Marine Institute

Bannow Bay Special Protection Area:

Updated Assessment of Potential Displacement Impacts

July 2017

ATKINS

Marine Institute Bird Studies

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We are grateful to Hookhead Shellfish Ltd. for giving us permission to use the data from the Bird Survey Ireland 2014/15 and 2015/16 waterbird surveys, and to Bird Survey Ireland for providing us with this data.

1. Introduction

1.1 Atkins (Ecology) was commissioned by the Marine Institute to provide ornithological services in relation to the appropriate assessment of aquaculture and shellfisheries on coastal Special Protection Areas (SPAs).

1.2 In 2016, Atkins (Ecology) prepared an Appropriate Assessment report (referred to hereafter as the AA Report) on the impact of aquaculture in Bannow Bay (Gittings and O'Donoghue, 2016a). In this report we concluded that there is potential for the development of the aquaculture sites within Bannow Bay to cause:

- high levels of displacement (9-13%) to the Bannow Bay Grey Plover, Dunlin and Bar-tailed Godwit populations;
- significant, or near-significant, displacement levels of around 5% to the Bannow Bay Light-bellied Brent Goose, Curlew and Redshank populations;
- measurable but non-significant displacement levels of 1.3-3.5% to the Bannow Bay Lapwing, Knot and Black-tailed Godwit populations; and
- and negligible displacement levels of 0.1-0.2% to the Bannow Bay Shelduck and Golden Plover populations.

1.3 However, due to the limited data available on waterbird distribution within Bannow Bay, and, in some cases, uncertainty about the nature of species responses to intertidal oyster cultivation, we considered that there was:

> *a high level of uncertainty to these predictions. Therefore, the actual displacement levels to these species could be significantly less than predicted. Conversely the displacement levels to these species could be significantly greater than predicted.*

1.4 Waterbird surveys were carried out in the winters of 2014/15 and 2015/16 by Bird Survey Ireland for Hook Head Shellfish (Bird Survey Ireland, 2015, 2016), but the data from these surveys were not available to us at the time that we prepared the AA Report. This data has now been made available to us.

1.5 The purpose of the present report is to use the 2014/15 and 2015/16 data to update the assessment in Section 8 of AA Report of the potential displacement impacts to wintering waterbird species that are Special Conservation Interests of the Bannow Bay SPA (excluding Pintail). This report does not address the other species that are assessed in Section 9 of the AA Report.

1.6 The report contains an updated analysis of waterbird distribution patterns in Bannow Bay. This analysis considers whether there is any evidence that the expansion in trestle occupancy in recent years has caused detectable displacement impacts.

1.7 The report also contains an updated assessment of potential displacement impacts. The results of the waterbird distribution analyses have been used to help inform the interpretation of the predicted displacement impacts.

1.8 This report is a supplement to the AA Report and should be read in conjunction with that report.

1.9 This report refers to the results of a study on the interaction between waterbird distribution and oyster trestles (the trestle study), which were initially published as a report for the Marine Institute (Gittings and O'Donoghue, 2011; referred to hereafter as the trestle study report), with the key results being subsequently published as a peer-reviewed paper in the journal *Wader Study* (Gittings and O'Donoghue, 2016b).

2. Methodology

General

2.1 This report is an update of the assessment presented in the AA Report, and that report should be consulted for full details of data sources, general methodology, etc.

2.2 The additional data sources used in the present report are:

- Revised classification of the status of the aquaculture sites.
- Waterbird counts carried out by Bird Survey Ireland in the winters of 2014/15 and 2015/16 (referred to hereafter as the BSI counts).

Aquaculture sites

2.3 The classification of the aquaculture sites has been revised to separate the sites into applications for renewals of licensed sites (renewal sites), applications to convert trial sites to full licences (trial sites), and applications for licences for new sites (application sites). This revised classification has been used in the present report.

2.4 The revised classification of the sites is shown in Figure 2.1. The classification of the sites used in the AA Report is compared with the revised classification in Table 2.1.

Table 2.1 - Revised classification of aquaculture sites in Bannow Bay.

Site	Classification used in AA Report	Classification used in present report
T03/068A	Application	Application
T03/086A	Application	Application
T03/086B	Application	Application
T03/086C	Application	Application
T03/087A	Application	Application
T03/087B	Application	Application
T03/087C	Application	Application
T03/087D	Application	Application
T03/088A	Application	Application
T03/088B	Application	Application
T03/088C	Application	Application
T03/089A	Application	Application
T03/025A	Renewal	Renewal
T03/025B	Renewal	Renewal
T03/031A	Renewal	Renewal
T03/031B	Renewal	Renewal
T03/032A	Renewal	Renewal
T03/032B	Renewal	Renewal
T03/041A	Renewal	Renewal
T03/041B	Renewal	Renewal
T03/025/1A	Application	Trial

Site	Classification used in AA Report	Classification used in present report
T03/031/1A	Renewal	Trial
T03/032/1A	Application	Trial
T03/041/1A	Application	Trial
T03/041/1B	Application	Trial

Waterbird survey datasets

2.5 The waterbird survey datasets used in this report are:

- NPWS bird usage counts, carried out in the winter of 1998/99 (bird usage counts). These counts were used to draw up a bird usage map that was included in a draft conservation plan for the Bannow Bay SPA. However, this conservation plan was never finalised.
- Waterbird Survey Programme counts carried out in the winter of 2009/10 (WSP counts). These counts were carried out as part of a programme of waterbird counts covering all the major coastal wintering waterbird SPAs and the results of the counts were used to inform the development of conservation objectives for these SPAs.
- Counts carried out as part of a study on waterbird interactions with oyster trestles in the winter of 2010/11 (trestle study counts). This study was commissioned by the Marine Institute with the objective of providing data that could be used to assess the potential impact of intertidal oyster cultivation on waterbirds.
- Bird Survey Ireland waterbird counts carried out in the winters of 2014/15 and 2015/16 (BSI counts). These counts were commissioned by Hookhead Shellfish Ltd.

