BTO RESEARCH REPORT 735

Pilot study to investigate Oystercatcher (*Haematopus ostralegus*) feeding behaviour to enhance bird food modelling and shellfisheries management on The Wash

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Pilot study to investigate Oystercatcher (*Haematopus ostralegus*) feeding behaviour to enhance bird food modelling and shellfisheries management on The Wash

Report of work carried out by the British Trust for Ornithology[1, 2] on behalf of Natural England and Eastern Inshore Fisheries and Conservation Authority

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EXECUTIVE SUMMARY

1. The Wash is an important and protected estuarine system in the UK supporting large aggregations of wintering birds, as well as a variety of commercial industries such as considerable shellfisheries. The winter population of Oystercatcher (*Haematopus ostralegus*) on The Wash is c. 20,000 individuals and has been shown previously to be sensitive to declines in shellfish abundance. Consequently modelling approaches are used to set sustainable limits of shellfish take to ensure both conservation and commercial interests are balanced. These models require parametrisation using data collected on the waders within The Wash.

2. We deployed 10 solar powered GPS-GSM devices to Oystercatchers using leg-loop harnesses to investigate their daily movements around The Wash during the 2020/21 winter. It was only possible to deploy devices at a single site on the eastern shore of The Wash during this pilot study.

3. Device performance was not known during winter deployments in the UK. Solar recharging performance was poorer than anticipated but nonetheless between 4–24 GPS fixes were recorded per day for 35–64 days between deployments in November/December up until mid-February.

4. All tagged individuals made use of multiple roost sites throughout the tracking period. Seven birds remained on the eastern shore but apparently moved freely up and down the coast. Two individuals made repeat visits between the east and west shores of The Wash over the winter but spent the majority of time near the catch site. One individual left the site entirely for c. 1 month, moving up to the Humber Estuary before returning to The Wash. The mean (± S.E.) maximum distance recorded away from the previous high tide roost location during the following low tide was 5.8 ± 0.14 km.

5. Our findings confirm that while patch switching does occur, and even visits outside of the estuary system entirely, this was a minority strategy for the sample of birds tracked in this study and individuals mostly remained close to the roost location where they were originally caught. However, it is expected that individuals caught at different sites and from different age classes may behave differently. Recommendations are made for expanding this pilot work to ensure a representative sample of birds is included from multiple sites.

6. The devices used in this study were suitable for investigating broad individual movement patterns over a period of several months and benefited from flexible programming. Alternative lower power options might be more suitable however for investigating fine-scale behaviour where a higher temporal resolution is required.

1. INTRODUCTION

1.1. BACKGROUND

The Wash is an extremely important estuarine site in the UK supporting large aggregations of over 350,000 wintering birds (Frost *et al.* 2020). As such The Wash is designated as a Special Protection Area (SPA) (Stroud *et al.* 2016), Ramsar site and Site of Special Scientific Interest (SSSI) for its conservation value. It is also a hugely important area for annual shellfish fisheries which has been a growing industry in the UK generally (Ellis *et al.* 2015) and The Wash contains many areas of productive Mussel (*Mytilus edulis*) and Cockle (*Cerastoderma edule*) beds managed both privately and by the Eastern Inshore Fisheries and Conservation Authority (EIFCA).

The current winter population of Oystercatcher (*Haematopus ostralegus*) on The Wash is c. 20,000 individuals (Frost *et al.* 2020) and is a designated feature of the site, but has been shown previously to be sensitive to declines in shellfish abundance and declined during a period of heavy fishing pressure and a crash in Mussel stocks between c.1980-–2000 (Atkinson *et al.* 2010) and therefore is the focus of this study. Management measures were developed in 2008 in line with The Wash SSSI conservation objectives, which stipulate that the target total stock of Cockles and Mussels in The Wash should not fall below a certain value per Oystercatcher at the start of the winter to ensure there is sufficient food resources. These shellfish stock levels are calculated using a Bird Food Model (BFM) (Stillman *et al.* 2004) which can be used to inform how much shellfish the fishing industry can take sustainably, similar to modelling approaches used elsewhere in the UK to help inform fisheries management (West *et al.* 2003, Caldow *et al.* 2004).

The overall low tide distribution of waders on The Wash is relatively well known (Ross-Smith *et al.* 2013) and ringing data have shown roost site fidelity was high (Rehfisch *et al.* 1996), but it is unclear how individuals behave in regards to movements between roosts and foraging sites throughout the winter. At present, the BFM considers both the shellfish stocks and the size of the Oystercatcher population across the The Wash as a single unit, however this assumes that all birds in the population have free access to all shellfish resources across the whole site. Given the size of The Wash, there are, however, likely to be energetic costs to moving to new patches of shellfish resource to exploit, and benefits in terms of foraging efficiency and local dominance from being site faithful. This makes it unlikely that all birds will have perfect knowledge of the changing profitability of the shellfish resources available on all shellfish beds across The Wash or to be in a position to freely access them all. Oystercatchers have been successfully tracked using bio-logging devices to investigate individual movements (Schwemmer & Garthe 2011) and these techniques have the potential to improve our knowledge of the individual behaviour of birds on The Wash to test the free movement hypothesis and better inform the BFM.

1.2. PROJECT AIMS

This project is part of a partnership project between Natural England, BTO and EIFCA to improve our understanding of Oystercatcher feeding behaviour, ultimately to improve site and fisheries management by better informing BFM approaches.

This report includes;

1. Investigation into winter feeding site fidelity of individual Oystercatchers on The Wash using bird-borne telemetry data.

2. An assessment of the current telemetry methods used and recommendations for improvements to future studies.

2. METHODS

2.1. FIELD METHODS

We used cannon nets to capture Oystercatchers for this study, which involves burying cannons in the ground and attaching a net (up to a maximum size of 25 m x 12.5 m) to weighted projectiles. The net is then propelled over the birds, if in a suitable position, using a small explosive charge (Figure 1). Cannon netting has the potential to be dangerous to both birds and people if carried out incorrectly, so is closely regulated and licensed by the BTO on behalf of JNCC. All catching operations were led by experienced members of the Wash Wader Ringing Group (WWRG) which have many years of experience catching waders using cannon nets on The Wash.

The fieldwork for this project was carried out in November/December 2020 and all catching operations were designed to be compliant with restrictions in place at the time to mitigate the spread of the SARS-CoV-2 virus. These included restricted team sizes, using local personnel where possible, social distancing and face coverings, same household groups where applicable

Figure 1. Example of a cannon net being set on Heacham Beach (taken before the SARS-CoV-2 virus). Photo © Chantal Macleod-Nolan.

for close proximity work and additional equipment disinfection. The size of catches intended and size of nets used was also reduced to correspond to what was safe to carry out with a smaller team size. All activities adhered to government restrictions at the time.

It was intended to deploy devices on individuals at two different roost locations on The Wash (Figure 2), Snettisham/Heacham beaches in the east and a lagoon site near Wrangle Marsh on the western shore, to provide contrasting data from multiple locations. However, only a single suitable catching window was available at the western shore site during the timeframe of this project due to constraints of sufficiently high tides (and reduced ability to visit sites to identify suitable alternative catching locations). Visits ahead of this high tide indicated no roosts were present therefore all subsequent capture and deployment efforts were focussed on the eastern beach site.

Figure 3. Bill measurements recorded on all captured individuals. From van de Pol *et al*. (2009).

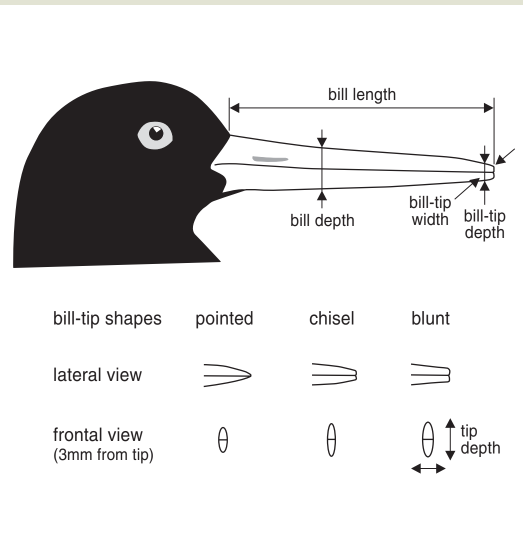


Figure 2. Planned catch locations (red circles) within The Wash estuary. Devices were only deployed on the Heacham Beach site on the eastern shore.

Two successful catching attempts were carried out on Heacham beach 20/11/20 and 13/12/20, where a total of 10 and 17 Oystercatchers were captured respectively. A total of 10 devices were deployed across these two catches and all capture information for tagged individuals is shown in Table 2.1. For the purpose of this pilot study, only full adult individuals (fourth calendar year plus) were tagged, and a range of bill measurements as described in Fig. 2.3 and total head length were recorded to help determine probable sex (Zwarts *et al.* 1996) and feeding preferences of individuals (van de Pol *et al.* 2009). All tagged individuals bill tip shapes were classified as blunt or intermediate chisel-blunt according to van de Pol *et al.* (2009).

Devices were attached to birds so that they sat on the lower back (Fig. 2.4) using a modified Rappole-Tipton style leg-loop harness (Rappole & Tipton 1991, Sanzenbacher *et al.* 2000) and raised up with a 3 mm closed cell foam pad attached to the underneath of the device. The harness was made of an elasticated 2 mm diameter silicone cord (Polymax Ltd, UK) passed through 2.4 mm internal diameter, 3.2 mm outer diameter Silastic hypoallergenic tubing, following a design successfully used on other wader species (Le Rest *et al.* 2019). This method was preferable to alternative options, such as glue-mounting which may last up to c. 1 month on waterbirds in similar habitats (Green *et al.* 2019), as it facilitated data collection throughout the winter period for one sample of individuals rather than multiple short-term samples on different individuals.

All trapping and ringing activities were carried out by licensed individuals holding valid BTO ringing permits and all tags and harnesses were fitted under endorsement (Ref. 11846) from the Special Method Technical Panel (SMTP) of the BTO Ringing Committee. A requirement of the SMTP license was all additional attachments (colour ring, harness and device combined) must be <3% of individual body mass at time of capture which is a well-established threshold in the UK to reduce the risk of negative effects of tagging (Geen *et al.* 2019). Colour marks were excluded if it put the total additional mass >3% of body mass.

Figure 4. Position of additional colour marks and telemetry device on adult Oystercatcher prior to release. Photo © Sam Franks.

2.2. TELEMETRY SYSTEM

We used devices produced by Ornitela (Vilnius, Lithuania) (model: OrniTrack-9, 10.5 g, 37x19x12 mm) in this study (www.ornitela.com/ornitrack) with a 100 mm external flexible whip antenna and modified with front and rear attachment tubes. These devices consist of a Global Positioning System (GPS) logger and a Global System for Mobile Communications (GSM) module to allow data to be transmitted directly from the device anywhere with mobile phone network coverage as well as new settings to be remotely updated. In areas of no network coverage, data are stored locally on the device on 2 MB flash memory until the next successful upload.

These devices contain a primary battery which is recharged via a solar cell, but solar recharging conditions are very poor around the latitudes of The Wash in winter due to short day lengths (and low sun angles). Furthermore, device performance may be reduced through a combination of bad weather, bird behaviour, attachment method and feather shading. Nonetheless it was expected that 4–24 GPS fixes would be obtained per day, giving a least one location at each low tide.

