are also active developments in tag attachment methods for Wigeon, which may make it possible to deploy tags using a longer term harness attachment method in the near future. This would enable the tags to be deployed at the beginning of the winter, and for data to be collected throughout the winter and potentially beyond this.

A further recommendation would be to explore the possibility of deploying sound recorders along the proposed powerline route. Wigeon tend to call whilst in flight, and it may be possible to record these calls as they cross the powerline route at night. This technique has recently been used to identify the migration routes of Common Scoter *Melanitta nigra*[3]. If the sound recorders do record Wigeon calls successfully, this may help to provide data on the number, location and frequency of movements between the two SPAs.

[3] Citizen science reveals nocturnal scoter migration routes - https://www.birdguides.com/articles/migration/citizen-science-reveals-nocturnal-scoter-migration-routes/

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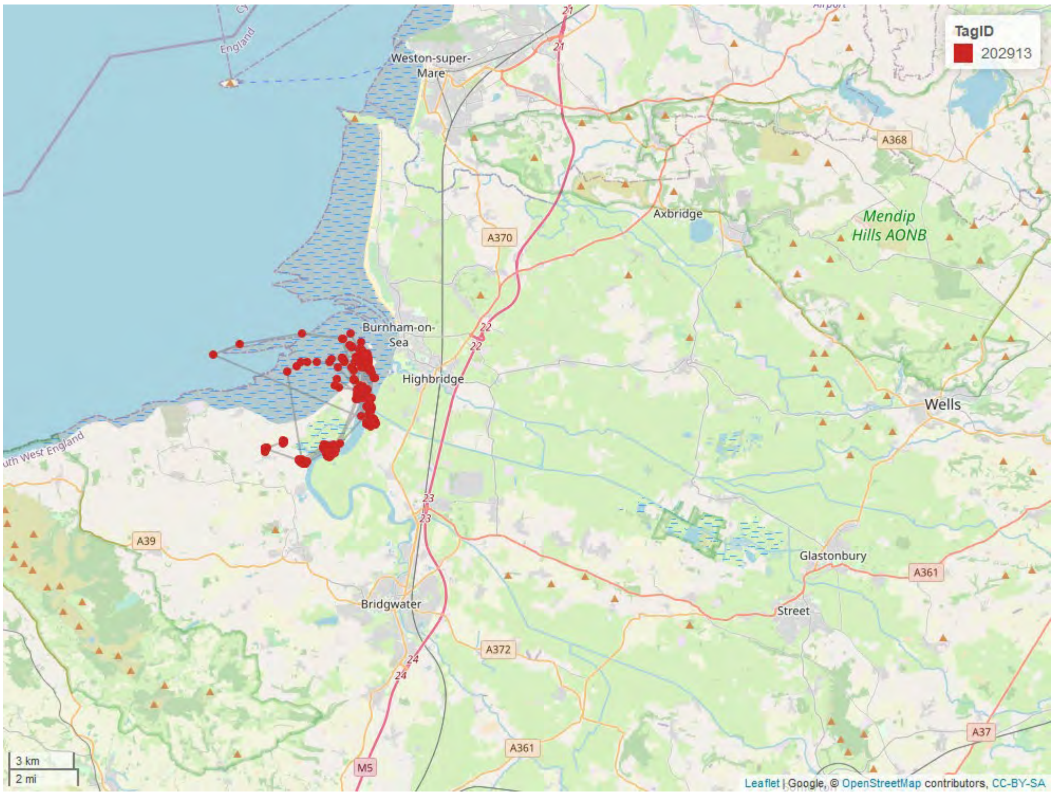
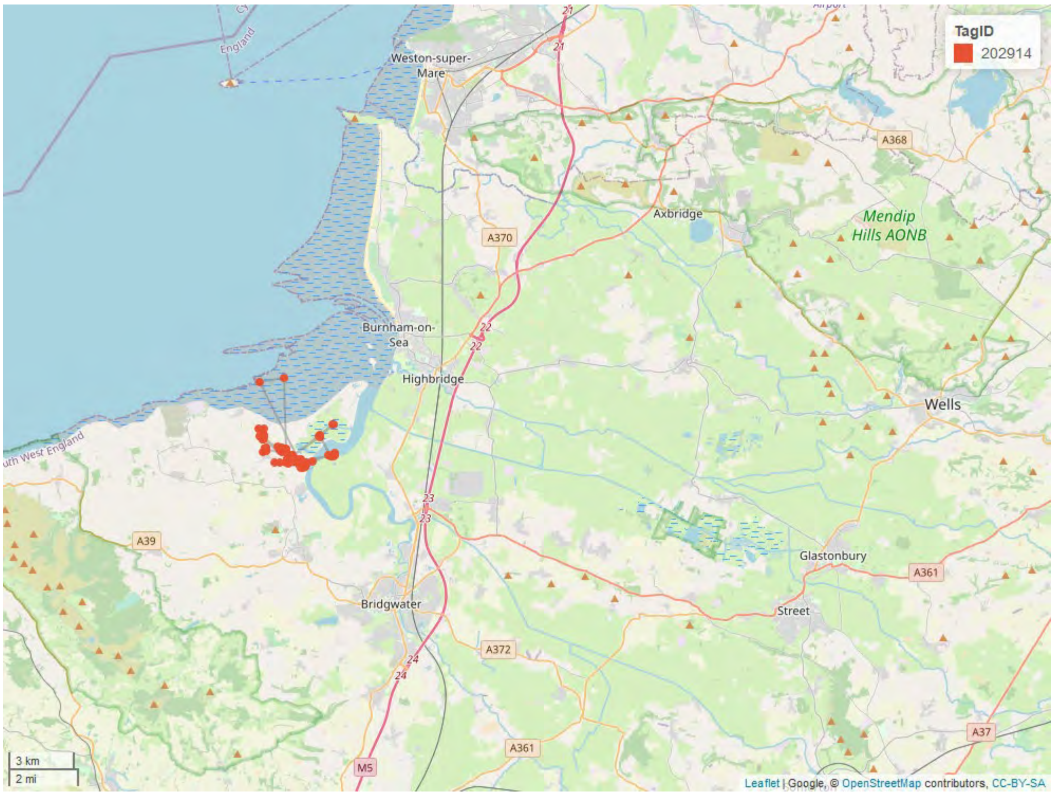
Appendix A1. Raw tracking maps

A1.1. Overall movements of each individual in relation to the Severn Estuary SPA and Somerset Levels and Moors SPA and proposed powerline.