2.6 Relevant details about the timings and methodologies of the NPWS bird usage counts, the Waterbird Survey Programme counts, and the trestle study counts are included in the AA Report.

2.7 The Bird Survey Ireland waterbird counts were carried out in the winters of 2014/15 and 2015/16, following the same methodology as the Waterbird Survey Programme (WSP) counts from 2009/10. In each winter four low tide, and one high tide, counts were carried out. The dates, and tidal conditions, during the BSI counts are compared with those during the WSP counts in Table 2.2.

2.8 Flock mapping was carried out for the BSI counts, as for the WSP counts. However, only incomplete flock mapping data from the BSI counts was available to us for this assessment.

Table 2.2 - Count dates and tidal conditions for the 2009/10, 2014/15 and 2015/16 waterbird counts.

Season	Count	Date	Low/high tide time	Low/high tide height (m)
2009/10	LT1	08/10/2009	14:48	0.9
	LT2	18/11/2009	12:20	0.9
	LT3	16/12/2009	11:30	1.0
	LT4	12/02/2010	11:05	1.0
	HT	25/02/2010	14:34	3.4
2014/15	LT1	24/10/2014	12:34	0.8
	LT2	25/11/2014	13:16	0.4
	LT3	12/12/2014	15:13	1.4
	LT4	05/02/2015	12:40	0.8
	HT	17/01/2015	14:43	3.6
2015/16	LT1	16/10/2015	14:09	1.0
	LT2	16/11/2015	14:14	1.2
	LT3	15/12/2015	14:04	1.0
	LT4	23/02/2016	12:22	0.6
	HT	18/01/2016	11:57	3.6

Two high tide counts were carried out in 2009/10. The first count, in January 2010, was affected by fog, so the count was repeated in February 2010.

Analyses of waterbird distribution

2.9 Waterbird distribution has been mainly analysed by calculating the mean percentage distribution count data across subsites and/or zones in the bird usage counts, BSI, WSP and trestle study datasets. For the analyses from the WSP and BSI datasets we used the low tide counts only (unless otherwise stated). We also excluded counts from non-tidal habitats as these counts did not cover all the non-tidal habitat potentially used around Bannow Bay.

2.10 For calculations of percentage distributions we have excluded counts with exceptionally low numbers, because inclusion of such counts would be likely to bias the analyses: when very low numbers are present, very small numbers of birds in a zone/subsite will result in high percentage occupancy. We defined cut-offs for exclusion of less than 10 birds for Grey Plover, or less than 100 birds for all other species. The lower cut-off for Grey Plover was due to the much lower overall numbers of this species that occur in Bannow Bay. These criteria resulted in the exclusion of three counts of Shelduck and one count of Golden Plover from the combined BSI/WSP dataset.

2.11 For analysing broad distribution patterns, the WSP/BSI subsites have been amalgamated into three broad zones: the Lower Estuary, the Middle Estuary and the Upper Estuary (Figure 2.2). The sectors used for the bird usage counts have been similarly amalgamated into three broad zones that correspond approximately to the zones used for analysing the WSP counts (Figure 2.3). For comparison with the WSP/BSI counts, the sectors used for the trestle study counts have been divided into two groups that correspond approximately to subsites 0O416 and 0O418 (Figure 2.4).

2.12 To compare between datasets, we corrected the percentage distributions for differences in the relative areas of the zones. We first calculated adjusted percentage distributions for the bird usage and trestle study counts ($adj\%dist_{zone\text{-}bu}$ and $adj\%dist_{zone\text{-}ts}$) using the following formulas: -

$$adj\%dist_{zone\text{-}bu(raw)} = (\%dist_{zone\text{-}bu} \times \%area_{zone\text{-}bu}/\%area_{zone\text{-}wsp})$$

$$adj\%dist_{zone\text{-}ts(raw)} = (\%dist_{zone\text{-}ts} \times \%area_{zone\text{-}ts}/\%area_{zone\text{-}wsp})$$

where $\%dist_{zone\text{-}bu(raw)}$ and $\%dist_{zone\text{-}ts(raw)}$ are the mean percentage distributions of the waterbird species in the zone in the bird usage (bu) and trestle study (ts) counts, respectively; $\%area_{zone\text{-}bu}$ and $\%area_{zone\text{-}bu}$ are the percentages of the total area counted occupied by the zone, as defined for the bird usage and trestle study counts, respectively; and $\%area_{zone\text{-}wsp}$ is the percentage of the total area counted occupied by the zone, as defined for the WSP counts. We then standardised the raw adjusted percentages so that, for each species, they totalled 100%, using the following formulas:

$$adj\%dist_{zone\text{-}bu(stand)} = adj\%dist_{zone\text{-}bu(raw)}/adj\%dist_{sum\text{-}bu(raw)}$$

$$adj\%dist_{zone\text{-}ts(stand)} = adj\%dist_{zone\text{-}ts(raw)}/adj\%dist_{sum\text{-}ts(raw)}$$

where $adj\%dist_{sum\text{-}bu(raw)}$ and $adj\%dist_{sum\text{-}ts(raw)}$ are the sums of the raw adjusted percentages across all the zones for the bird usage and trestle study counts, respectively.

2.13 For comparison of the bird usage and WSP/BSI counts, we excluded the subsite 0O410 (see Figure 2.3) from the calculations of percentage areas and percentage distributions in the WSP/BSI counts, as this area was not covered in the bird usage counts. For this comparison, we used the total areas of the zones, rather than the intertidal areas, because there were major changes in the distribution of the intertidal habitat in the bay between the two counts.

2.14 We restricted the comparison of the trestle study and WSP/BSI counts to the mid and upper zones. We excluded the subsites 0O417 and 0O418 from the calculations of percentage areas and percentage distributions in the WSP/BSI counts, as these areas were not covered in the trestle study counts. For this comparison we used areas of intertidal habitat.

2.15 In addition, WSP and BSI flock map data, and observations from our site visits (see AA Report), have also been used to inform our interpretation of the distribution patterns.