These devices allow for flexible programming of the GPS sampling and GSM upload schedules. The first two devices deployed were set to upload data via GSM every 24 hours, which allowed close monitoring of performance. This was reduced to every 10 days after a period of a few weeks, and the subsequent eight devices deployed also uploaded data every 10 days. We pre-programmed varying GPS sampling rates dependent on battery levels to reduce the likelihood of data gaps from depleted batteries;

>75%	=	1 hr sampling
50–75%	=	2 hr sampling
25–50%	=	4 hr sampling
<25%	=	6 hr sampling

Additional features to alter the sampling schedule, based on either time (day/night) or location (user-defined geofences), were available but were not used for this pilot study; we aimed to collect data from as many discrete low tides as possible. Both the foraging and roosting locations are of interest in this study but, given the low frequency of daily GPS fixes scheduled, there was little benefit reducing sampling schedules further during periods of high tide roost use.

2.3. DATA ANALYSIS

All data collected by these devices were uploaded to the Ornitela severs (www.glosendas.net) which were then automatically forwarded to the online tracking data repository Movebank (www.movebank.org, study ID 1358891788). Storing the data on Movebank ensures a more standardised method of archiving and sharing.

We only include data collected up until 15/02/21 in this pilot report although all the devices continued to collect data after this date. Telemetry data were cleaned prior to analysis to remove any potentially erroneous data. Any incomplete or duplicate data were removed, as well as any GPS fixes obtained from three or fewer satellites where locational error is likely to be higher. Finally a speed filter was applied to remove any fixes considered unreliable based on calculated speed between two consecutive points using a threshold of 30 m/s which was appropriate for other waterbird species (Shamoun-Baranes *et al.* 2016). A summary of included data is shown in Table 2.

High water time and height data for the study period were obtained for King's Lynn (KLCB 2020) and matched to the GPS data. Individual GPS fixes were categorically defined as occurring at high tide if recorded within 2 hrs either side of the nearest high water time. All other fixes were classified as occurring during low tide.

Table 1. All capture data for tagged individuals. All measurements recorded in millimetres unless stated otherwise. Ring type; N = New fitted, S = Subsequent encounter. Age; EURING age codes (Redfern & Clark 2001). Moult score; Individual primary feather scores following Ginn & Melville (1983), 5= Fully grown new feather, 1–4 = Growing feathers. Wing length was not recorded for actively growing wings as measurements are unreliable for final length.

Site	Date	Ring ID	Colour ID	Tag ID	Ring type	Age	Wing	Moult score	Tarsus & Toe	Total head length	Bill Length	Bill depth	Bill tip width	Bill tip depth	Weight (g)	Attached mass %
Heacham	13/12/2020	FH30820	O,GW(A3Y)	203275	S	8	269	5555555555	96.0	109.0	65.3	5.6	2.1	5.6	572.1	2.91
Heacham	13/12/2020	FH81060	O,GW(A3N)	203276	S	8		5555555554	93.5	113.0	69.5	6.9	2.6	6.9	548.4	2.98
Heacham	20/11/2020	FJ30115	O,GW(A3A)	203277	N	8I		5555555554	97.5	113.7	70.5	11.1	1.5	6.1	567.2	2.91
Heacham	13/12/2020	FJ30126		203278	N	8	271	5555555555	98.0	114.0	71.1	6.8	3.2	6.8	506.6	2.83
Heacham	13/12/2020	FJ30131	O,GW(A3P)	203279	N	8		5555555554	94.0	117.0	74.1	5.4	1.9	5.4	575.3	2.91
Heacham	13/12/2020	FJ30129	O,GW(A3K)	203280	N	8		5555555543	102.0	115.0	69.3	5.4	1.3	5.4	612.9	2.72
Heacham	13/12/2020	FJ30130		203281	N	8	256	5555555555	93.0	112.0	68.7	6.0	2.5	6.0	529.0	2.69
Heacham	13/12/2020	FH81048	O,GW(A3V)	203282	S	8		5555555554	99.0	122.0	77.7	5.5	2.1	5.5	563.9	2.93
Heacham	20/11/2020	FJ30113	O,GW(A3H)	203283	N	8		5555555554	96.5	115.4	71.7	10.7	1.6	6.1	544.2	2.99
Heacham	13/12/2020	FP99757	O,GW(A3M)	203284	S	8		5555555554	95.0	110.0	65.8	6.0	2.0	6.0	545.2	2.96

Two GIS layers provided by EIFCA were used to provide likely shellfish distribution in context of the GPS tracking data. One layer outlined the boundaries of the majority of Mussel beds on The Wash, surveyed in 2020 and a separate layer included interpolated Cockle distribution, of two size classes, at different densities derived from point surveys at stations located across The Wash in spring 2019. A further GIS layer provided by Natural England included the densities of Oystercatcher in different areas around The Wash as surveyed as part of a low tide distribution survey carried out in the 2020/21 winter by Garbutt *et al.* (in prep.) following the same methods as Garbutt *et al.* (2010).

High tide roost sites were categorised by intersecting the high tide GPS fix locations with manually-defined polygons broadly covering the main roost areas within the tracking dataset. Maximum foraging distances were calculated by uniquely identifying each discrete high and low tide period and extracting the maximum low tide distance from the last GPS fix from the previous high tide using the 'pointDistance' function within the 'raster' R package (Hijmans 2020). Any incomplete tides with gaps in the data were excluded to ensure only the immediate subsequent low tide foraging ranges were included.

All analyses were carried out using R v3.6.1 (R Core Team 2019) and tracking data handled and time of day assigned, excluding dawn and dusk, using the 'amt' package (Signer *et al*. 2019). Maps were produced using QGIS v3.4.1 (QGIS Development Team 2019).

Table 2. Summary of tracking periods GPS fixes collected for Oystercatchers tagged on The Wash during the 2020/2021 winter.

Tag ID	Start	End	N days	N fixes	Notes
203277	20/11/2020	03/01/2021	45	286	
203283	20/11/2020	09/02/2021	35	226	
203284	13/12/2020	14/02/2021	44	219	
203279	13/12/2020	14/02/2021	61	275	
203281	13/12/2020	14/02/2021	64	306	Only 33 days within The Wash. Visited Humber Estuary.
203280	13/12/2020	13/02/2021	49	230	
203278	13/12/2020	14/02/2021	59	284	
203276	13/12/2020	14/02/2021	63	301	
203282	13/12/2020	14/02/2021	53	229	
203275	13/12/2020	14/02/2021	50	249	

3 RESULTS

3.1. BROAD MOVEMENT PATTERNS

Generally, the sample of Oystercatchers tracked in this pilot made greatest use of the eastern shore of The Wash, from Wolferton in the south up to Holme Dunes in the north, during the peak winter period (Figure 5). All individuals (Appendix A1) were mostly recorded within a few hundred metres of the shore at low tide on the eastern side of The Wash and used multiple roost sites at high tide. Two of the tagged individuals (203276 and 203282) made several visits to the western side of The Wash, both feeding and roosting in the area before returning to the eastern beaches (see section 3.2). A further individual (203281) also made wider visits to the western side of The Wash, but then was recorded leaving the estuary entirely and spending over a month, between mid-December and January, approximately 75 km north of the catching area on the Humber Estuary before returning again to The Wash.

The broad patterns of GPS data collected were similar, across all individuals, for both day and night periods. Birds made use of opportunities to visit the exposed intertidal areas, presumably to feed, at low tide regardless of time of day (Figure 6) as well as fixes recorded closer to the shore where birds may be resting on suitable areas or visiting very recently uncovered intertidal areas nearer the high water mark. It was not possible to determine behaviour at time of location with the frequency of fixes recorded in this pilot.

Across all individuals, there did not appear to be any selection for those few discrete patches likely to contain higher densities of shellfish, and there was little overlap between GPS fixes recorded and the boundaries of the main Mussel bed sites or areas previously likely to contain higher densities of larger Cockles (Figure 7). It should be noted that the majority of the low tide fixes were recorded within the Le Strange private Cockle fishery along the eastern shore, for which the location for Mussel and Cockle beds are not shown within the information provided by EIFCA. The context of how the tracking data collected in this study relate to the wider distribution of Oystercatcher at different densities around The Wash in the same winter period are shown in Figure 8.

Figure 5. Overview of all GPS fixes, separated by state of tide, recorded from 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter period. The bottom panel shows the data for birds that remained within The Wash.

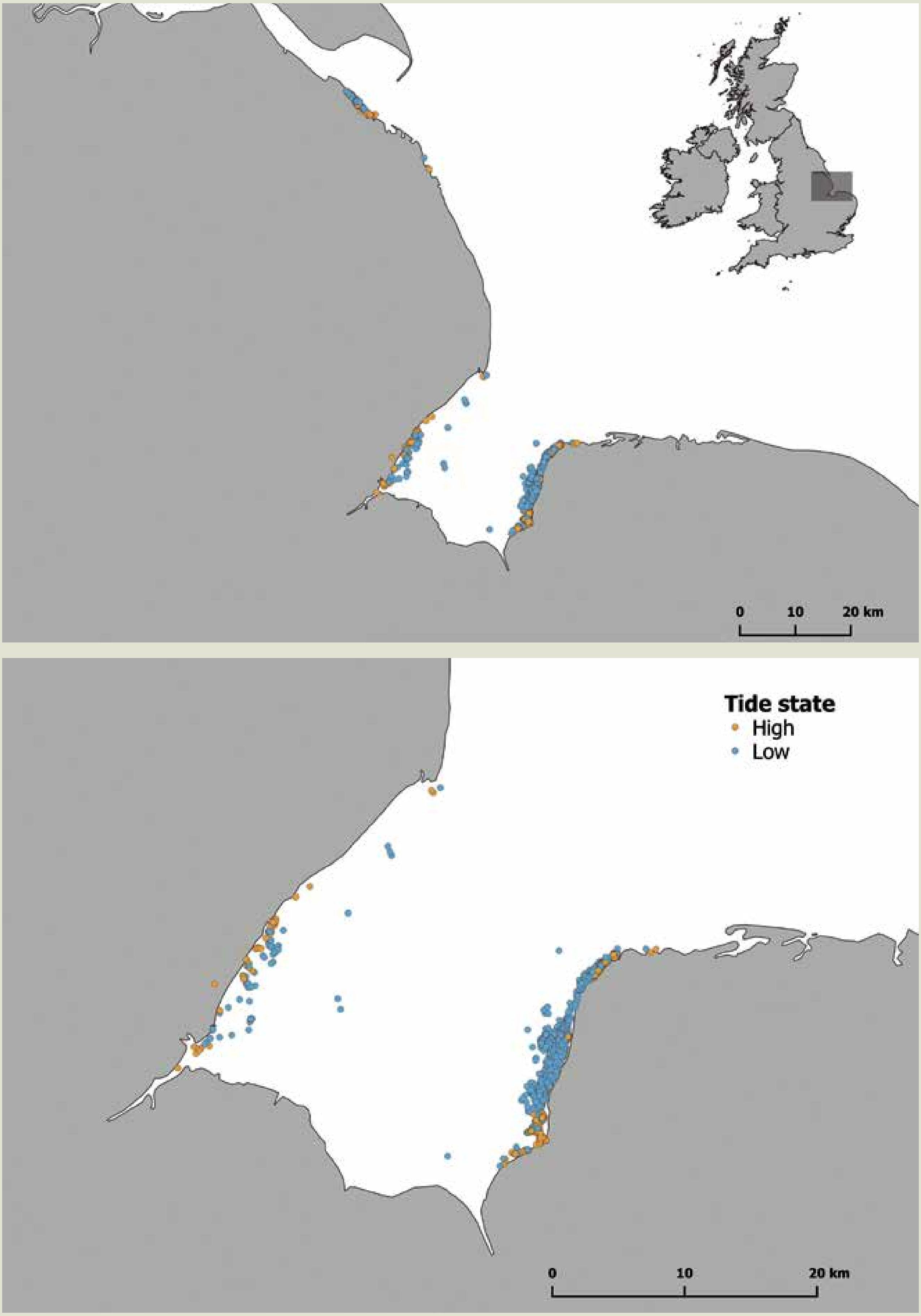


Figure 6. Overview of GPS fixes (blue dots) recorded at low tide either during the day (top) or night (bottom), excluding dawn and dusk, for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter period.

