Distribution and Ecology of wintering grebes and divers in the Falmouth Bay to St. Austell Bay pSPA

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Summary

Natural England, in conjunction with JNCC, is progressing work to inform potential classification of a new Special Protection Area, in south Cornwall: Falmouth Bay to St Austell Bay (pSPA). The site is recommended for three wintering bird species; Black-throated Diver *Gavia arctica*, Great Northern Diver *G. immer* and Slavonian Grebe *Podiceps auritus*.

This report was commissioned by Natural England in order to provide information on the distribution, abundance and ecology of the three birds in the pSPA. Fieldwork was focussed around 12 vantage points spread along the shore of the pSPA and fieldwork was entirely shorebased. Each of these vantage points was visited 12 times between mid-January and mid-March 2014 and all records of the two diver species and Slavonian Grebe were carefully mapped. In addition all boat activity was also recorded. For the bird counts we focussed on counting within a 2km radius of the survey points (2km representing the maximum distance at which we felt birds may be picked up with any confidence); this area of search represented around one sixth of the pSPA. Due to the shore-based focus of the work, the distribution and abundance of birds further offshore is not assessed here.

Over the 12 visits to the 12 vantage points there were 252 sightings of Black-throated Divers (totalling 535 individuals as many were in flocks), 263 sightings of Great Northern Divers (332 individuals) and 24 sightings of Slavonian Grebe (27 individuals). The maximum count (across all vantage points combined) in a single survey visit was 82 Black-throated Divers (on 20/21st January); 63 Great Northern Divers (4/5th March) and 10 Slavonian Grebes (on 20/21st January).

The two diver species clearly overlapped markedly in distribution. Great Northern Divers tended to be scattered and relatively evenly distributed between the survey points. They favoured relatively sheltered areas (i.e. more coastline within 1km). They were recorded as lone individuals (41% of birds counted were on their own) or occasionally in groups of up to 6 birds. Great Northern Divers tended to be closer inshore than Black-throated Divers and the water-depth band where the most individuals were observed was 0-2m below MHWM. After controlling for detection (which declined with distance from vantage point) Great Northern Divers tended to be in water with a maximum depth of less than 15m and especially in areas where the water depth is below 10m, and in areas surrounded by more shoreline, suggesting water depth and shelter are important variables for this species. Models suggested a change in distribution around high tide.

Black-throated Divers by contrast were concentrated in Falmouth Bay (off Mawnan Smith and Pendennis Point), at Gerrans Bay and Veryan Bay, with these locations holding significantly higher numbers of Divers than other locations after controlling for water depth. These are all sheltered bays with a south-easterly aspect.

Of the 535 individual Black-throated Divers counted, less than a third (31%) were lone individuals and 38% (202 individuals) were in groups of 5 or more. Nine sightings involved groups of 10 or more individuals. Some of these groups were actively fishing but there was no evidence that sightings of birds in flocks were feeding more than birds in small groups or on their own. There was no suggestion either that the occurrence of the larger flocks was linked to a particular tide state. Black-

throated Divers tended to feed slightly further out than Great Northern Divers, with records peaking in water 5-10m deep. Predicted densities after accounting for detection suggest density declines markedly where minimum water depth exceeds 10m.

Ten sightings of Great Northern Divers involved birds handling prey at the surface, namely seven crabs and three flatfish. This suggests Great Northern Divers are regularly feeding on the bottom, potentially supported by the results showing Great Northern Divers occurring in shallower water, closer inshore. Only one Black-throated Diver was recorded with prey at the surface, a possible flat fish. Observations indicate Black-throated Divers were regularly resurfacing some distance from where they dived and they were sometimes observed with large groups of other fish eating species such as Shags. We can infer that Black-throated Divers are therefore pursuit fishing and capturing small fish that are consumed while underwater or as the bird surfaces.

The survey period was dominated by an exceptional series of deep depressions and storms. While field visits were focussed in windows between the storms, the weather will potentially have had implications on the levels of boat activity and distribution/abundance of the birds. The results are therefore unlikely to represent a typical winter and the effects of high levels of boat activity on the birds cannot be determined from this work. The size of the counts should not be used to draw conclusions relating the condition of the site and the numbers of Slavonian Grebe recorded were too low to allow any detailed analysis of distribution/occurrence.

Implications of the results are:

- Data shows the detection of divers declined with distance such that – at around 1km – the number of birds recorded was a quarter of that at 100m. This has implications for future monitoring.
- Future monitoring is best conducted at sea states of 3 or less
- The distribution of both diver species overlap. Divers seem to be concentrated in sheltered bays and in areas with water depths of less than 20m. These areas are likely to be particularly important as a focus for conservation.
- Black-throated Divers in particular appear relatively erratic in their distribution, with marked aggregations occurring and numbers fluctuating quite markedly between visits at individual survey points. This means repeat counts are important for future monitoring and given the propensity of the birds to gather in flocks, makes the species the more vulnerable of the two diver species to chance events (disturbance, isolated pollution incidences etc).
- Great Northern Divers appear to be feeding on the bottom of the seabed and often on crabs. Potting may therefore have the potential to impact on this species. Sheltered areas relatively close to the shore are preferred by the birds.
- Fixed nets could be issues for both species given the choice of water depths and areas where the birds are recorded. Black-throated Divers appear to move considerable distances underwater, which may make them vulnerable.

Contents

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Survey work was coordinated by Fenella Lewin and conducted by Louise Floyd, Neil Gartshore, Nick Hopper, Durwyn Liley and John Waldon. All data were entered by Louise Floyd.

1. Introduction

Introduction

1.1 Natural England, in conjunction with JNCC, is progressing work to inform potential classification of a new Special Protection Area, in south Cornwall, the Falmouth Bay to St Austell Bay pSPA. The site is likely to be recommended for three species; black-throated diver (*Gavia arctica)*, great northern diver (*G. immer*) and Slavonian grebe (*Podiceps auritus*).

1.2 This contract involves fieldwork and analysis to:

- Qualitatively and quantitatively define behaviour of divers and grebes at the site;
- Collect accurate spatial information on the parts of the site supporting these behaviours
- Collect accurate spatial information on the parts of the site supporting anthropogenic activities, and qualitatively and quantitatively define these activities
- Overlay bird distribution maps with likely determinants of distribution to model habitat preferences within the site
- Make recommendations on likely site-specific bird sensitivities to inform advice on site management and impact assessment.

Overview of target species

Black-throated Diver

1.3 The Eurasian breeding range of the Black-throated Diver extends eastwards from the Hebrides to northern Siberia. The bulk of the population breeds in Russia.

1.4 Studies of seabird distributions off north-west Europe show that most individuals remain inshore, with concentrations around Denmark, Germany, the Netherlands and Belgium, with smaller numbers around the UK coast (Stone, cited in Wernham *et al.* 2002). It is thought that wintering birds in the UK are from the Scottish (c.150 pairs) and Scandinavian breeding population (Wernham *et al.* 2002). The Great Britain wintering population is thought to be around 500 - 700 individuals (Baker *et al.* 2006; Musgrove *et al.* 2011).

1.5 The most recent WeBS report for the UK (Austin *et al.* 2014) gives a current threshold for international importance of 3,500 individuals and a Great Britain threshold (for national importance) of 6 birds. Gerrans Bay is the premier UK site, with site maxima of 124 birds recorded in 2009/10 and 69 in 2010/11 (Austin *et al.* 2014). While the counts at Gerrans Bay are exceptional within the UK, recent WeBS data indicates the presence of the species at 50 sites in the UK over the winter 2009/10; however most of these were in Scotland and in total 14 sites had counts of national importance (Austin *et al.* 2014). The Migration Atlas account highlights the lack of knowledge of key sites for the species during the winter and a lack of understanding of the winter ecology.

1.6 During the winter the species is not thought to be especially gregarious. Large groups have however sometimes been recorded during passage or cold weather periods (see Wernham *et al.* 2002) and large feeding flocks have been reported for the very similar Pacific Diver (D. Jackson *pers. comm.*).

Great Northern Diver

1.7 Great Northern Divers breed almost exclusively in the Nearctic, from the Aleutians across Canada, the north-western US and Greenland. The only area within Europe where the species breeds regularly is Iceland, where there are around 300 pairs (Wernham et al. 2002).

1.8 The Great Britain wintering population is thought to be around 2500-3000 individuals (Baker et al. 2006; Musgrove et al. 2011) and Great Britain is estimated to hold around 75% of the north-west European total (Skov et al., cited in Brown & Grice 2005). The UK stronghold is the west coast of Scotland and further counts are needed along the west coast of Scotland in order to illustrate the true status of the species in UK waters (Holt et al. 2012). The most recent WeBS data (Austin *et al.* 2014) shows Gerrans Bay as the English site with the highest count (28).

1.9 Literature suggests Great Northern Divers tend to remain farther offshore than Black-throated Divers although they will occur closer inshore during periods of bad weather (see Wernham et al. 2002 for discussion). The species is highly dispersed in its distribution in winter, with some authors suggesting that the species is territorial during the winter (McIntyre 1978). They typically only occur in small numbers at individual sites. Only in the waters off Cornwall are double figure counts regularly made; the area between the Helford River and St. Austell is highlighted by Brown and Grice (2005) and a count of over 100 was made here in 2000 (Geary and Lock cited in Brown & Grice 2005)

Slavonian Grebe

1.10 Slavonian grebes have a circumpolar breeding distribution somewhat further north than other small grebes (Cramp & Simmons 1977). Birds wintering in the UK are thought to come from several breeding areas with south coast birds originating from Fenno-scandia and further north from breeding areas in Greenland, Iceland and northern Norway (Wernham *et al.* 2002). Increases in the number of Slavonian Grebes wintering in Shetland and Orkney have been associated with an increase in birds of Icelandic origin, while numbers on the south and east coasts have declined – either because of a shift in winter distribution or a decline in the continental population (Holt *et al.* 2012). Slavonian grebes winter mainly in sheltered inlets, bays and estuaries, feeding on small fish, especially sculpins, and crustaceans (mysids, amphopods and decapods), insects and molluscs (Cramp 1977).

1.11 The Winter Atlas, based on fieldwork during winters 1981-84 estimated a total wintering population of 400 Slavonian grebes in Britain excluding Ireland (Chandler, in Lack 1986), considerably smaller than the estimate by Prater (1981) of 670. More recent estimates are of a Great Britain wintering population of around 735 individuals (Evans 2000; Baker *et al.* 2006) and 1,100 (Musgrove *et al.* 2011).

1.12 The most recent WeBS report for the UK (Austin *et al.* 2014) gives a current threshold for international importance (NW Europe) of 55 individuals and a Great Britain threshold (for national importance) of 11 birds. In recent years Gerrans Bay has held up to 20 individuals (2009/10), (Austin *et al.* 2014).

Need for detailed study

1.13 As the above species counts indicate, relatively little is known about the wintering ecology of divers and grebes in UK waters. It is clear that – for the species discussed – the Falmouth-St. Austell section of coastline has exceptional counts compared to other sites in England. The section of coast is therefore clearly of considerable nature conservation importance for these species, and further work to understand distribution and winter ecology is necessary to underpin the long-term protection and management of these important bird populations.

2. Methods

2.1 In this section we describe the methods for fieldwork and analysis. Fieldwork included snapshot counts from vantage points, behavioural observations and casual observations (focused at dusk). These are described separately below.

Snapshot counts from vantage points: Distribution of birds and activities

2.2 In order to map the distribution of birds and the distribution of human activities 'snapshot' counts were undertaken from a series of vantage points. The counts involved surveyors scanning the sea from a particular vantage point and accurately recording the location of target species (black-throated diver, great northern diver and Slavonian grebe) and all human activities (such as fishing boats) on the water.

Locations of Vantage Points and survey effort

2.3 The vantage points are shown in Map 1. Survey effort was focussed within 2km of the survey point (2km representing a maximum distance at which it was felt divers may be recorded with any confidence from the shore), giving a total area of search of 5,285 hectares(as indicated by the red lines) approximately one sixth of the total area of the pSPA. Details of the vantage points, including their elevation, are given in Appendix 1.

2.4 The snapshot counts from individual vantage points were conducted relatively quickly – each scan took around thirty minutes to complete. The length of time taken varied according to sea state, number of birds/activities and the amount of sea visible from each vantage point.

2.5 For logistical reasons points were split into two zones either side of Carrick Roads (i.e. survey points 1-4 and then points 5-12). Points 1-4 could be covered by a single surveyor in a half day and points 5-12 took approximately three quarters of a day to survey. A total of 12 visits were made to each vantage point between 15/1/2014 to 15/3/2014. Most of the surveys were conducted over two successive days (i.e. a single surveyor on one day covering points 1-4 and on the other day points 5-12). On some occasions all points were surveyed on the same day (using two surveyors). Where survey effort was split over two days, weather conditions were carefully chosen to ensure similar weather conditions on both days. The order of visiting different vantage points was varied and effort was spread to cover different tide conditions and days of the week. Effort was targeted so that the majority of vantage points were surveyed in calm conditions, however as birds may use different areas in rougher conditions, survey effort was not exclusively undertaken in calm conditions.

Survey method at each vantage point

2.6 Birds were located by scanning at a steady, slow pace (from left to right or vice-versa, with direction varied between visits) using a scope at relatively low magnification (20 or 25x). Due to the variation in height of the vantage points, the amount of sea visible and different weather conditions we did not fix the level of survey effort or the number of scans, however no more than 45 minutes was spent scanning at any single vantage point count. Typically around 3-4 scans were conducted from each vantage point. Scans were repeated until the surveyor was confident that additional birds were not being detected and only birds thought to be 'new' were logged on each scan. Each surveyor ensured effort was similar at each survey point for each visit. Particular attention was paid to ensuring areas close to the surveyor (e.g. near base of cliffs) and at greater distances were 'covered'.

Data recorded for each sighting

2.7 Each record of a target species was logged at the location where first picked up. At the start of each vantage point count surveyors ensured their tripod was level (using a spirit level) and set to a standard height (standardised for each surveyor). In order to accurately determine location of birds/activities on the water, surveyors located each bird or activity through their scope and recorded a compass bearing and a sighting angle recorded using a digital inclinometer[1]. The inclinometer was mounted on the tripod or the telescope, depending on the model. In most cases the inclinometer was attached directly to the tripod head, and aligned to the side of the scope (Figure 1).

2.8 Where the horizon was clearly visible, surveyors recorded the sighting angle to the horizon and then subsequently the angle to each bird/activity. At vantage point 4 counts were conducted from sea level and the horizon was not visible due to the northerly aspect. At this location distances were estimated based on landmarks around the shoreline and using rangefinders.

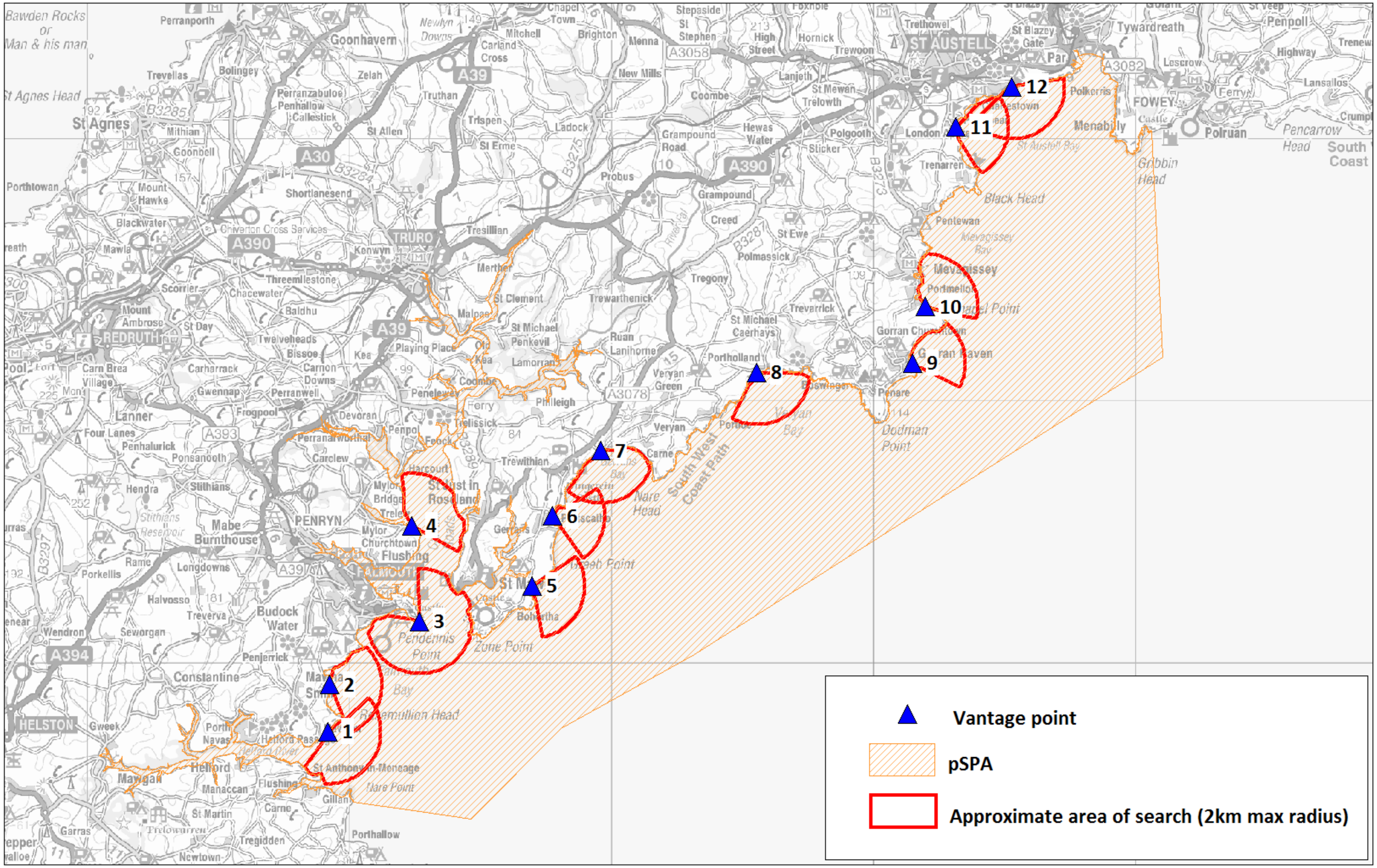
Figure 1: Telescope and inclinometer

2.9 In addition surveyors estimated the distance to each sighting. This provided a means of double checking the recorded locations of the birds. In order to facilitate this estimate, surveyors had maps showing each vantage point, with distance measurements to key landmarks. Surveyors also carried laser rangefinders which accurately measure

[1] Digi-Pas digital level, accurate to 0.5 degrees

distances of large objects at distances of around 500m and sometimes out to 1km, but are not able to pick up birds on the water, they were therefore useful to confirm distance measurements to boats, buoys and rocks.