Assessment of displacement impacts

2.16 The potential displacement impact has been quantified as the predicted percentage of the total Bannow Bay population that will be displaced from the area occupied by the trestles. The basic method of calculation is simple and uses the following formula:

$$\text{displacement} = occ_{bird} * occ_{trestle}$$

where occ_{bird} (bird occupancy) is the mean percentage of the total Bannow Bay population that occurs within the subsite(s) containing the trestles and $occ_{trestle}$ (trestle occupancy) is the percentage of intertidal habitat within the subsite(s) that will be occupied by the trestles under the scenario being assessed.

2.17 We used the combined WSP/BSI dataset to calculate bird occupancy data, but excluded counts with exceptionally low numbers, where relevant. Therefore, the total sample size was n = 12 counts, except Shelduck (n = 9 counts) and Golden Plover (n = 11 counts). We also excluded counts of birds in non-tidal habitats from calculations of occupancy levels, because, due to the incomplete coverage of non-tidal habitats around Bannow Bay, inclusion of such counts may have biased the analyses.

2.18 Where the subsite(s) already contain trestles, the potential for existing displacement impacts need to be taken into account, by calculating a corrected bird occupancy level ($occ_{bird(corrected)}$) using the following formula:

$$occ_{bird(corrected)} = occ_{bird} * 1/(1-occ_{trestle(existing)})$$

where $occ_{trestle(existing)}$ is the existing level of trestle occupancy at the time the bird occupancy data was collected.

2.19 We assumed that the 2009 trestle mapping represented the trestle occupancy during the WSP counts, and that the 2015 trestle mapping represented the trestle occupancy during the BSI counts, and we used the following formula to calculate $occ_{bird(corrected)}$:

$$occ_{bird(corrected),comb} = (1/(1-occ_{trestle(existing),WSP}) * n_{WSP} + 1/(1-occ_{trestle(existing),BSI}) * n_{BSI}) / (n_{WSP} + n_{BSI})$$

where $occ_{trestle(existing),WSP}$ is the existing level of trestle occupancy from the 2009 trestle mapping, $occ_{trestle(existing),BSI}$ is the existing level of trestle occupancy from the 2015 trestle mapping, n_{WSP} is the number of counts included in the analysis from the WSP dataset and n_{BSI} is the number of counts included in the analysis from the BSI dataset.

2.20 We also calculated 95% confidence intervals for the predicted displacement impacts. We did this by calculating the 95% confidence intervals for the mean bird occupancy levels, and then applying the above correction factors to the upper and lower confidence limits. Where the corrected confidence limits were less than zero, or greater than one, they was adjusted to zero, or one, respectively, to avoid ecologically meaningless figures.

2.21 We considered three scenarios of aquaculture development:

- Full occupation of the renewal sites (the renewal site scenario).
- Full occupation of the renewal and trial sites (the renewal/trial sites scenario).
- Full occupation of the renewal, trial and application sites (the all sites scenario).

2.22 We also calculated displacement impacts separately for three separate spatial scales of analysis:

- Using data on bird occupancy levels from 0O413 only.
- Using combined data on bird occupancy levels from 0O413 and 0O416.
- Using combined data on bird occupancy levels from 0O413, 0O416 and 0O418.

2.23 These three scales of analysis each have their advantages and disadvantages. Using larger scales for the analysis will tend to smooth out the random fluctuations in occupancy levels, which will be more significant at the smaller scales. The larger scales are also less likely to be affected by any displacement that is already occurring due to the existing levels of trestle occupancy. However, the larger scales of analysis may result in high occupancy levels for species that do not use the area around the aquaculture sites due to unsuitable habitat conditions, and/or some other factor unrelated to the presence of trestles.

2.24 The area occupied by the aquaculture sites in 0O413 is contiguous with similar habitat in 0O416, while it is separated from 0O418 by the main tidal channel and by a large area of sandflat that appears to be unfavourable habitat for most species. Therefore, for the purposes of this assessment, 0O413 and 0O416 is a more natural grouping than 0O413 and 0O418, so it has been chosen as the intermediate spatial scale for the analyses.

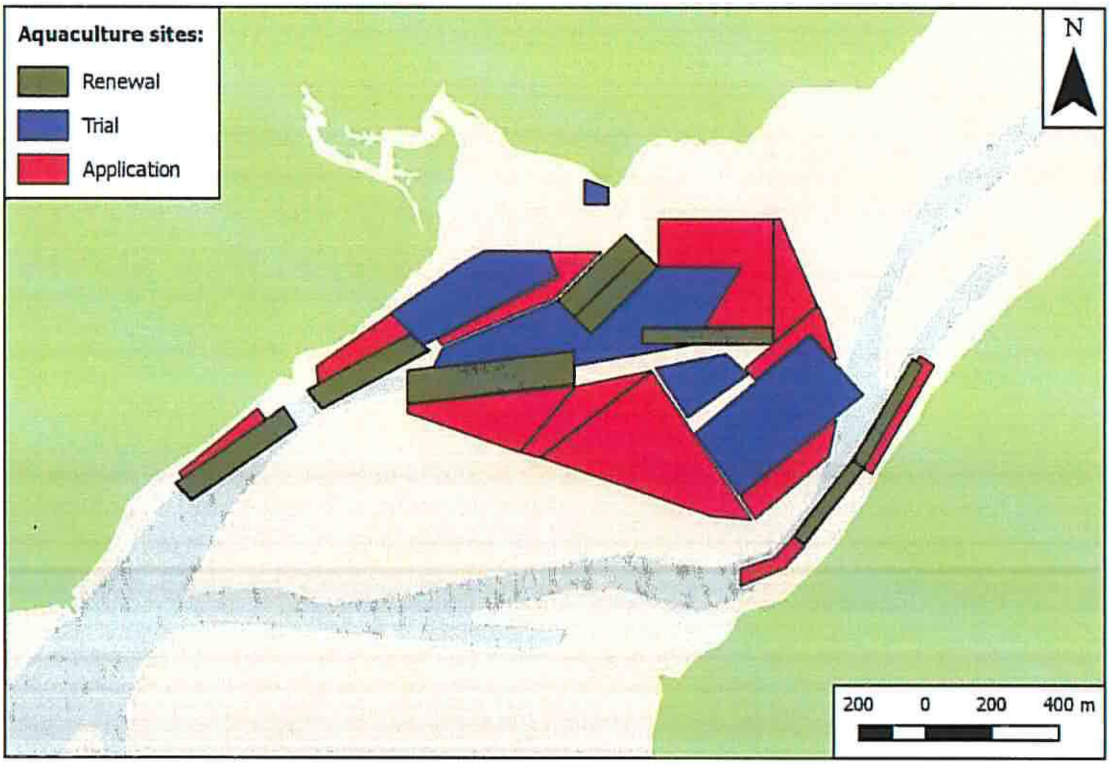


Figure 2.1 - Revised classification of aquaculture sites in Bannow Bay.