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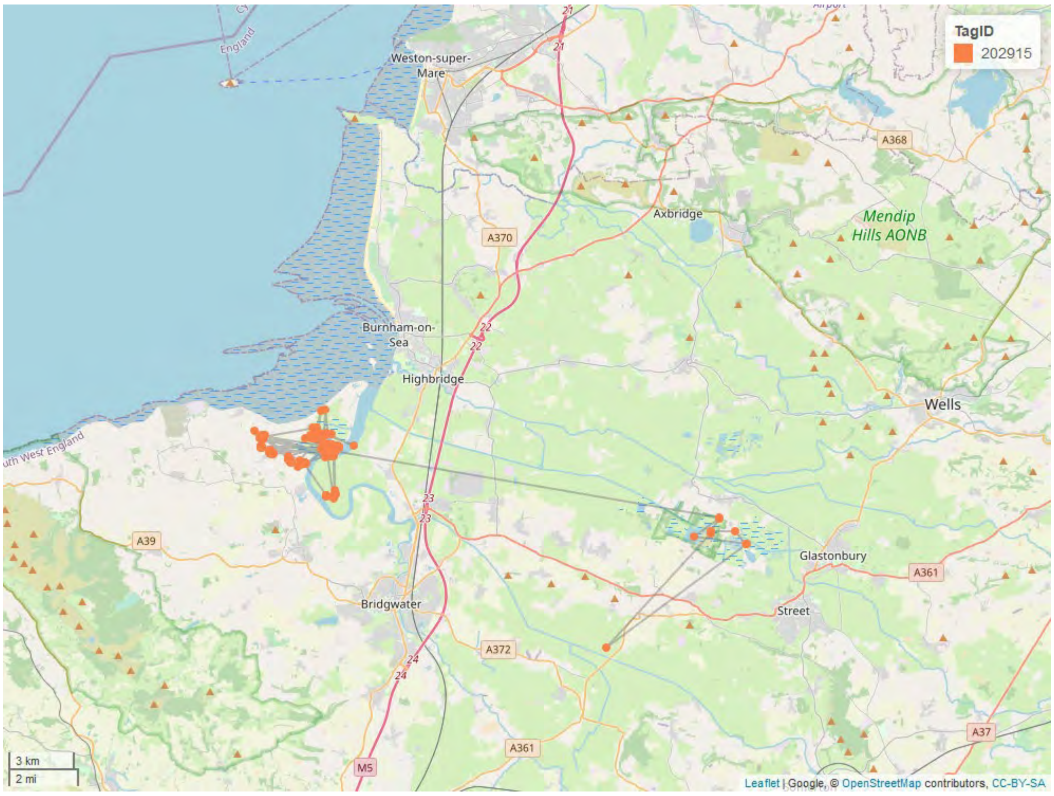
Axbridge
Mendip Hills AONB
Burnham-on-Sea
Highbridge
Wells
Glastonbury
Street
Bridgwater
A368
A370
A39
A361
A372
A37
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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A361
A372
A37
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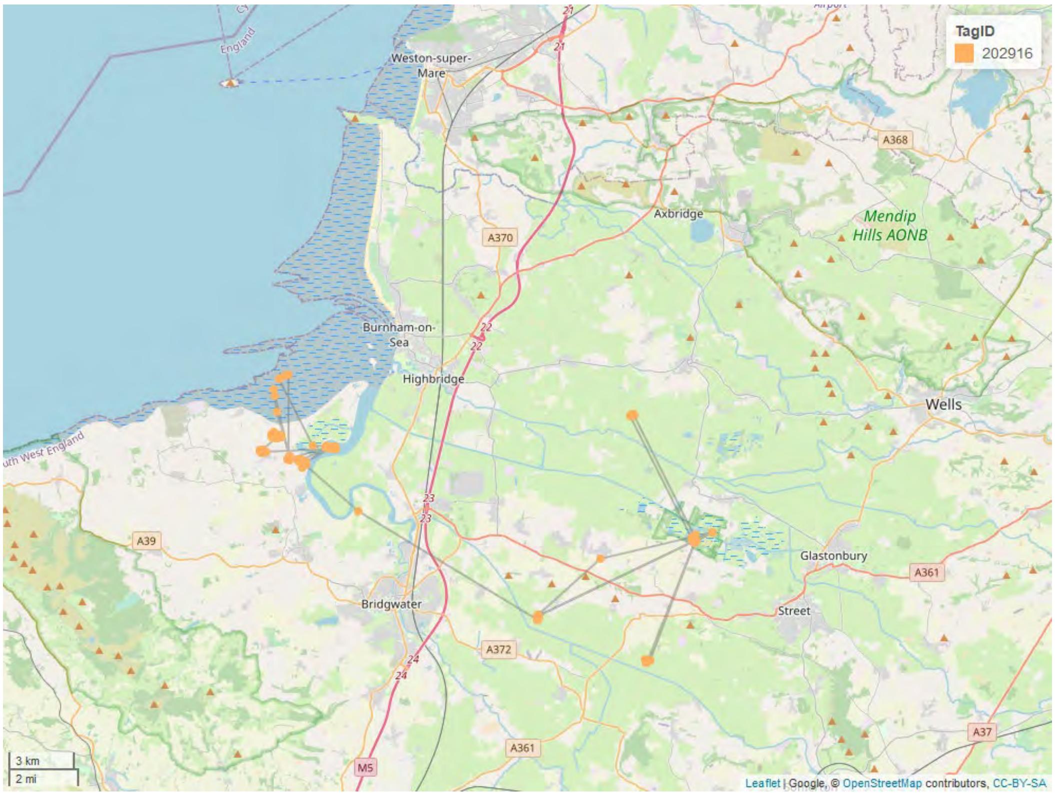
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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Street
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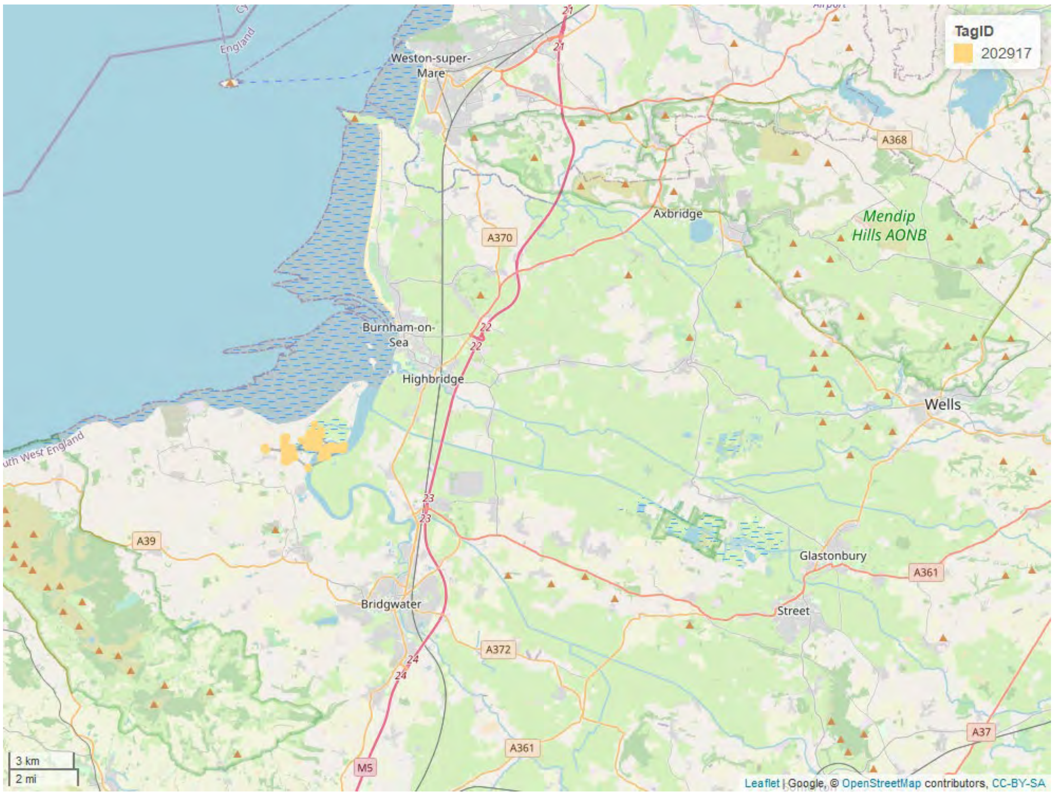
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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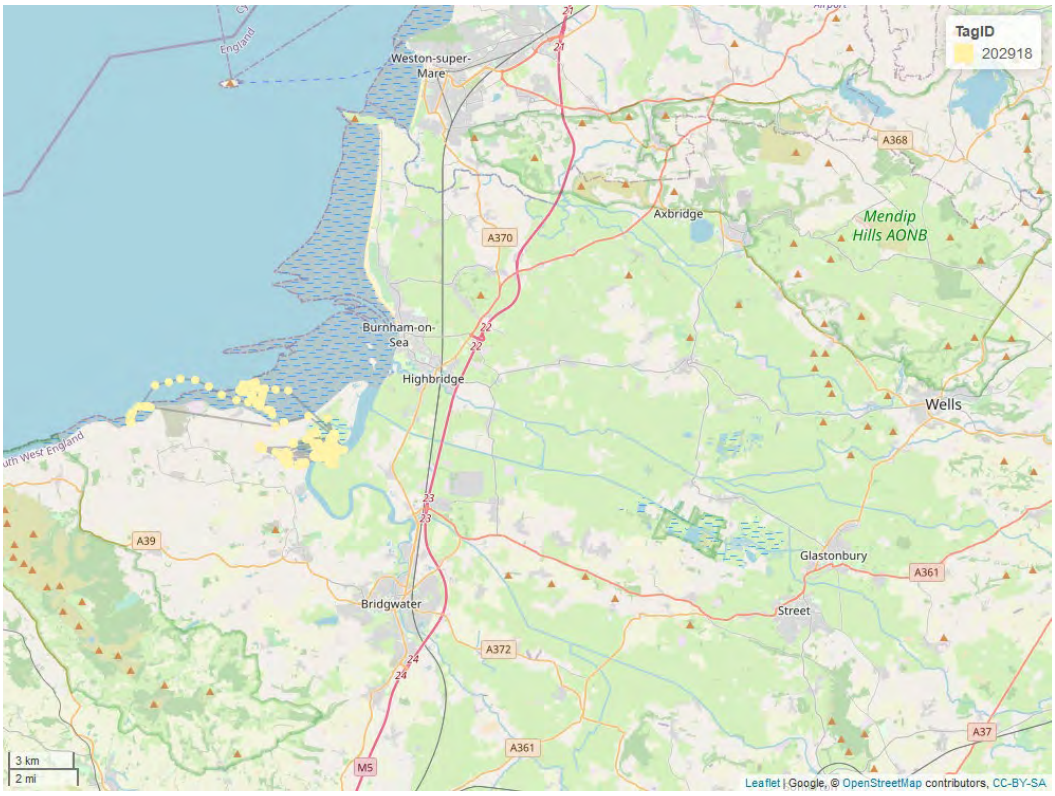
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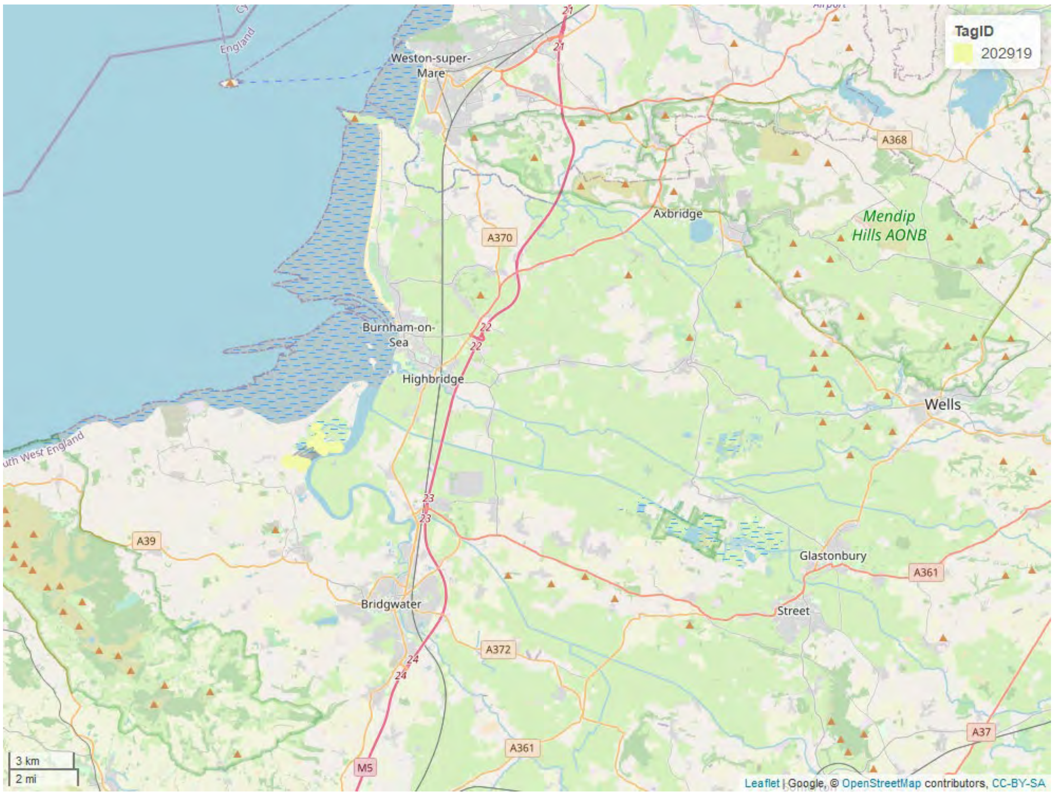
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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Highbridge
Wells
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Glastonbury
A361
Bridgwater
Street
A372
A37
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
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Axbridge
Mendip Hills AONB
A368
A370
Burnham-on-Sea
Highbridge
Wells
A39
Glastonbury