2.10 For each sighting of birds, data were recorded on behaviour, number of individuals, flock size (where greater than 1) and any notes on plumage (in case it is possible to recognise individuals). Activities were categorised by activity (see Appendix 1) and notes enabling individual craft to be recognised were recorded (e.g. vessel number, colour etc). Sea state, weather and wind direction were summarised for each visit to each vantage point.



Map 1: Surveyed vantage points

Casual observations

2.11 As a separate component of the fieldwork it had been intended to undertake behavioural observations of birds in order to collect information on prey choice, dive times and any disturbance impacts. Unfortunately the period from January – early March was dominated by a series of very strong storms that meant fieldwork was frequently postponed, curtailed and limited to narrow windows of calm weather between storms. Survey effort was focussed on the vantage point counts and limited behavioural data were collected. The data that were collected are summarised within the text. Alongside these are some casual observations of notably large flocks (recorded outside the vantage point focal areas), casual observations of prey items and some information on roost locations. This information was recorded as opportunities arose, and some time was spent searching for roosting birds (roosts potentially providing a good opportunity for gathering relatively complete counts, see Shackleton 2012).

GIS

2.12 All sightings from the vantage point surveys were plotted within a GIS (MapInfo). Bird locations were plotted as points using the excel work books produced by Colin Macleod[2,] , using the data from the survey point location, vertical angle (inclinometer) and horizontal angle (compass bearing) recorded in the bird surveys.

Tide

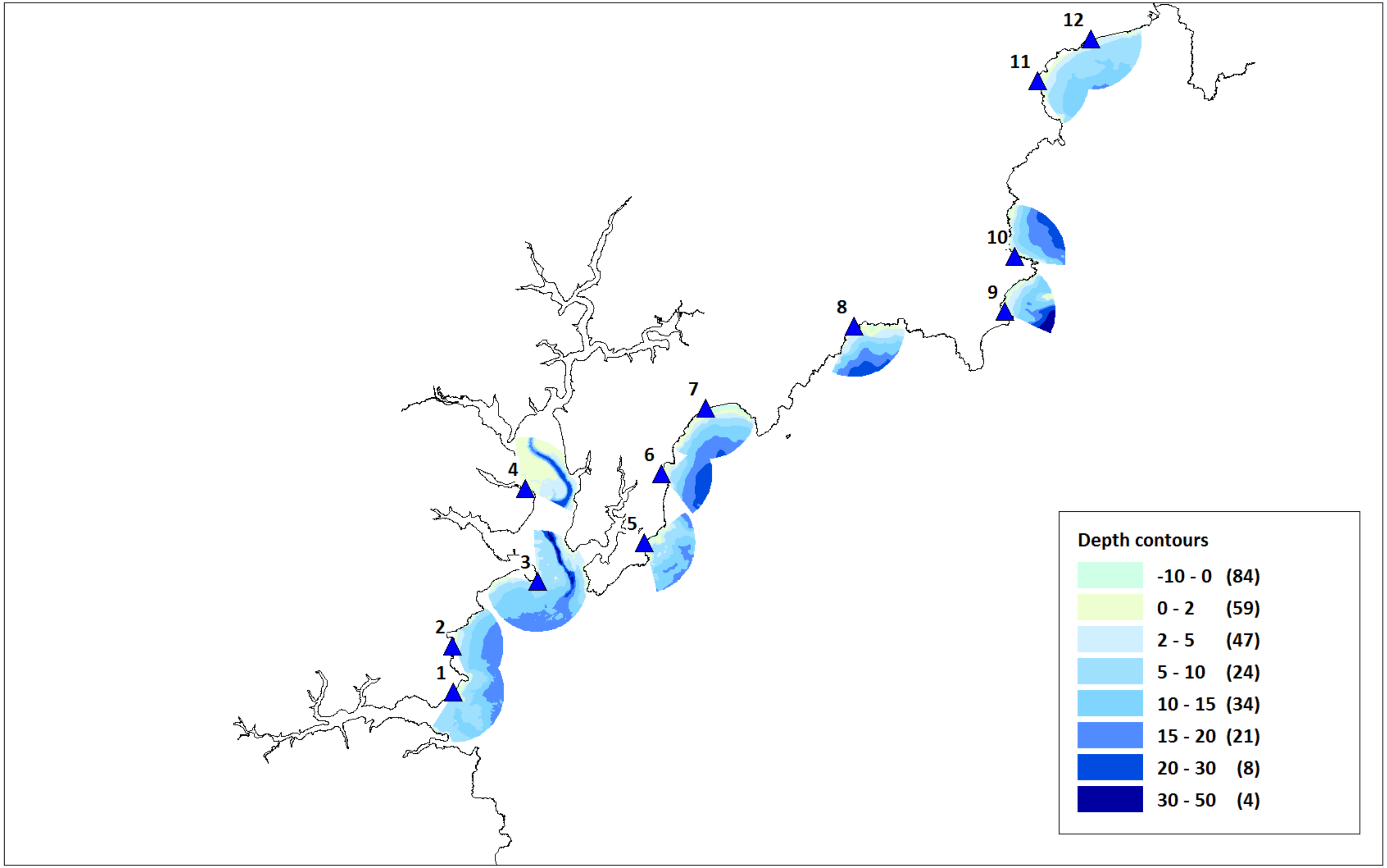
2.13 Tide times (high water) were extracted from admiralty data for Falmouth and Mevagissey. Tide data from Falmouth was used for the southern survey points (1-7) and data from Megavissey was used for the northern ones (8-12). Within the analysis observations are classified as within 3 hours of high tide using these tide times and locations.

Bathymetry data

2.14 A simplified version of UKHO S57 vector data were supplied by Natural England under licence EK001-20120601 and the data were cut to the search areas defined in Map 1.

2.15 The bathymetry data consisted of a sequence of depth contours. The area of each contour within each search area was extracted as was the depth gradient of each bird sighting allowing calculation of the density of birds per depth contour (Map 2). Thirteen records were outside the search area and excluded from these analyses.

[2] MacLeod, C.D. 2011. A position estimator for cetacean sightings data. Unpublished Microsoft Excel Workbook. http://www.gisinecology.com/



Map 2: Depth contours within each vantage point survey area against the mean high water mark (MHWM)

Multivariate Analysis and Use of Grid

2.16 To consider bird numbers in relation to the measured variables a 100m grid was placed over the vantage point search area. Each cell was assigned to a single vantage point and following attributes were then extracted from the GIS for each cell:

- Distance (m) from centroid of cell to the shore (MHWM)
- Distance (m) to vantage point
- Maximum and minimum depth of seabed
- Depth range of the sea bed (m) within cell
- Number of depth ranges within cell (taken from UKHO S57)
- Total length (m) of shoreline within 1km of cell
- Number of boats recorded within the cell

2.17 It had been hoped to include seabed habitat variables within the models but unfortunately suitable coverage of the target area was not available.

2.18 Cells which were visible from two vantage points (and therefore potentially double counted) were assigned to the nearest vantage point and only bird data from that vantage point were included in any analyses.

2.19 Generalised linear models (GLM) were then used to explore the relative importance of these variables on the counts of Black-throated Diver or Great Northern Diver in a given cell. Basic GLMs involved Poisson models with log link (McCullagh & Nelder 1989). Effects of any extra-Poisson residual dispersion in bird numbers (evaluated using the Pearson chi-squared statistic) were allowed for by re-fitting models using a negative binomial distribution and log link function.

2.20 A particular complication with the analyses is that the detection of birds on the sea is likely to decrease with distance from the vantage point. Other variables such as water depth and distance to shore will also vary with distance from the vantage point, and the correlation with the likelihood of detection brings potential bias into any analysis (Gu & Swihart 2004). In order to account for this bias, a weighted variable relating to distance from the vantage point was included as an offset term within the model. This weighted variable represented detectability. The weighting was calculated based on a curve fitted to a plot of the density of birds in relation to distance from the vantage point. This plot was derived only using bird data (total count of Black-throated Diver and Great Northern Divers) recorded in shallow water, i.e. grid cells with a minimum depth of 5m. These cells were all relatively close to the shore but were at varying distances from vantage points as in many cases vantage points provided a view along a shoreline as well as directly out to sea.

2.21 A potential problem with many species data is that there may have a spatial component. This can result in spatial autocorrelation which causes problems for statistical methods that make assumptions about the independence of residuals. Spatial autocorrelation occurs where the presence of some quantity (e.g. a feeding diver) makes presence in neighbouring areas more or less likely. This may occur for example if birds are territorial and therefore exclude birds nearby or else if social interactions (courtship, social feeding, flocking) results in clumped distributions. If there is spatial autocorrelation in data it will lead to a spatial correlation of residuals, for example positive residuals will tend to occur together. Spatial autocorrelation of residuals can influence the reliability of any such statistical models relating environmental factors to species' distributions, both in terms of accuracy of statistical significance of effects and accuracy of the effect sizes (i.e. model coefficients). In order to accommodate spatial autocorrelation we included an autologistic term in our models (following Augustin, Mugglestone & Buckland 1996). This term was added an as additional covariate in all models and was calculated based on a moving window (eight adjacent, surrounding cells), within which the average probability of occupation was weighted by the inverse of the Euclidean distance.

2.22 The different predictor variables such as measures relating to distance from shore and water depth are highly correlated. The aim of the analysis was not to build a comprehensive predictive model for the target bird species across a wide area, but instead to explore the range of factors that influence the ecology and distribution of these birds within the pSPA. Variables were therefore tested singly and different combinations of variables (including biologically meaningful interactions) subsequently added.

2.23 Further tests included subsets of the count data relating to cells where divers were recorded at high tide and, for Black-throated Divers, cells with flocks. GLMs for these data took the form of binary logistic models.

3. Results

Numbers of birds recorded

Target Species, numbers per vantage point

3.1 Overall numbers of birds of each of the target species recorded during the vantage point counts are summarised in Table 1 and the vantage point survey dates are detailed in Appendix 2. There were 252 sightings of Black-throated Divers (totalling 535 individuals), 263 sightings of Great Northern Divers (332 individuals) and 24 sightings of Slavonian Grebe (27 individuals). Some 55 individual divers (around 6%) were not conclusively identified to species (i.e. were either Black-throated or Great-northern) and there were 4 individual grebes that were not identified to species (around 13% of the total of Slavonian and unidentified grebes).

3.2 The highest number of Great Northern Divers was observed from location 7 with 54 individuals and from location 3, where 53 individuals were recorded (note that the search area of location 3 is almost twice that of location 7) (Table 1and Map 3). The fewest number of Great Northern Divers were recorded from location 2 (Table 1 and Map 3).

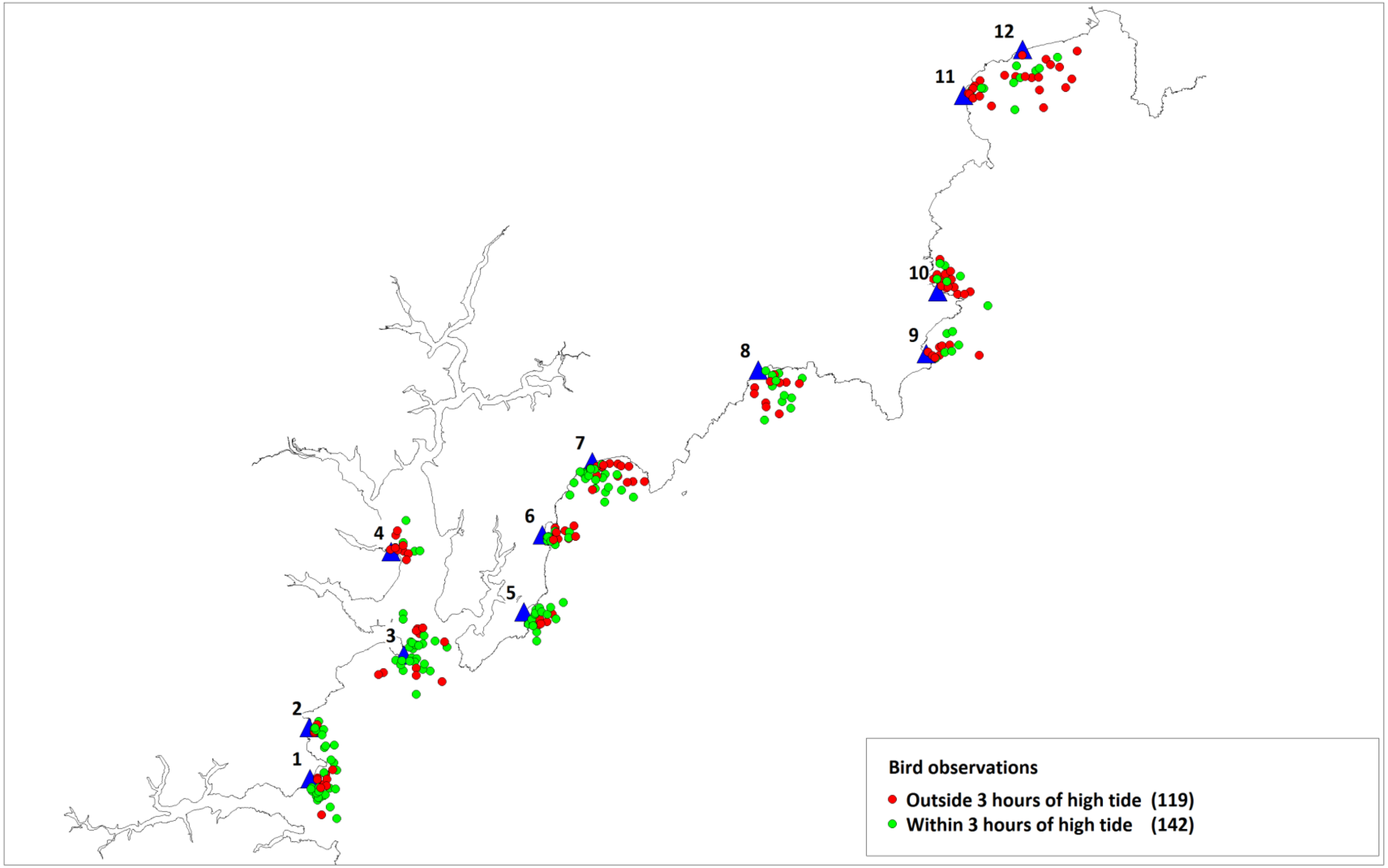
3.3 The highest number of Black throated Divers (135) was recorded from location 3 and only 10 individuals were recorded from vantage point 9 (Table 1 and Map 4).

3.4 Slavonian grebe sightings were clustered around location 6 and 7 with 6 individuals from each point. Half of all Slavonian grebe sightings were made within the three hour high tide window as were all the Slavonian grebe sightings at location 7 (Map 5).

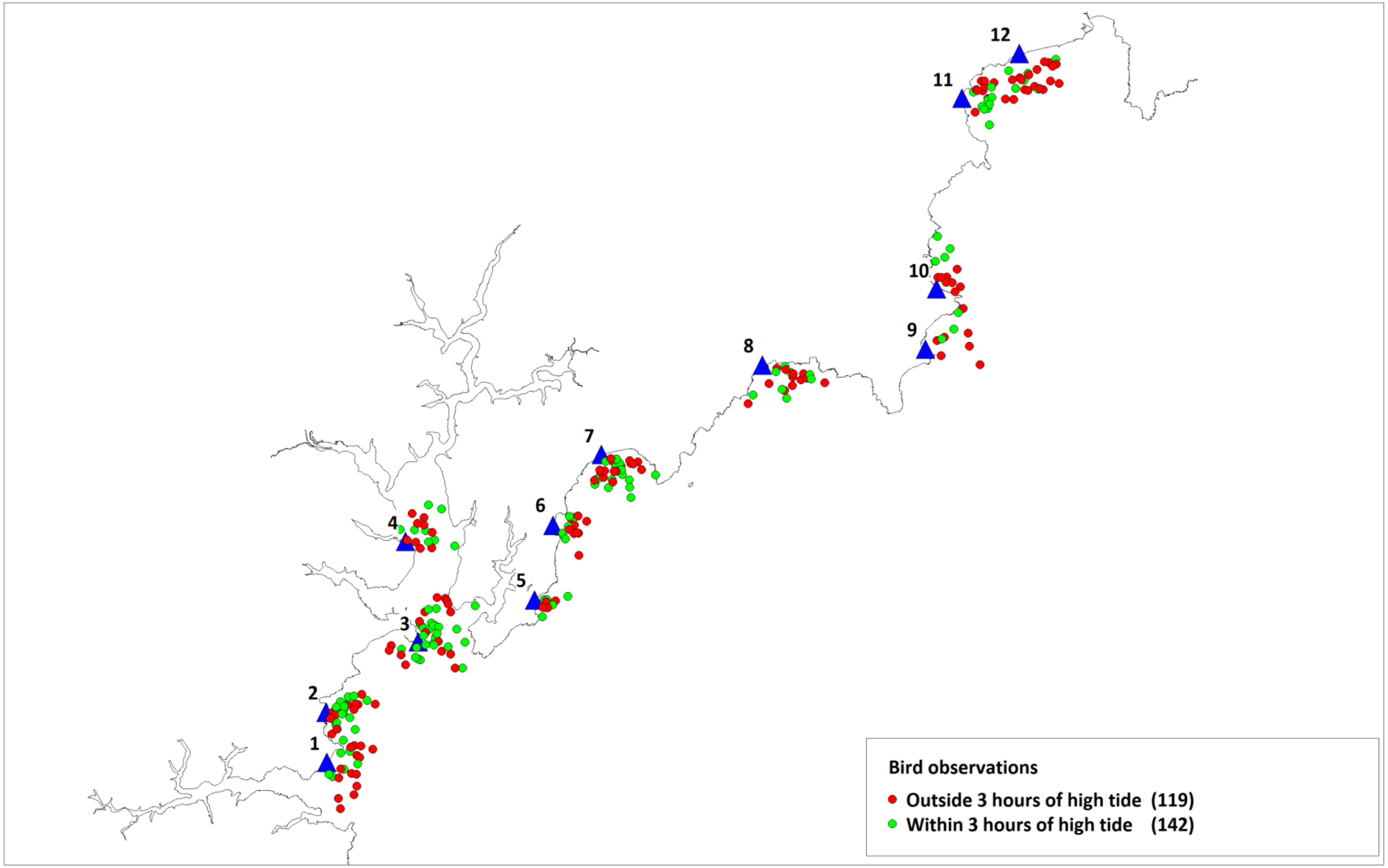
3.5 Maps 3 – 5 show recorded sightings per bird species. There do appear to be subtle differences in the sighting location when tide is considered in that sightings appear to be clustered and closer together within three hours of high tide and distributed across a larger area within the search zone outside the three hour high tide window (Maps 3 – 5). The distribution of sightings is explored further in paragraphs 3.16-3.23.