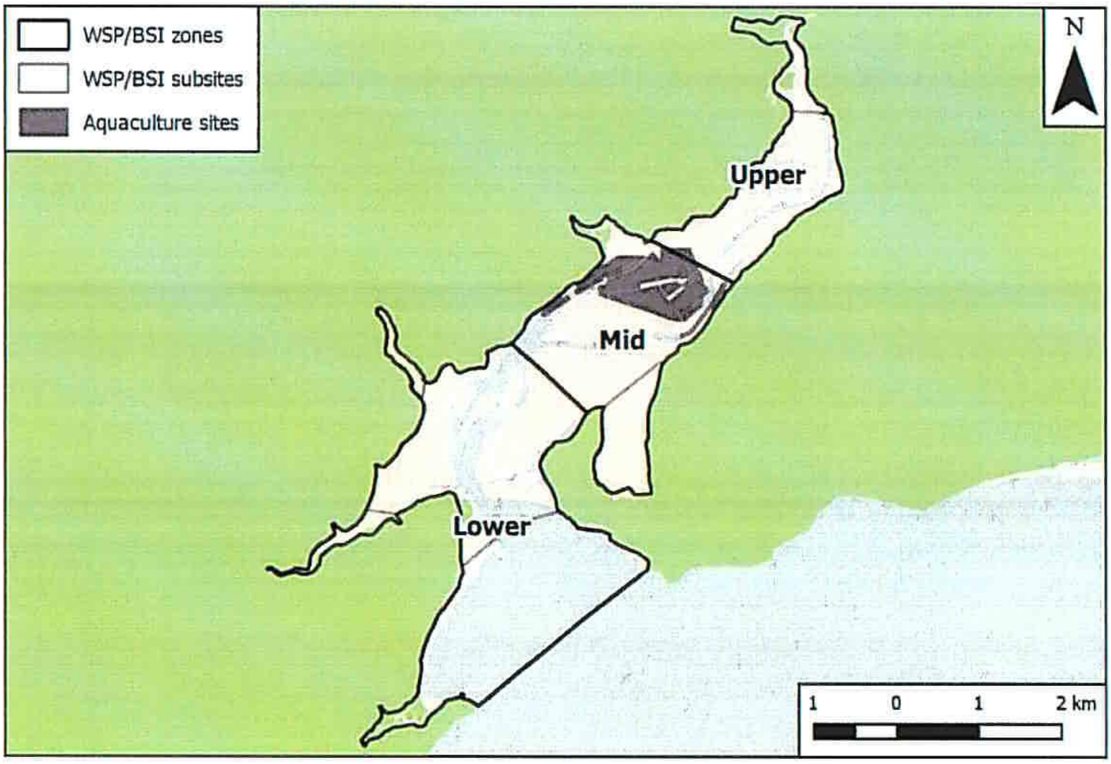


Figure 2.2 - Broad zones used to analyse the WSP and BSI count data.

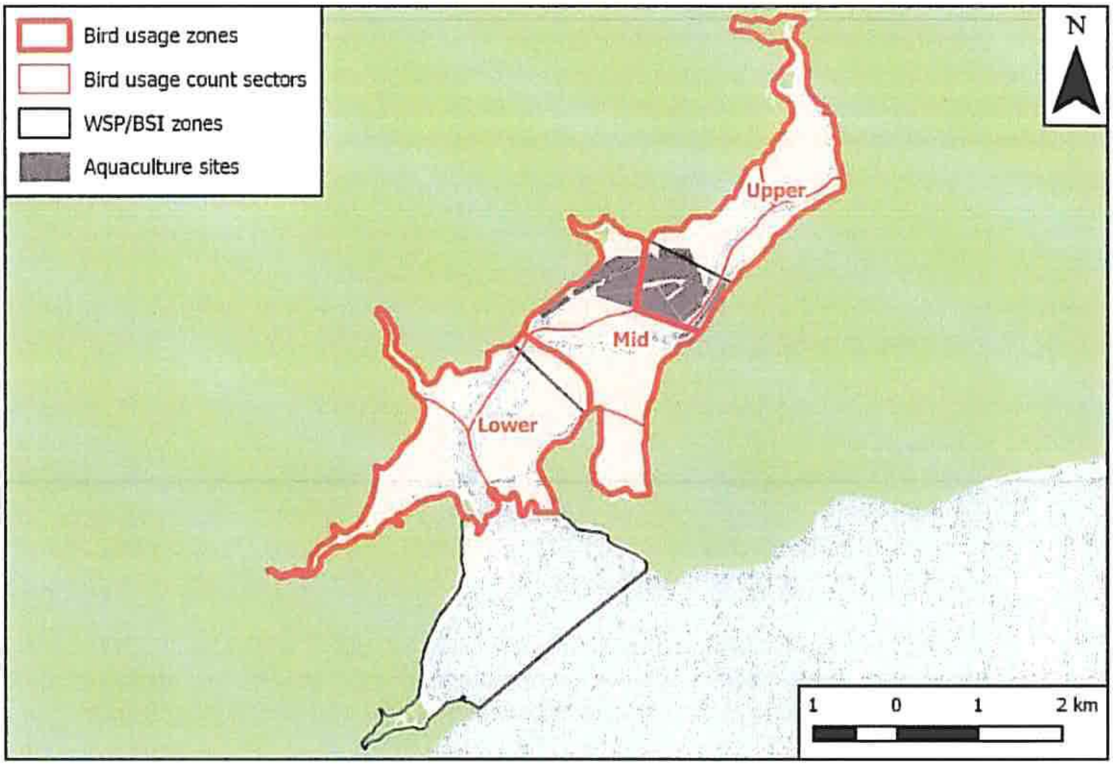


Figure 2.3 - Broad zones used to analyse the 1998/99 bird usage counts.