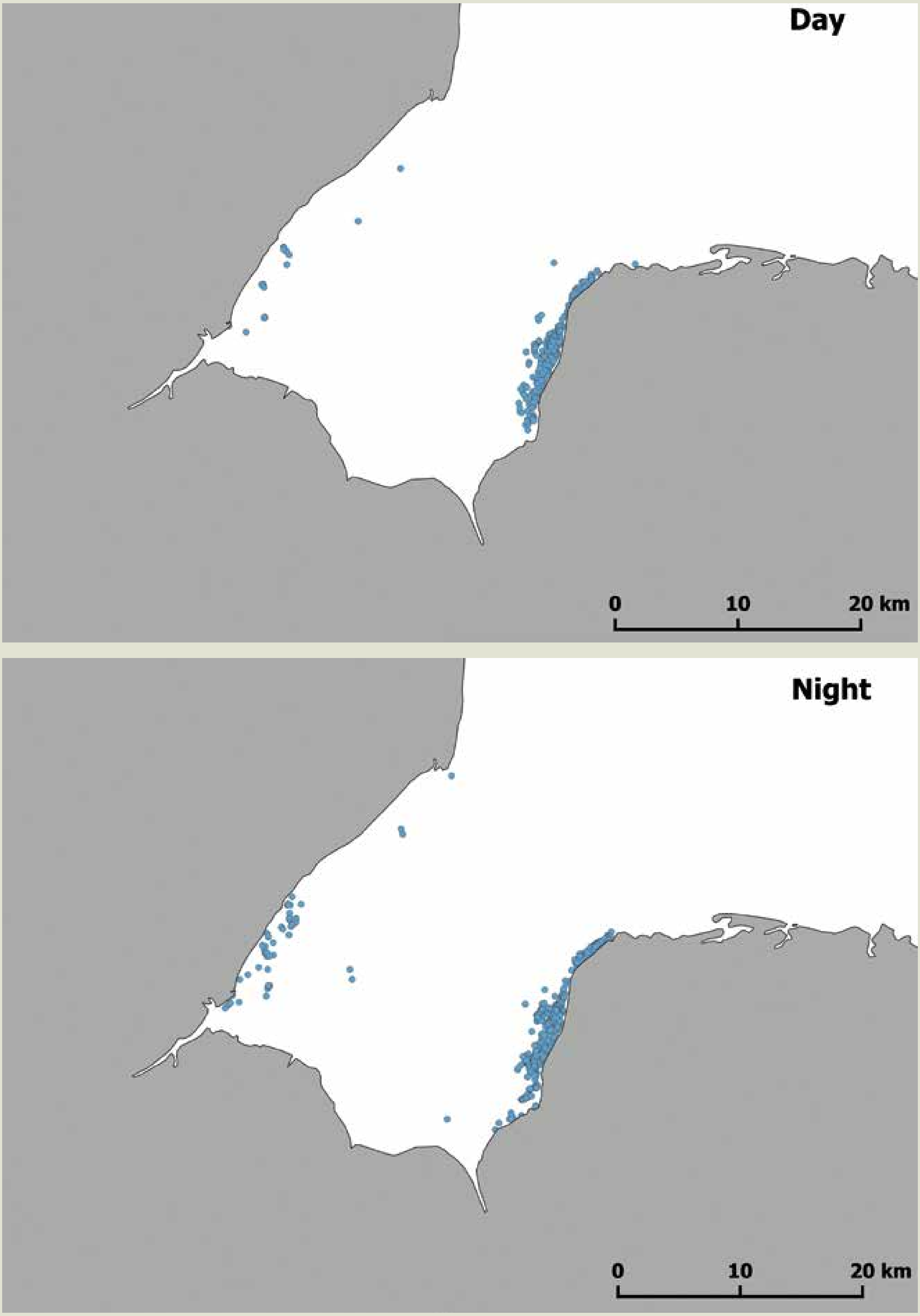
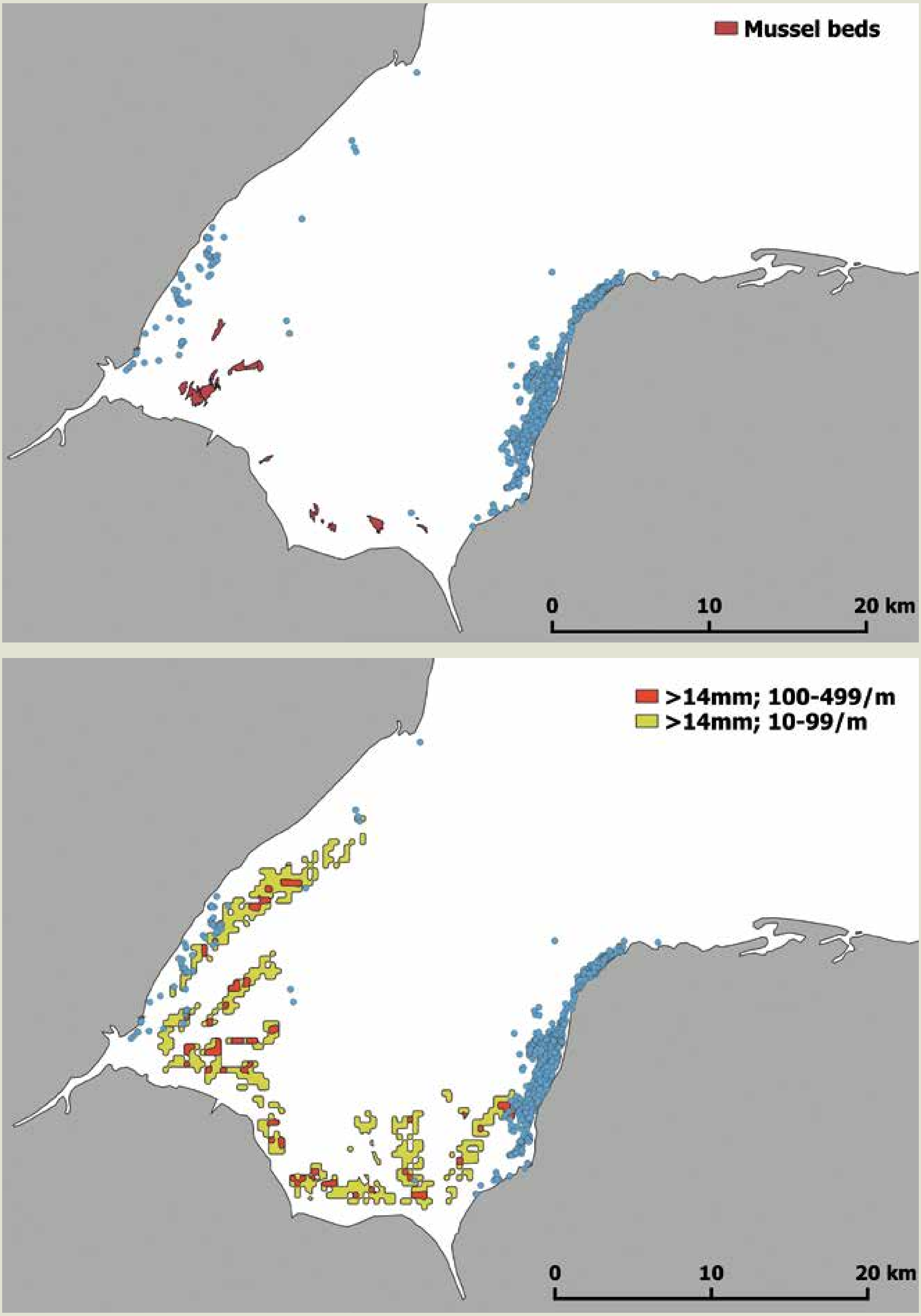


Figure 7. Overlap between GPS fixes (blue dots) recorded during low tide for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter with the main Mussel bed areas (above) and areas previously stocked (spring 2019) with different densities of Cockles >14 mm width (below). Some beds within private fisheries on the eastern shore of The Wash are not shown.



3.2. INDIVIDUAL MOVEMENT BEHAVIOUR

There were some individual differences in the number and preference for different high tide roosts around The Wash (Table 3). The majority of individuals remained on the eastern shore for the duration of the study and predominantly used roosting sites (Figure 9) at the northern (Holme Dunes) and southern (Snettisham RSPB Reserve area) extremes of the shore followed by roosting on the beaches in between, which are also known to hold pre-roost aggregations. Including only the data recording within The Wash, the mean (± S.E.) maximum distance recorded away from the previous high tide roost location during the following low tide was 5.8 ± 0.14 km. This was largely consistent across individuals (Figure 10) although some small distances <500 m as well as larger movements over 25 km were also recorded for the individuals which switched to the Lincolnshire shore of The Wash.

Because of the orientation of the system the two sides of The Wash are readily distinguished based on longitude (East (Norfolk) side ~0.45°E; West (Lincolnshire) side ~0.1°E). Figure 11 shows the longitude over time for the two individuals (203276 and 203282) who switched patches and were recorded on the Lincolnshire marshes. The timing of the trips away from the catch area were very consistent during December but less so in January and February. For individuals which stayed on the eastern shore, movements were recorded along the entire length as indicated by latitude over time (Fig. 12). As indicated above, there was a tendency to use the northern and southern extremes of the shore for high tide roosts. Some individuals were apparently more consistently using the central areas during low tide (e.g. 203284), whereas others (e.g. 203277) were recorded at a wider range of areas during low tide throughout the winter. It seems reasonable to assume that, at a large scale, all the individuals tracked in this study are using the eastern shore as a single patch, although some preference for particular areas even within the eastern shore is likely. There appears to be a slight tendency for all birds, where data are present, to be recorded further north during February, which coincided which a spell of colder temperatures (<0°C), but this link has not been explored.

Figure 9. Locations around The Wash of all high tide roost locations used by 10 Oystercatchers tracked from Heacham Beach during the 2020/21 winter period.

Figure 8. Overlap between GPS fixes (blue dots) recorded during low tide for 10 Oystercatchers tracked from Heacham Beach within The Wash with different densities of Oystercatchers in areas surveyed by *Garbutt et al.* (in prep.) following the same methods as Garbutt *et al.* (2010) during the 2020/21 winter.