Table 1: Numbers and densities of target species recorded at each vantage point. Ind. is individuals, i.e. the total number counted, while obs. is observations, the number of sightings (i.e. sightings could involve more than one bird). Dens is density, expressed as birds per ha.

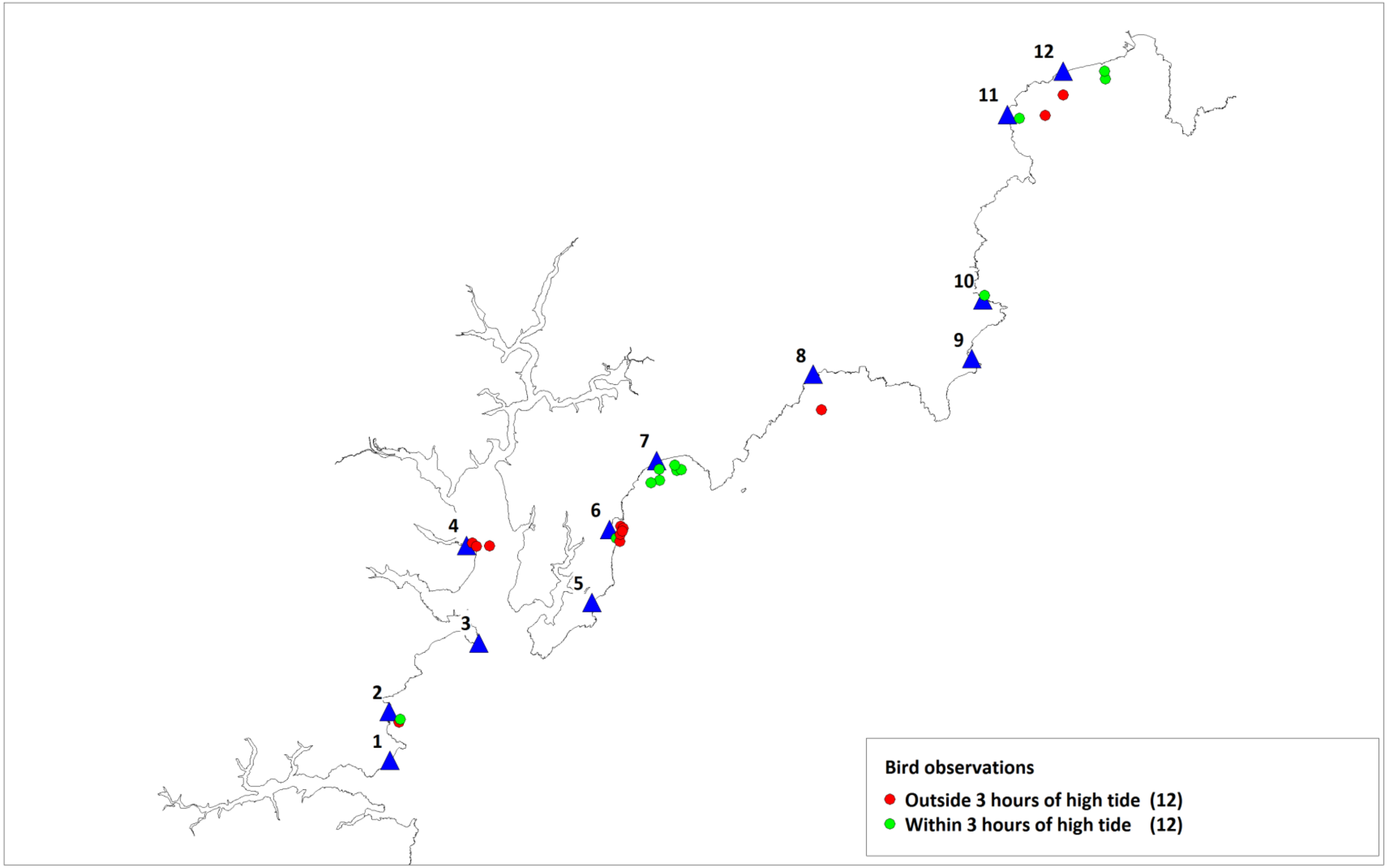
Vantage Point	Approx search area (ha)	Black-throated Diver			Great-northern Diver			Unidentified Diver			Slavonian Grebe			Unidentified Grebe		
		Inds	Obs	Dens (ha-1)	Inds	Obs	Dens (ha-1)	Inds	Obs	Dens (ha-1)	Inds	Obs	Dens (ha-1)	Inds	Obs	Dens (ha-1)
1	534	24	18	0.045	40	29	0.075	7	2	0.013	0	0	0	0	0	0
2	424	79	33	0.186	13	13	0.031	1	1	0.002	3	2	0.007	0	0	0
3	940	135	44	0.144	53	34	0.056	9	3	0.01	0	0	0	0	0	0
4	452	19	17	0.042	22	17	0.049	0	0	0	5	3	0.011	1	1	0.002
5	392	11	10	0.028	24	23	0.061	3	3	0.008	0	0	0	0	0	0
6	303	17	14	0.056	23	19	0.076	1	1	0.003	6	6	0.02	0	0	0
7	449	86	32	0.192	54	37	0.12	13	11	0.029	6	6	0.013	3	2	0.007
8	407	82	20	0.201	26	22	0.064	1	1	0.002	1	1	0.002	0	0	0
9	318	10	10	0.031	17	15	0.053	5	1	0.016	0	0	0	0	0	0
10	400	15	12	0.038	24	20	0.06	4	3	0.01	1	1	0.003	0	0	0
11	377	24	18	0.064	14	13	0.037	2	2	0.005	1	1	0.003	0	0	0
12	513	33	24	0.064	22	21	0.043	9	4	0.018	4	4	0.008	0	0	0
Total	**5509**	**535**	**252**	**0.097**	**332**	**263**	**0.06**	**55**	**32**	**0.01**	**27**	**24**	**0.005**	**4**	**3**	**0.001**



Map 3: Great Northern Diver sightings within and outside the three hours surrounding high tide against the MHWM



Map 4: Black-throated Diver sightings within and outside the three hours surrounding high tide against the MHWM



Map 5: Slavionian Grebe sightings within and outside the three hours surrounding high tide against the MHWM

Target Species, variation with date

3.6 Vantage point counts were undertaken in two day windows, with all survey points being visited in each survey window. These survey windows were spread between mid-January and mid-March, and selected to coincide with better weather conditions. While it is possible that birds may have been double counted (for example moving between points as the surveyor moved), the total number of individuals counted across all survey points in a two-day window gives a rough indication of the total number of birds using the area. As the whole coastline was not surveyed these are not total estimates of the wintering population of the pSPA. Data are summarised for the two target diver species in Figure 2. Count data by vantage point and visit are given in Appendix 3.

3.7 The first visit (20th and 21st January) resulted in the highest number of Black-throated Divers counted (82 individuals). Counts in late January (18 individuals) and the final count (13th and 14th March, 17 individuals) were the lowest counts and the only ones under 20. Most counts were around 50 individuals, with 5 counts (i.e. nearly half of counts) falling in the range of 49-53 individuals (mean across the 12 counts =44.6$\pm$5.6 individuals; median =50.5).

3.8 Great Northern Diver counts within the 2 day windows ranged from 6 – 53 individuals (mean across the 12 counts =27.7$\pm$4.5 individuals; median =4.5). The highest count was in early March (4th and 5th March) while the lowest count was late January (21st Jan).

3.9 Slavonian Grebe numbers in a particular survey window varied from 0-10, with the highest count (10) made on 20th-21st January. On six of the 12 surveys, no Slavonian Grebes were recorded at all.

3.10 There was some evidence of a correlation between the number of Black-throated Divers and the number of Great Northern Divers counted during a particular survey window (across all 12 counts, Pearson correlation coefficient=0.402; p=0.195; with the omission of the outlier of the first count when particularly high numbers of Black-throated Divers were recorded, Pearson correlation coefficient=0.739; p=0.009, n=11). This would seem to suggest that counts of both species tended to be similar – i.e. both high or both low.

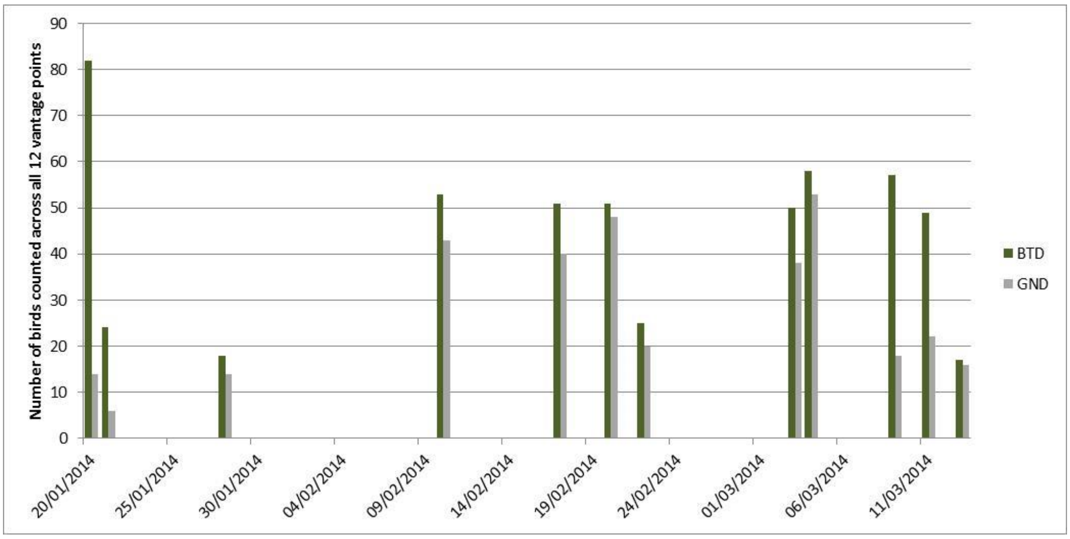


Figure 2: Number of birds counted across all 12 vantage points in each visit. Dates show the initial visit date (i.e. each pair of bars indicates the count made across all 12 vantage points visited in a 2 day window)

Other Species

3.11 The numbers of other species recorded at each vantage point are summarised in Table 2.

Table 2: Numbers of other (non-target) species recorded from vantage points during standard surveys (12 visits to each vantage point).

Vantage Point	Grebes & Diver					Wildfowl			Seabirds							Total
	Black-necked Grebe	Great-crested Grebe	Little Grebe	Red-necked Grebe	Red-throated Diver	Red-breasted Merganser	Eider	Common Scoter	Cormorant	Shag	Fulmar	Gannet	Auk sp	Guillemot	Razorbill	
1								1	10	188		6		34	12	251
2				2					5	694		2		13	6	722
3							1		35	573		2		33	3	647
4	137	3	19			75	11		27	67					3	342
5								1	6	70				10	12	99
6		1			1				6	46	2	4	55	29	5	149
7					3			2		29			36	21	14	105
8	1		1		2				2	89	10		99	30	10	244
9									2	41	2		24	51	21	141
10					1			6	1	82		2	50	28	38	208
11		11							4	22	47			3	3	90
12	11	6						30		20	10	2		4	2	85
Total	**149**	**21**	**20**	**2**	**7**	**75**	**12**	**40**	**108**	**2210**	**71**	**18**	**264**	**256**	**129**	**3382**

Target species, flock size

3.12 Black-throated Divers were recorded in groups that ranged from 1-24 individuals (mean group size=2.12+0.19, median=1) and Great Northern Divers were recorded in groups that ranged from 1-6 (mean group size=1.26+0.04, median=1). For Slavonian Grebes all but two records were of lone individuals, with one sighting of two birds together and one sighting of three birds together.

3.13 The flocking behaviour of Black-throated Diver and Great Northern Diver was markedly different (Figure 3). Of the 535 individual Black-throated Divers counted, less than a third (31%) were lone individuals and 38% (202 individuals) were in groups of 5 or more. Nine sightings involved groups of 10 or more individuals. By contrast 41% of Great Northern Divers were recorded as lone individuals and only 2% were in groups of 5 or more.

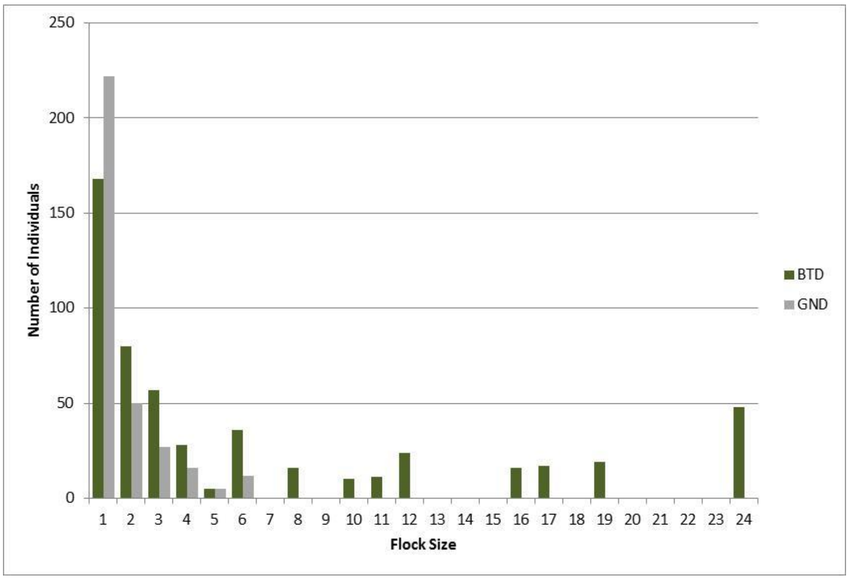
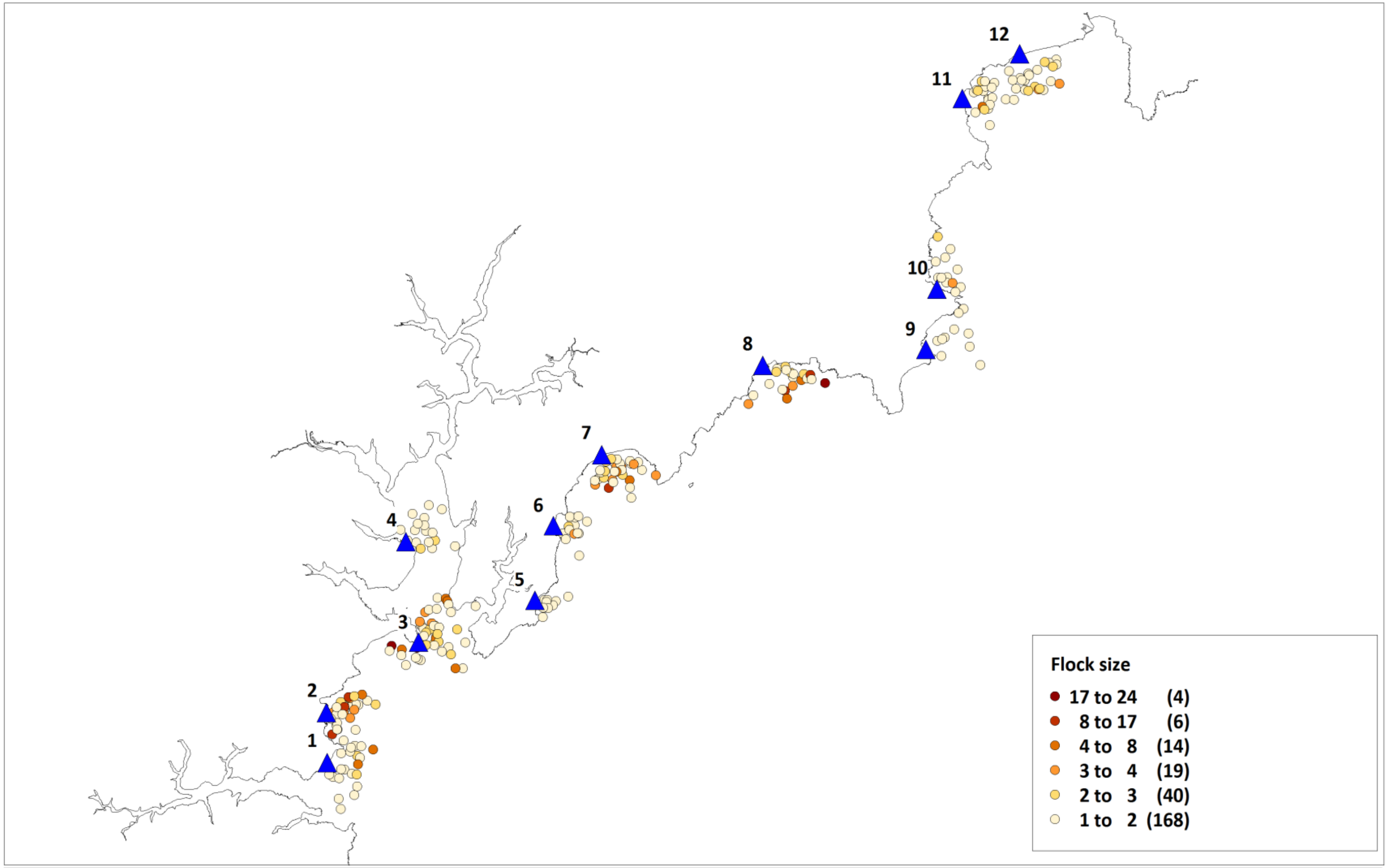


Figure 3: Numbers of individuals of the two main diver species by flock size. Data from all 12 vantage points, 12 visits to each.

3.14 Sightings of Black-throated Diver flocks, recorded from the vantage point counts, are shown in Map 6. The large groups of Black-throated Divers were slightly closer in shore than the other sightings but not significantly so (median distance from MHWM for flocks of less than 4 birds=517.7m, n=234; for flocks of 5-14 birds=578m, n=13; for flocks above 14 birds = 394.8m, n=5; Kruskal Wallis H= 4.31; 2 df, p=0.116). The larger flocks did appear to be significantly closer to the vantage points however (median distance from vantage point for flocks of less than 4 birds=922.7m, n=234; for flocks of 5-14 birds=1236.8m, n=13; for flocks above 14 birds = 632.4m, n=5; Kruskal Wallis H= 7.50; 2 df, p=0.023). There was no clear pattern in the behaviour of the larger flocks of Black-throated Divers. For example 3 (60%) of the flocks of 15+ birds were diving repeatedly, whereas for the groups of 4 or less Black-throated Divers 132 sightings (57%) were diving repeatedly. Two of the sightings of the larger flocks (40%) were loafing/inactive, compared to 26% of the groups of 4 or less birds.

3.15 There was no suggestion that the larger flocks were linked to particular tide states. Of the eighteen observations of Black-throated Diver flocks above 5 birds, 9 were within 3 hours of high tide. There was no significant difference in the proportion of observations involving birds in flocks above or below five birds in relation to visits within or outside 3 hours of high tide ($X^2_1=0.099$; $p=0.753$).