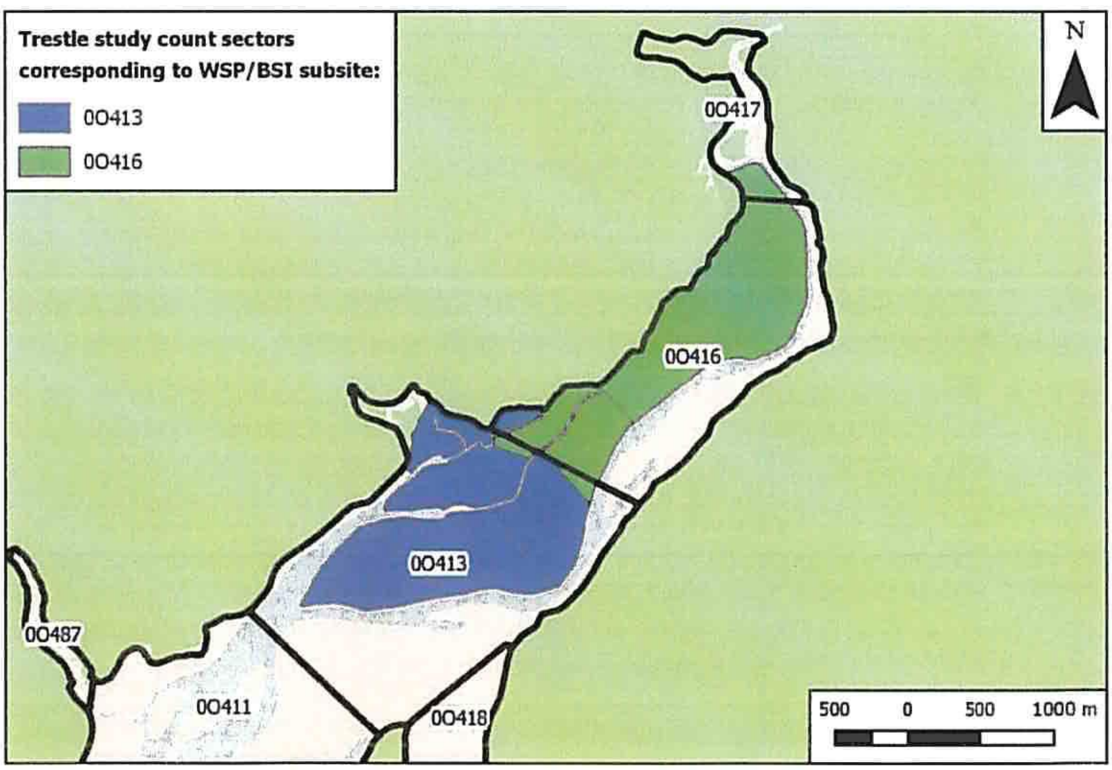


Figure 2.4 - Correspondence between sectors used in the 2011 trestle study counts and the WSP/BSI subsites.

3. Analysis of species occurrence patterns

Introduction

3.1 This section analyses species trends and distribution patterns in the BSI dataset and compares these with the other datasets analysed in the AA Report. The interpretation of the results of these analyses are discussed in Section 4 of the present report.

Species numbers

3.2 The total numbers recorded in the BSI and WSP counts across the three winters surveyed are compared in Text Figure 3.1. Shelduck, Lapwing and Curlew showed relatively similar numbers, and consistent seasonal patterns, across the three winters. Numbers of Light-bellied Brent Goose and Redshank appear to have been generally higher in 2009/10, and numbers of Knot appear to have been generally higher in 2014/15, compared to the other two winters. The other species showed a lot of variation in numbers within winters without clear differences between the winters.

3.3 The high tide counts of Grey Plover and Bar-tailed Godwit in 2009/10 and 2014/15 were noticeably higher than the low tide counts for those winters. This pattern was not shown in 2015/16, but the 2015/16 high tide count appeared to have relatively low numbers of most species.

Distribution patterns in 2009/10, 2014/14 and 2015/16

3.4 The broad patterns of distribution of the species covered by this assessment during the WSP and BSI low tide counts are summarised in Table 3.1, and their percentage occurrence in the mid zone on the individual counts in each of the winters are compared in Text Figure 3.2.

3.5 For most species, the broad distribution patterns were similar between the two winters of the BSI counts. However, Black-tailed Godwit, Knot and Dunlin all occurred in higher relative numbers in the mid zone in 2015/16, compared to 2014/15. These differences were generally consistent across the individual counts within the winters (Text Figure 3.2). For Black-tailed Godwit, there was a shift in distribution from the lower zone to the mid zone, while for Knot and Dunlin, there was a shift in distribution from the upper zone to the mid zone.

3.6 There were several differences in distribution patterns between the 2009/10 and 2014/15-2015/16 counts. Light-bellied Brent Goose and Black-tailed Godwit occurred in relatively higher numbers in the mid zone in 2014/15-2015/16. For Black-tailed Godwit, there was a shift in distribution from the lower zone to the mid zone, while for Light-bellied Brent Goose, there was a shift in distribution from the upper zone to the mid zone. Grey Plover and Bar-tailed Godwit occurred in relatively lower numbers in the mid zone in 2014/15-2015/16, with, in both cases, a shift in distribution from the mid zone to the upper zone. In the case of Grey Plover, there was a much bigger decline in its relative occurrence in subsite 0O413, compared to subsite 0O418. These differences were generally consistent across the individual counts within the winters (Text Figure 3.2).