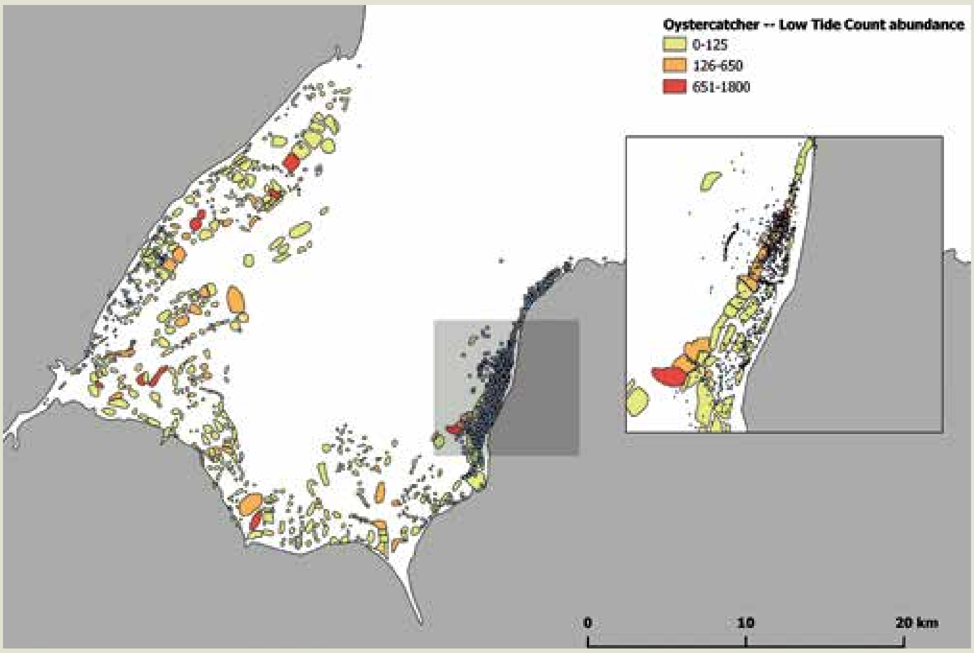


Table 3. Proportion of all recorded high tides at each roost site for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter.

Tag ID	N high tides	Snettisham & Heacham Beaches	Gibraltar Point	Holme Dunes	Lincolnshire Marshes	Snettisham Sailing Club & RSPB Reserve	Fosdyke Wash	Wolferton Marsh
203275	82	0.27		0.30		0.32		0.11
203276	94	0.16		0.20	0.20	0.34	0.07	0.03
203277	91	0.02		0.23		0.66		0.09
203278	90	0.17		0.72		0.10		0.01
203279	80	0.13		0.52		0.35		
203280	75	0.31		0.36		0.28		0.05
203281	41	0.17	0.05	0.51		0.20	0.05	0.02
203282	75	0.07		0.37	0.27	0.28		0.01
203283	74	0.07		0.17		0.69		0.07
203284	67	0.06		0.64		0.26		0.04
TOTAL	**769**	**0.14**	**<0.01**	**0.40**	**0.05**	**0.36**	**0.01**	**0.05**

Figure 10. Maximum distance from the previous high tide roost sites recorded for each complete tidal cycle (sample size above each boxplot) recorded for 10 Oystercatchertracked from Heacham Beach within The Wash during the 2020/21 winter. *Individual moved between east and west shore of The Wash. **Individual left The Wash system for c. 1 month.

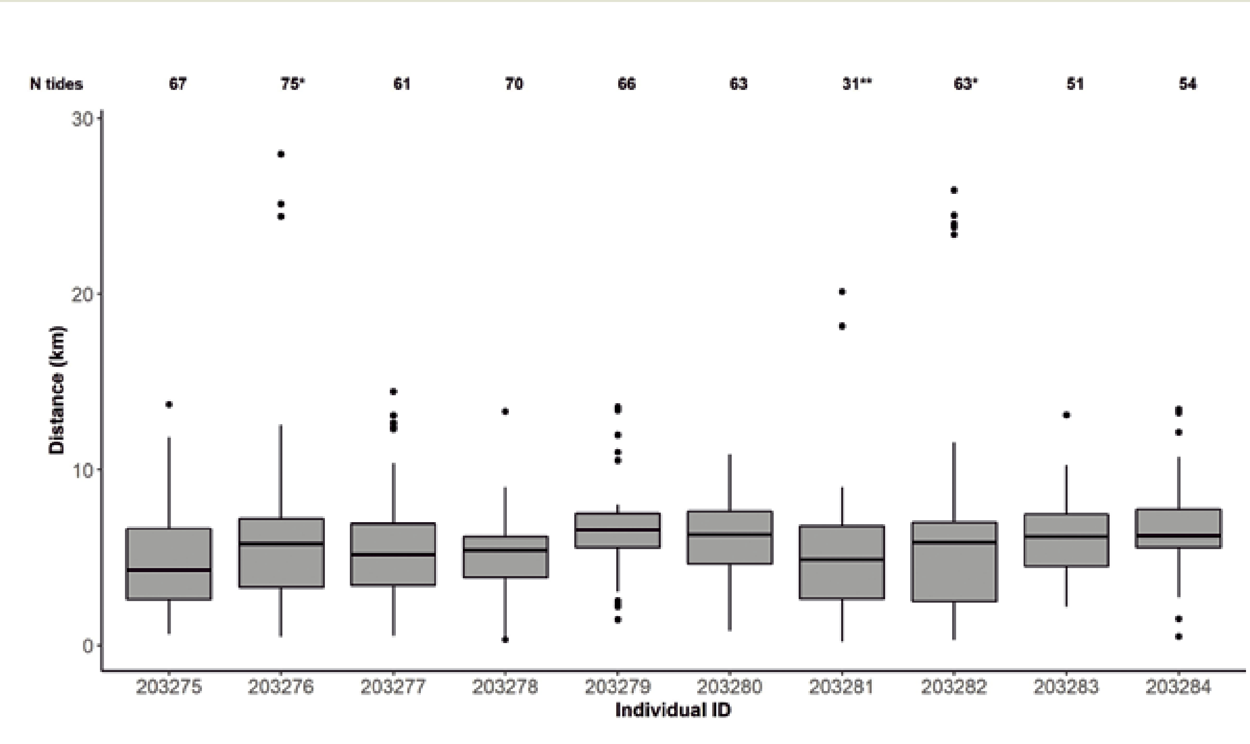


Figure 11. Longitude over time for the duration of tracking for two individual Oystercatchers tagged on The Wash during the 2020/21 winter. Shifts in longitude show the timing of broad movements between the east and west shores of the estuary. Tag ID is shown on the right of each plot.

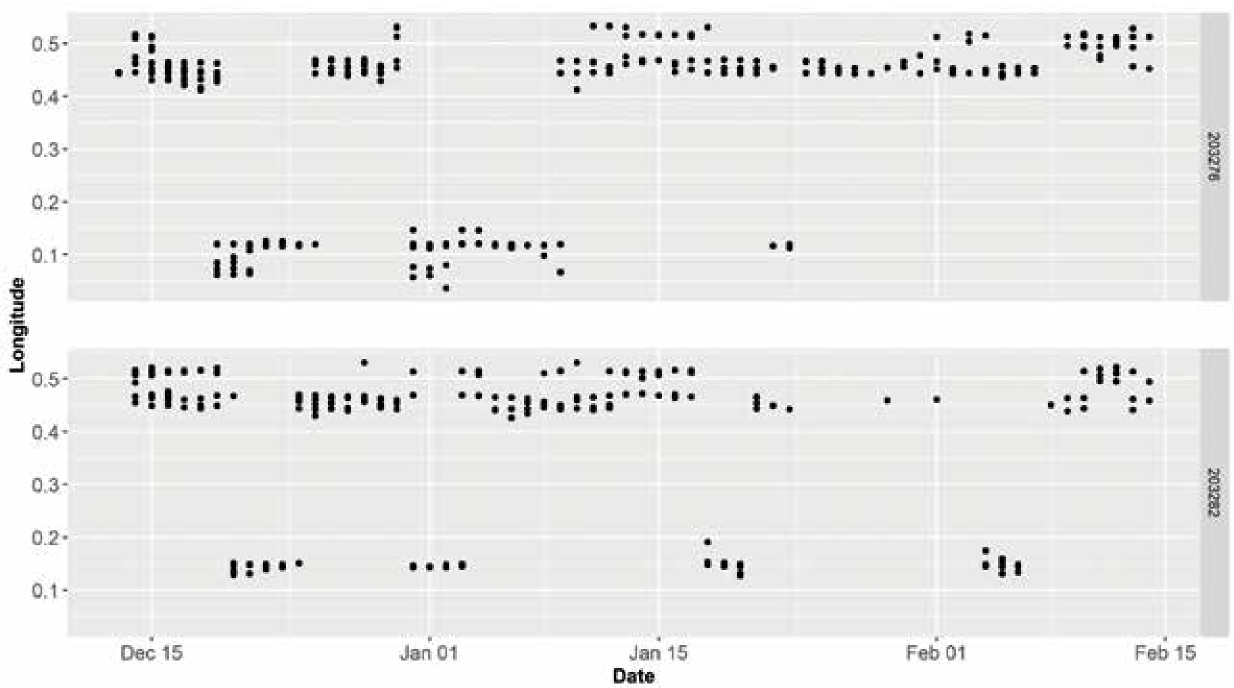
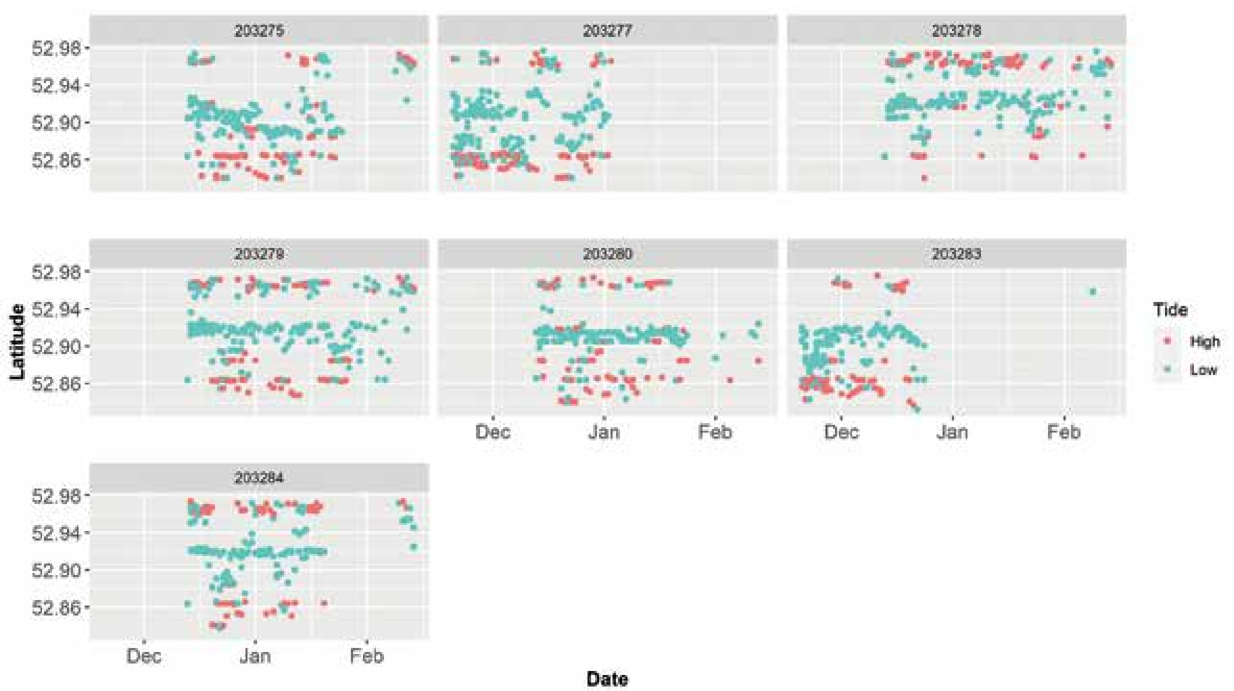


Figure 12. Latitude over time for the duration of tracking for seven individual Oystercatchers tagged on The Wash during the 2020/21 winter which remained solely on the eastern Norfolk shore. Location fixes recorded within two hours either side of high water are shown in red and all other fixes in blue. Tag ID is shown above each plot. Data are missing for some individuals where the device battery levels were depleted.