Map 6: Flock size of Black-throated Divers

Detection of target species in relation to distance from vantage point and sea state

3.16 The density of birds declined with distance from vantage point, potentially because either birds were missed further offshore and/or because birds have a preference for feeding at a particular distance from the shore (for example because of shallower water or the shelter provided by the cliffs). In order to understand the extent to which birds may have been missed we used a 100m grid within the GIS and identified only those cells that had a minimum depth of 5m or above. These were mostly close inshore and the data essentially therefore capture birds feeding along the coast from the vantage point rather than directly out. Cells were grouped according to distance from the vantage point (100m categories) and density calculated for each category. Density of all divers (i.e. all species and unidentified divers) was then calculated and plotted in relation to distance (Figure 4). Detectability appears to decline strongly with distance.

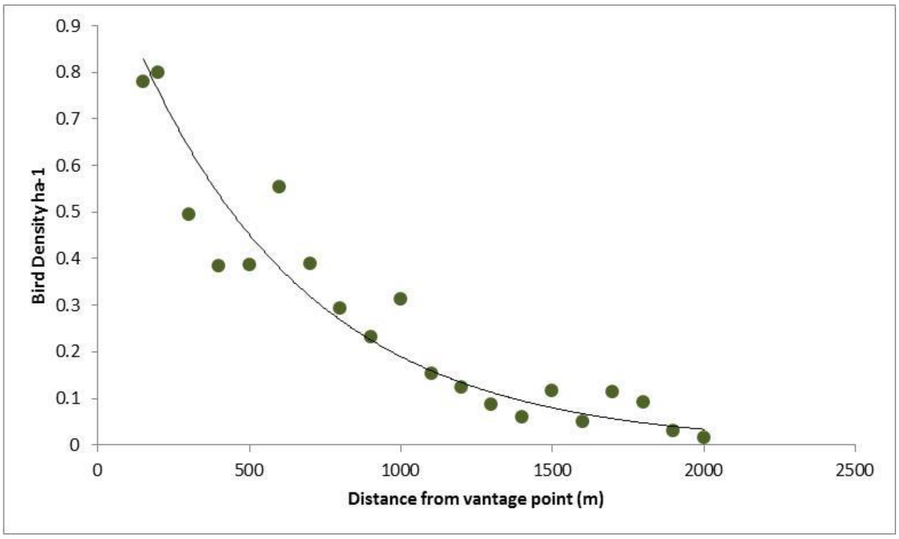


Figure 4: Density of all diver species in relation to distance from vantage point, based on grid cell data and cells with a minimum depth of 5m or less. $y=1.0755e^{-0.002x}$; $r^2=0.88$

3.17 There was some evidence that birds were recorded closer to the vantage points in rougher sea conditions – conditions where detectability is perhaps reduced. Birds may also come closer to the cliffs in rougher conditions because they may offer some shelter; if this were the case then it might be expected that bird density would vary in relation to distance from the shore (MWHM) in different sea states. There is little evidence that birds did come closer in shore (Figure 5) in rougher conditions.

3.18 For Black-throated Divers there were significant differences in the distance birds were recorded from the vantage point in relation to sea state (Kruskal-Wallis H=11.06, 5df, p=0.050) but not in relation to distance from shore (Kruskal-Wallis H=5.57, 5df, p=0.350). It is sea states of 4 and 5 where the distances drop and birds are not recorded further out (Figure 5). For Great Northern Divers the pattern was slightly different, but analysis was made difficult by relatively few observations in the rough sea-states (only 6 sightings in total for sea states above 3). For Great Northern Divers there were no overall significant differences in the distance birds were recorded from the vantage point in relation to sea state (Kruskal-Wallis H=10.11, 5df, p=0.072) while there was a significant difference in distance from the shore with sea state (Kruskal-Wallis H=13.42, 5df, p=0.020). The median distance from the vantage point at which Great Northern Divers were recorded for sea state 5 (just 2 observations) is low (Figure 5).

3.19 For Slavonian Grebe, as might be expected for a much smaller bird, there was a clearer pattern of sightings close to vantage points but more evenly distributed according to distance from shore (Figure 5). However for this species overall the small sample sizes (with only two sightings in sea state 3 and only 3 sightings in sea state 4), make any statistical tests based on these categories difficult.

3.20 In general it would appear that detectability is likely to be reduced above sea state 3. A check of the data indicates that out of the 146 vantage point counts (12 counts at 12 locations) a total of 10 (7%) counts were undertaken where the sea state was 4 or 5. These counts were spread between locations (single visits made to vantage points 1,2,3,4,5,11 and 12 where the sea state was 5 and single visits to vantage points 1,2,3 and 8 where the sea state was 4).

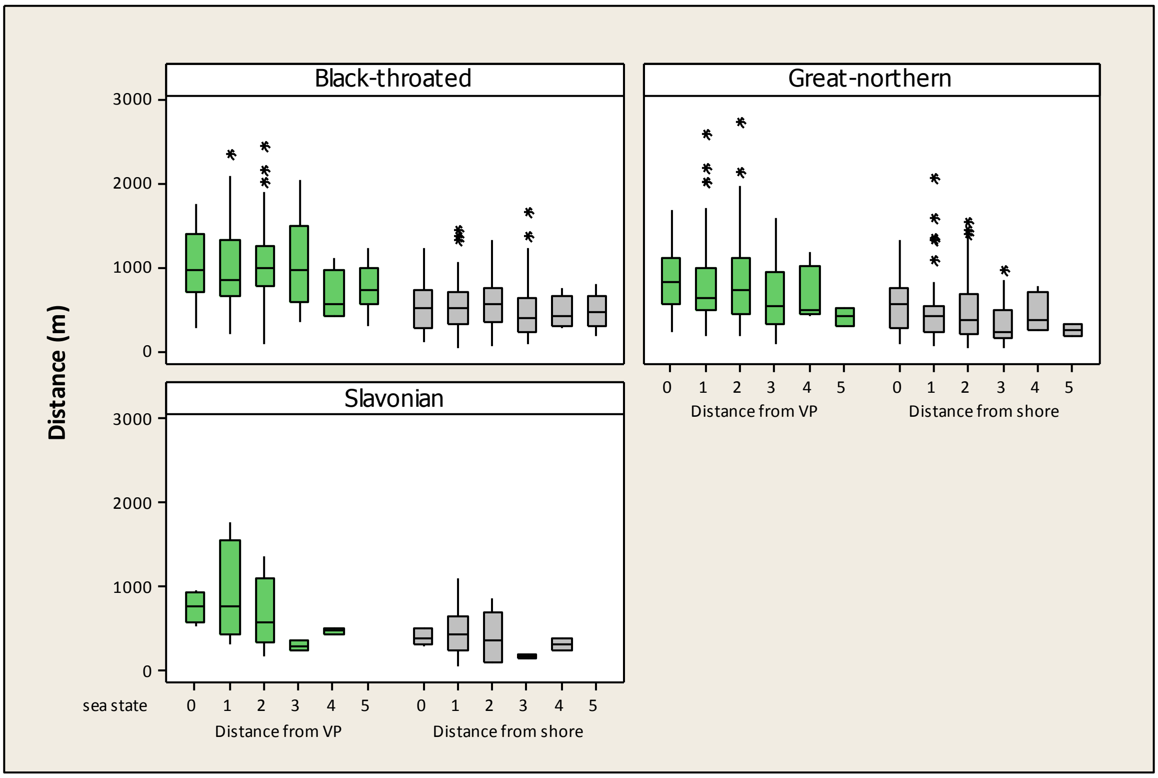


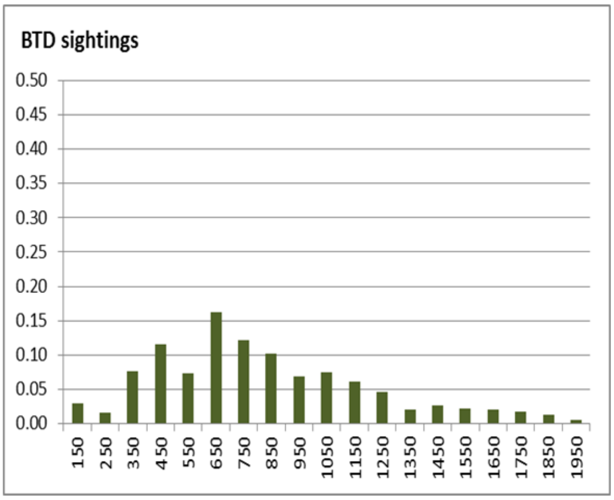
Figure 5: Distance from the Vantage Point (green) and Distance from shore (grey) in relation to sea state.

Distribution of birds in relation to distance from shore and water depth

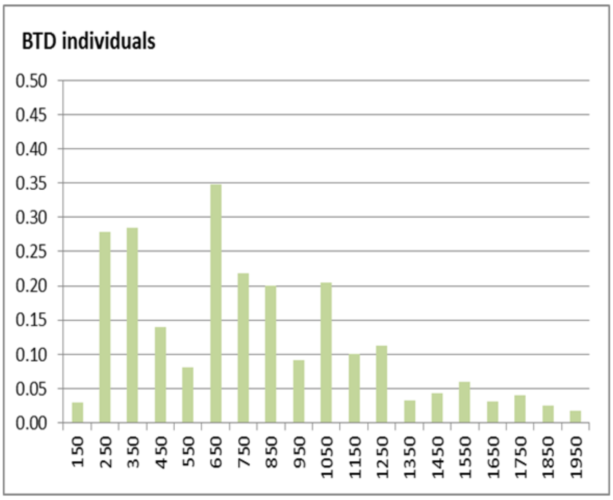
3.21 Data for both divers are summarised by distance from vantage point, distance from shore and water depth in Figure 6 and Figure 7. These variables potentially correlate and interact, so we present the data side-by-side in the plots.

3.22 There were significant differences between the two diver species in the distance from shore that they were recorded. In general Black-throated Divers tended to be further off-shore (median distance from shore = 514.73, n=252) compared to Great Northern Divers (median = 384.01, n=263), a difference that is significant (Mann-Whitney W = 71117.5, $p<0.001$).

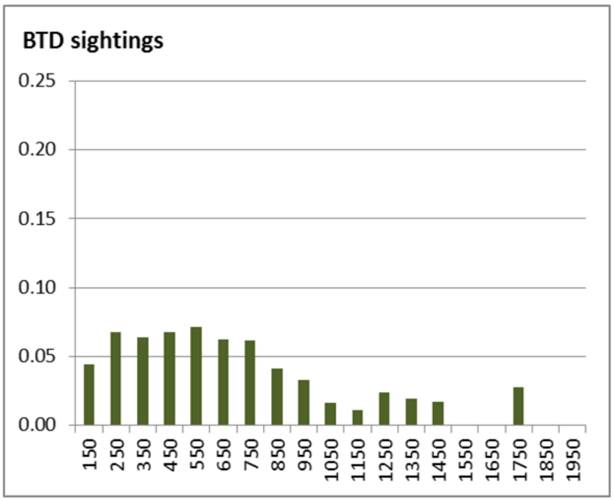
3.23 The distance off-shore was not significantly different between high and low tide for either diver species (median distance from the shore for Black-throated Diver sightings within 3 hours of high tide = 483.3m (n=117); other times = 526.1m, (n=135); Mann-Whitney W = 17999, p = 0.1105; for Great Northern Divers median distance = 395.6 (n=141) compared to 383.7m (n=122) at other times Mann-Whitney W = 18895, p = 0.646).



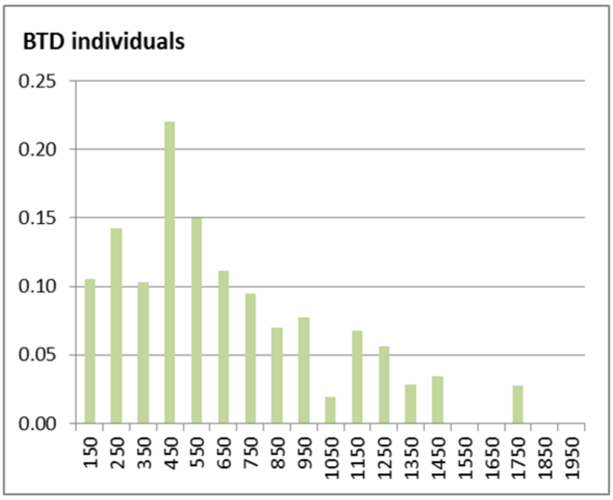
i) Density of black throated diver sightings with distance (m) from vantage point



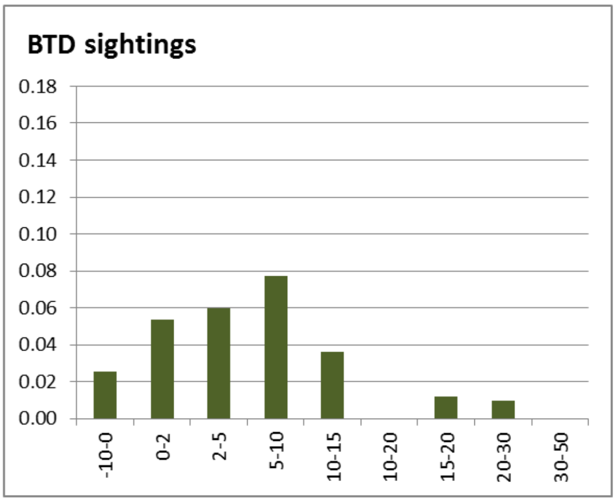
ii) Density of individual black throated divers with distance (m) from vantage point



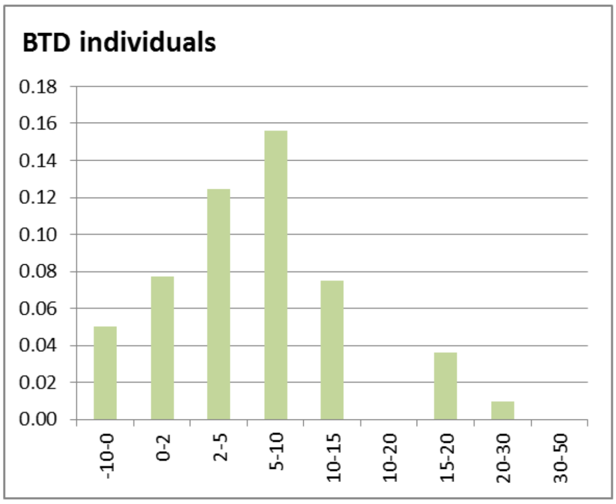
iii) Density of black throated diver sightings with distance (m) from the shore (MHWH)



iv) Density of individual black throated divers with distance (m) from the shore (MHWM)

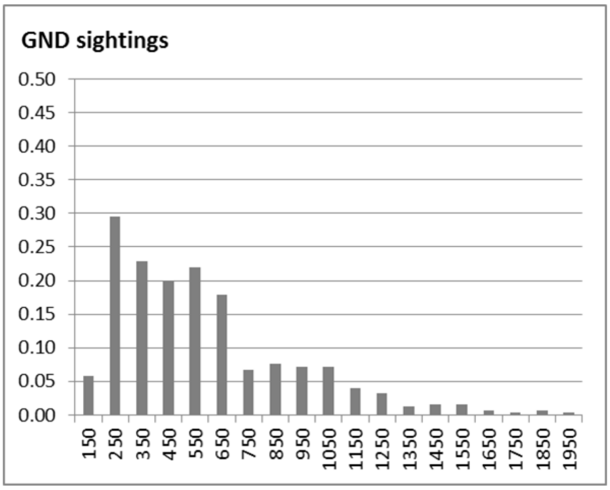


v) Number of black throated diver sightings against sea bed depth (m)

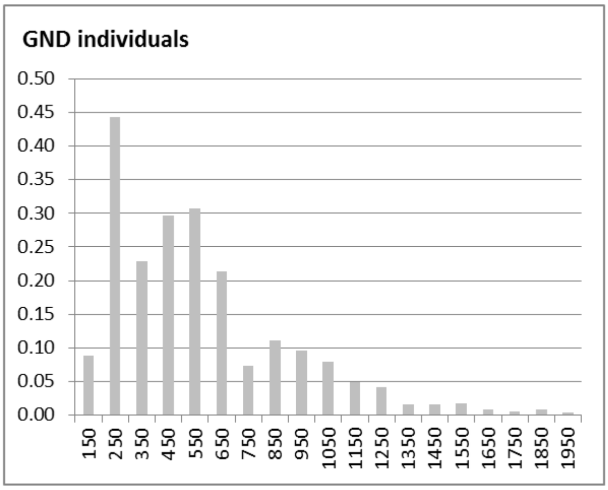


vi) Number of individual black throated divers against sea bed depth (m)

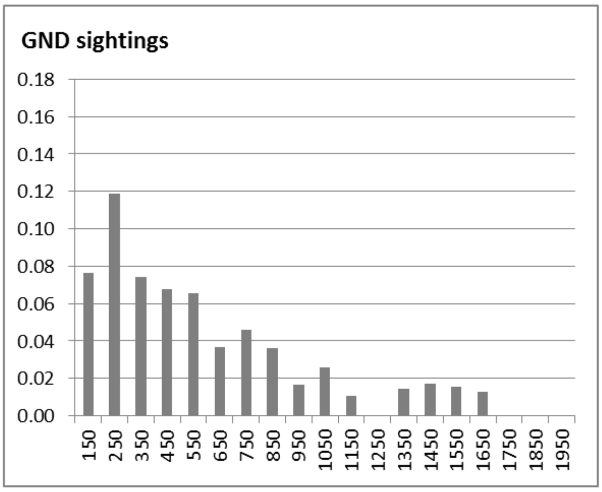
Figure 6: Black throated diver observations grouped by distance from vantage point, shore (MHWM) and sea bed depth. Note that these plots do not allow for variation with detectability with distance.