3.7 The occupancy levels in the mid zone of some other waterbird species are shown for comparison in Text Figure 3.3. These are all species that are associated with intertidal habitat, and which regularly occur in numbers suitable for analysis in Bannow Bay.

Comparison of distribution patterns in 1998/99, 2009/10, and 2014/15-2015/16

3.8 The broad patterns of distribution of waterbird species in the bird usage, WSP and BSI datasets datasets are compared in Text Figure 3.4.

3.9 The additional data from the BSI dataset supports some of the patterns previously reported from the comparison of the bird usage and WSP datasets, including: the strong concentration of Lapwing in the upper zone, the more or less even distribution of Curlew across the three zones, and the increase since 1998/99 in relative numbers of Shelduck and Redshank in the mid zone. However, there were also some marked changes in the distribution of some species between the WSP and BSI counts, including: a shift in distribution of Light-bellied Brent Goose from the lower zone to the mid zone, a shift in distribution of Grey Plover, Bar-tailed Godwit and Dunlin from the lower (Bar-tailed Godwit and Dunlin only) and mid zones to the upper zone; and a shift in distribution of Black-tailed Godwit from the upper zone to the mid zone. However, it should be noted that the apparent shift in distribution of Bar-tailed Godwit and Dunlin is based on the average across the two winters in the BSI dataset and there were marked differences between the two winters (see above).

Comparison of distribution patterns in 2009/10, 2010/11 and 2014/15-2015/16

3.10 The study area for the 2011 trestle study counts broadly corresponded to the subsites 0O413 and 0O416 from the WSP and BSI counts. Therefore, the distribution of species between these two subsites in the three datasets are compared in Table 3.2.

3.11 Light-bellied Brent Goose, Curlew and Redshank show relatively consistent patterns of occurrence across the three series of counts. Grey Plover, Bar-tailed Godwit and Dunlin all appear to show a trend of decreasing relative occurrence in 0O413 across the three series of counts. Black-tailed Godwit shows a weak trend of increasing relative occurrence in 0O413 across the three series of counts.

Table 3.1 - Mean percentage distribution of waterbird species between the three broad zones of Bannow Bay, and within the two subsites in the mid zone, during the WSP and BSI low tide counts.

Species	Season	Lower zone	Mid zone		Upper zone
			0O413	0O418	
Light-bellied Brent Goose	2009/10	78%	15%	5%	2%
	2014/15	51%	17%	29%	3%
	2015/16	43%	22%	20%	14%
Shelduck	2009/10	20%	1%	78%	2%
	2014/15	9%	22%	44%	25%
	2015/16	8%	11%	76%	5%
Golden Plover	2009/10	33%	0%	50%	17%
	2014/15	4%	0%	2%	94%
	2015/16	3%	0%	29%	68%
Grey Plover	2009/10	12%	39%	44%	5%
	2014/15	12%	0%	21%	67%
	2015/16	6%	5%	25%	64%
Lapwing	2009/10	23%	5%	6%	66%
	2014/15	12%	1%	10%	77%

Species	Season	Lower zone	Mid zone		Upper zone
			0O413	0O418	
	2015/16	18%	2%	10%	70%
Curlew	2009/10	30%	14%	22%	34%
	2014/15	33%	11%	5%	52%
	2015/16	13%	15%	19%	53%
Black-tailed Godwit	2009/10	9%	4%	0%	86%
	2014/15	33%	5%	17%	45%
	2015/16	8%	17%	41%	34%
Bar-tailed Godwit	2009/10	15%	46%	7%	32%
	2014/15	4%	19%	1%	76%
	2015/16	4%	14%	2%	80%
Knot	2009/10	37%	11%	34%	18%
	2014/15	0%	0%	0%	99%
	2015/16	0%	11%	47%	42%
Dunlin	2009/10	35%	28%	13%	24%
	2014/15	0%	0%	0%	99%
	2015/16	12%	13%	25%	51%
Redshank	2009/10	23%	18%	35%	24%
	2014/15	32%	10%	29%	29%
	2015/16	21%	15%	40%	24%

Data sources: 2009/10 Waterbird Survey Programme as undertaken by the National Parks & Wildlife Service (2009/10 counts); counts carried out by Bird Survey Ireland (2014/15 and 2015/16 counts).