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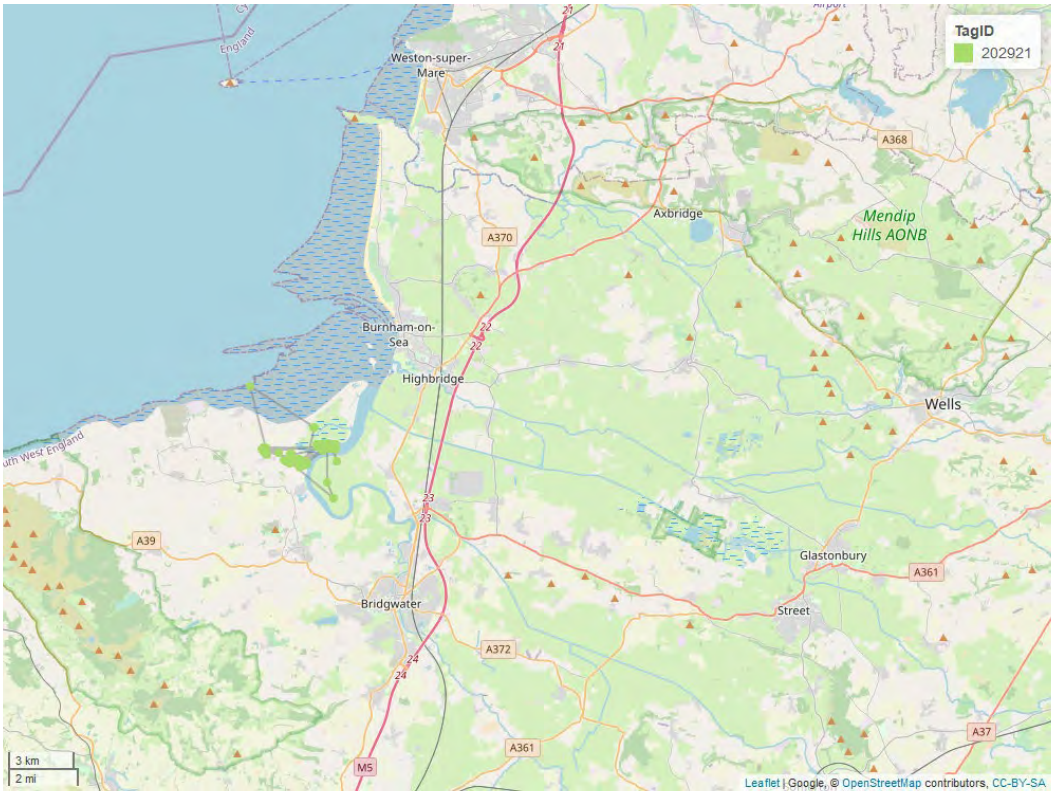
A37
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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Glastonbury
A361
Bridgwater
Street
A372
A361
A37
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
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Axbridge
Mendip Hills AONB
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Highbridge
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2 mi
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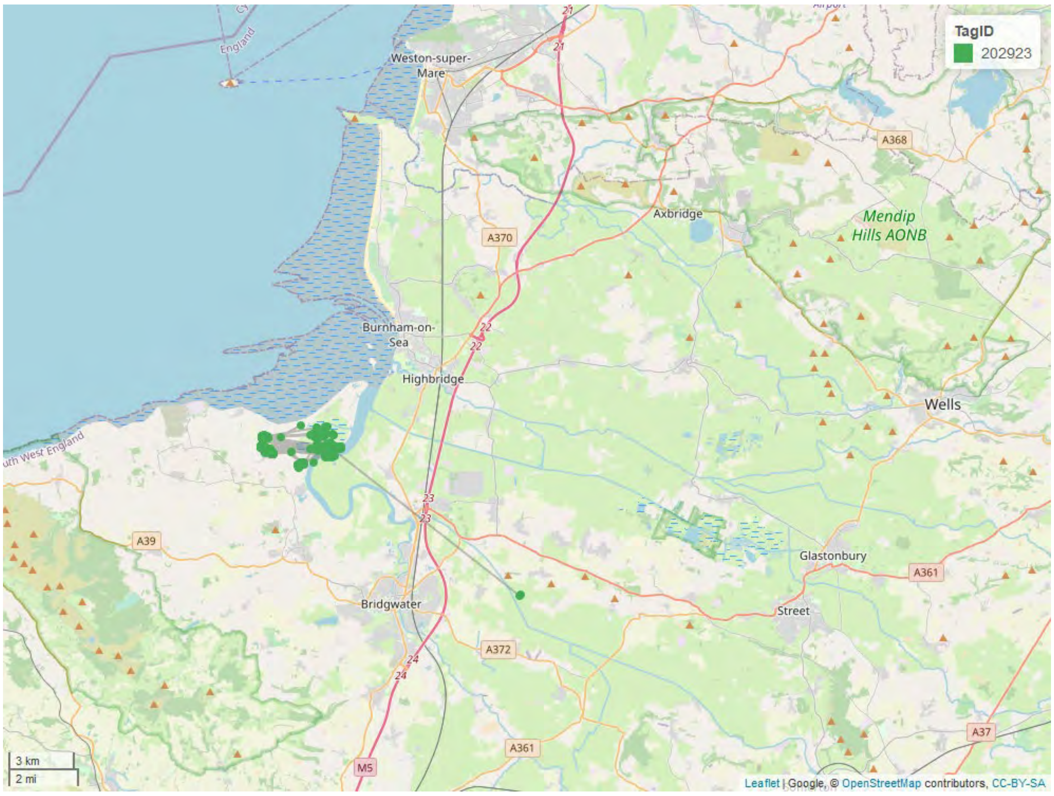
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Street
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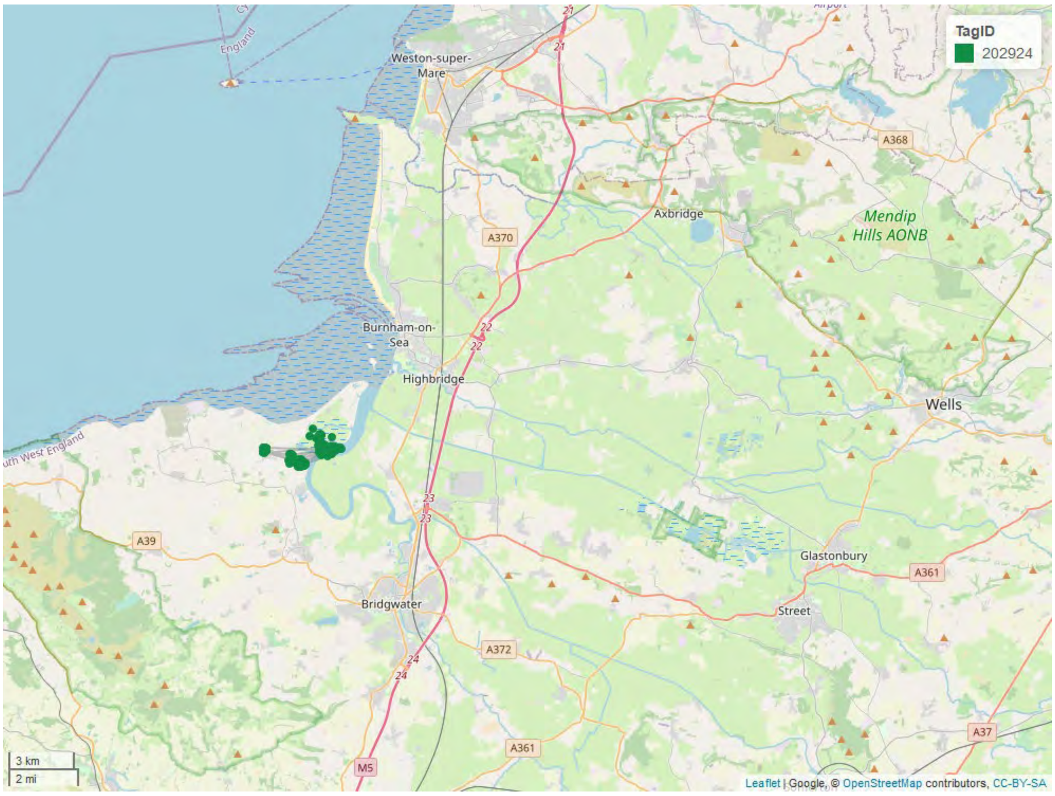
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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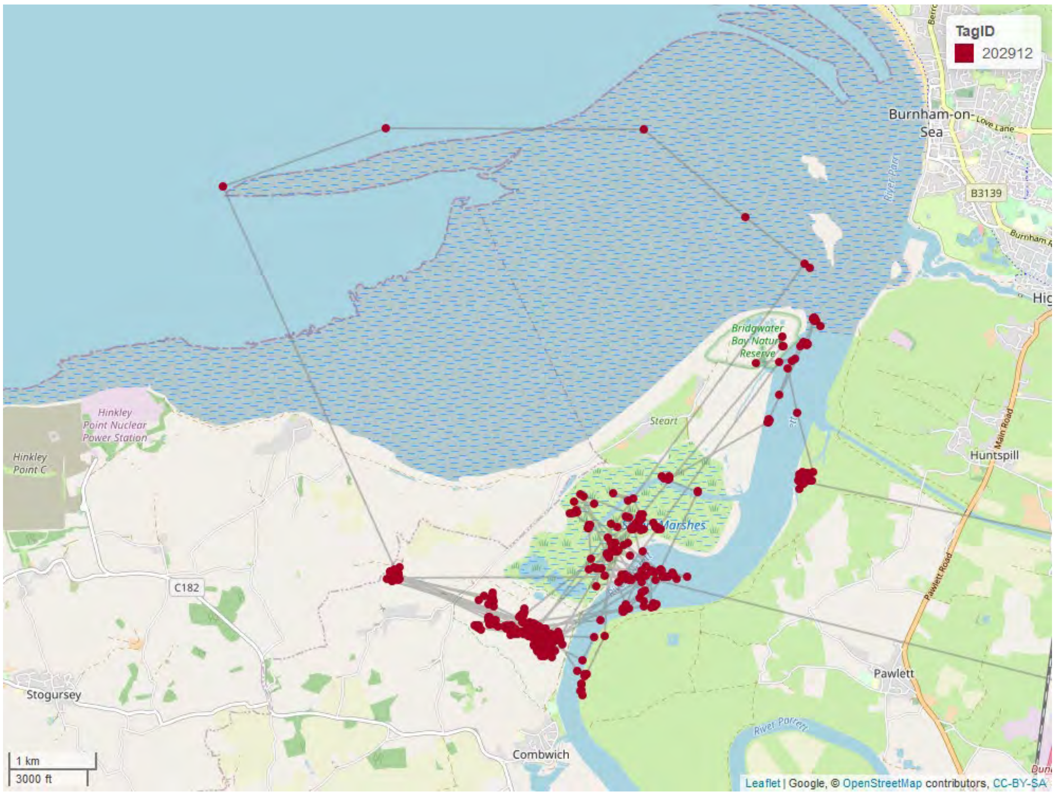
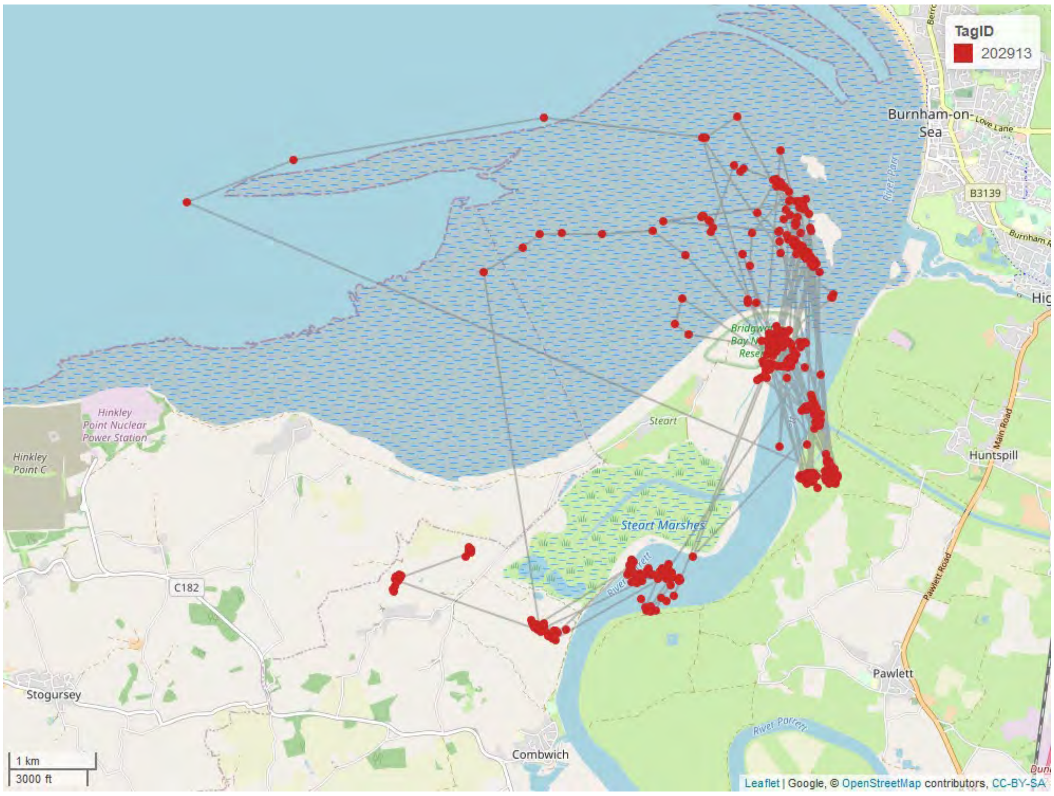
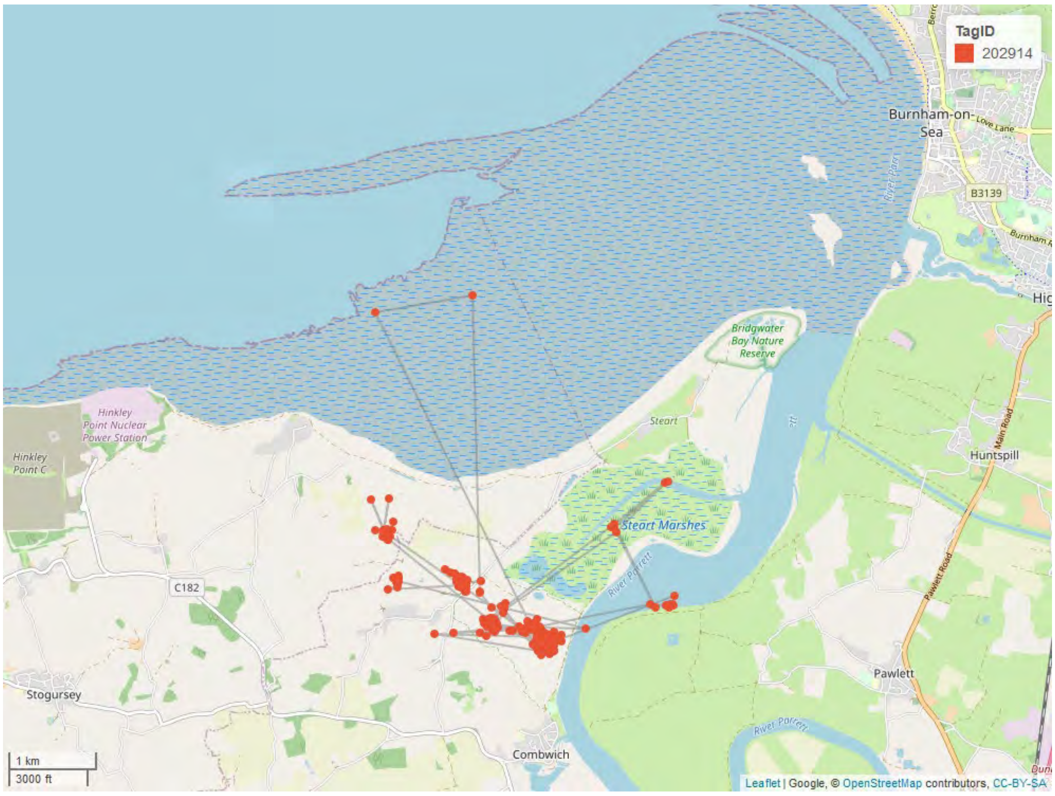
Axbridge
Mendip Hills AONB
Burnham-on-Sea
Highbridge
Wells
Glastonbury
Street
Bridgwater
A368
A370
A39
A361
A372
A37
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
202926
Weston-super-Mare
Axbridge
Mendip Hills AONB
Burnham-on-Sea
Highbridge
Wells
Glastonbury
Street
Bridgwater
A368
A370
A39
A361
A372
A37
M5
3 km
2 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