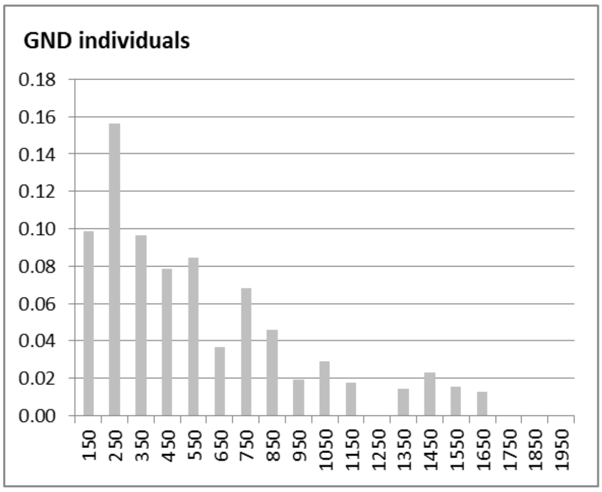
i) Density of great northern diver sightings with distance (m) from vantage point



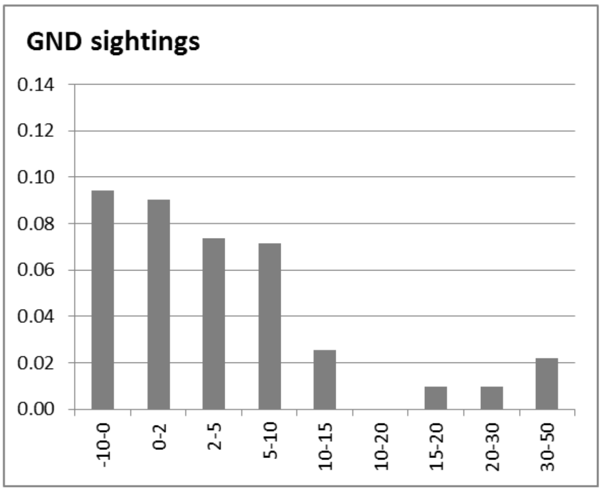
ii) Density of great northern divers with distance (m) from vantage point



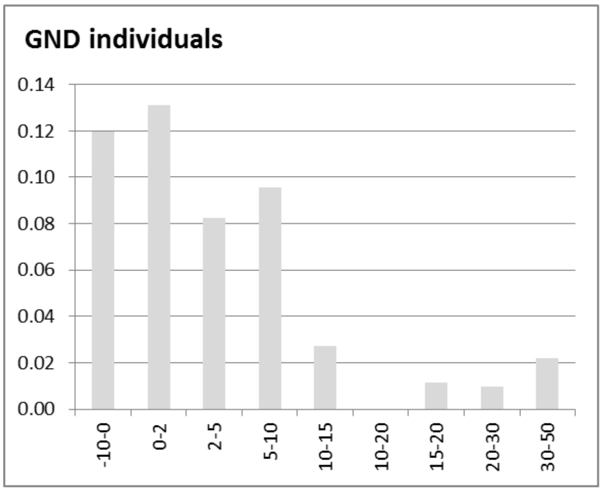
iii) Density of great northern diver sightings with distance (m) from the shore (MHWH)



iv) Density of individual great northern divers with distance (m) from the shore (MHWM)



v) Number of great northern diver sightings against sea bed depth (m)



vi) Number of individual great northern divers against sea bed depth (m)

Figure 7: Great-northern diver observations grouped by distance from vantage point, shore (MHWM) and sea bed depth. Note that these plots do not allow for variation with detectability with distance.

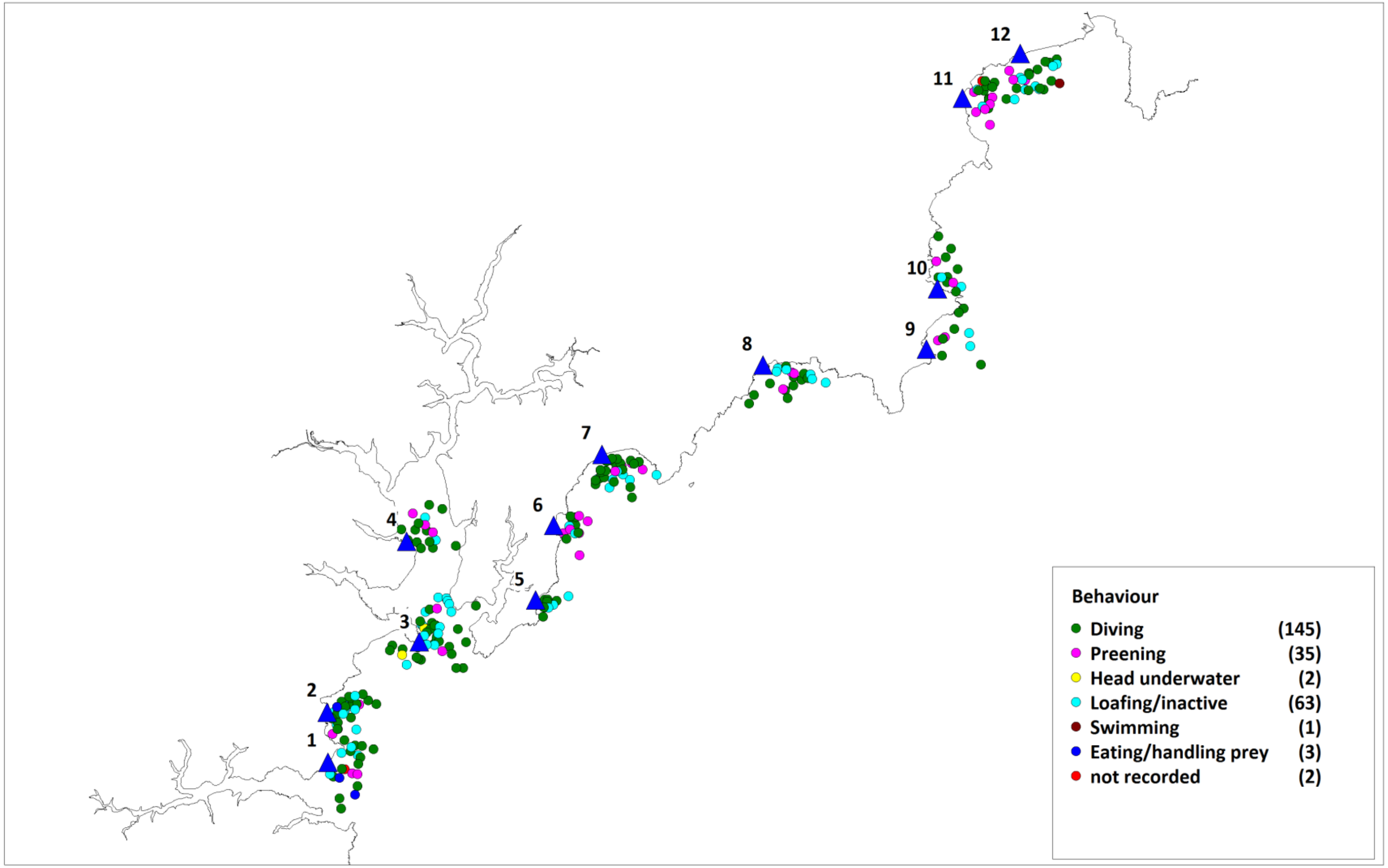
Behaviour

3.24 Behaviour data are summarised in Maps 8 and 9. For 250 of the Black-throated Diver sightings the main behaviour was categorised. The majority (144 sightings, 58%) involved birds diving repeatedly. Around one quarter (65 sightings, 26%) were of birds loafing/asleep and a further 35 sightings (14%) were birds preening. Taking these three main behaviours, there was no significant difference in the distances Black-throated Divers were recorded from the vantage point (Diving median distance = 922.7m; loafing/inactive =945.9m; preening=980.3; Kruskal Wallis H=0.12m 2df, p=0.944). Similarly there was little difference in the distance birds were offshore and the behaviour being undertaken (median distance (m) from MHWM for birds diving=486.4; loafing/inactive=486.3; preening=589; Kruskal Wallis H=1.41; 2df, p=0.495).

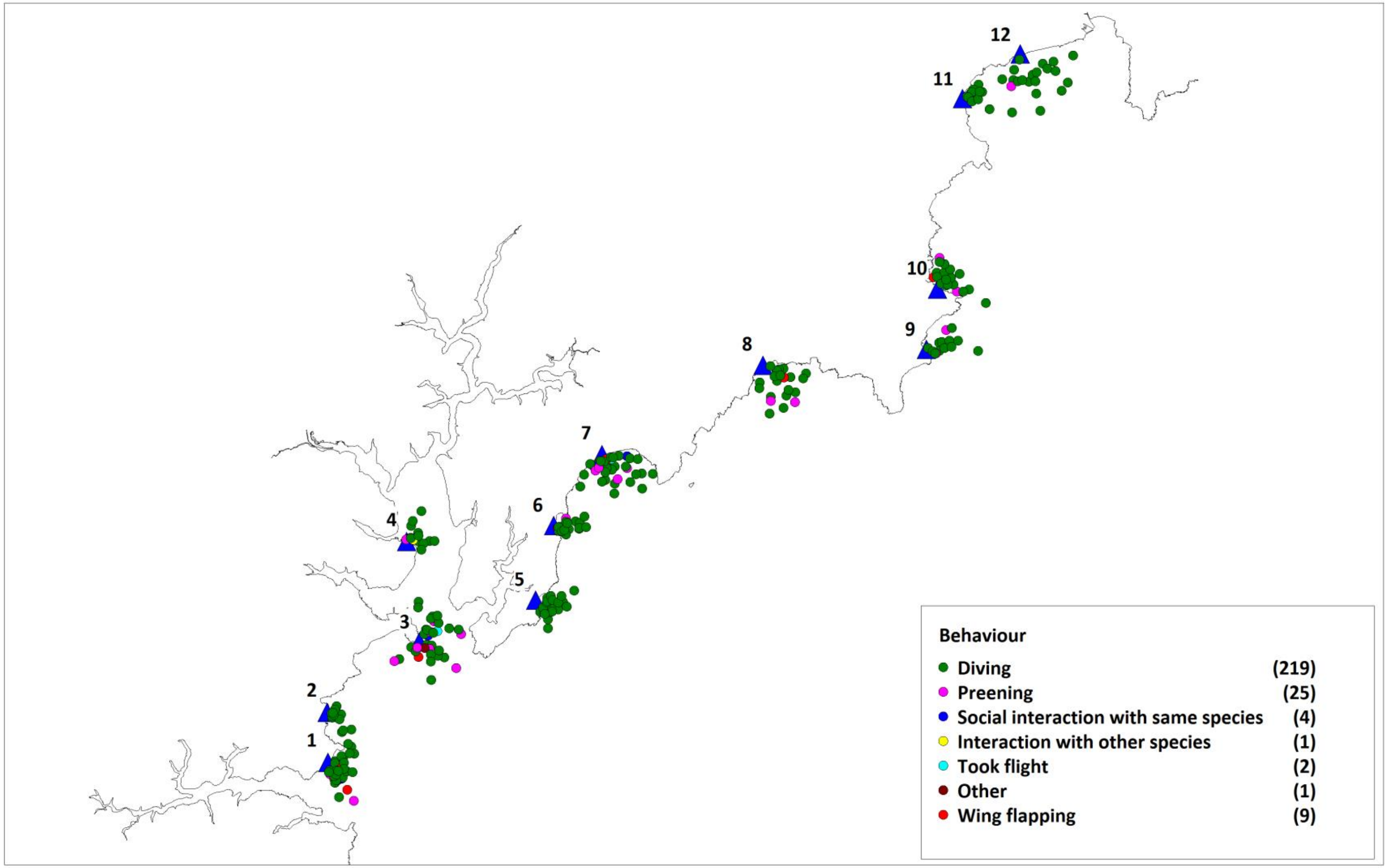
3.25 There were no significant differences in the proportion of Black-throated Divers undertaking the three main different behaviours and tide state (within or outside 3 hours of high tide)(X^2_2=3.004; p=0.223).

3.26 For Great Northern Divers, two-thirds of sightings (176, 67%) involved birds diving repeatedly. A total of 57 sightings (22%) involved birds loafing/inactive and a further 23 (9%) were preening. There was no significant difference between the two diver species in the proportion of sightings involving birds undertaking particular activities (X^2_3=5.929; p=0.115).

3.27 Great Northern Divers that were loafing/inactive tended to be slightly further from the vantage points than those recorded undertaking other behaviours, although differences were not significant (median distance (m) for birds diving=623.8m, (n=176); loafing/inactive=847.3m, (n=57); preening=566.2 (n=23); Kruskal Wallis H=5.16, 2 df, p=0.076). Similarly the distance from the MHWM was not significantly different between birds categorised undertaking different behaviours (median distance (M) from MHWM = 378.5m, (n=176); loafing/inactive=440.1m, (n=57); preening=383.4 (n=23); Kruskal Wallis H=4.15, 2 df, p=0.126).



Map 7: Behaviour (when first seen) of Black-throated Divers



Map 8: Behaviour (when first seen) of Great Northern Divers

Observations of Diet

3.28 Ten observations of Great Northern Divers with prey were made during the vantage point counts: seven of these involved crabs and the other three were flat fish. There was only one observation of a Black-throated Diver with any prey, a possible flat fish. Black-throated Divers appeared to be actively pursuing prey, often in flocks; some observations of them feeding actively with large groups of shags in shallow water of bays suggests fish being trapped. The lack of observations of birds with fish at the surface would suggest that prey are potentially eaten underwater or as the bird surfaces. Recording behavioural data on individuals within a flock proved difficult as birds appeared to synchronise their dives and also resurface simultaneously (making following individuals impossible). For Black-throated Divers birds also often reappeared a long way from where they went down suggesting that they were travelling considerable distances underwater, for example one bird was estimated to have resurfaced 200m from the point where dived. Great Northern Divers by contrast seemed to be resurfacing more or less close to where they dived.

Roosting Behaviour

3.29 Anecdotal records were kept relating to roosting birds during the survey. In addition some targeted visits were made to certain areas to search for any marked concentrations of roosts. No major concentrations or rafts of roosting divers were recorded, but some noteworthy observations are summarised below:

- Gerrans Bay, 20th Jan; 18 Black-throated Divers present until darkness fell. Scattered across bay, in three groups: one group of 12 (approximately 600m out) and two further groups of 3. All birds were loafing/sleeping when last seen.
- Pendennis Point, 28th Jan, at dawn no birds visible but 2 Great Northern Divers recorded flying into the estuary from offshore just after dawn, suggesting they had roosted outside the estuary
- Nare Head 18th Feb; 11+ Great Northern Divers at far side of Bay, closer to Pendower Beach. By the time dusk, fell birds spread out and 6 were sleeping or preening.
- Black Head Point, 22nd Feb; no divers recorded from head at dusk
- Dolman’s Point, 3rd March towards dusk. Walk around point searching for roosting birds and 3 Great Northern Divers and 1 Black-throated Diver seen, all scattered
- Mylor Churchtown, 4th March, 72 Black-necked Grebes present (distant so flock possibly containing Slavonians too) just after dawn, mostly in a single main group and thought to be a roost. No larger grebes were present with the flock but 1 Black-throated Divers (feeding) and 1 Great Northern Diver (loafing/inactive) were present relatively close to the small grebes and an additional Black-throated Diver was present feeding much further out.
- Portscatho, 9th March, 8 Black-throated Divers and Great Northern Diver present near dusk, loosely scattered, although one group of 3 Black-throated Divers were present (all 3 birds asleep/inactive, as was the Great Northern Diver). The remaining 5 Black-throated Divers were preening.
- Carylon Bay, 11th March. 5 Black-throated Divers, 4 Great Northern Divers and 1 unidentified diver present and scattered offshore at distances ranging

from 550m – 1100 offshore just before dusk. Three birds were still fishing and the rest were preening or asleep/inactive.

Comparison with historic bird counts

3.30 While this survey was not commissioned to give an indication of the total numbers of birds using the area or any information on bird trends, it is useful to consider the count data from 2014 in context with other years.

3.31 Visual aerial survey work of the study area was conducted in 2009 and a subsequent aerial survey for waterbirds has also been undertaken as part of a strategic environmental assessment for a development (O'Brien et al. 2012). Shore based WeBs counts have also been regularly undertaken on the Fal complex, Helford estuary and Gerrans Bay which cover part of the study area in this project. The highest numbers of divers have been recorded in Gerrands Bay which are covered by survey locations 6 and 7 in this project (Table 3). It would be unwise to draw comparisons between the results of these previous surveys as the data were collected and or reported using different methods and spatial scales.

Table 3: WeBs Annual peak counts[3] from locations within the study area

Year/location	07/08	08/09	09/10	10/11	11/12	5 year average
Gerrans Bay						
BTD	53	55	124	58	69	72
GND	13	17	24	20	28	20
Helford Estuary						
BTD	0	0	-	0	0	0
GND	1	0	-	1	1	1
Fal Complex						
BTD	0	5	3	0	0	2
GND	2	3	2	3	2	2

3.32 Previous shore based bird counts were undertaken in the Winter of 2009/2010 and 2010/2011 at 35 locations of which we believe ten were resurveyed within this project (O'Brien *et al.* 2012). The resurveyed locations were identified using Figure 3.5 in (O'Brien *et al.* 2012) but we cannot be confident that the search areas were identical even though it appears the survey were undertaken from the same location.

Table 4: Comparative locations of shore based bird counts in 2014 and 2009-2011

2014 Code and location	2009 - 2011 Location name after O'Brien *et al.* (2012)
1 - Old Church Road	**Not comparable**
2 - West Bay (private Road)	Maenporth
3 - Pendennis Point Car Park	Pendennis point
4 - Mylor Churchdown	Penarrow point
5 - Towan Beach	**Not comparable**
6 - Portscatho car park	Pednvaden
7 - Pendower Beach	Pendower Beach
8 - West Portholland	Perbargas Point

[3] http://www.bto.org/volunteer-surveys/webs/publications/webs-annual-report

2014 Code and location	2009 - 2011 Location name after O'Brien *et al.* (2012)
9 - Gorran Haven	Maenease Head
10 -Portmellon	Chapel Point
11 -Porthpean	Lower Porthpean
12 -Carlyon Bay	Carlylon Hotel

3.33 To draw comparisons across the ten location between the two surveys, count data from visits 1 (20/01/2014), 4 (10/02/2014) and 9 (4/03/2014) (Figure 2) were selected as they were a balance between surveys with high (peak counts) and in terms of time were relatively equally spaced. The 2009 – 2011 survey data were taken from O'Brien et al. (2012) Tables 8.1 – 8.4 for the ten comparable locations listed in Table 4 (see Appendix 4 for the data table)

3.34 The comparison of bird count totals over the ten survey locations fluctuates annually and seasonally with a peak counts in February 2011 (due to two substantial sized black throated diver flocks (accounting for 60 individuals) sighted of West Portholland and Carlyon Bay) and minimum counts in December 2009 (Figure 9).

3.35 The January, February and March 2014 peak diver counts appear relatively consistent suggesting survey consistency and potentially providing a bench mark as to the minimum number of birds distributed around the ten search areas (Figure 9).