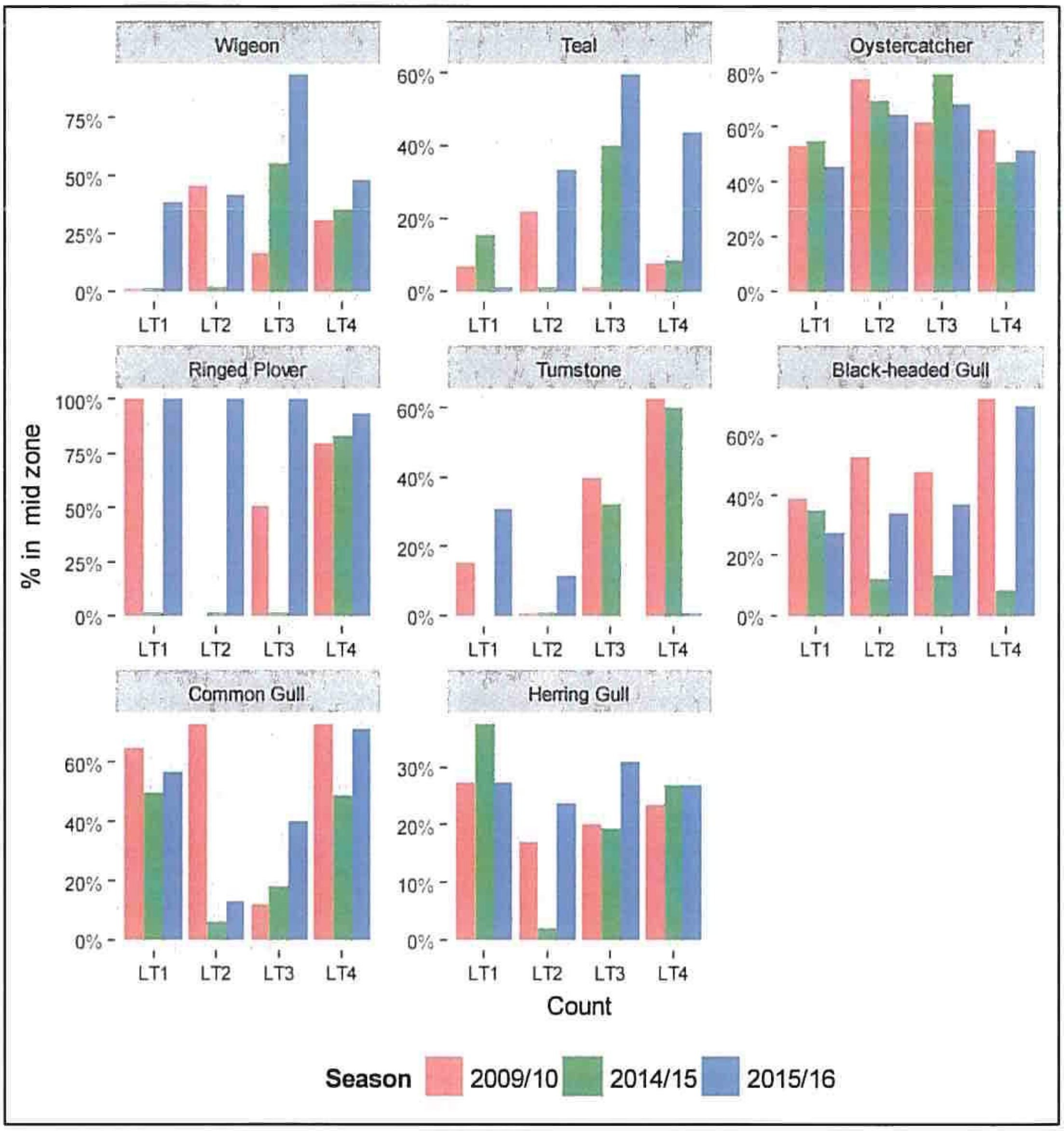
Table 3.2 - Comparison of waterbird distribution patterns in 2009/10 and 2010/11 and 2014/15-2015/16.

Species	Mean % in 0O413 and 0O416		Mean % in 0O413 out of total count for 0O413 and 0O416		
	2009/10	2014/15-2015/16	2009/10	2010/11	2014/15-2015/16
Light-bellied Brent Goose	17%	28%	94%	94%	78%
Shelduck	2%	31%	-	23%	45%
Golden Plover	17%	75%	-	-	0%
Grey Plover	43%	61%	82%	59%	6%
Lapwing	29%	40%	7%	63%	5%
Curlew	43%	51%	28%	24%	27%
Black-tailed Godwit	89%	46%	9%	19%	24%
Bar-tailed Godwit	76%	87%	61%	34%	22%
Knot	29%	76%	69%	-	8%
Dunlin	51%	73%	59%	23%	9%
Redshank	39%	36%	43%	33%	39%

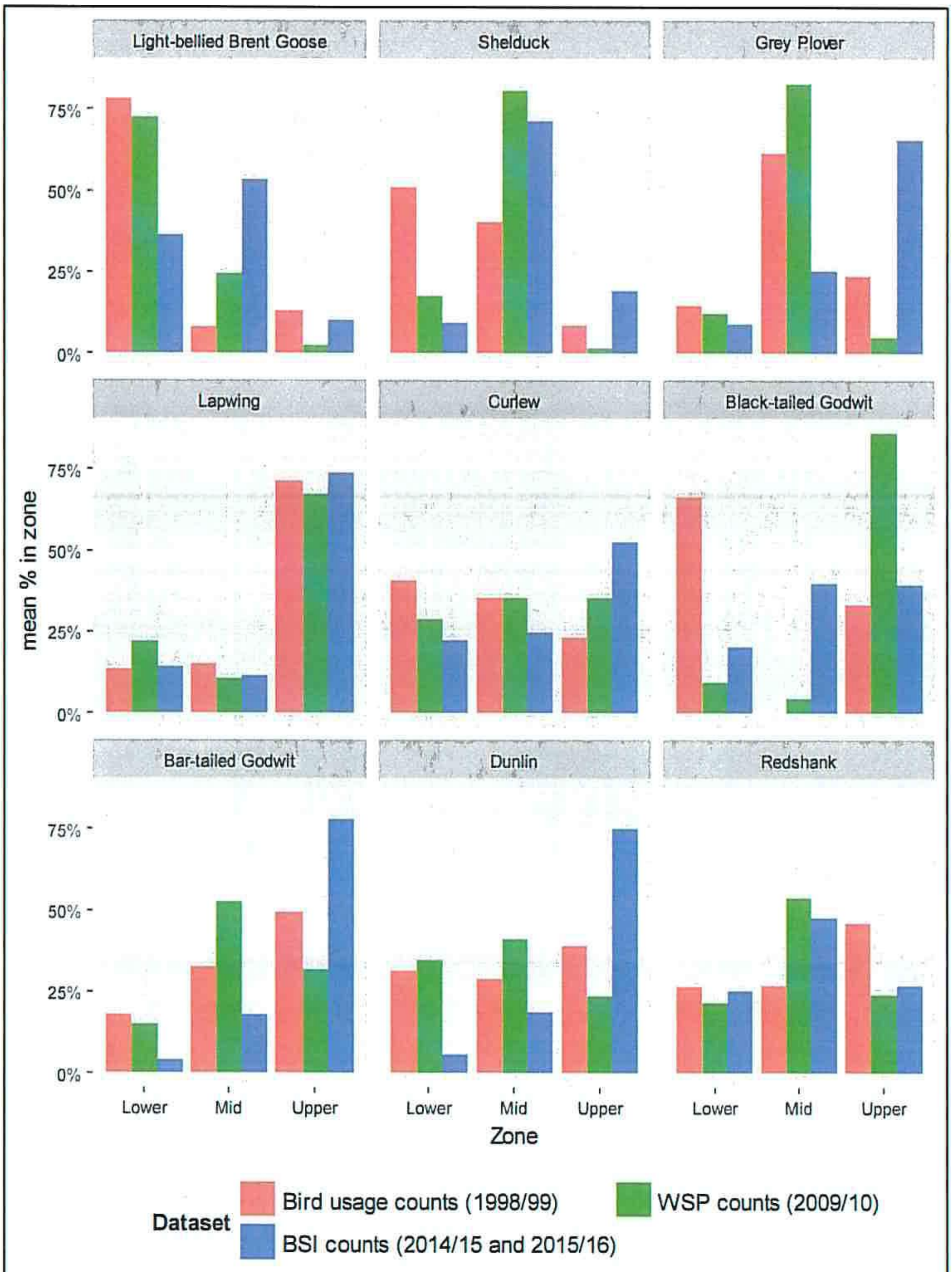
2009/10 data source: 2009/10 Waterbird Survey Programme as undertaken by the National Parks & Wildlife Service. See text for details of adjustments to 2011 data.