4 DISCUSSION

4.1 INDIVIDUAL MOVEMENTS

Unfortunately, it was not possible to deploy devices at multiple locations within The Wash during this pilot, which would have allowed a more rigorous test of the free movement hypothesis underlying the BFM. If the assumption that all birds are equally able and willing to make use of shellfish resources across the entire site to forage was true, then it may be expected that birds from multiple sites would have a high degree of overlap in foraging locations.. Nonetheless, our findings confirm that while patch switching between shores of The Wash is exhibited by some birds and one even left the estuary system entirely for a few weeks, such movements were not exhibited by the majority of the birds tracked and were infrequent and relatively short-lived events even amongst the birds which made such movements. Individuals mostly foraged close to the catch location and subsequently to their high tide roost locations. On the basis of this pilot study, it would seem a reasonable starting assumption in setting up behaviour-based models of The Wash Oystercatcher population that the population be split into groups that exhibit fidelity to one or other of the three shores of The Wash, i.e. western, southern and eastern, and which are constrained (either totally or significantly) from exploiting resources elsewhere by costs imposed on them when seeking to forage on resources outside their home shore. Based on this pilot study, such a model formulation may be closer to reality than one in which all individuals are assumed, as has been the case until now, to be free to exploit any resources anywhere on The Wash.

There was little overlap between the broad movements of Oystercatchers and the provided shellfish location GIS layers. However, as stated in Section 2.3, some Mussel bed sites were not digitised for 2020 and the Cockle data provided by EIFCA is not representative of conditions during the timing of Oystercatcher tracking, as it was derived from the most recent spring 2019 survey information available. The distribution of Cockles during 2020/21 winter will have changed and likely have very few large (>14 mm width) Cockles after recent atypical mortality (R. Jessop, EIFCA, Pers. comm.) and be dominated by 2020 year cohort. Therefore the Cockle overlap shown in Figure 7 is indicative of what may be carried out after a future spring 2021 survey to provide data matching the tracking data. Up to date monitoring of the shellfish stocks will continue to be an important dataset to help predict expected Oystercatcher survival (Stillman *et al.* 2003) and should ideally include currently unsurveyed areas on the eastern shore. Similarly, it appears that some of the areas identified with the highest densities of Oystercatcher at low tide, were not selected by the tracked individuals, even within the eastern shore.

It is known that different age classes and sexes of Oystercatcher have different distributions within The Wash (Durell & Atkinson 2004), with those caught on the eastern shore most likely to be adult males with blunt shaped bills, contrasting with chisel shaped bills on the western shore indicating different feeding strategies for shellfish and pointed bills, preferring soft invertebrates in the mudflat substrate in the south. The relative age structure and foraging strategies of the Oystercatchers on The Wash can have important implications for the BFM. If a model assumes reliance on shellfish for all individuals, this may be precautionary if protected stocks are sufficient for all individuals but only a subset utilise them, although this may mean that potentially sustainably harvestable stocks are going unexploited for the fisheries industry and other foraging resources are not monitored as well reducing efficacy of the model predictions.

There are still other data gaps which may be useful in refining the BFM (Stillman *et al.* 2004). It is unknown what penalties may be incurred for individuals moving away from a home patch, either in foraging efficiency or reduced dominance. One predicted variable from the BFM is the proportion of the time during a single low tide cycle that birds are actively foraging. This is something which could be validated in the future using telemetry data if different behaviours could be sufficiently classified, and would require higher temporal resolution data than collected within this study.

4.2 DEVICE PERFORMANCE

The performance of the Ornitela OrniTrack-9 devices was unknown when deployed on Oystercatcher around the latitude of The Wash in mid-winter. We found the GPS data collected from these devices to be reliable and very consistent to the programmed collection schedules. There were no spurious positions recorded detected by the speed filter, incomplete records or failed GPS attempts present in the dataset prior to cleaning as obtained directly from the Ornitela user platform. A total of seven duplicate fixes was identified and removed as a result of simultaneous SMS and GPRS transmission. Also, only seven fixes were obtained with fewer than four satellites which were likely to have a higher locational error. Although the data processing time was not necessarily reduced as routine checking and cleaning of telemetry data is always prudent, the relatively small number of records needing to be filtered out does reduce the likelihood of any erroneous data accidentally being included.

The solar recharging performance during these deployments was poorer than anticipated, although there were few very clear bright days during the initial few weeks of tracking and environmental conditions are known to have a large effect on recharging performance. Consequently the battery levels declined consistently after deployment (Appendix A2) meaning higher fix rates were not sustained, reducing data collection to one or two fixes only per high or low tide state each day. The first two devices deployed were on a more intensive GSM transmission schedule initially, and both stopped collecting data part way through the study. This is not unusual for small solar powered devices in mid-winter but nonetheless problematic for the data collection to address the key project aims of this study. There were early signs of better solar recharging performance during the last data transmission for the data included in this study which has continued for more devices since mid-February.

The second batch of devices deployed was adjusted to a less intensive transmission schedule which worked well to reduce battery depletion. Unfortunately, despite being placed in suitable outdoor areas to maintain charge between successful catches during periods of sunshine, the second batch was deployed with battery levels <100% which would lead to reduced longevity. We have since confirmed with the manufacturer a protocol to ensure all devices are charged to 100% before deployment using artificial lighting without causing any overheating damage to the devices.

It was also reported to us that the same devices were deployed on Curlew (*Numenius arquata*) elsewhere in Northern Europe during the same study period and the recharging performance was better than observed in this study (Ornitela, Pers. comm.). However, the attachment methods were different between studies and the position of the device was lower down on the back using leg-loop harness in this current study, as opposed to a backpack harness (Chan *et al.* 2016), which is not currently accepted as best practice for deployments on waders in the UK. It does, however, suggest increasing the height with a larger foam pad placed underneath the tag could improve performance and reduce feather shading. The leg-loop attachment method used in this study was very successful for a longer-term tracking duration, compared with other methods such as glue-mounting, as data continue to be collected several months after deployment. Further modifications may improve device performance while using the leg-loop attachment method in the future, such as increasing the depth of the foam pad under the device to increase the height and reduce the effect of feather shading on solar recharging. All details from the deployments in this study are reported to the SMTP.

4.3 FUTURE WORK AND RECOMMENDATIONS

Further tracking work would benefit from additional time and resource to ensure devices could be deployed at multiple locations around The Wash (particularly on the southern and eastern shores), which will also be easier without the movement restrictions in place during the course of this study. The attachment methods used in this pilot would be suitable for attaching devices to individuals earlier in the year. This would also increase the chances of successful deployments as there are more catching opportunities, particularly for the western shore of The Wash where opportunities are more tide limited. The approach would also enable data to still be collected throughout the duration of the winter.

It is an important question to consider, how many animals are needed to be tracked to be sufficient to answer the questions of the project? Sequeira *et al.* (2019) report some useful generalisations that sample sizes up to 10 can be useful for initial insights into individual variability and scales of movement and between 10 and 100 to define norms in space use and understand differences between groups e.g. age or sex. However, this is still a wide sample size range when including ethical and cost considerations and each project may differ.

Thaxter *et al.* (2017) carried out an investigation into suitable sample sizes and tracking duration required for tracked Lesser Black-backed Gulls (*Larus fuscus*) to be able to describe home ranges and offshore area use characteristic of the population as a whole. They suggest a minimum of 13 birds and a precautionary upper maximum of 41 birds to describe 95% of the estimated area use of the population. However, it was more effective tracking fewer birds for longer periods than many birds for a short duration so this upper maximum may be reduced if individuals are able to be tracked for several months. Similarly, Soanes *et al.* (2013) demonstrated for two species of seabird that the number of individuals required to predict the home range area of a colony was lower when more foraging trips from each individual were included in the dataset.

There needs to be some caution applying these estimates to different species and systems and we would recommend that an initial task for any future tracking work would be to make an assessment, using data from this pilot study, of the effect of different sample sizes to address different questions. We do suggest however that a minimum sample size for each sampling group, such as age class, is unlikely to be less than 10 to have a high degree of confidence the data will be representative of the wider population.

The GSM devices used in this pilot were broadly suitable to answer the study questions. The ability to modify and set flexible recording schedules and receive data directly from the individuals without need for recapture or local base station downloads was extremely beneficial and allowed us to identify larger scale movements away from the capture area. Future modifications to the attachment procedure (to raise the height of the device on the bird) and using a less intensive transmission schedule should allow for a minimum of two fixes per tide to be maintained for most, if not all, of the winter period. However, some data gaps during the shortest days may still be expected.

Although the GSM devices used in this study have the capacity to record high resolution temporal fixes (i.e. <10 mins), or accelerometer data bursts around the GPS fix (which can allow the classification of fine-scale behaviour), the power requirements mean they would not be able to be sustained for more than 1–2 days during the winter period before incurring long gaps in the data collection while the device recharges (which may not occur at all during mid-winter). We would recommend that alternative devices may be more suitable to address the data gaps of fine-scale behaviour within a tide, such as GPS-VHF devices. These devices can be lighter (or the same weight if using larger batteries) than the devices used in this pilot and still collect the same locational data anywhere the bird travels to but differ in that, instead of using the mobile phone network, data are retrieved via radio when the bird is in proximity to a base station unit which uses less power per transmission. Depending on the manufacturer, design and topography, base stations are likely to need to be placed within 500–3,000 m to retrieve the data, but this would be suitable in this system as the birds are known to use few discrete sites for roosting. The limitation of a GPS-VHF device, however, is less flexibility in remotely updating settings and the potential of collecting no data if an individual leaves the study site entirely and does not return.

Other devices using different transmission options which may give a local download range of >10 km are also being developed and may be feasible within the next 1–2 years. All alternative options for devices may be fitted to the birds using the same (approved) attached method.

It was not possible in this report to match the tracking data to the most representative spatial distribution of Cockle and Mussel beds of interest, as the survey work had yet been carried out. Future studies would benefit from specific analyses of resource selection using contemporary shellfish data, which may be collected through a bespoke survey during the winter or taken from existing monitoring undertaken by EIFCA during the following spring after data collection from tagged Oystercatchers. It would also be beneficial to obtain the same shellfish data describing the boundaries of Cockle and Mussel beds for the private fishery along the eastern shore of The Wash, as most of the tracked birds stayed local to that patch.

Additionally, there are other options to add value to the data collected either during routine catching activities or during deployment of additional devices. These may include taking blood or feather samples to accurately determine the sex of any individual and also take faecal samples to better determine individual diet using either morphological or molecular methods.

The WWRG have nearly 60 years of data from ringing and re-encountering Oystercatchers on The Wash. There is likely to be utility in using this historic capture data of individuals on The Wash to explore further the link between shellfish availability and body condition, moult timing and survival. These data can be used to update previous analyses (Atkinson *et al.* 2003, Stillman *et al*. 2003) and potentially explore if individuals suspending their annual moult can be used as an early indicator of foraging stress. Routinely collecting bill tip shape information may also provide suitable data in the future to help estimate the proportion of shellfish specialists there are present in the population, perhaps just within specific patches, from year to year. This may be used to help refine the estimate of birds that the shellfish stocks are required to support.