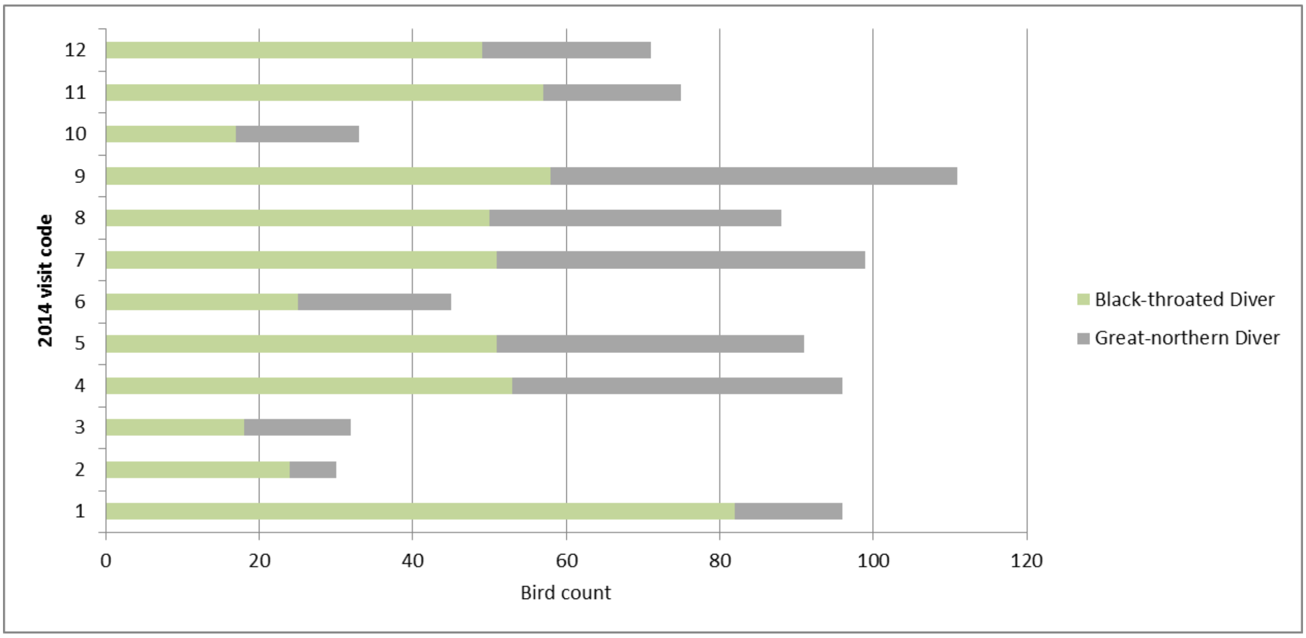


Figure 8: Summary of the number of divers recorded on different visits during 2014 survey work (links in with Figure 2)

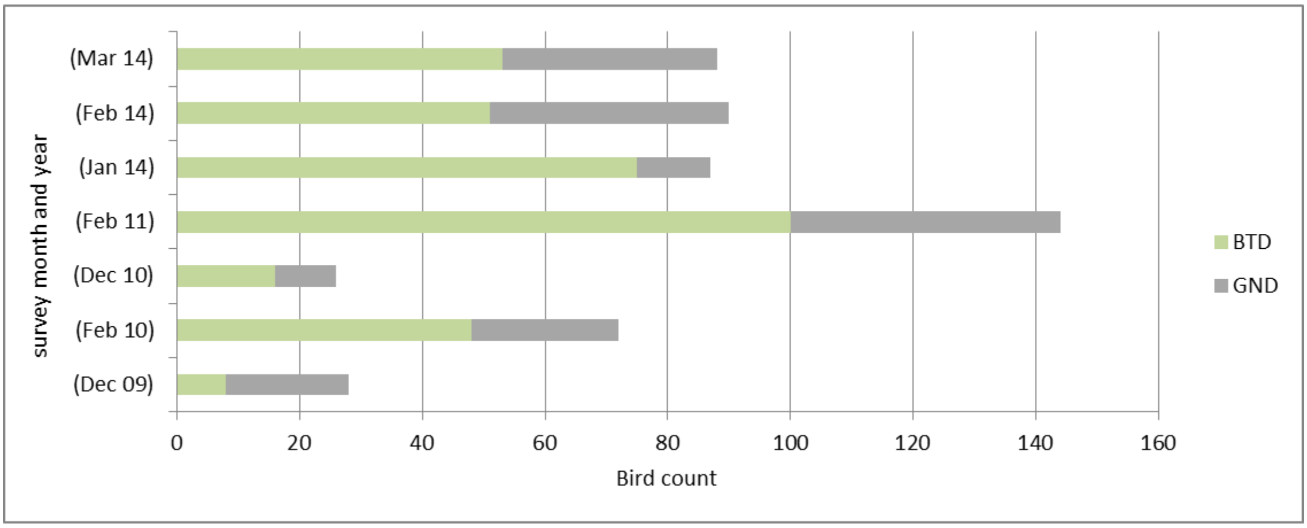


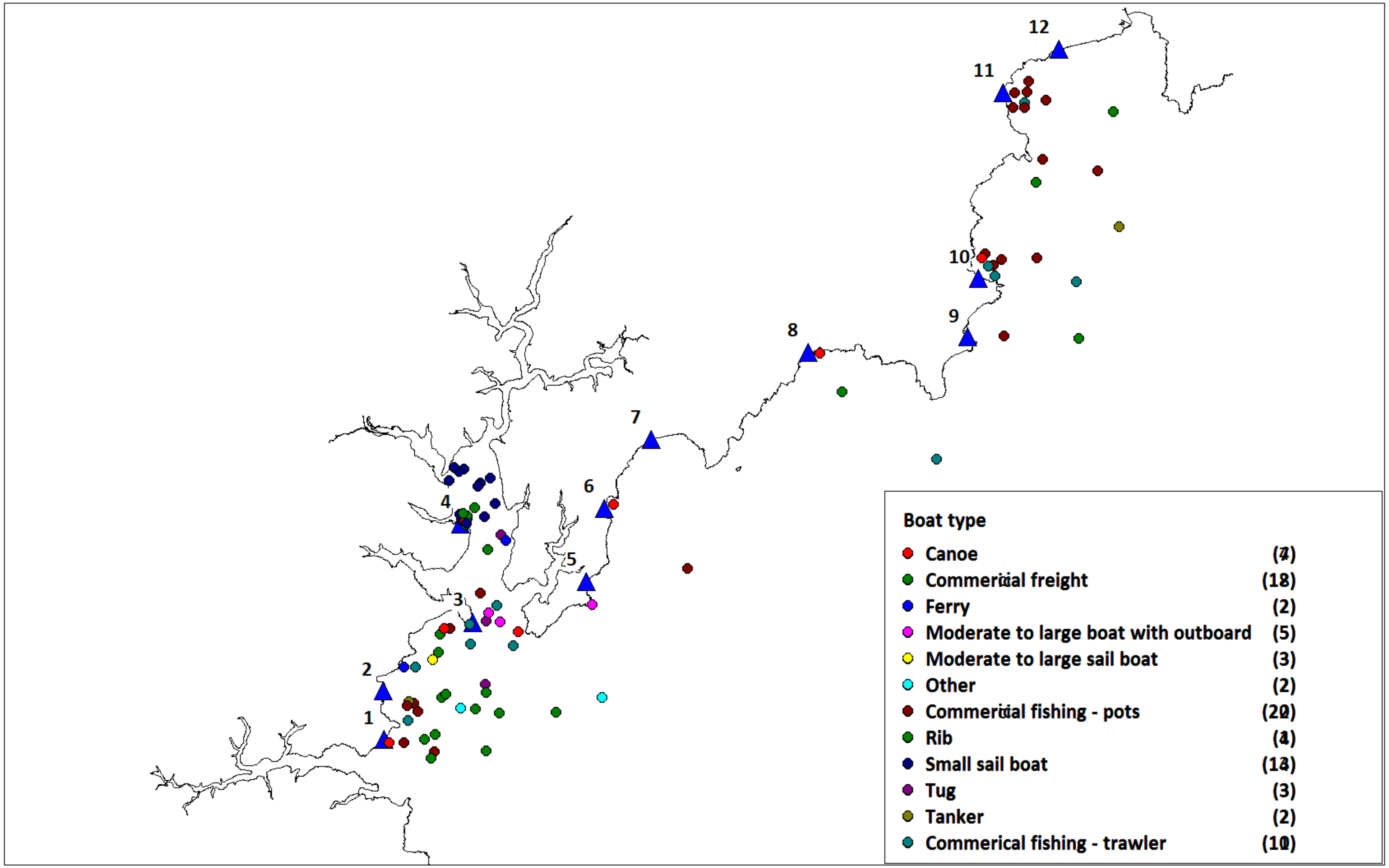
Figure 9: Summary of the diver count data gathered across ten survey locations between 2009 and 2014

Boat Traffic

3.36 Mapped boats, recorded during the vantage point counts are shown in Map 9. Boat traffic was concentrated around the Fal Estuary. Commercial fishing (particularly potting) was notably concentrated around the north-eastern survey points, particularly St. Austell Bay.

3.37 Relatively few boats were close to birds. In particular it is interesting that Gerrans and Veryans Bay were particularly quiet in terms of boat use, these locations also held the highest counts of Black-throated Divers.

3.38 There was a notable increase in kayaks (including people fishing from kayaks) in March, after the storms had abated.



Map 9 - Location of observed boats against the MHWM

Multi-variate Analysis on Distribution of Divers, incorporating detectability with distance from shore

3.39 Prior to any analysis relating to the spatial distribution of birds, a generalised linear model was used to check for confounding survey variables. The total number of divers recorded at each visit to each vantage point was the dependent variable, with the natural log of the search area at each vantage point included as an offset variable, to account for the different area of sea visible. There were significant differences between survey points ($F_{11,131}$=2.882, p=0.002), with vantage points 2,3,7 and 8 having the highest coefficients (indicating highest counts). After controlling for differences between vantage point there was no significant effect of which surveyor undertook the count ($F_{4,127}$=1.776, p=0.138), no effect of start time (nearest hour) of the count ($F_{11,120}$=1.776, p=0.09); no effect of sea state ($F_{5,126}$=1.776, p=1.869) and no effect on the amount of cloud cover (recorded in 1/8ths) ($F_{8,116}$=5.937, p=0.654). Data from different counts were therefore pooled.

3.40 A 100m grid was placed over the vantage point survey area and a data collated for each cell including vantage point of the cell, shortest distance to MHWM (approximated as the shore) and the vantage point, the minimum and maximum depth of the sea bed within the cell, the number depth contours (interpreted as a function of cell depth variability) and finally bird data to include the number of black throated and great northern diver observations and individuals recorded within each cell. The values associated with each 100m cell were used in the multivariate analyses to identify those variables most closely associated with the presence of each diver species.

3.41 In total 5,276 grid cells covered the survey areas with 235 cells containing observations of Black throated Divers, totalling 497 individual birds and also 235 cells contained Great northern diver observations totalling 325 individuals (Table 5). In total 413 grid cells contained a bird observation. There were 16 cells that contain flocks of over five Black throated Divers and five cells contained flocks with five or more Great Northern Divers. There were 27 cells which contained observations of both Great Northern and Black Throated Divers (Table 5).

Table 5: Summary cell data from 100m grid. Values in brackets are expressed as a % of the total number of cells. The totals do not exactly tally with those in Table 1 as they exclude casual observations, records that fall outside of the search area and only bird observations from a single vantage point where the search areas of two locations overlapped.

Bird summary data from 100m grid cells	Black throated diver	Great northern diver	Total
Individual birds	497	325	822
Number bird sightings	246	256	502
Cells with bird sightings	235 (4)	235 (4)	
Cells with more than 1 bird sighting	10 (0)	19 (1)	39 (1)
Cells with flocks over 5	16 (0)	5 (0)	21 (0)
Cells with both black throated and great northern divers			27
Total number of cells	**5276**	**5276**	**5276**

3.42 GLM models were fitted to test a range of variables relating to depth and distance from shore on the distribution and abundance of each diver species. Models included an autologistic term to account for spatial autocorrelation and the detection function was included as an offset variable to account for birds potentially being missed at greater distances from the shore. Parameter estimates are summarised in Appendix 5.

3.43 For Black-throated Divers both minimum depth and maximum depth were significant (when included separately), minimum depth produced a slightly better fit (lower AiC). Neither the distance from shore, the total amount of shoreline within a 1km radius of the cell or the number of boats recorded within a cell were significant predictors of Black-throated Diver numbers ($p>0.05$). Vantage point was significant ($F_{11,5263}=1.997$, $p=0.025$) when included in the model on it's own and when included with minimum depth. While there was an indication that there was a significant interaction between minimum depth and vantage point ($F_{38,5195}=2.697$, $p<0.001$), there was no improvement in model fit with the inclusion of the interaction term.

3.44 The model outputs indicate relatively similar, high densities of Black-throated Divers at survey points 2,6,7 and 8 (point 8, Veryan Bay, marginally the highest), while locations 4,5 and 9 had the lowest densities (Figure 10). Density varied with water depth and the highest densities (after controlling for vantage point) were in cells with a minimum water depth of 0-2m and densities appear low in areas with a minimum water depth greater than 10m (Figure 10).

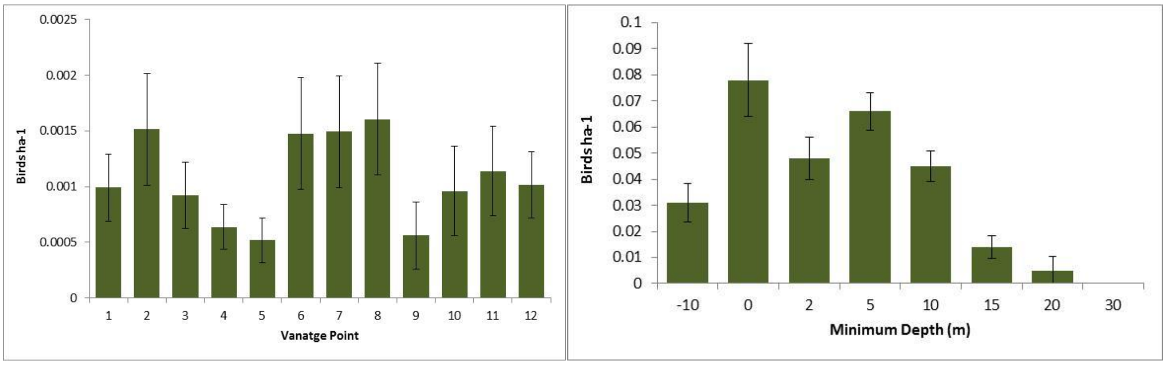


Figure 10: Predicted density of Black-throated Divers in relation to vantage point and minimum depth. Graphs show model-estimated marginal means +1SE.

3.45 Cells with high counts of Black-throated Divers were also those with high counts of Great Northern Divers. Inclusion of the number of Great Northern Divers as a covariate was significant ($F_{1,5273}=11.263$, $p=0.001$).

3.46 The only significant explanatory variables for the distribution of Black-throated Divers at high tide (cells with records within three hours of high tide) related to water depth (GLM with binomial probability distribution and logit link, including offset term and autologistic term, minimum depth, $p=0.003$). The probability of Black-throated Diver flocks (groups of 5 or above) being recorded in a cell was not significantly related to water depth, vantage point, distance to shore or amount of shoreline within 1km ($p>0.05$ in all cases when included as single variables in the model).

3.47 These results suggest that Black-throated Diver counts are related to water depth and there were also significant differences between vantage points. The vantage points with the highest numbers are all ones in bays with a southerly aspect.

3.48 For Great Northern Divers both maximum ($F_{7,5267}$=8.744, p<0.001) and minimum depth ($F_{7,5267}$=5.463, p<0.001) were significant predictors of the number of birds recorded in the cell, maximum water depth resulted in the better model fit (lower AiC). There was no significant effect (when included singly in the model) for vantage point or the number of boats within a cell (p>0.05), however distance to shore ($F_{1,5273}$=22.452, p<0.001) and the amount of shoreline within 1km ($F_{1,5273}$=31.312, p<0.001) were both significant when included singly in the model. There was little difference in the fits of models that included maximum water depth of a cell and distance to shore or maximum water depth of a cell and the amount of shoreline within 1km; the amount of shoreline within 1km was marginally better (lower AiC). The inclusion of both distance to shore and the amount of shoreline within 1km as covariates resulted in neither being significant and there was no evidence of an interaction between the two.

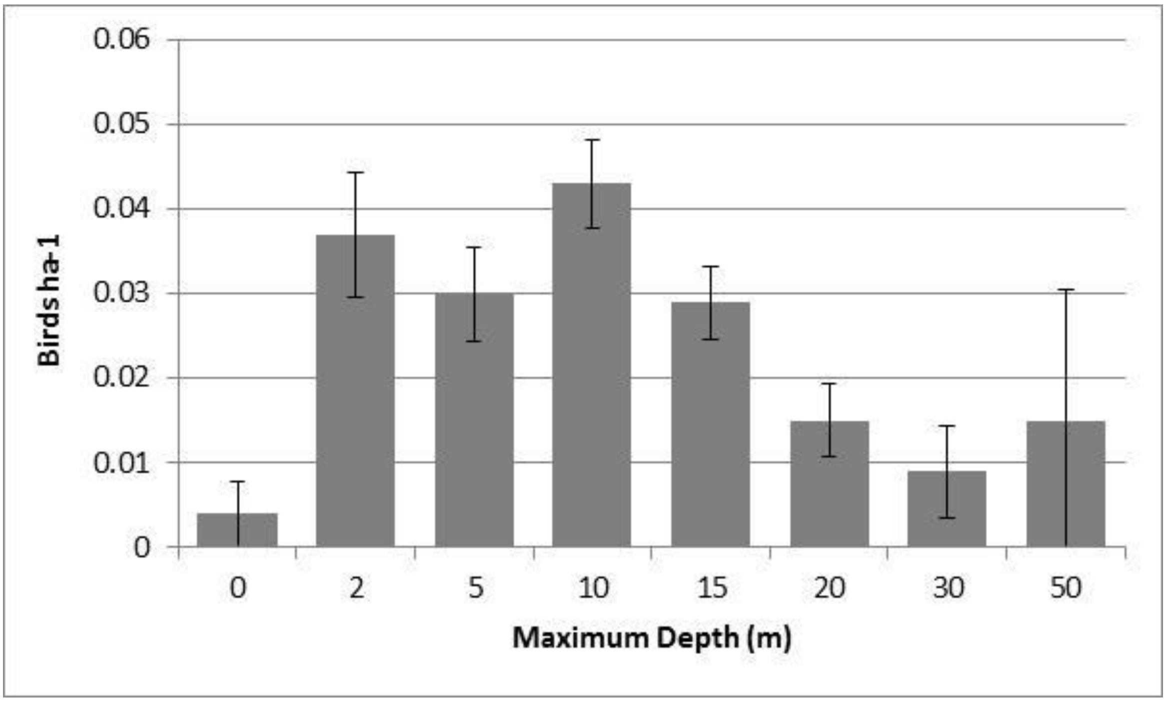


Figure 11: Predicted density of Great Northern Divers in relation to maximum water depth. Graph show model-estimated marginal means +1SE.

3.49 Great Northern Diver distribution at high tide (i.e. within 3 hours of high tide) was modelled using GLM with a binomial probability distribution and logit link function. The detection function was included as an offset and an autologistic term included to account for spatial autocorrelation. There was no significant effect of maximum water depth on the probability of cells having Great Northern Diver records at high tide (p=0.062) but minimum water depth was significant (Likelihood ratio chi-square=15.195, p=0.034), with the results suggesting the Great Northern Divers exploit different areas at high tide.