A1.2. Movements of each individual around WWT Steart Marshes and the Severn Estuary SPA.



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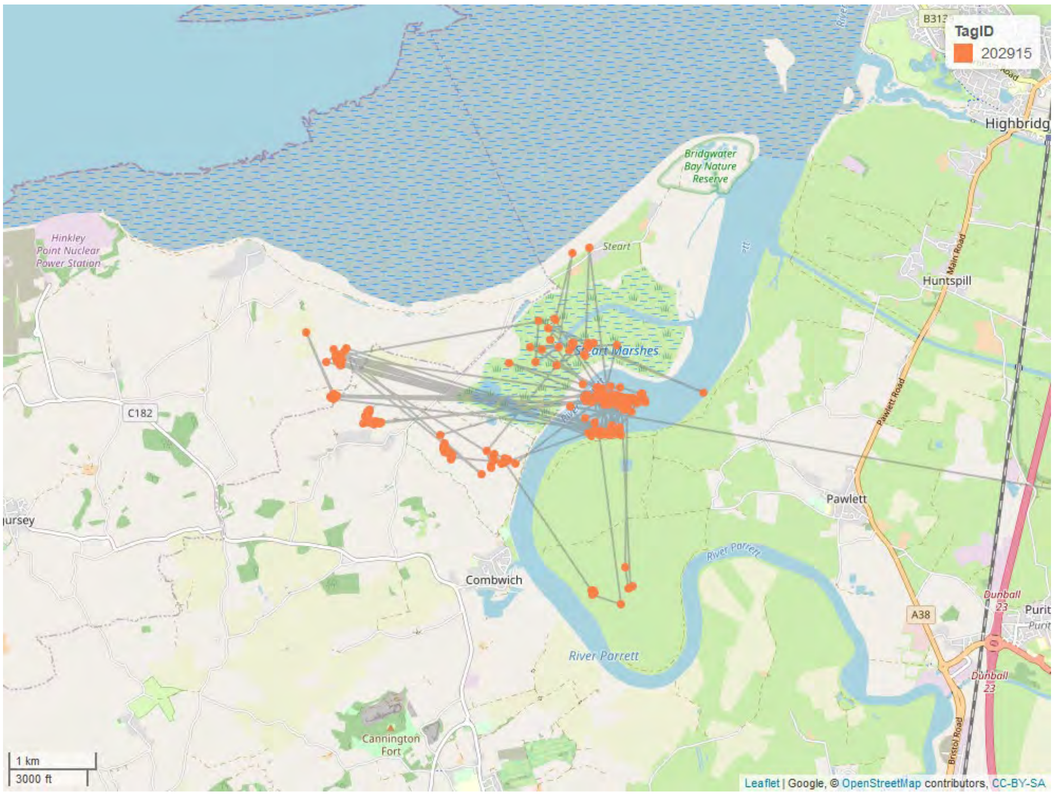
Burnham-on-Sea
B3139
Bridgwater Bay Nature Reserve
Hinkley Point Nuclear Power Station
Hinkley Point C
Steart
Huntspill
Steart Marshes
River Parrett
C182
Pawlett
Stogursey
Combwich
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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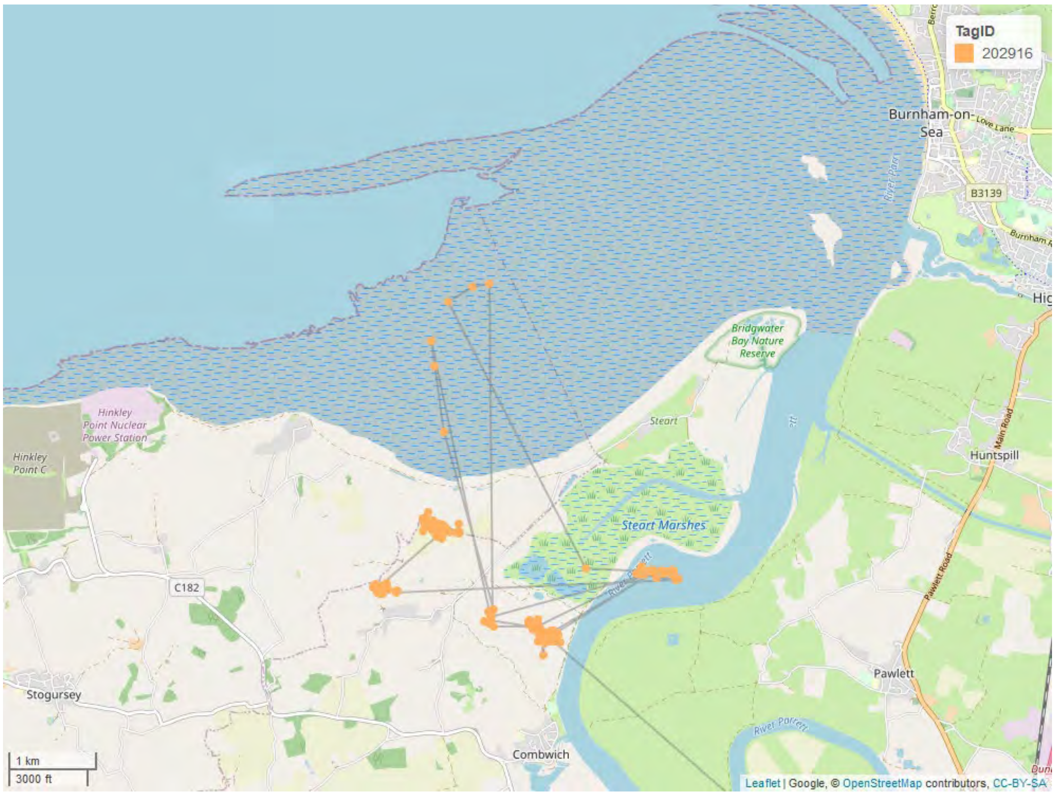
Bridgwater Bay Nature Reserve
Hinkley Point Nuclear Power Station
Steart
Huntspill
C182
Pawlett
Combwich
River Parrett
A38
Cannington Fort
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA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Burnham-on-Sea
B3139
Bridgwater Bay Nature Reserve
Hinkley Point Nuclear Power Station
Hinkley Point C
Steart
Huntspill
Steart Marshes
C182
Stogursey
Pawlett
Combwich
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
202917
Stolford
Steart
Steart Marshes
River Parrett
Somerset West and Taunton
Sedgemoor
Stockland Bristol
Otterhampton
500 m
1000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
202918
Bridgwater Bay Nature Reserve
Hinkley Point Nuclear Power Station
Hinkley Point C
Steart
C182
Stogursey
Combwich
River Parrett
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
202919
Steart
Steart Marshes
River Parrett
Somerset West and Taunton
Sedgemoor
Stockland Bristol
Otterhampton
Hinkley Point Road
Withycombe Hill
Combwich
500 m
1000 ft
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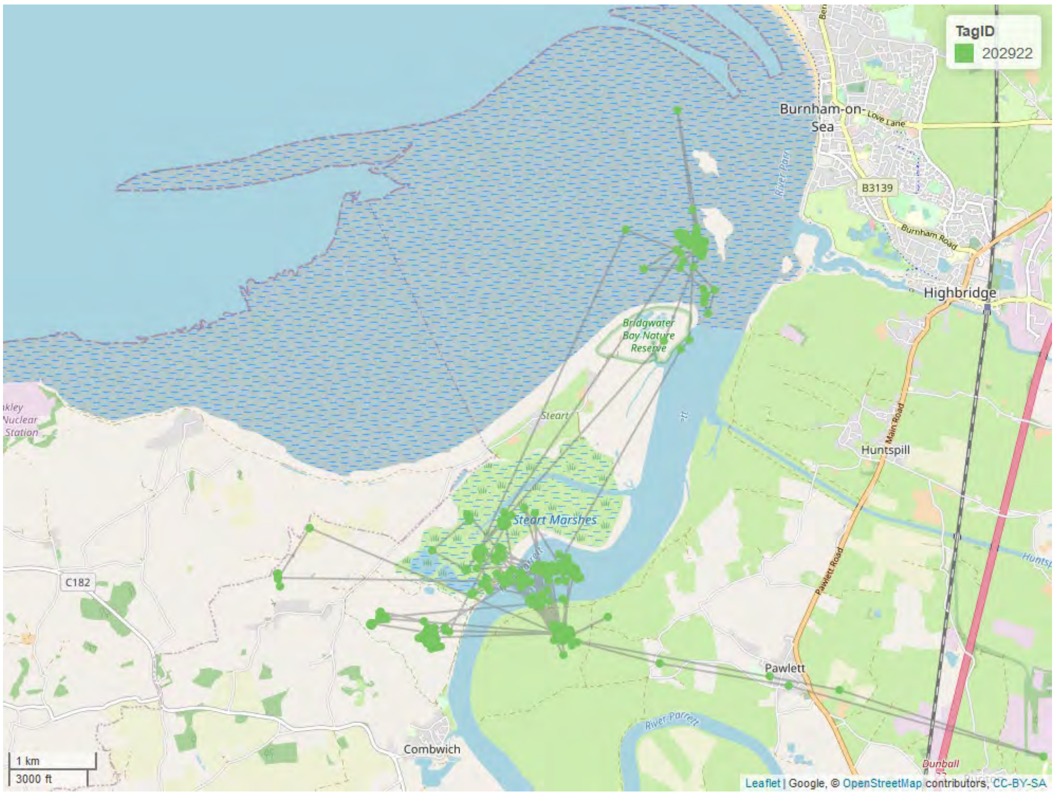
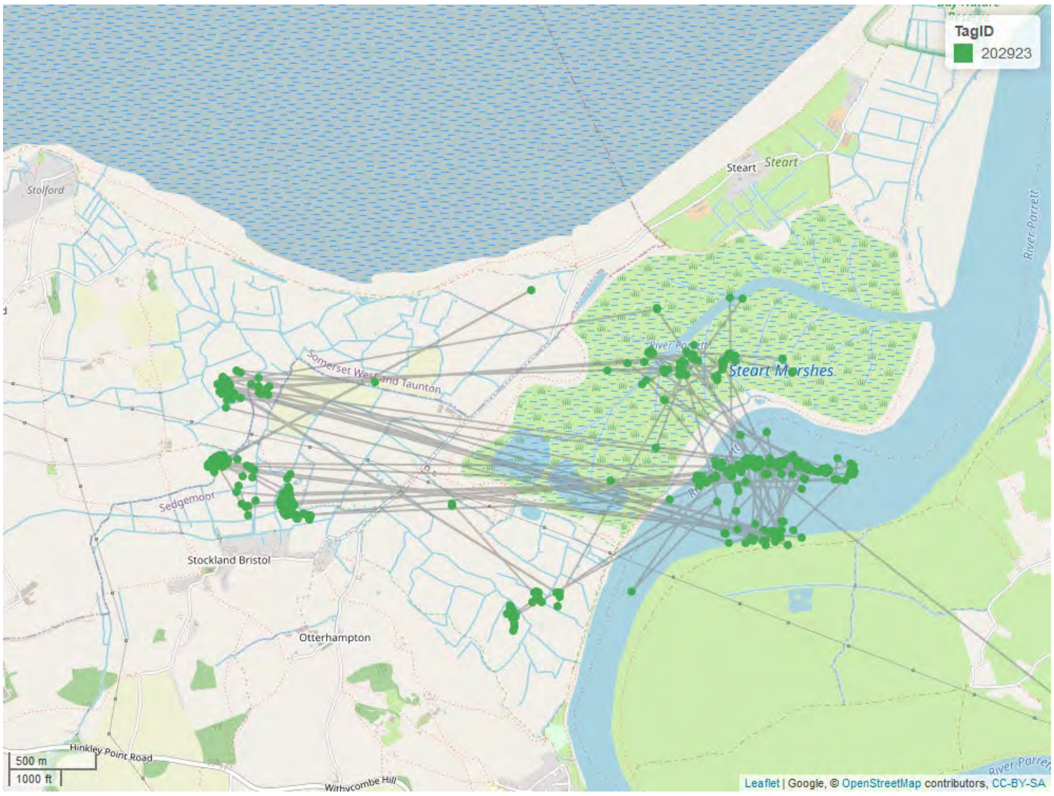
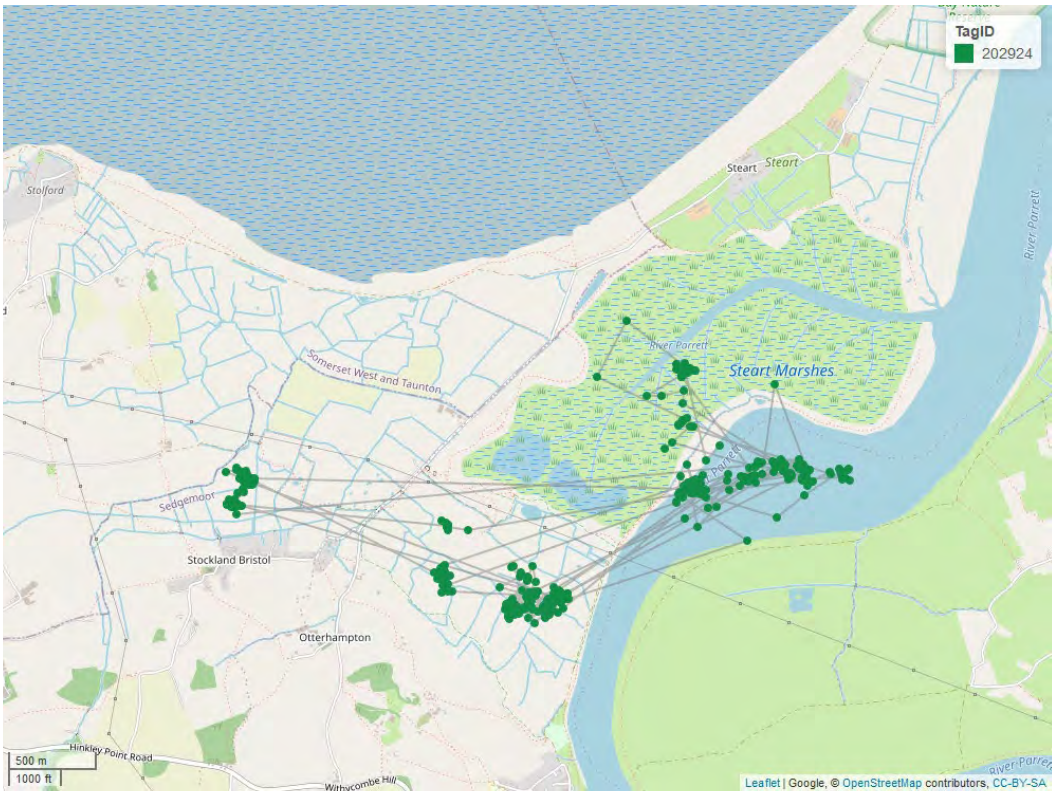
TagID
202920
Steart
Steart Marshes
River Parrett
Huntspill River
Somerset West and Taunton
Stockland Bristol
Otterhampton
Stretcholt
Withycombe Hill
Combwich
500 m
1000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA


TagID
202921
B3139
Bridgwater Bay Nature Reserve
Hinkley Point Nuclear Power Station
Hinkley Point C
Steart
Steart Marshes
Huntspill
Main Road
Pawlett Road
Pawlett
C182
Stogursey
Combwich
River Parrett
A38
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

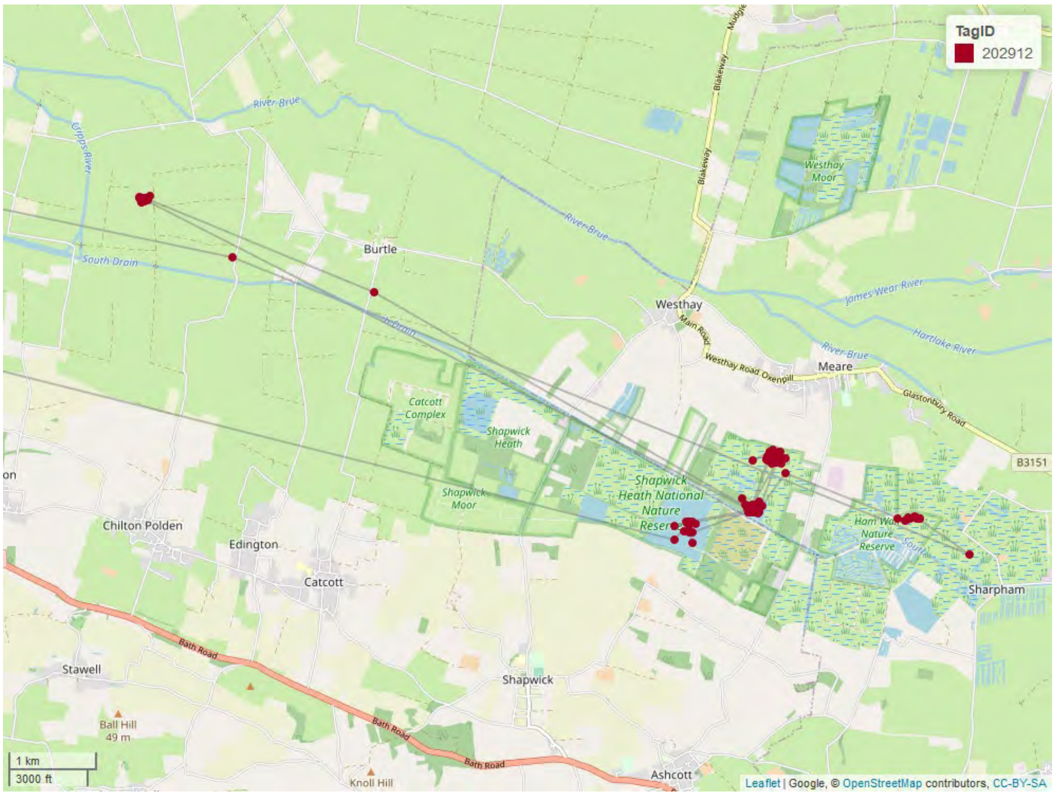

TagID
202922
Burnham-on-Sea
Highbridge
Bridgwater Bay Nature Reserve
Steart
Huntspill
Steart Marshes
Pawlett
Combwich
Dunball
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

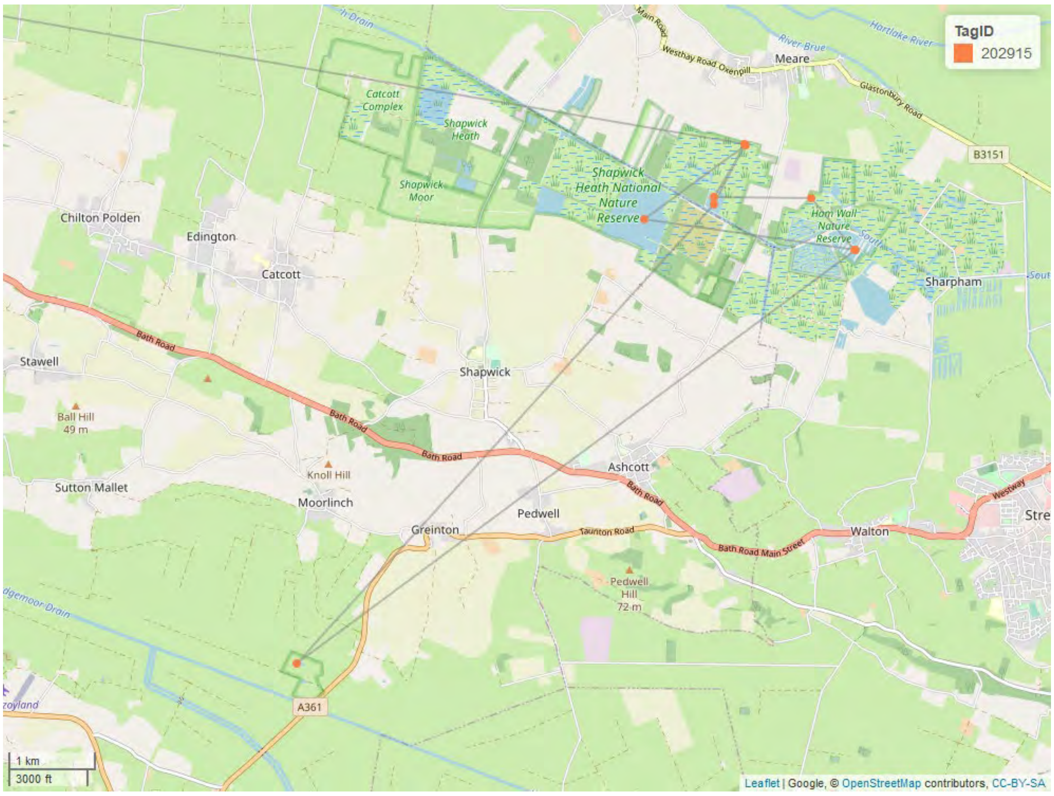

TagID
202923
Stolford
Steart
Steart Marshes
River Parrett
Stockland Bristol
Otterhampton
Sedgemoor
500 m
1000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

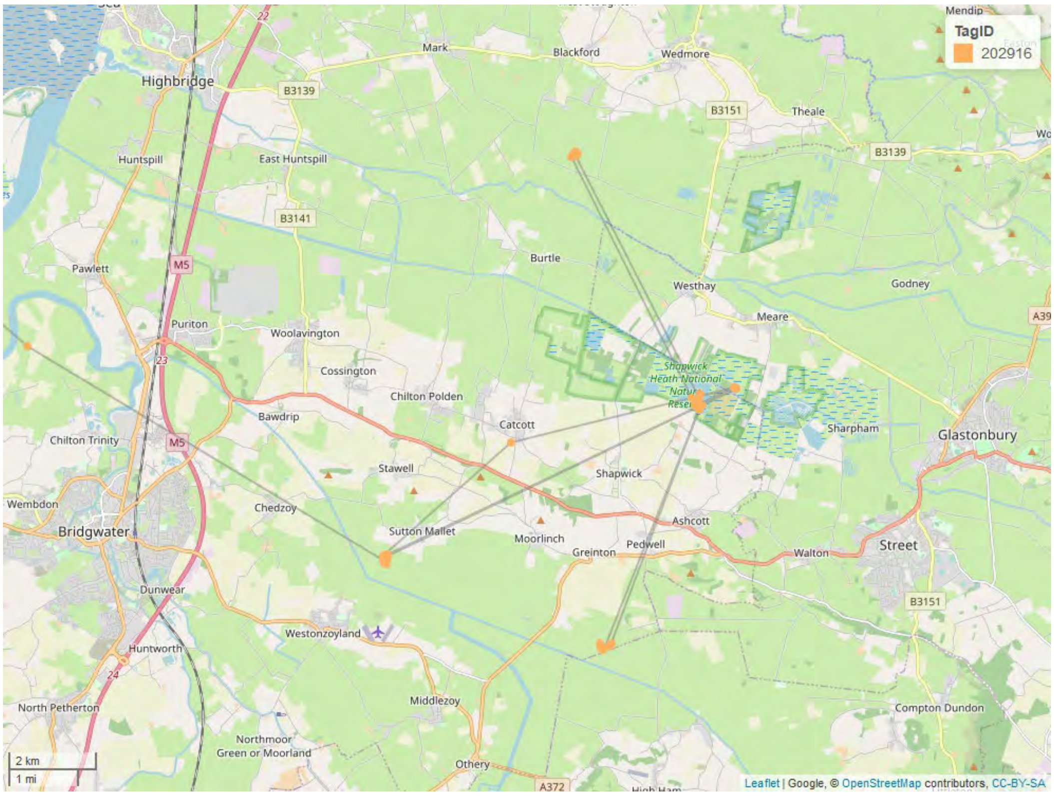

TagID
202924
Steart
Stolford
Somerset West and Taunton
River Parrett
Steart Marshes
Sedgemoor
Stockland Bristol
Otterhampton
Hinkley Point Road
Withycombe Hill
500 m
1000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