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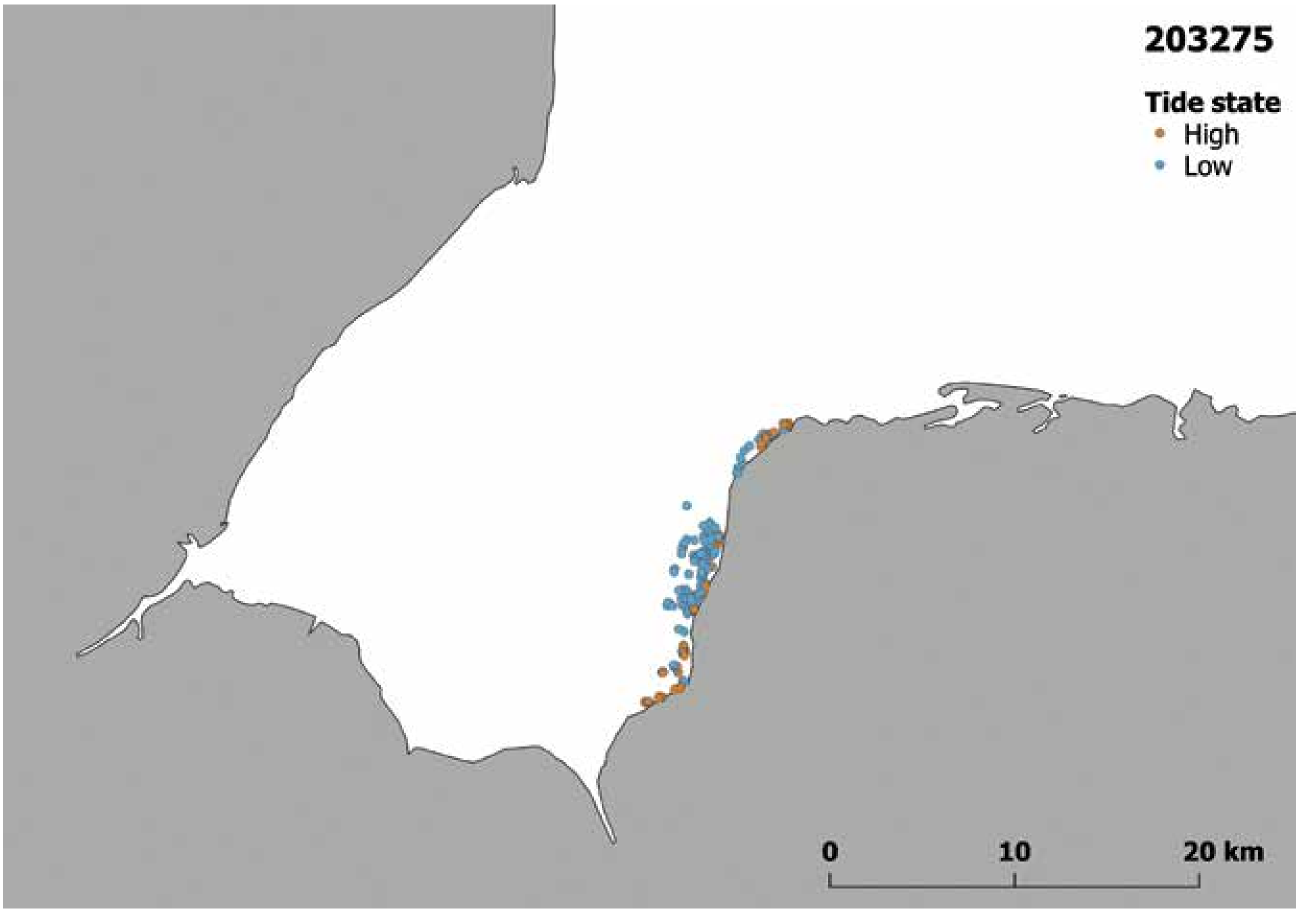
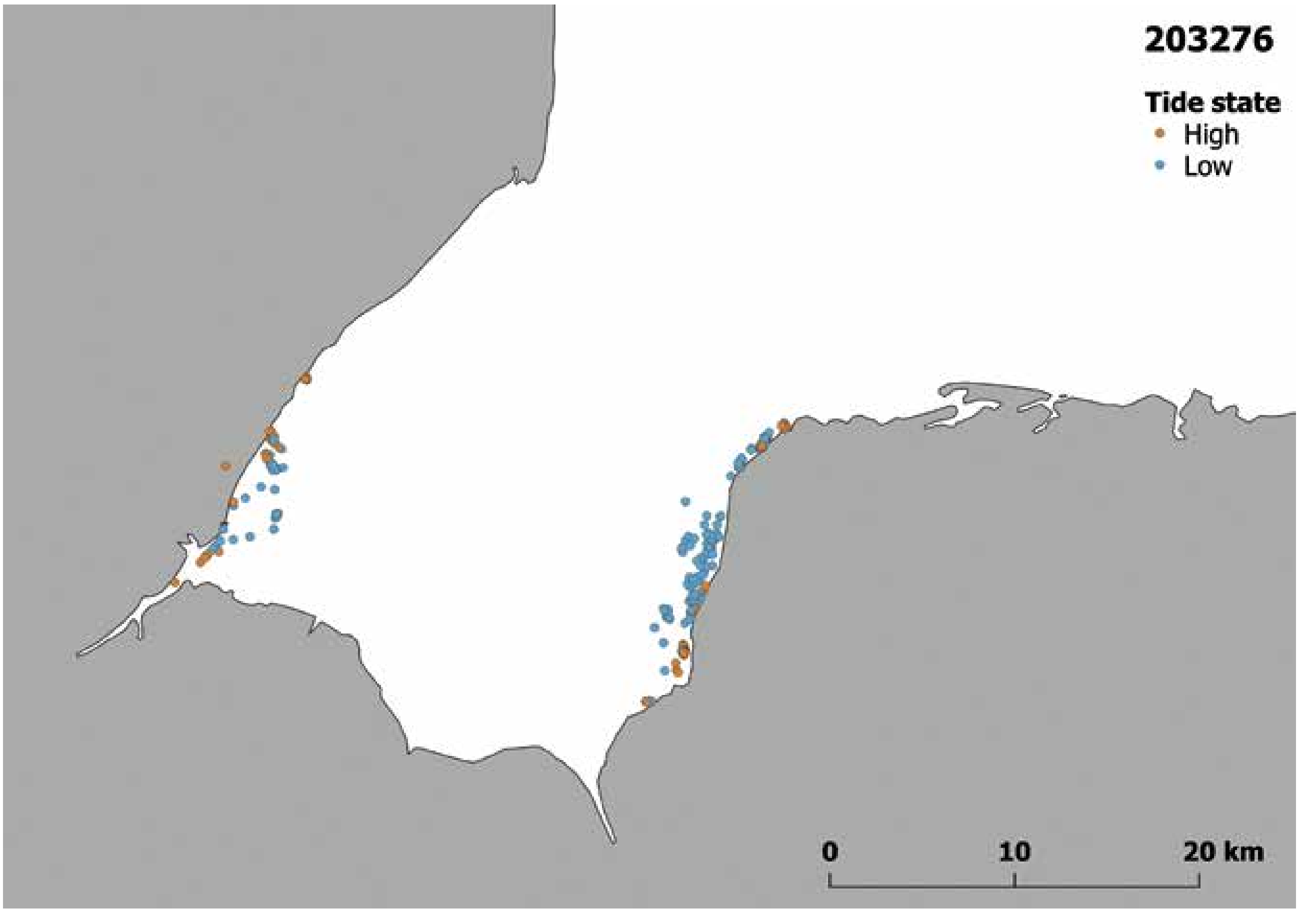
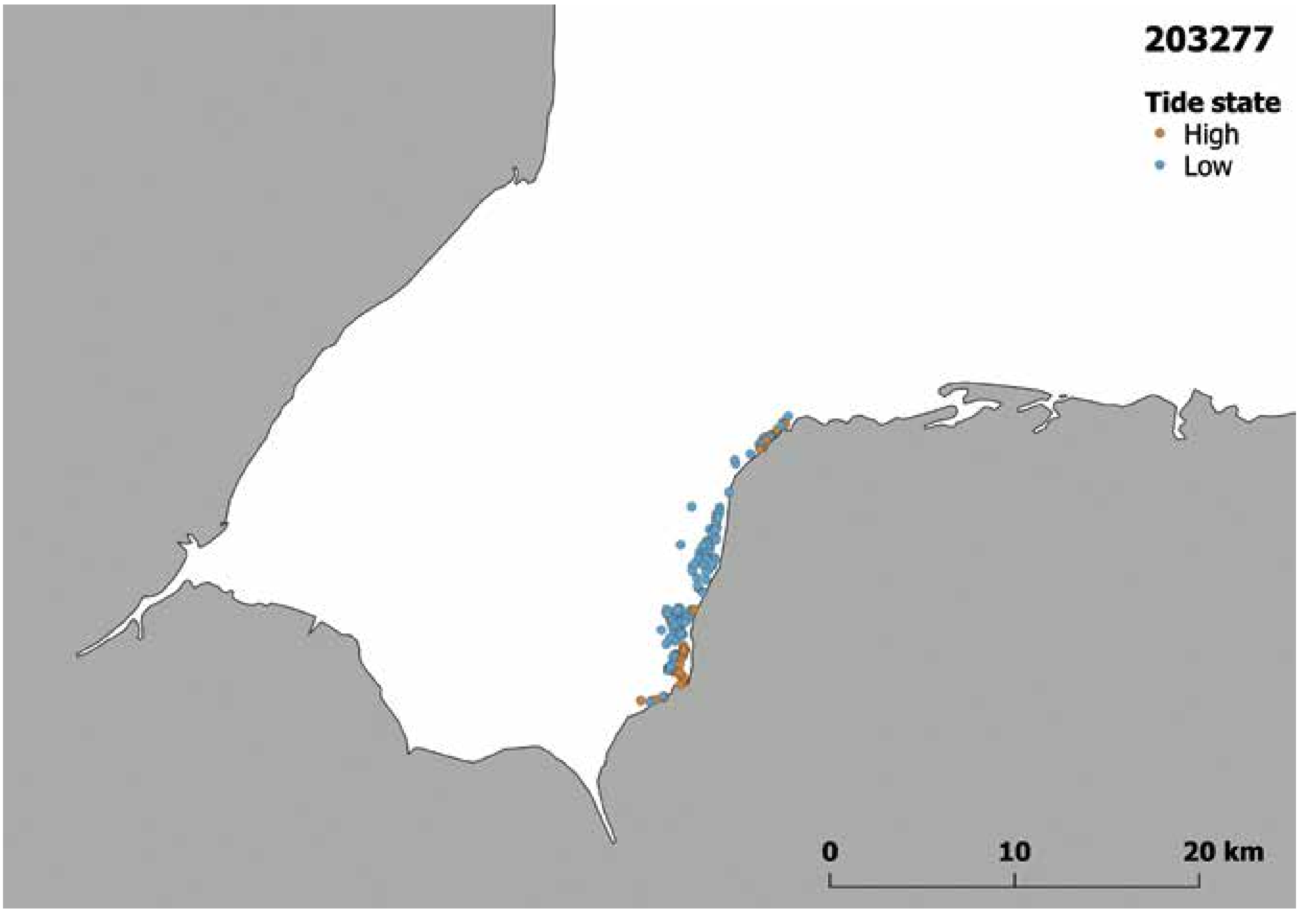
APPENDICES