3.50 These results suggest that Great Northern Diver sightings tended to be in water below 20m and especially in areas where the water depth is below 10m, and in areas surrounded by more shoreline, suggesting water depth and shelter are important variables for this species.

4. Discussion

Overview of results

4.1 The results indicate that the area clearly holds exceptional numbers of wintering Black-throated and Great Northern Divers. Of the two species, Black-throated were the more abundant and records were to some extent concentrated in Falmouth Bay (off Mawnan Smith and Pendennis Point), at Gerrans Bay and Veryan Bay, with these locations holding significantly higher numbers of Divers than other locations after controlling for water depth.

4.2 Great Northern Divers tended to be scattered and relatively evenly distributed between the survey points. They favoured relatively sheltered areas, fed slightly closer inshore and tended to be on their own or in small groups.

4.3 Ten sightings of Great Northern Divers involved birds handling prey at the surface, namely seven crabs and three flatfish. This suggests Great Northern Divers are regularly feeding on the bottom, potentially supported by the results showing Great Northern Divers occurring in shallower water, closer inshore. Only one Black-throated Diver was recorded with prey at the surface, a possible flat fish. Observations indicate Black-throated Divers were regularly resurfacing some distance from where they dived and they were sometimes observed with large groups of other fish eating species such as Shags. We can infer that Black-throated Divers are therefore pursuit fishing and capturing small fish that are consumed while underwater or as the bird surfaces. These prey inferences relate to the habitat variables. The models included water depth as explanatory variables and there were two measures for each grid cell, the maximum depth and the minimum depth. Maximum water depth was the best predictor variable for Great Northern Divers and it perhaps makes sense that the birds select areas where they can get to the bottom to feed. For Black-throated Divers minimum depth was the best depth variable in the models: for a species that is pursuit fishing it is perhaps plausible that this variable explains distribution better.

Influence of Weather

4.4 Winter 2013/2014 was an exceptionally stormy season with six major storms (Table 6) affecting the UK between late January and February separated by intervals of only two to three days[4]. The storms combined with the persistent heavy rainfall resulted in the wettest winter since 1910. High winds combined with high tides and tidal surges caused dangerous conditions and considerable damage to many coastal areas, particularly in the south west of England[5.] The frequency of the winter storms was caused by a powerful jet stream driving low pressure systems and associated storms across the Atlantic[6].

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[4] http://www.metoffice.gov.uk/research/news/2014/uk-storms-and-floods
[5] http://www.metoffice.gov.uk/climate/uk/summaries/2014/winter
[6] http://www.metoffice.gov.uk/climate/uk/interesting/2014-janwind

Table 6: Details of the major winter storms in Winter 2013/2014[7]

Dates of major storms in survey period	Low pressure from
25th – 26th January	North West
31st January – 1st February	West
4th – 5th February	South West
8th – 9th February	West
12th February	West
14th – 15th February	South West

4.5 The persistent nature of the storms, risk of tidal surges and exceptional weather conditions disrupted the survey schedule and made access to the coast difficult. It proved a challenge to undertake surveys in optimal conditions for the time of year given the frequency and severity of the storms. Despite this 12 bird counts were completed at each survey location between 20th January and 14th March, albeit perhaps not as evenly spaced as had been hoped. The conditions during some of the surveys were not always optimal. By targeting the calmest days we have reduced the impact on detecting birds, and the GLMs found significant effect of sea state on bird counts per cell. The weather may well have had an impact on the birds as some may have pushed in shore (other authors suggest divers come closer in shore in response to bad weather: Wernham *et al.* 2002), and increased turbidity and storminess may well have affected their ability to feed and the abundance of prey. In addition, due to the adverse conditions birds may well have been feeding more intensively, potentially affecting our ability to record them.

4.6 A further influence of the weather will have been on the amount of craft on the water. It was notable that the appeared to be an increase in canoes and other leisure activity around early March, after the storms had abated. We recorded very few boats on the water for much of the survey, in particular recreational use. This is likely to be because of the weather. Automatic Identification System (AIS) data shows that the Falmouth area is particularly busy compared to other parts of the UK coast, with average shipping densities of between 100-250 vessels per 2km grid cell per week (MMO 2014). These data considerably underestimate recreation and smaller craft and primarily rate to large commercial freight vessels and passenger vessels, but potentially highlight the comparatively low levels of use recorded during the fieldwork for this project. As a result of the low levels of boat activity it is not possible to rule out impacts from boat activity on the bird interest.

4.7 The results presented in this report should therefore be interpreted with some consideration to the unusual weather conditions over the survey period and their impact on the birds, the habitat and levels of boat activity.

[7] Annotated from http://www.metoffice.gov.uk/climate/uk/interesting/2014-janwind

Black-throated Divers and Flocks

4.8 One of the particularly interesting findings is the occurrence of Black-throated Divers in large flocks. While these were not always feeding, some observations would suggest that the birds are flocking in response to their prey (rather than – for example – birds aggregating to roost) and also that Black-throated Divers are aggregating with other species. For example on the 11th February the surveyor (JW) noticed a gathering of birds between vantage point 2 (near Mawnan Smith) and vantage point 3 (Pendennis Point), and drove to a better vantage point to count the birds involved. There were over 300 birds, many intensively feeding in a mixed flock close inshore, between Gyllygvase Beach and the base of Pendennis Point (observed from SW819321). The flock included some 289 Shags, 1 Slavonian Grebe, 18 Black-throated Divers and 2 Great Northern Divers. Counts of up to 36 Black-throated Divers were reported by local bird watchers in the survey area during the survey period. Many of the observations of large groups of Black-throated Divers feeding appeared to involve birds diving and surfacing together, suggesting that the birds were feeding as a group. There is little information in the literature describing this behaviour and the occurrence of feeding flocks during the winter is not widely reported in the UK.

4.9 It would seem that the flocks were erratic in time and space. The overall counts of Black-throated Divers were reasonably consistent across the 12 counts, suggesting that birds are moving in response to prey abundance and coming together to exploit marked aggregations of prey. Such behaviour is documented for very similar Pacific Loons which use visual clues of feeding kittiwakes when deciding whether to join flocks and the Loons apparently can tell from the behaviour of the kittiwakes whether fish shoals are present (Hoffman, Heinemann & Wiens 1981).

4.10 The flocking behaviour of the Black-throated Divers may have conservation implications, as it means a high proportion of the wintering population could be affected by a single isolated event.

Roosts

4.11 Roosts are important to document as they are potentially particularly sensitive locations. As many birds gather in one location, any event or disturbance in that area has the potential to affect a large number of individuals.

4.12 The count of 72 Black-necked Grebes on the 4th of March was made just after dawn and it was thought the birds had roosted nearby. While not a target species for this survey, 72 is a high count, even in context of the recent increases and spread of this species in winter (Balmer et al. 2013). Birds coming together in rafts such as this provide a good opportunity of gathering accurate counts and roost sites are likely to be key sites to protect within the pSPA. While potentially not an interest feature of the pSPA, the Black-necked Grebe roost area would warrant further checks and protection. Similar gatherings have been consistently reported from other south coast sites (e.g. Poole Harbour, pers. obs.).

4.13 Unfortunately no similar marked roosts of Divers were recorded, and it would seem that birds were roosting close to where they were feeding and not in large rafts in consistent locations. This is supported by the various observations of scattered birds roosting at or near dusk (see para 3.29). This is in contrast to Mull, where Shackleton's (2012) descriptions and photographs show Great Northern Divers swimming purposefully towards regular roost sites, which appear to be relatively constant locations where birds coalesce in rafts. Such behaviour has also been documented in Shetland (see Shackleton 2012 for discussion) and has been reported for Balck-thrated Divers, at least in late summer (Fuller 2003). It may be that sheltered bays and sea lochs are more attractive and important roost sites in northern locations and that in an open coast environment like the Falmouth-St. Austell area, set roost sites are less important to the birds, alternatively the roosting behaviour of birds may have been disrupted by the weather and atypical in the winter 2013/14. .

Target Species Habitat and Behaviour

4.14 The results presented here clearly add to our understanding of the importance of the Falmouth-St. Austell area and it's use by the target bird species. Unfortunately Slavonian Grebe numbers were too low to allow detailed analysis of distribution. While the adverse weather may have affected distribution and abundance, the counts and key sites (for Black-throated Diver) do seem to mimic previous years data. Regular counts off Ireland indicate consistent use of particular areas and reasonably consistent numbers of wintering Great Northern Divers (Suddaby 2010), albeit supplemented by an influx in the late spring. While there is little evidence to support site faithfulness, the regular sightings of a leucistic individual Great-northern Diver in the same bays in Shetland over 19 successive winters (Suddaby 2010) would suggest that these birds do return to the same sites. We have identified particular bays that appear to hold higher densities of Black-throated Divers and the results also highlight the importance of inshore areas with relatively shallow water. The differences in feeding ecology between the two species suggest the seabed habitats may be important for Great Northern Divers, which appear to be feeding on the bottom and that, for Black-throated Divers, stocks and shoaling behaviour of small fish will be important.

4.15 Our fieldwork was focussed on the areas already identified as important for the target bird species (i.e. the pSPA), so we are unable to identify why this area has such high numbers of these birds. The area is sheltered from prevailing weather systems (south-westerlies) by the Lizard, and the coastline is characterised by a series of bays with a particular aspect and cliffs that provide shelter. The water is relatively clear and free of silt (many of the bays lack a strong freshwater input) and some of the bays (at least based on the results presented here) are relatively undisturbed.

Further work

4.16 The modelling was relatively complex as all the variables were correlated and varied with distance from the shore. Given that detectability also declines with distance it is difficult to tease the various variables apart. There would therefore be merit in a more random sampling approach, potentially involving boat based transects or aerial transects, and then the data used to build a spatial model of distribution in relation to environmental variables. It was hoped that additional environmental variables would have been incorporated into this study, in particular more detailed bathymetry data and data on benthic habitats. As these become available in the future it may well be possible to use them with the bird data collected here in further analyses.

4.17 Aerial or boat-based surveys might also provide larger sample sizes for analysis, which would be particularly useful with respect to Slavonian Grebe.

4.18 The results suggest depth is important for both diver species in slightly different ways – minimum water depth gave a better fit in the models for Black-throated Diver while maximum water depth was the best depth predictor variable for Great Northern Diver. More detailed bathymetry data would perhaps shed more light on these differences and the importance of seabed character. It may be that variation in depth, presence of vertical faces etc. may be factors which influence the bird distributions. Other habitat variables such as currents may also be important.

4.19 Boat-based or aerial surveys would also ensure better coverage of the areas further offshore. The shore-based focus of the work does mean that it is difficult to draw conclusions relating to how birds use the deeper waters well offshore. While the data presented here indicates higher densities in shallower water, given the extensive area of offshore waters compared to those closer inshore, overall abundance of birds may well be higher offshore (i.e. lower densities but more birds due to the extensive area).

4.20 Extending survey work to cover a wider period would also be beneficial. This survey was commissioned to cover the period from January and February. Fieldwork could cover earlier in the winter and also extend through to the spring (potentially into April). It is possible that different areas are important for the birds at different times of year and that the bird's behaviour may change at different times of the year.

4.21 Given the limited data on boat traffic and boat activity collected here, further work on the interactions between boats and divers/small grebes is clearly warranted. Further work could build these elements in, ensuring detailed mapping of the intensity of boat use over the area in typical conditions and detailed behavioural observations relating to divers and boats. Targeted watches that follow individual birds and record the response to boats may be difficult, but are potentially possible. Such data would indicate the distances at which birds respond to different boats and how they respond. It may then be possible to combine such results with the modelling to determine what proportion of the habitat used by the birds is disturbed.

4.22 Finally the high densities of divers in the area are exceptional. Further understanding of the winter ecology of the birds will help underpin the conservation of the area. Regular monitoring is essential to understand the variation in numbers over time, and the variation in counts for Black-throated Divers in particular indicates that regular, repeat counts are important. Further work on feeding ecology – particularly the flocking of Black-throated Divers would be useful. A larger dataset may inform how often birds flock, how the flocking behaviour varies between winter and to what extent flocks stay together or represent temporary aggregations in response to prey aggregations. It would be fascinating to know more about where the birds breed.

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6. Appendix 1: Summary of Vantage Points

ID	Location	OS grid reference	Directions	Elevation (m)
1	Old Church Road	SW7916027377	At old Church Road junction, continue almost to the end of the road, stop at Public Footpath sign (next to 'Charlton House'). Walk down from the road follow the hedge line (on the right hand side of the field) to the coastal path down the steep hill. Turn right on the coastal path and go over the stile to the first open area looking out to sea	20
2	West Bay (private Road)	SW7920229184	Park on road side by the private road. Gate to left of private road (bridleway) – walk over field to the coast path and turn right….just past the dead tree on the path is a small open area to view from.	26
3	Pendennis Point Car Park	SW8265431587	VP on the higher of the car park levels	21
4	Mylor Churchdown	SW8234835236	Follow signs into Mylor Churchdown. Parking in the village (by the Quay), pay & display. Walk around to right along path and stop just before the sailing club)	4
5	Towan Beach	SW8694032937	National Trust car park for Towan Beach. Just before the beach (ca 150m) turn left up the short rise to get a better view.	7
6	Portscatbo car park	SW8770735607	Turn right by church into village and veer left to Portscatbo. Beyond the last houses is a large car park on the right. Walk through gate to right of car park, walk down to the right to a seat (below a white house). Private pay & display car park (£1/hr, £3 all day).	16
7	Pendower Beach	SW8956338101	Turn left off A3078 just after Treworlas to beach, VP from the first large layby overlooking sea.	25
8	West Portholland	SW9552641093	Parking by beach – walk up coastal path to right. Go through the top gate and take the man-made path to the left into the gorse/bracken (just before the sign). Continue up the coastal path until come out of the scrub to a clear view (just past 2 stunted trees)	61
9	Gorran Haven	SX0146241444	At T-junction, turn right towards Gorran Haven (narrow road, gate may be closed because of stock …open/close it). Park in village car park (£1) or possible roadside and walk back to the slipway. Turn right (Foxhole Lane) to pick up the coastal path, walk up hill mid-way to the 2nd gate (open area just after end of sheep fence).	37
10	Portmellon	SX0194443603	Park on roadside ('Portmellon Park', left turn just before pub). Walk to main road, turn right and head up hill. Turn left into Chapel Point Lane and walk beyond houses as far as two seats (close together) out in the open. VP by first seat.	35
11	Porthpean	SX0311450461	Head towards Lobb's Shop then right to Lower Porthpean – narrow road down to car park, £3. Walk to beach, turn right along coastal path. Views obscured by scrub but VP = second gap (higher up path)	32
12	Carlyon Bay	SX0525251998	Turn right from Portpean towards Duporth – Charlestown. Drive through Charlestown to the big car park at the end of the road (Carlyon Bay). Walk along coastal path to right as far as fence (large hotel behind) - gap in scrub here.	38

7. Appendix 2: Survey dates of each vantage point

Visit	Date/ Survey location	1	2	3	4	5	6	7	8	9	10	11	12	Total
1	20/01/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
	21/01/2014	✓	✓	✓	✓									**4**
2	21/01/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
	22/01/2014	✓	✓	✓	✓									**4**
3	28/01/2014	✓	✓	✓	✓							✓	✓	**6**
	29/01/2014					✓	✓	✓	✓	✓	✓			**6**
4	10/02/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
	11/02/2014	✓	✓	✓	✓									**6**
5	17/02/2014	✓	✓	✓	✓									**4**
	18/02/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
6	20/02/2014											✓	✓	**2**
	21/02/2014				✓	✓	✓	✓	✓	✓	✓			**7**
7	22/02/2014	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	**11**
	23/02/2014	✓	✓	✓	✓									**4**
8	03/03/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
	04/03/2014	✓	✓	✓	✓									**4**
9	04/03/2014					✓	✓	✓	✓	✓	✓			**6**
	05/03/2014	✓	✓	✓	✓							✓	✓	**6**
10	09/03/2014						✓	✓	✓	✓	✓	✓	✓	**7**
	10/03/2014	✓	✓	✓	✓									**5**
11	11/03/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
	12/03/2014	✓	✓	✓	✓									**4**
12	13/03/2014					✓	✓	✓	✓	✓	✓	✓	✓	**8**
	14/03/2014	✓	✓	✓	✓									**4**
	Total	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**146**

8. Appendix 3: Totals (counts of the number of individuals) by Species, Visit and Vantage Point

Black-throated Diver. Grey shading indicated highest two counts in the column. Bold indicates counts in double figures

VISIT	Vantage point												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1	6			2	1	2	**18**	**45**	2	1	3	2	82
2	2	9	3	3				1	2	1		3	24
3		4				1	5			4	1	3	18
4	1	1	**21**	3	1	1	**15**	4		2	3	1	53
5	2	13	**23**	5				2	3		1	2	51
6		8	8	1				2	2	3	1		25
7	1	**29**	7	3	1		1	2		1	2	4	51
8	4	5	**37**	2						1		1	50
9	2	5	**32**		3	2	4	6				4	58
10		1	1			2	2	6			2	3	17
11	6	4			2	8	**29**	1	1	1	1	4	57
12			3		3	1	**12**	**13**		1	**10**	6	49
Total	**24**	**79**	**135**	**19**	**11**	**17**	**86**	**82**	**10**	**15**	**24**	**33**	**535**

Great Northern Diver. Grey shading indicated highest two counts in the column.