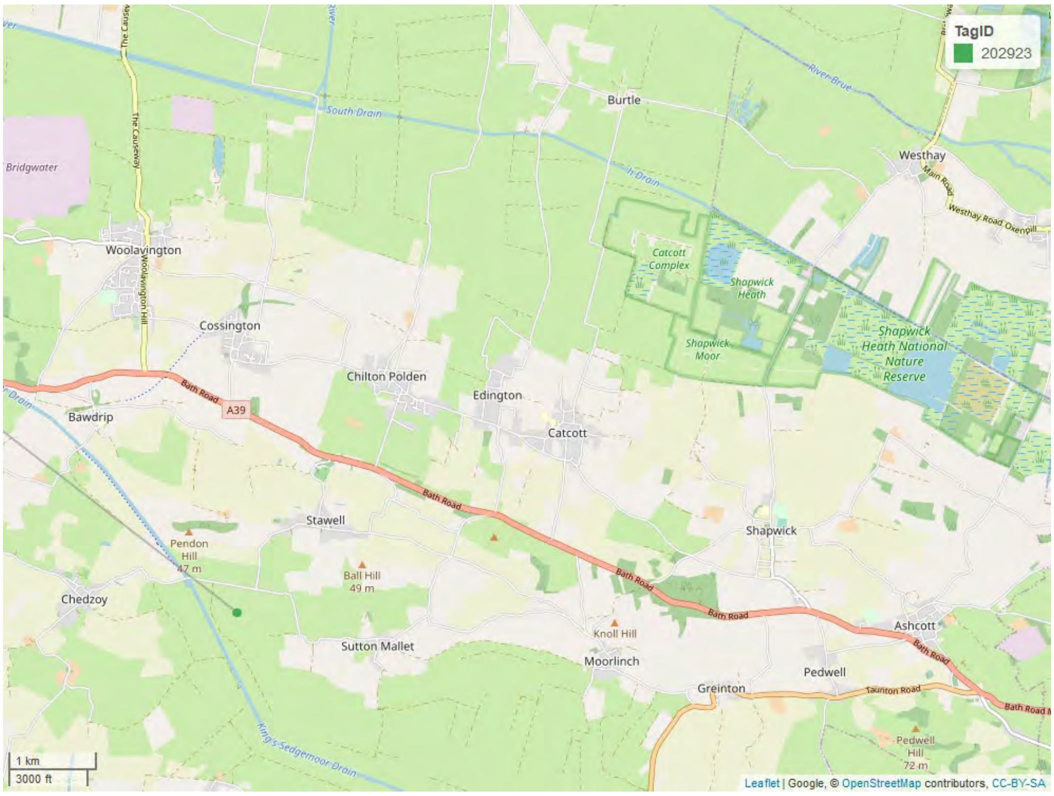

TagID
202926
Steart
Huntspill River
River Parrett
Somerset West and Taunton
Steart Marshes
Sedgemoor
Stockland Bristol
Otterhampton
Stretcho
Withycombe Hill
Combwich
500 m
1000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

A1.3. Movements of each individual around the Somerset Levels and Moors SPA.






TagID
202916
Highbridge
Mark
Blackford
Wedmore
Theale
Huntspill
East Huntspill
Pawlett
Puriton
Woolavington
Cossington
Chilton Polden
Bawdrip
Catcott
Burtle
Westhay
Meare
Godney
Shapwick Heath National Nature Reserve
Sharpham
Glastonbury
Chilton Trinity
Stawell
Shapwick
Wembdon
Bridgwater
Chedzoy
Sutton Mallet
Moorlinch
Greinton
Pedwell
Ashcott
Walton
Street
Dunwear
Westonzoyland
Huntworth
Middlezoy
North Petherton
Northmoor Green or Moorland
Othery
Compton Dundon
2 km
1 mi
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

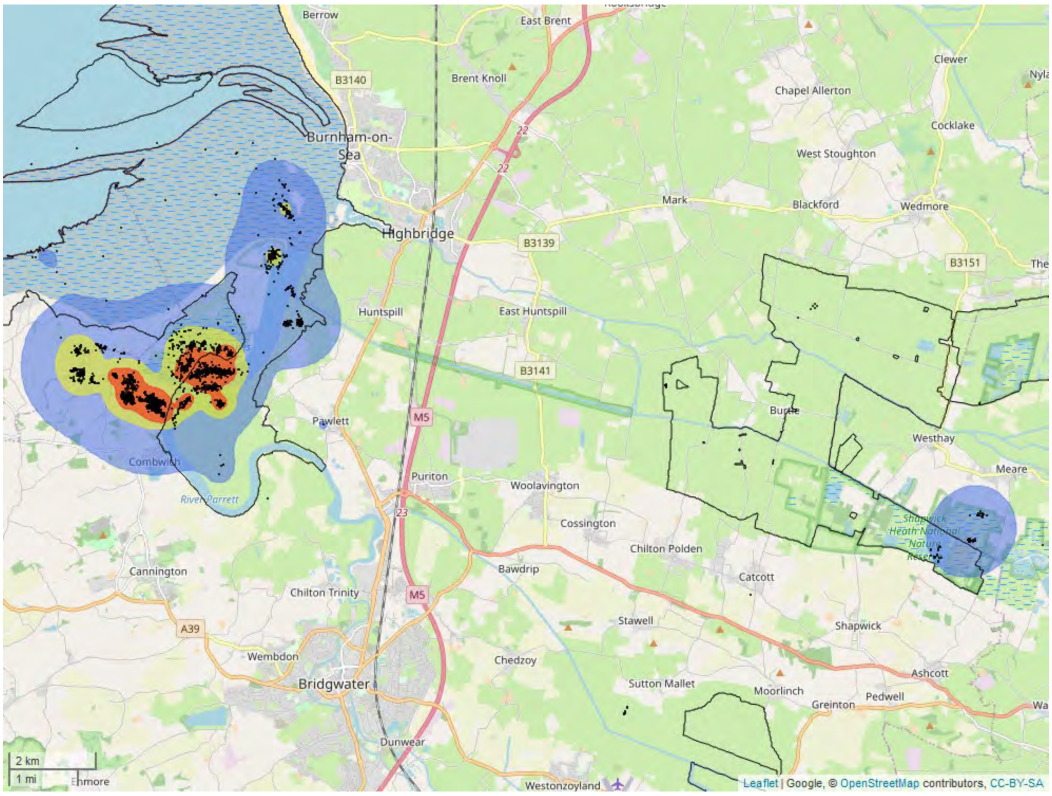

TagID
202923
Burtle
Westhay
South Drain
River Brue
Bridgwater
Woolavington
Cossington
Catcott Complex
Shapwick Heath
Shapwick Moor
Shapwick Heath National Nature Reserve
Chilton Polden
Edington
Catcott
Bawdrip
A39
Bath Road
Stawell
Shapwick
Pendon Hill 47 m
Ball Hill 49 m
Chedzoy
Sutton Mallet
Knoll Hill
Moorlinch
Greinton
Pedwell
Ashcott
Taunton Road
Pedwell Hill 72 m
King's Sedgemoor Drain
1 km
3000 ft
Leaflet | Google, © OpenStreetMap contributors, CC-BY-SA

Appendix A2. Processed utilisation distributions

A2.1. KDEs sub-sampled to 90 minute data points and mapped on a 50 m grid

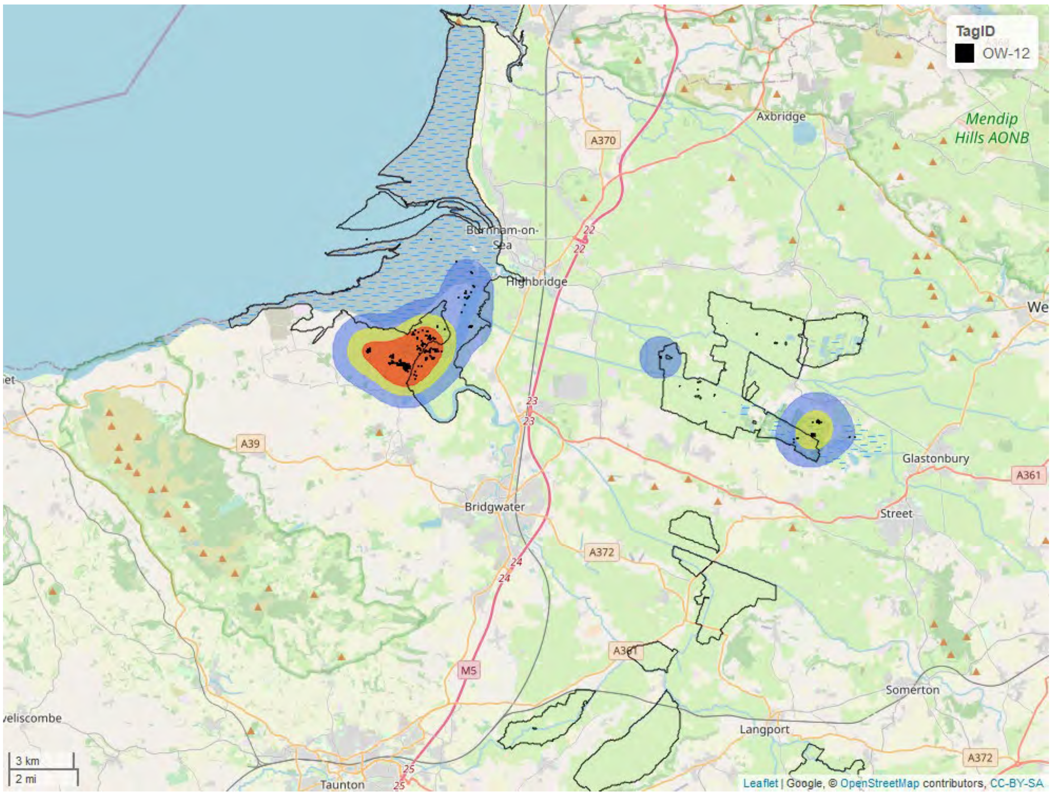
The tracking point sample size (n) and smoothing parameter (Href) used to produce each KDE are presented under each figure. The 50% utilisation distribution (UD) (core area) is in red, with the 75% UD in yellow and the 95% UD (total home range) in blue. The raw tracking points used for each KDE are displayed as black dots. The Severn Estuary SPA is outlined in black to the west, with the Somerset Levels and Moors SPA outlined to the east.