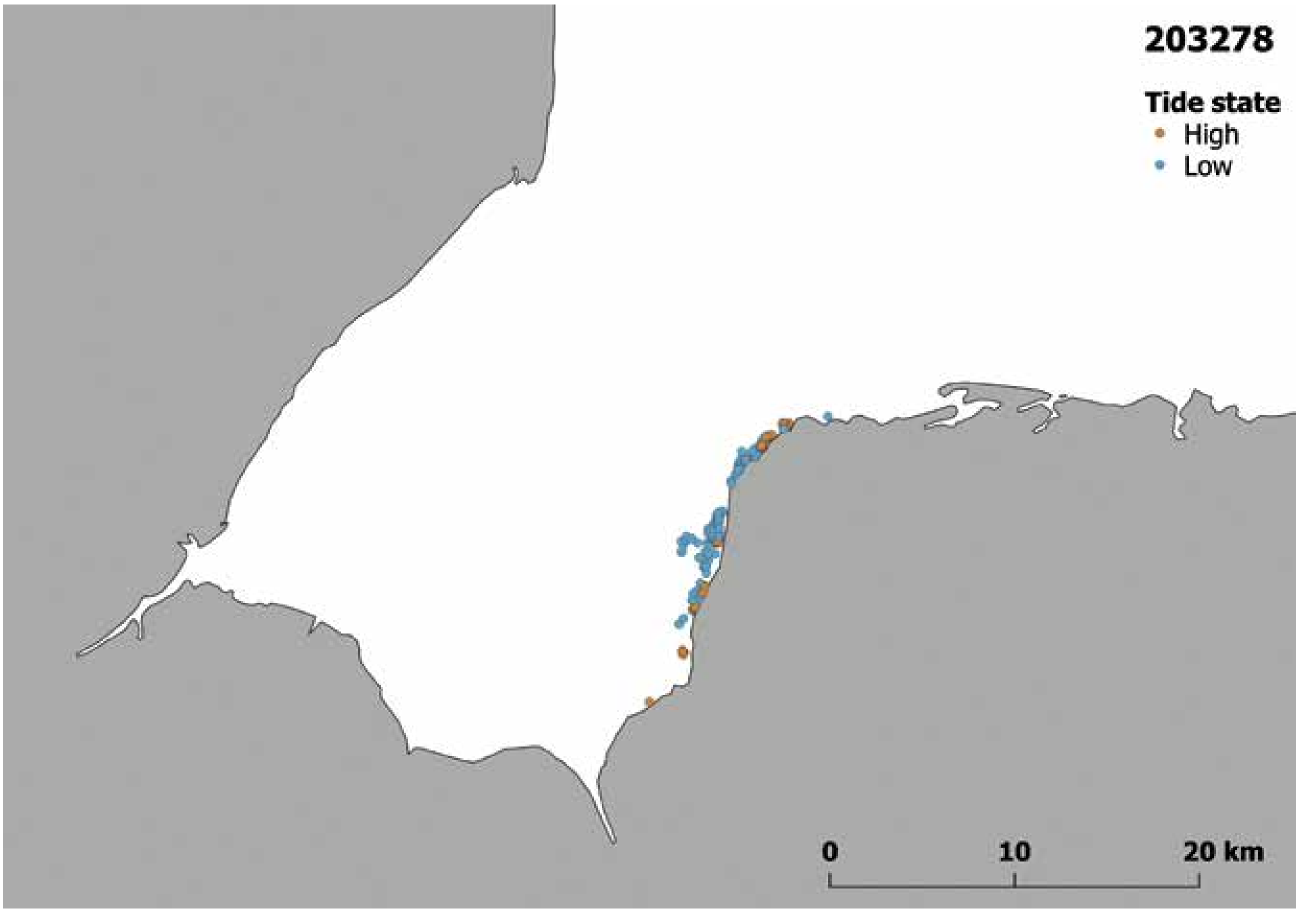
Appendix A1. Individual GPS fixes for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter



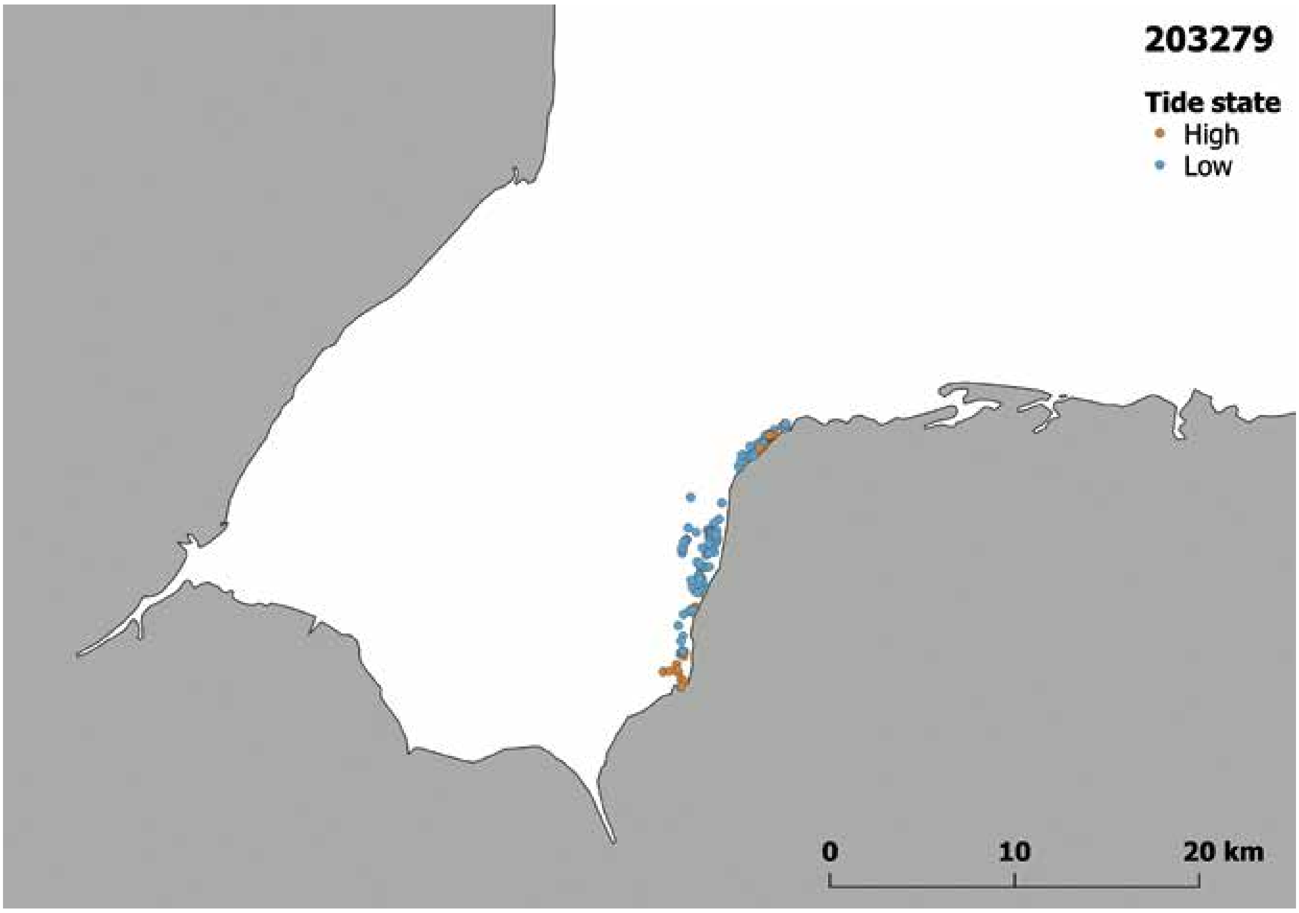


Appendix A1. Individual GPS fixes for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter

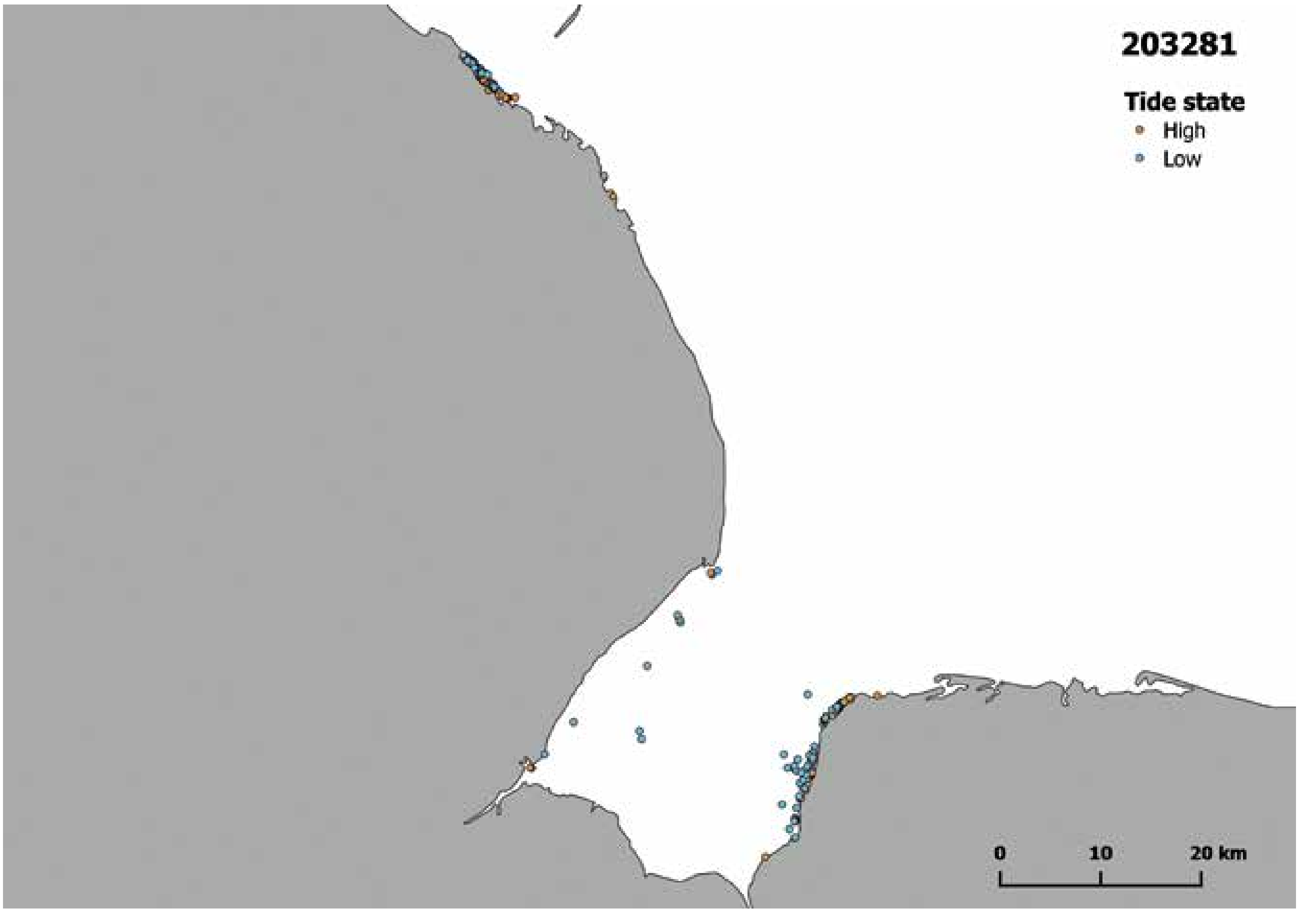


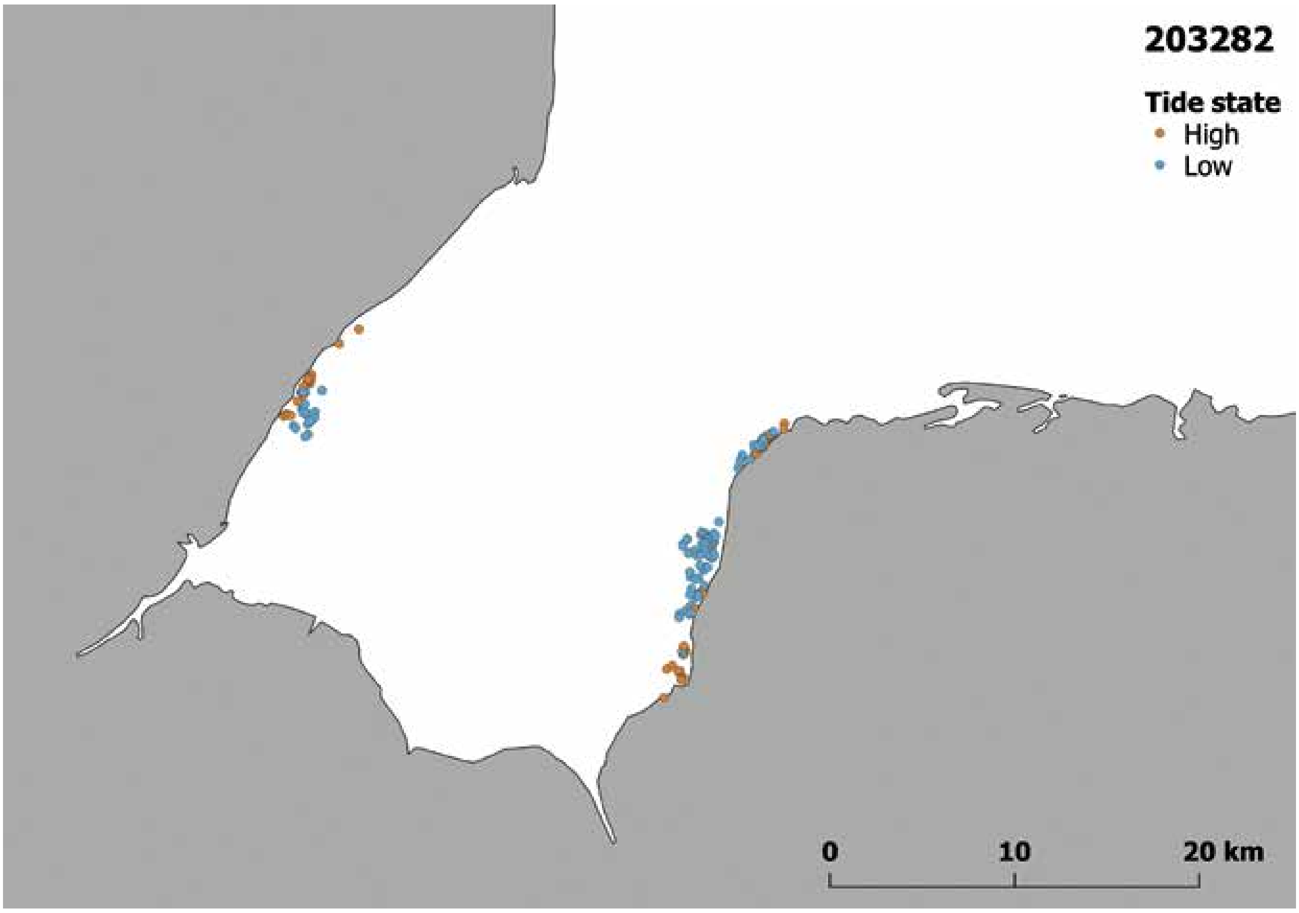


Appendix A1. Individual GPS fixes for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter

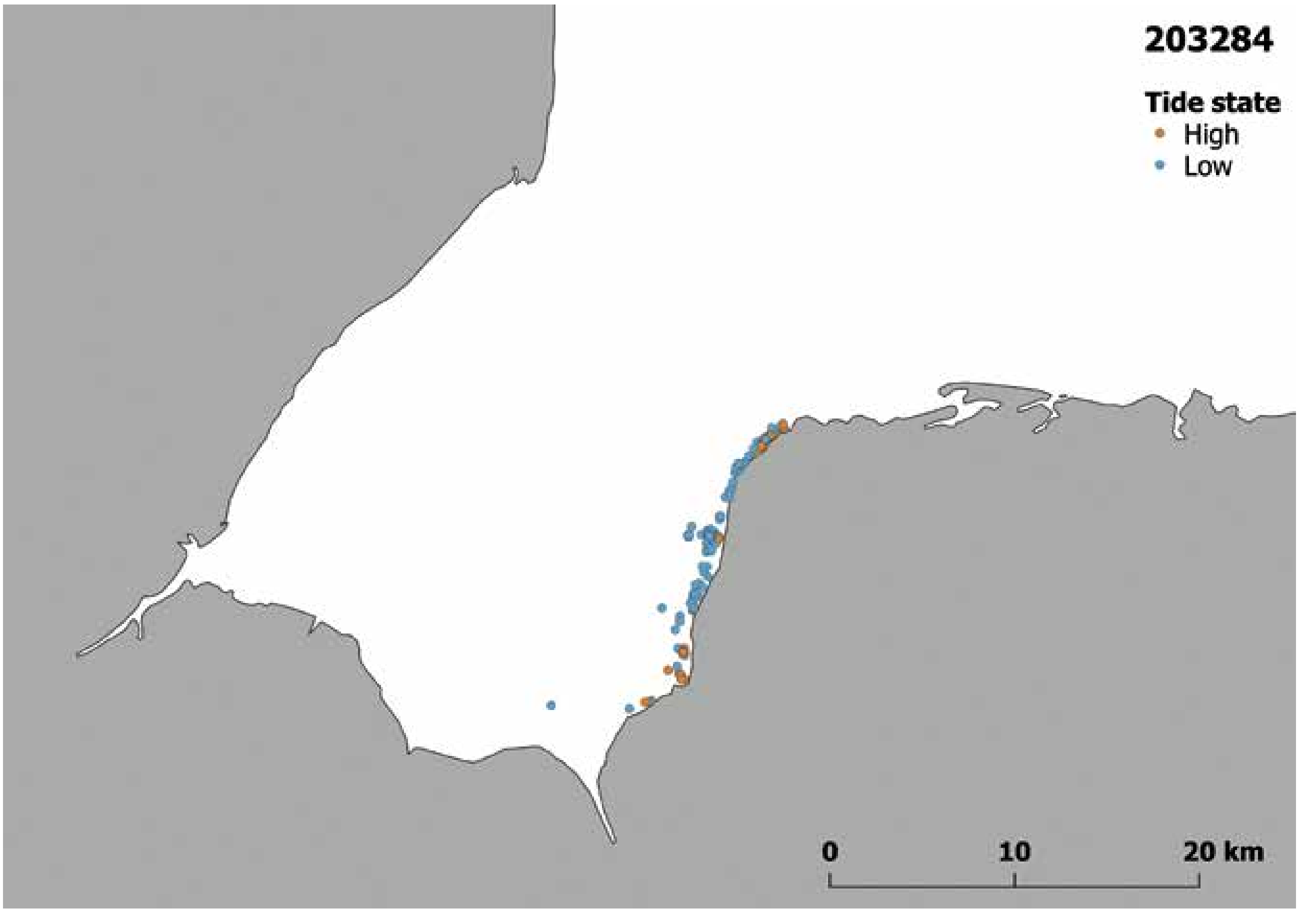


Appendix A1. Individual GPS fixes for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter

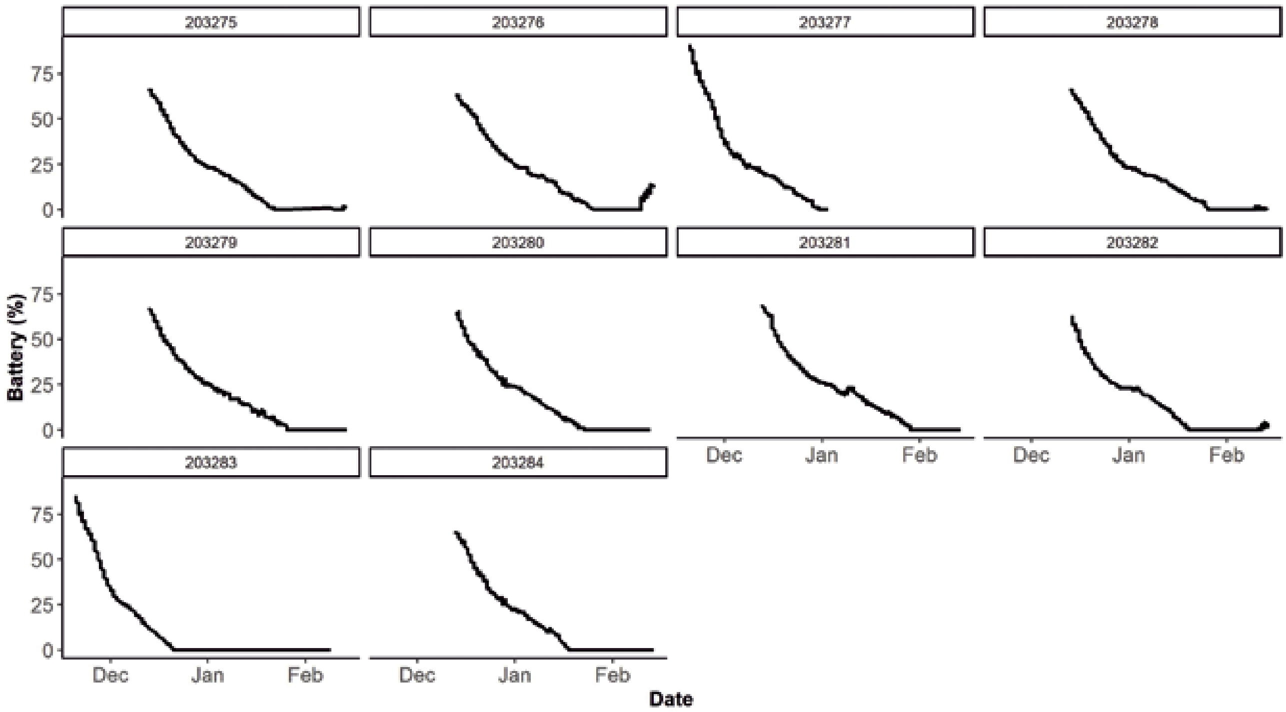




Appendix A1. Individual GPS fixes for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter



Appendix A2. Individual device battery performance for 10 Oystercatchers tracked from Heacham Beach within The Wash during the 2020/21 winter using Ornitela OrniTrack-9 GPS-GSM devices fitted using leg-loop harnesses



Cover image: Philip Croft / BTO; back cover: Edmund Fellowes / BTO

Pilot study to investigate Oystercatcher (*Haematopus ostralegus*) feeding behaviour to enhance bird food modelling and shellfisheries management on The Wash

The Wash is an important and protected estuarine system in the UK supporting large aggregations of wintering birds as well as a variety of commercial industries such as considerable shellfisheries. The winter population of Oystercatcher (*Haematopus ostralegus*) on The Wash is c. 20,000 individuals and has been shown previously to be sensitive to declines in shellfish abundance. Consequently, modelling approaches are used to set sustainable limits of shellfish take to ensure both conservation and commercial interested are balanced. These models require parametrisation using data collected on the waders within The Wash. We deployed 10 solar powered GPS-GSM devices to Oystercatcher using leg-loop harnesses to investigate their daily movements around The Wash during the 2020/21 winter. Our findings confirm that while patch switching does occur, and even visits outside of the estuary system entirely, this was a minority strategy for the sample of birds tracked in this study and individuals mostly remained close to the catch location. However, it is expected that individuals caught at different sites and from different age classes may behave differently. Recommendations are made for expanding this pilot work to ensure a representative sample of birds is included from multiple sites.

Clewley, G.D., Franks, S.E., Clark, N.A. & Robinson, R.A. (2021). Pilot study to investigate Oystercatcher (*Haematopus ostralegus*) feeding behaviour to enhance bird food modelling and shellfisheries management on The Wash. BTO Research Report **735**, BTO, Thetford, UK.

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