VISIT	Vantage point												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1	1			3	1	1	4	2	1			1	14
2		1				3	1					1	6
3			3	3				3	2	1		2	14
4	3	1	17	1	1	1	7	1	3	4	2	2	43
5	6	1		6	1	2	13	1		7	3		40
6			2	2	2	3	3	3	2	1		2	20
7	13	4	7	4	1	4	3	2	1	6	1	2	48
8	5	1	13	1	5	2	4	4	2		1		38
9	8	2	10		10	3	8	3	2		3	4	53
10	1	1					7	1	2	1	2	1	16
11	1	1	1	1	3	1	2		1	3	1	3	18
12	2	1		1		3	2	6	1	1	1	4	22
Total	**40**	**13**	**53**	**22**	**24**	**23**	**54**	**26**	**17**	**24**	**14**	**22**	**332**

Slavonian Grebe. Grey shading indicates positive counts

VISIT	Vantage point												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1	0	0	0	4	0	1	2	0	0	0	1	2	10
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	1	0	0	0	0	2	4
5	0	0	0	1	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	1	0	0	0	1	0	0	2
7	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0
10	2	0	0	0	0	0	3	0	0	0	0	0	5
11	1	0	0	0	0	0	0	1	0	0	0	0	2
12	0	0	0	0	0	3	0	0	0	0	0	0	3
Total	**3**	**0**	**0**	**5**		**6**	**6**	**1**		**1**	**1**	**4**	**27**

9. Appendix 4: Comparative count data 2009 – 2014

		Dec-09		Feb-10		Dec-10		Feb-11		Jan-14		Feb-14		Mar-14	
2014 Location Code	**2009/2011 Location Name (O'Brien *et al.* (2012)**	**GND**	**BTV**	**GND**	**BTD**	**GND**	**BTD**	**GND**	**BTD**	**GND**	**BTD**	**GND**	**BTD**	**GND**	**BTD**
1	**Not comparable**									1	6	3	1	8	2
2	Maenporth	0	0	0	0	1	0	0	0	0	0	1	1	2	5
3	Pendennis point	1	0	0	0	2	0	0	0	0	0	17	21	10	32
4	Penarrow point	0	0	0	0	0	0	0	0	3	2	1	3	0	0
5	**Not comparable**									1	1	1	1	10	3
6	Pednvaden	1	0	2	2	1	4	1	0	1	2	1	1	3	2
7	Pendower Beach	6	2	4	5	2	11	6	16	4	18	7	15	8	4
8	Perbargas Point	1	6	1	6	0	0	5	33	2	45	1	4	3	6
9	Maenease Head	0	0	6	34	0	0	5	17	1	2	3		2	0
10	Chapel Point	1	0	2	0	0	0	16	1	0	1	4	2	0	0
11	Lower Porthpean	6	0	6	1	2	0	6	6	0	3	2	3	3	0
12	Carlylon Hotel	4	0	3	0	2	1	5	27	1	2	2	1	4	4
Total counts (excluding records from locations 1 and 5)		20	8	24	48	10	16	44	100	12	75	39	51	35	53
Total from all locations										14	82	43	53	53	58

10. Appendix 5: Model Outputs

This appendix gives further details of selected models (see 3.42 and onwards). Table 7 summarises the model effects and Table 8 gives the parameter estimates.

Table 7: Summary of model effects for selected models referred to in the text. Variables are MINdepth (minimum water depth, categorical data); MAXDepth (maximum water depth; categorical); AUTOlog (auto logistic term, see methods); distMHWM (distance to mean high water mark), MHWMwithin1km (length of shoreline within 1km radius) and VantagePoint (Survey location, categorical data).

	Wald Chi-square	d.f.	p
1) dependent variable: number Black-throated Divers per cell; model: (Intercept), MINdepth, AUTOlog, offset = detectability_function. AIC=2568.923			
Intercept	446.738	1	<0.001
MINdepth	32.031	6	<0.001
AUTOlog	376.337	1	<0.001
2) dependent variable: number Black-throated Divers per cell; model: (Intercept), MINdepth, MAXDepth, AUTOlog, offset = detectability_function. AIC=2563.733			
(Intercept)	3380.975	1	<0.001
MINdepth	19.323	5	0.002
MAXDepth	16.608	5	0.005
AUTOlog	491.249	1	<0.001
3) dependent variable: number Black-throated Divers per cell; model: (Intercept), AUTOlog, Vantagepoint, offset = detectability_function. AIC=2605.295			
(Intercept)	4981.548	1	<0.001
AUTOlog	532.268	1	<0.001
Vantagepoint	21.965	11	0.025
4) dependent variable: number Black-throated Divers per cell; model: Model: (Intercept), AUTOlog, Vantagepoint, MINdepth, offset = detectability_function AIC=2559.677			
(Intercept)	3527.117	1	<0.001
AUTOlog	399.034	1	<0.001
MINdepth	51.259	6	<0.001
Vantagepoint	27.137	11	0.004
5) dependent variable: presence of Black-throated Divers at high tide; Model: (Intercept), MINdepth, AUTOlog, offset = detectability_function. AIC=798.635			
(Intercept)	1162.473	1	<0.001
MINdepth	21.534	7	0.003
AUTOlog	230.535	1	<0.001
6) dependent variable number Great Northern Divers per cell; model: (Intercept), MINdepth, AUTOlog, offset = detectability_function. AIC=1752.347			
(Intercept)	1543.918	1	<0.001
MINdepth	38.239	7	<0.001

	Wald Chi-square	d.f.	p
AUTOlog	256.548	1	<0.001
7) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, offset = detectability_function. AIC=1756.635			
(Intercept)	6232.047	1	<0.001
AUTOlog	161.107	1	<0.001
MAXDepth	58.447	7	<0.001
8) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, Vantagepoint, offset = detectability_function. AIC=1756.493			
(Intercept)	5469.330	1	<0.001
AUTOlog	143.118	1	<0.001
MAXDepth	67.870	7	<0.001
Vantagepoint	22.141	11	0.023
9) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, MHWMwithin1km, offset = detectability_function. AIC=1750.081			
(Intercept)	6208.269	1	<0.001
AUTOlog	162.766	1	<0.001
MAXDepth	33.063	7	<0.001
MHWMwithin1km	8.553	1	0.003
10) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, DistMHWM, offset = detectability_function. AIC=1751.952			
(Intercept)	5979.505	1	<0.001
AUTOlog	158.663	1	<0.001
MAXDepth	38.218	7	<0.001
DLdistMHWM	6.682	1	.010

Table 8: Parameter estimates for various GLMs referred to in text. Models based on grid cells. Variables are MINdepth (minimum water depth, categorical data); MAXDepth (maximum water depth; categorical); AUTOlog (auto logistic term, see methods); distMHWM (distance to mean high water mark), MHWMwithin1km (length of shoreline within 1km radius) and VantagePoint (Survey location, categorical data).

Parameter	Parameter estimate	SE	Lower 95% CI	Upper 95% CI	Wald Chi Square	df	p
1) dependent variable: number Black-throated Divers per cell; model: (Intercept), MINdepth, AUTOlog, offset = detectability_function. AIC=2568.923.							
(Intercept)	-30.610	1.0864	-32.740	-28.481	793.857	1	<0.0001
MINdepth=-10.0	26.934	1.1139	24.751	29.118	584.645	1	<0.0001
MINdepth=.0	27.718	1.0989	25.564	29.872	636.166	1	<0.0001
MINdepth=2.0	27.379	1.0998	25.224	29.535	619.786	1	<0.0001
MINdepth=5.0	27.703	1.0913	25.564	29.842	644.358	1	<0.0001
MINdepth=10.0	27.371	1.0937	25.227	29.515	626.297	1	<0.0001
MINdepth=15.0	26.278	1.1323	24.059	28.498	538.579	1	<0.0001
MINdepth=20.0	25.294	.	.	.	.	.	
MINdepth=30.0	0	.	.	.	.	.	
AUTOlog	.009	.0005	.008	.010	376.337	1	<0.0001

Parameter	Parameter estimate	SE	Lower 95% CI	Upper 95% CI	Wald Chi Square	df	p
2) dependent variable: number Black-throated Divers per cell; model: (Intercept), MINdepth, MAXDepth, AUTOlog, offset = detectability_function. AIC=2563.733							
(Intercept)	-30.431	1.4268	-33.227	-27.634	454.873	1	.000
MINdepth=-10.0	26.513	1.3736	23.821	29.206	372.549	1	.000
MINdepth=.0	27.095	1.3572	24.435	29.755	398.543	1	.000
MINdepth=2.0	26.632	1.3464	23.993	29.271	391.267	1	.000
MINdepth=5.0	26.861	1.3372	24.240	29.482	403.498	1	.000
MINdepth=10.0	26.443	1.3400	23.817	29.069	389.433	1	.000
MINdepth=15.0	25.532	1.3675	22.852	28.213	348.605	1	.000
MINdepth=20.0	25.980	.	.	.	.	.	.
MINdepth=30.0	0	.	.	.	.	.	.
MAXDepth=.0	-26.712	483684.7	-948031.3	947977.9	.000	1	1.000
MAXDepth=2.0	-.021	1.2357	-2.443	2.401	.000	1	.986
MAXDepth=5.0	.575	1.2028	-1.782	2.933	.229	1	.632
MAXDepth=10.0	.627	1.1810	-1.688	2.941	.282	1	.596
MAXDepth=15.0	.806	1.1782	-1.504	3.115	.467	1	.494
MAXDepth=20.0	.726	1.1909	-1.609	3.060	.371	1	.542
MAXDepth=30.0	-1.097	1.3389	-3.721	1.528	.671	1	.413
MAXDepth=50.0	0	.	.	.	.	.	.
AUTOlog	.009	.0005	.008	.010	360.898	1	.000
3) dependent variable: number Black-throated Divers per cell; model: (Intercept), AUTOlog, Vantagepoint, offset = detectability_function. AIC=2605.295							
(Intercept)	-3.078	.1878	-3.446	-2.710	268.704	1	.000
AUTOlog	.009	.0005	.008	.010	369.321	1	.000
Vantagepoint=1.0	-.127	.2705	-.657	.403	.220	1	.639
Vantagepoint=2.0	.171	.2536	-.326	.668	.453	1	.501
Vantagepoint=3.0	-.269	.2345	-.729	.191	1.316	1	.251
Vantagepoint=4.0	-.359	.3092	-.965	.247	1.347	1	.246
Vantagepoint=5.0	-.773	.3722	-1.503	-.044	4.316	1	.038
Vantagepoint=6.0	-.101	.3236	-.736	.533	.098	1	.754
Vantagepoint=7.0	.127	.2470	-.357	.611	.263	1	.608
Vantagepoint=8.0	.145	.2531	-.351	.641	.330	1	.566
Vantagepoint=9.0	-.841	.4198	-1.664	-.018	4.012	1	.045
Vantagepoint=10.0	-.474	.3339	-1.128	.181	2.015	1	.156
Vantagepoint=11.0	.109	.2976	-.474	.692	.134	1	.714
Vantagepoint=12.0	0	.	.	.	.	.	.
4) dependent variable: number Black-throated Divers per cell; model: Model: (Intercept), AUTOlog, Vantagepoint, MINdepth, offset = detectability_function AIC=2559.677							
(Intercept)	-30.723	1.1100	-32.898	-28.547	766.131	1	.000
AUTOlog	.009	.0005	.008	.010	292.984	1	.000
Vantagepoint=1.0	-.024	.2789	-.571	.523	.007	1	.932
Vantagepoint=2.0	.401	.2671	-.123	.924	2.252	1	.133
Vantagepoint=3.0	-.096	.2440	-.574	.383	.153	1	.695
Vantagepoint=4.0	-.465	.3502	-1.151	.222	1.760	1	.185
Vantagepoint=5.0	-.671	.3854	-1.427	.084	3.034	1	.082
Vantagepoint=6.0	.375	.3444	-.300	1.050	1.187	1	.276
Vantagepoint=7.0	.386	.2592	-.122	.894	2.214	1	.137
Vantagepoint=8.0	.458	.2682	-.068	.983	2.911	1	.088
Vantagepoint=9.0	-.590	.4365	-1.445	.266	1.825	1	.177
Vantagepoint=10.0	-.055	.3504	-.741	.632	.024	1	.876
Vantagepoint=11.0	.116	.3097	-.491	.723	.141	1	.707

Parameter	Parameter estimate	SE	Lower 95% CI	Upper 95% CI	Wald Chi Square	df	p
Vantagepoint=12.0	0	.	.	.	.	.	.
MINdepth=-10.0	27.047	1.1171	24.858	29.237	586.267	1	.000
MINdepth=.0	27.969	1.1054	25.803	30.136	640.202	1	.000
MINdepth=2.0	27.498	1.1032	25.336	29.661	621.319	1	.000
MINdepth=5.0	27.809	1.0962	25.661	29.958	643.613	1	.000
MINdepth=10.0	27.434	1.0973	25.283	29.585	625.090	1	.000
MINdepth=15.0	26.225	1.1327	24.005	28.445	536.019	1	.000
MINdepth=20.0	25.231	.	.	.	.	.	.
MINdepth=30.0	0	.	.	.	.	.	.
5) dependent variable: presence of Black-throated Divers at high tide; Model: (Intercept), MINdepth, AUTOlog, offset = detectability_function. AIC=798.635							
(Intercept)	4.829	.4693	3.910	5.749	105.884	1	.000
MINdepth=-10.0	17.709	15892.3	-31130.6	31166.0	.000	1	.999
MINdepth=.0	17.733	5672.8	-11100.8	11136.3	.000	1	.998
MINdepth=2.0	1.183	.8481	-.479	2.845	1.945	1	.163
MINdepth=5.0	.278	.5429	-.786	1.342	.263	1	.608
MINdepth=10.0	-.489	.4880	-1.445	.468	1.003	1	.317
MINdepth=15.0	-.203	.5504	-1.281	.876	.135	1	.713
MINdepth=20.0	-.887	.5272	-1.921	.146	2.832	1	.092
MINdepth=30.0	0	.	.	.	.	.	.
AUTOlog	-.058	.0039	-.066	-.051	219.296	1	.000
6) dependent variable number Great Northern Divers per cell; model: (Intercept), MINdepth, AUTOlog, offset = detectability_function. AIC=1752.347							
(Intercept)	-3.295	.1671	-3.622	-2.967	389.002	1	.000
MINdepth=30.0	.010	1.0137	-1.977	1.996	.000	1	.992
MINdepth=20.0	-2.032	1.0137	-4.019	-.045	4.019	1	.045
MINdepth=15.0	-1.454	.4127	-2.263	-.645	12.417	1	.000
MINdepth=10.0	-.694	.2457	-1.176	-.213	7.982	1	.005
MINdepth=5.0	-.033	.1836	-.392	.327	.032	1	.859
MINdepth=2.0	.144	.2187	-.285	.572	.432	1	.511
MINdepth=.0	-.141	.2250	-.582	.300	.393	1	.531
MINdepth=-10.0	0	.	.	.	.	.	.
AUTOlog	.010	.0006	.009	.011	262.972	1	.000
7) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, offset = detectability_function. AIC=1756.635							
(Intercept)	-5.592	1.0111	-7.574	-3.610	30.586	1	.000
AUTOlog	.010	.0006	.009	.011	258.267	1	.000
MAXDepth=50.0	1.117	1.4217	-1.670	3.903	.617	1	.432
MAXDepth=30.0	.592	1.1639	-1.690	2.873	.258	1	.611
MAXDepth=20.0	1.062	1.0479	-.992	3.116	1.027	1	.311
MAXDepth=15.0	1.918	1.0191	-.079	3.916	3.543	1	.060
MAXDepth=10.0	2.451	1.0083	.474	4.427	5.907	1	.015
MAXDepth=5.0	2.132	1.0167	.139	4.125	4.397	1	.036
MAXDepth=2.0	2.353	1.0197	.354	4.351	5.324	1	.021
MAXDepth=.0	0	.	.	.	.	.	.
8) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, Vantagepoint, offset = detectability_function. AIC=1756.493							
(Intercept)	-5.919	1.0427	-7.962	-3.875	32.221	1	.000
AUTOlog	.010	.0007	.009	.012	203.562	1	.000

Parameter	Parameter estimate	SE	Lower 95% CI	Upper 95% CI	Wald Chi Square	df	p
MAXDepth=50.0	1.497	1.4410	-1.327	4.321	1.079	1	.299
MAXDepth=30.0	.632	1.1768	-1.674	2.939	.289	1	.591
MAXDepth=20.0	1.202	1.0581	-.872	3.276	1.291	1	.256
MAXDepth=15.0	2.137	1.0290	.121	4.154	4.315	1	.038
MAXDepth=10.0	2.736	1.0202	.737	4.736	7.193	1	.007
MAXDepth=5.0	2.256	1.0208	.255	4.256	4.883	1	.027
MAXDepth=2.0	2.570	1.0293	.553	4.588	6.236	1	.013
MAXDepth=.0	0	.	.	.	.	.	.
Vantagepoint=12.0	-.241	.3117	-.852	.370	.596	1	.440
Vantagepoint=11.0	.073	.3356	-.585	.731	.047	1	.828
Vantagepoint=10.0	.449	.2951	-.129	1.028	2.318	1	.128
Vantagepoint=9.0	.213	.3344	-.442	.868	.406	1	.524
Vantagepoint=8.0	.490	.2943	-.086	1.067	2.776	1	.096
Vantagepoint=7.0	.305	.2693	-.223	.832	1.279	1	.258
Vantagepoint=6.0	.535	.2999	-.053	1.122	3.177	1	.075
Vantagepoint=5.0	.337	.2817	-.215	.889	1.431	1	.232
Vantagepoint=4.0	-.175	.3472	-.856	.505	.255	1	.614
Vantagepoint=3.0	-.357	.2541	-.855	.141	1.973	1	.160
Vantagepoint=2.0	-.032	.3378	-.694	.630	.009	1	.925
Vantagepoint=1.0	0	.	.	.	.	.	.
9) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, MHWMwithin1km, offset = detectability_function. AIC=1750.081							
(Intercept)	-6.070	1.0244	-8.078	-4.062	35.109	1	.000
AUTOlog	.010	.0006	.009	.011	257.995	1	.000
MAXDepth=50.0	1.405	1.4248	-1.387	4.198	.973	1	.324
MAXDepth=30.0	.910	1.1684	-1.380	3.200	.606	1	.436
MAXDepth=20.0	1.391	1.0533	-.673	3.455	1.744	1	.187
MAXDepth=15.0	2.053	1.0195	.054	4.051	4.053	1	.044
MAXDepth=10.0	2.431	1.0081	.455	4.407	5.813	1	.016
MAXDepth=5.0	2.063	1.0169	.070	4.056	4.117	1	.042
MAXDepth=2.0	2.283	1.0196	.284	4.281	5.013	1	.025
MAXDepth=.0	0	.	.	.	.	.	.
MHWMwithin1km	.000	5.0033E-5	5.008E-5	.000	8.767	1	.003
10) dependent variable: number Great Northern Divers per cell; model: (Intercept), AUTOlog, MAXDepth, DistMHWM, offset = detectability_function. AIC=1751.952							
(Intercept)	-5.558	1.0111	-7.540	-3.577	30.221	1	.000
AUTOlog	.010	.0006	.009	.011	252.135	1	.000
MAXDepth=50.0	1.647	1.4349	-1.166	4.459	1.317	1	.251
MAXDepth=30.0	1.179	1.1843	-1.142	3.501	.992	1	.319
MAXDepth=20.0	1.709	1.0771	-.402	3.820	2.518	1	.113
MAXDepth=15.0	2.343	1.0318	.320	4.365	5.155	1	.023
MAXDepth=10.0	2.673	1.0120	.690	4.656	6.977	1	.008
MAXDepth=5.0	2.222	1.0173	.228	4.216	4.772	1	.029
MAXDepth=2.0	2.420	1.0197	.422	4.419	5.634	1	.018
MAXDepth=.0	0	.	.	.	.	.	.
DistMHWM	-.001	.0003	-.001	.000	6.375	1	.012

Further information

Natural England evidence can be downloaded from our **Access to Evidence Catalogue**. For more information about Natural England and our work see **Gov.UK**. For any queries contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk** .

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