A2.1.1. KDEs for combined data from all birds

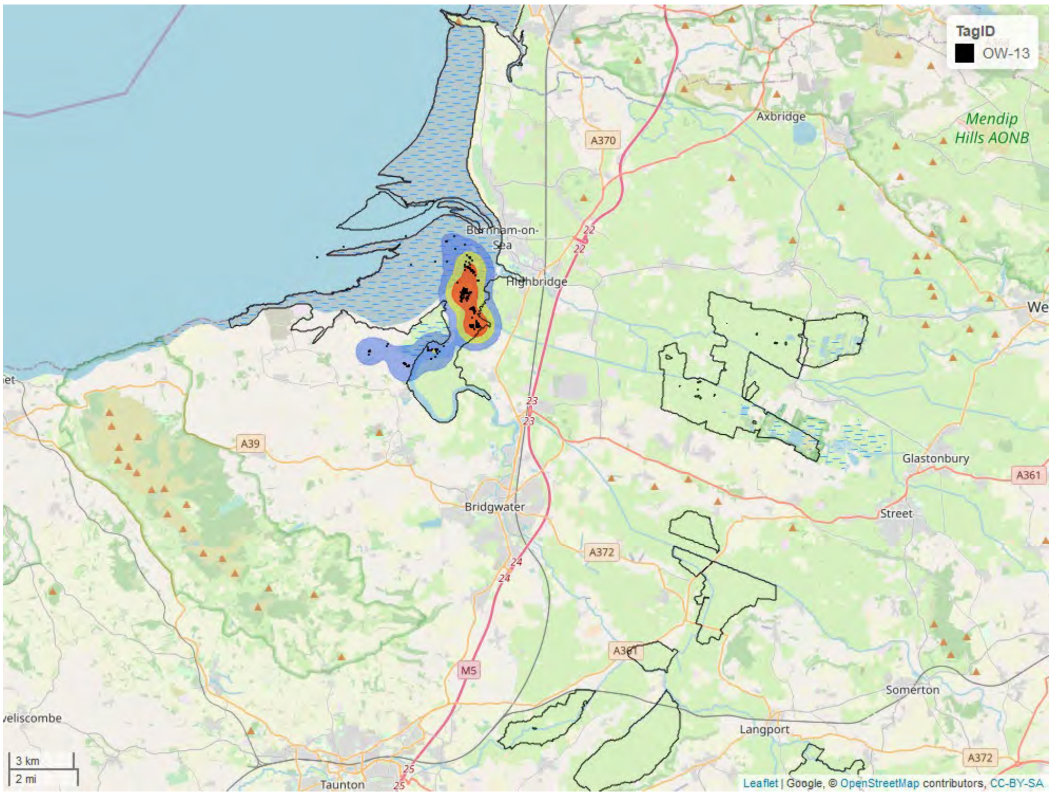


All bird: n = 3376; Href = 379.2978

A2.1.2. KDEs for each individual bird

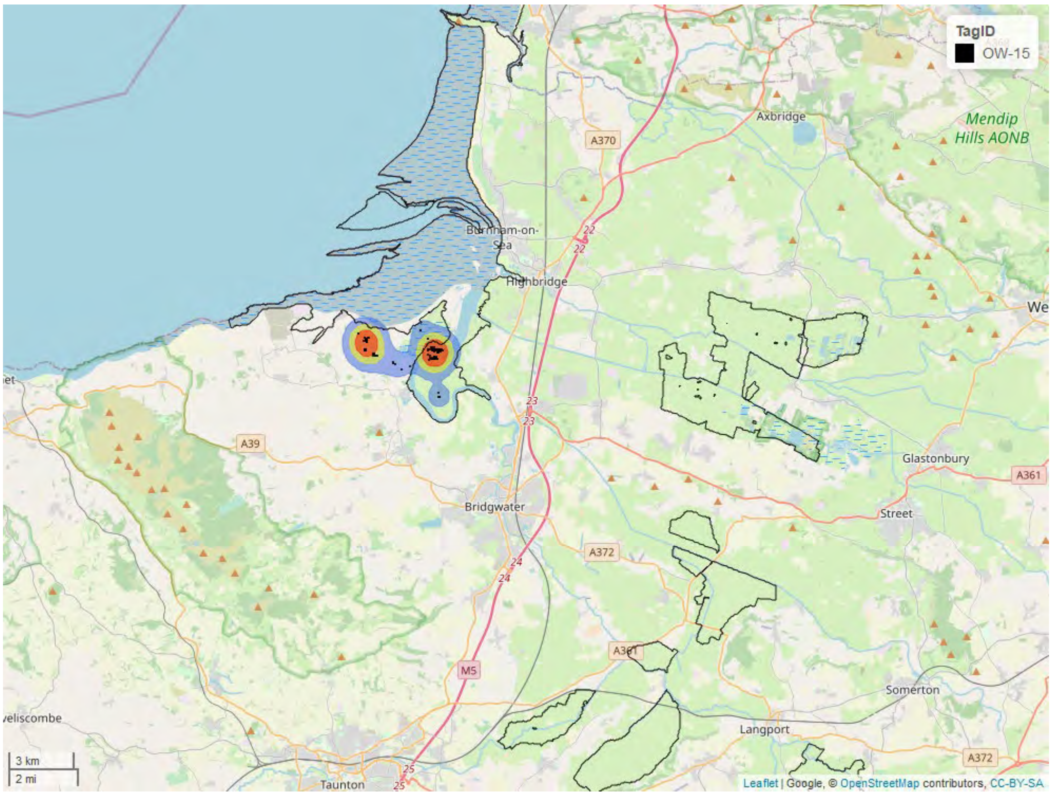


OW-12: n = 383; Href = 688.2974

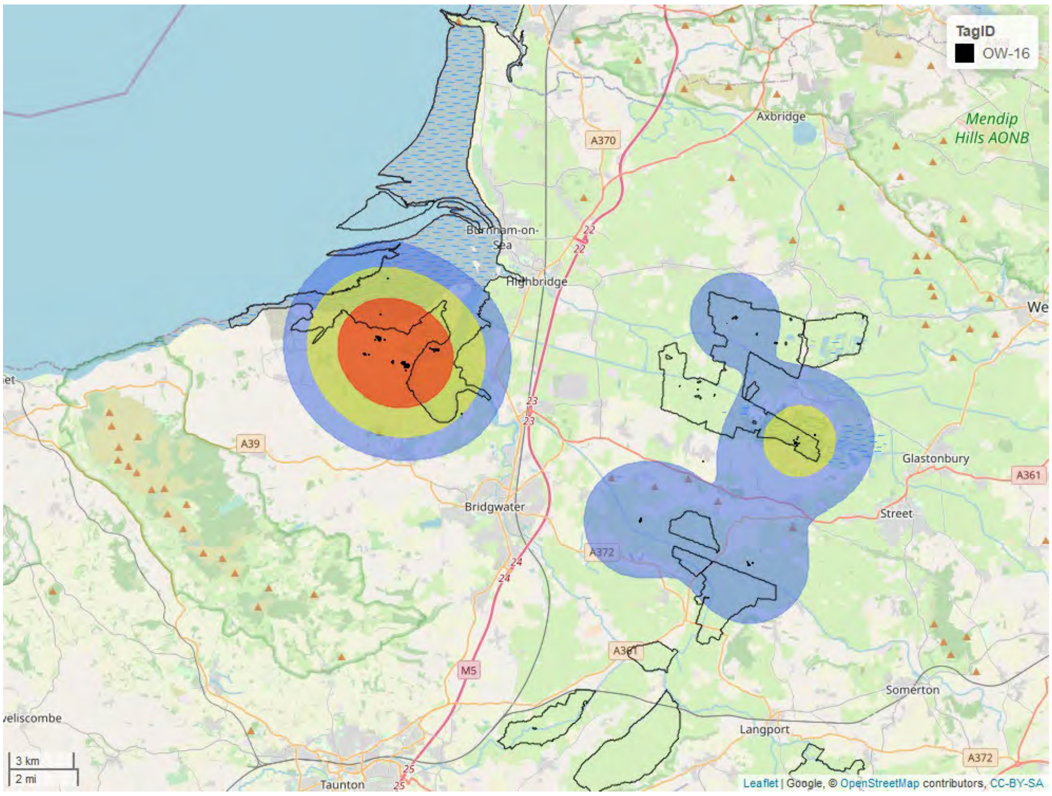


OW-13: n = 333; Href = 416.5754

OW-14: n = 190; Href = 151.5745

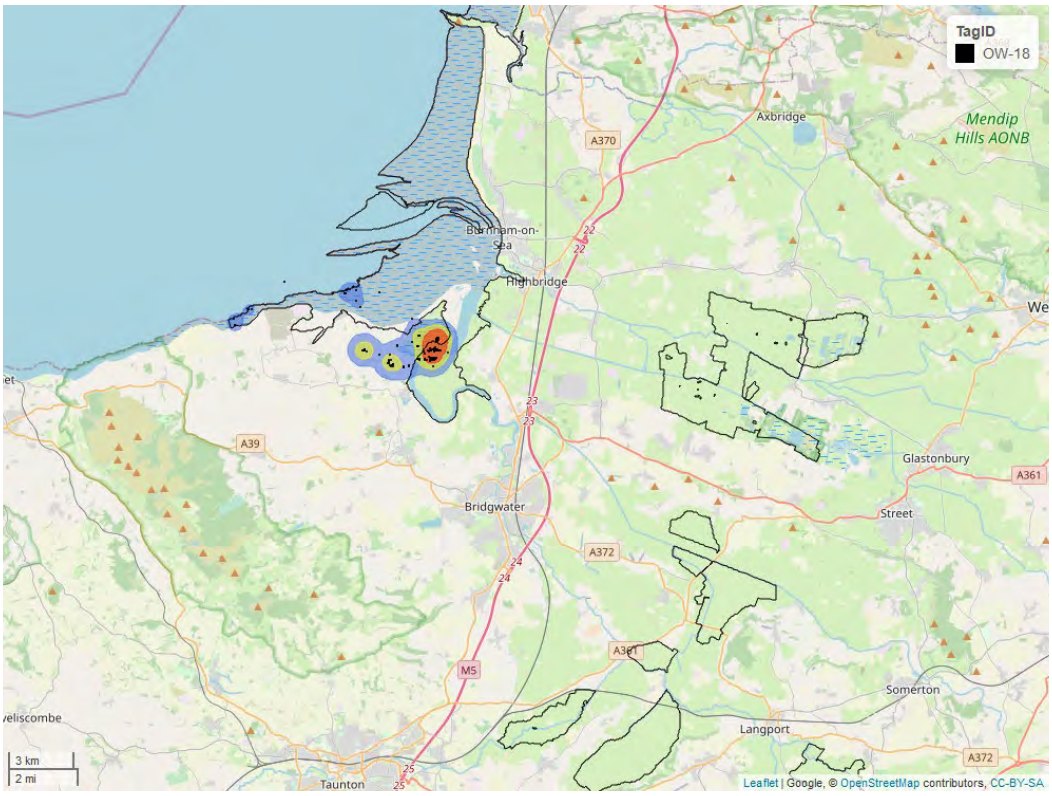


OW-15: n = 157; Href = 414.1074



OW-16: n = 190; Href = 1620.056

OW-17: n = 239; Href = 188.505



OW-18: n = 256; Href = 323.4428

OW-19: n = 191; Href = 249.5541

OW-20: n = 252; Href = 126.5148

OW-21: n = 205; Href = 246.6031

OW-22: n = 205; Href = 158.3971

OW-23: n = 283; Href = 377.5332

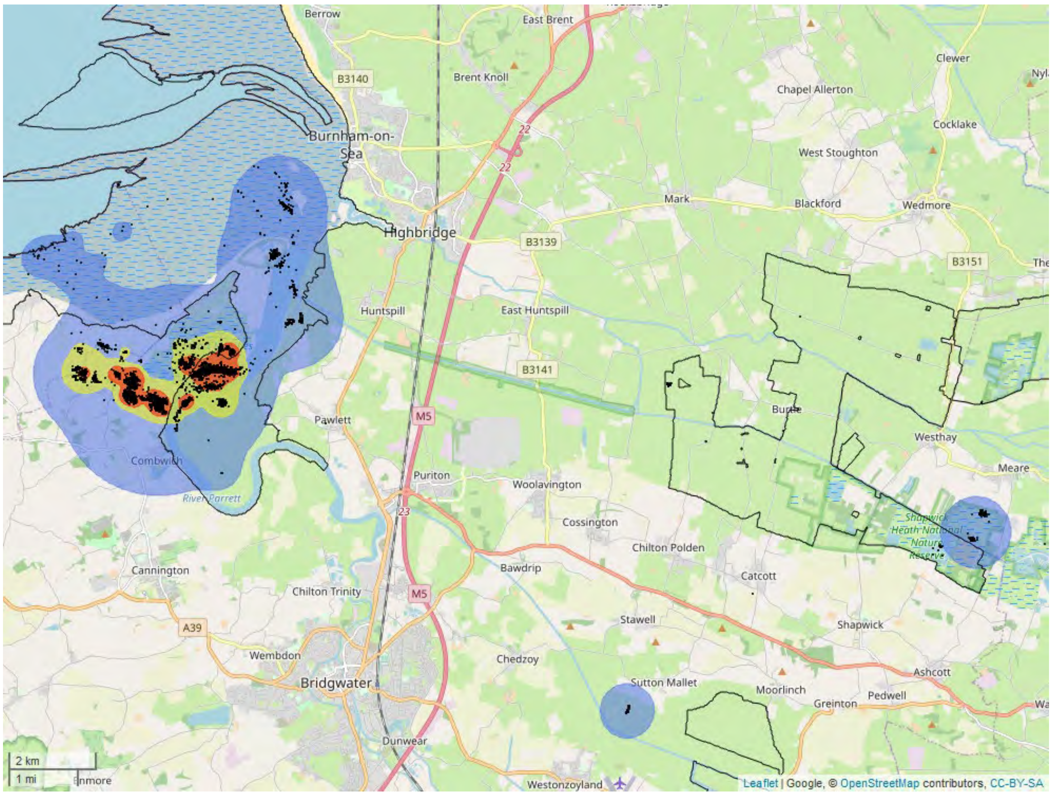
OW-24: n = 239; Href = 208.7985

OW-26: n = 253; Href = 116.1136

A2.2. KDEs sub-sampled to 30 minute data points and mapped on 25 m grid

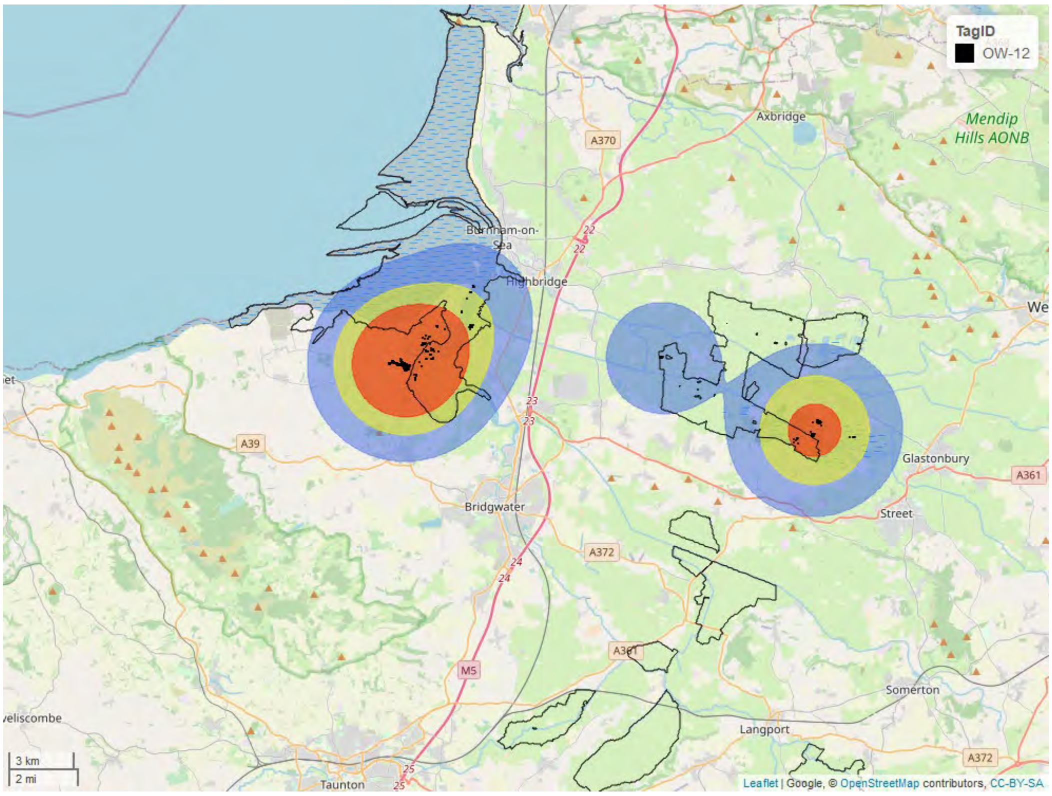
The tracking point sample size (n) and smoothing parameter (Href) used to produce each KDE are presented under each figure. The 50% utilisation distribution (UD) (core area) is in red, with the 75% UD in yellow and the 95% UD (total home range) in blue. The raw tracking points used for each KDE are displayed as black dots. The Severn Estuary SPA is outlined in black to the west, with the Somerset Levels and Moors SPA outlined to the east.

A2.2.3. KDEs for combined data from all birds.

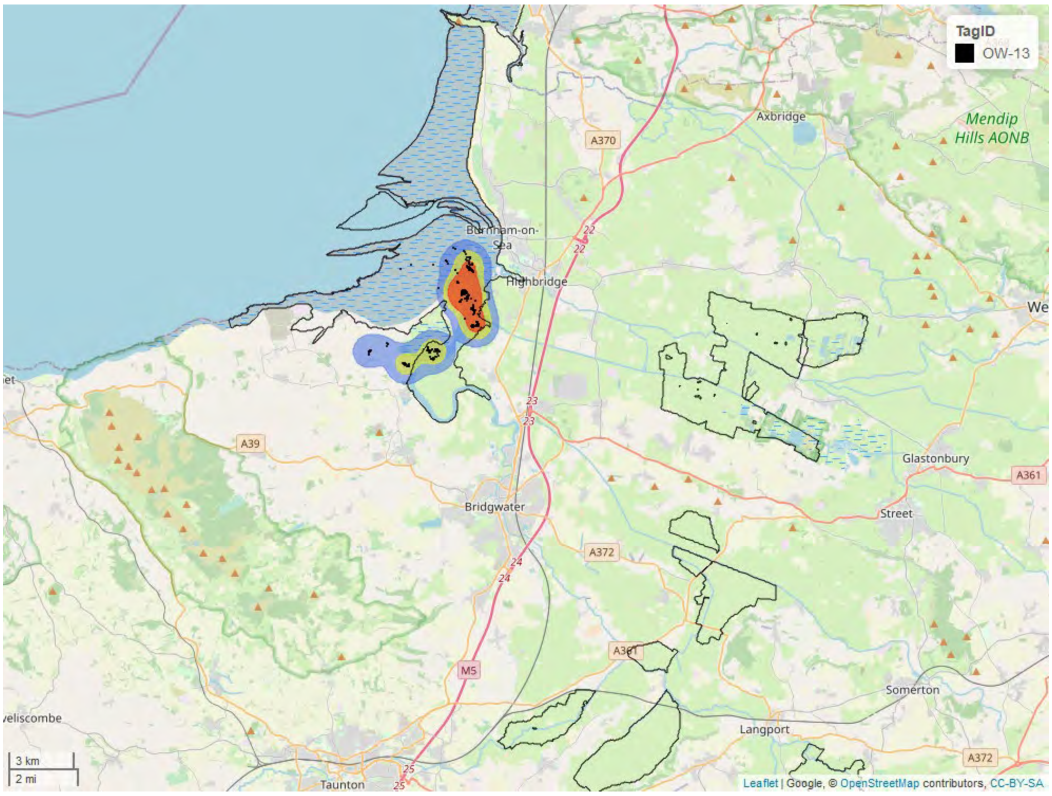


All bird: n = 6084; Href = 355.6

A2.2.4. KDEs for each individual bird.

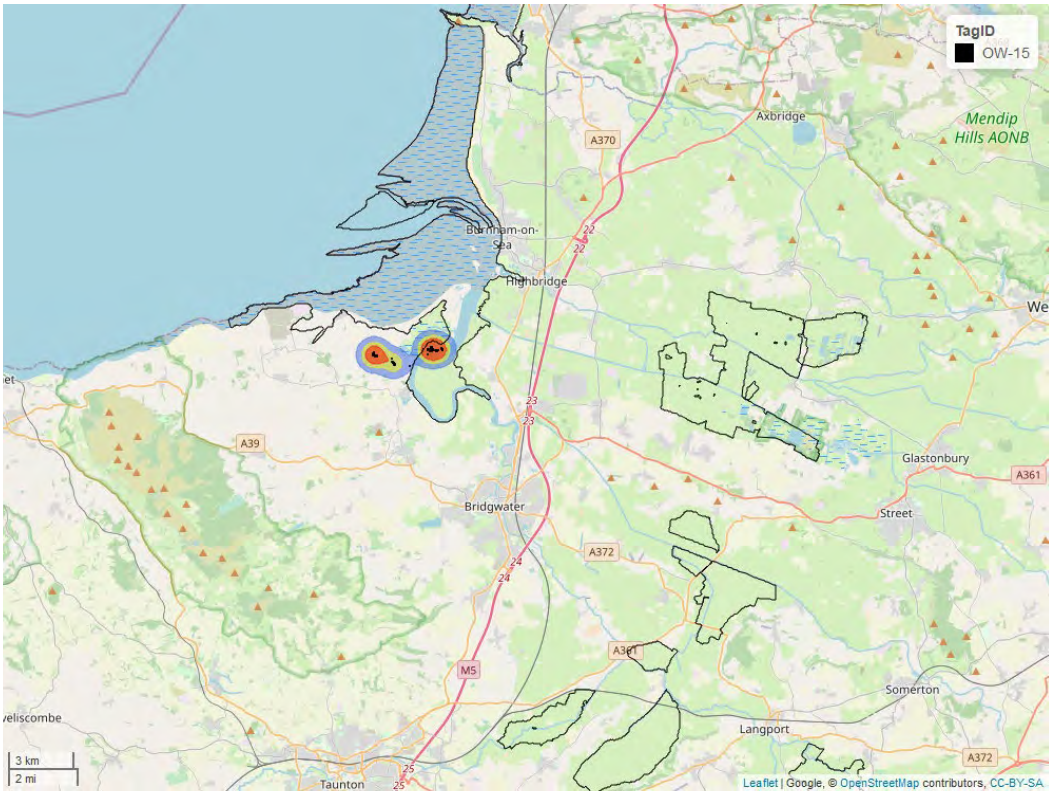


OW-12: n = 539; Href = 512.2

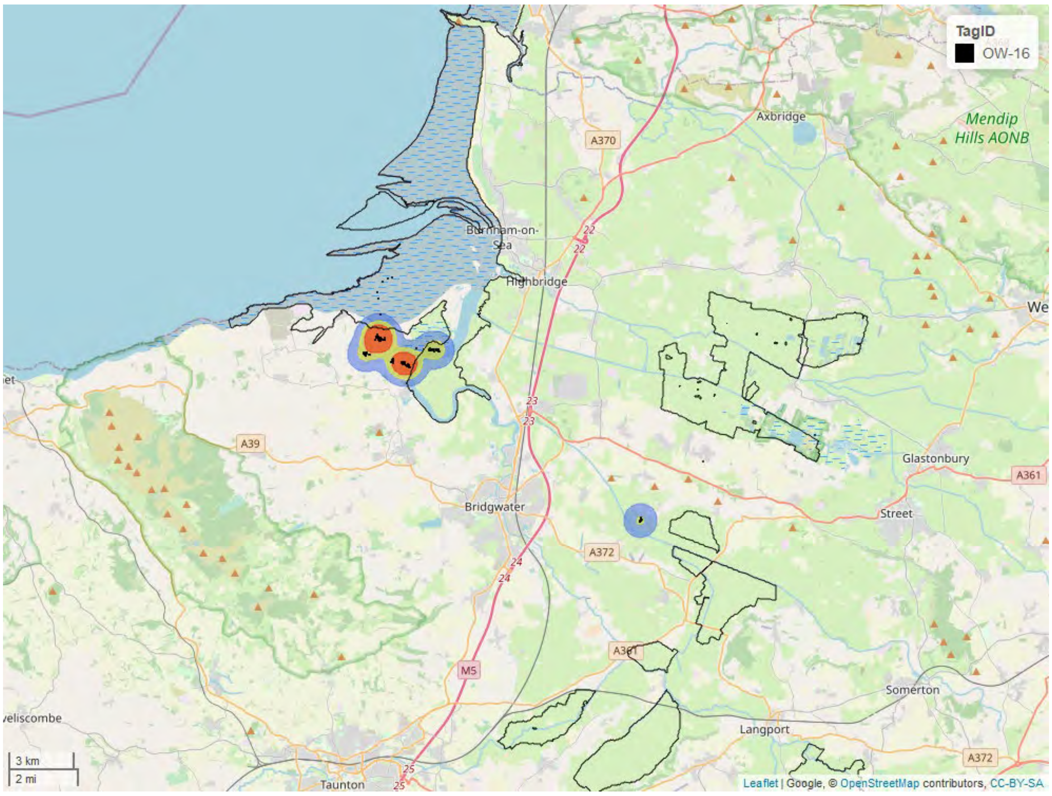


OW-13: n = 508; Href = 446.6433

OW-14: n = 420; Href = 140.9857



OW-15: n = 78; Href = 350.6109



OW-16: n = 378; Href = 391.1333

OW-17: n = 714; Href = 108.6955

OW-18: n = 761; Href = 311.5643

OW-19: n = 485; Href = 88.27168

OW-20: n = 433; Href = 116.0283

OW-21: n = 324; Href = 281.8275

OW-22: n = 472; Href = 283.4224

OW-23: n = 232; Href = 280.5129

OW-24: n = 262; Href = 246.9956

OW-26: n = 478; Href = 117.0911

Front cover: John Harding / BTO; back cover: Edmund Fellowes / BTO

Results of a tracking study of Wigeon to inform understanding of potential interactions with the National Grid Hinkley Connection Project.

As part of the consenting process for The National Grid Hinkley Connection Project, a tracking study was commissioned to track the movements of 15 Wigeon *Anas penelope*, with specific objectives to provide data on the flight paths that birds might take between the Severn Estuary SPA and the Somerset Levels and Moors SPA, and to explore how these relate to the route of the National Grid Hinkley Connection Project between Bridgwater and Seabank. Investigations also examined the frequency of movements through the winter period, and the flight heights and speeds of birds.

Suggested citation: Green, R.M.W., Thaxter, C.B. & Burton, N.H.K. 2021. Results of a tracking study of Wigeon to inform understanding of potential interactions with the National Grid Hinkley Connection Project. *BTO Research Report* **800**, BTO, Thetford, UK.

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