Text Figure 3.1 **Comparison of total numbers recorded in the WSP counts (2009/10) and the BSI counts (2014/15 and 2015/16). Note that the bar for the Black-tailed Godwit 2009/10 LT 1 count has been truncated to 1000 (actual value 5653) to allow an appropriate scale for comparison of the other counts.**

Text Figure 3.2 **Occupancy levels in the mid zone for the species covered by this assessment on each low tide count in 200/10, 2014/15 and 2015/16.**



Text Figure 3.3 **Occupancy levels in the mid zone for selected comparison species on each low tide count in 2009/10, 2014/15 and 2015/16.**



Text Figure 3.4 **Comparison of waterbird distribution patterns in the bird usage (1998/99), WSP (2009/10) and BSI (2014/15 and 2015/16) counts.**

4. Displacement assessment

Introduction

4.1 This section presents the results of the displacement analyses for the three aquaculture development scenarios considered, and at the three spatial scales analysed. The results for each species are then reviewed, using the results of the distribution analyses, combined with knowledge of the general ecology of the species, to inform the assessment of the likely displacement impact. We then discuss some of the issues affecting the reliability and interpretation of the predicted displacement levels, before concluding by presenting our best estimates of the likely displacement impact for the three scenarios considered.

Displacement analyses

4.2 Table 4.1 shows the predicted displacement levels calculated using the occupancy data for subsite 00413. Table 4.2 shows the predicted displacement levels calculated using the combined occupancy data for subsites 00413 and 00416. Table 4.3 shows the predicted displacement levels using the combined occupancy data for subsites 00413, 00416 and 00418.

Table 4.1 - Predicted displacement levels (% of total Bannow Bay population), calculated using occupancy data from subsite 00413, and showing the 95% confidence limits.

Species	Renewal sites	Renewal and trial sites	All sites
Light-bellied Brent Goose	0.9% (0.3%-1.5%)	3.2% (1.1%-5.2%)	6.2% (2.2%-10.3%)
Shelduck	0.6% (0%-1.2%)	2% (0%-4.1%)	3.8% (0%-8.1%)
Golden Plover	0% (0%-0%)	0% (0%-0%)	0% (0%-0.1%)
Grey Plover	0.7% (0%-1.5%)	2.6% (0%-5.1%)	5% (0%-10%)
Lapwing	0.1% (0%-0.2%)	0.4% (0.2%-0.7%)	0.9% (0.3%-1.4%)
Curlew	0.7% (0.5%-0.9%)	2.4% (1.6%-3.1%)	4.6% (3.1%-6.1%)
Black-tailed Godwit	0.4% (0.2%-0.7%)	1.6% (0.5%-2.6%)	3.1% (1%-5.1%)
Bar-tailed Godwit	1.3% (0.7%-2%)	4.6% (2.3%-7%)	9.1% (4.4%-13.7%)
Knot	0.4% (0%-0.7%)	1.3% (0.1%-2.4%)	2.5% (0.3%-4.7%)
Dunlin	0.7% (0.1%-1.3%)	2.4% (0.4%-4.5%)	4.7% (0.7%-8.7%)
Redshank	0.7% (0.5%-1%)	2.5% (1.7%-3.4%)	5% (3.3%-6.6%)

Table 4.2 - Predicted displacement levels (% of total Bannow Bay population), calculated using combined occupancy data from subsites 0O413 and 0O416, and showing the 95% confidence limits.

Species	Renewal sites	Renewal and trial sites	All sites
Light-bellied Brent Goose	0.8% (0.3%-1.2%)	2.7% (1.1%-4.2%)	5.2% (2.1%-8.3%)
Shelduck	0.7% (0.1%-1.3%)	2.4% (0.3%-4.5%)	4.7% (0.6%-8.8%)
Golden Plover	1.7% (0.9%-2.5%)	5.8% (3.1%-8.6%)	11.4% (6.1%-16.8%)
Grey Plover	1.6% (1.2%-2.1%)	5.6% (4.1%-7.1%)	11% (7.9%-14%)
Lapwing	1% (0.6%-1.5%)	3.6% (2%-5.2%)	7% (3.9%-10.2%)
Curlew	1.4% (1.2%-1.6%)	4.9% (4.1%-5.7%)	9.6% (8.1%-11.1%)
Black-tailed Godwit	1.8% (1.4%-2.2%)	6.3% (4.8%-7.8%)	12.3% (9.5%-15.2%)
Bar-tailed Godwit	2.4% (2.1%-2.7%)	8.4% (7.3%-9.5%)	16.5% (14.3%-18.7%)
Knot	1.8% (1%-2.5%)	6.1% (3.5%-8.8%)	12% (6.8%-17.2%)
Dunlin	1.9% (1.4%-2.4%)	6.7% (5%-8.3%)	13% (9.8%-16.2%)
Redshank	1.1% (0.8%-1.3%)	3.7% (2.8%-4.7%)	7.3% (5.4%-9.2%)

Table 4.3 - Predicted displacement levels (% of total Bannow Bay population), calculated using combined occupancy data from subsites 0O413, 0O416 and 0O418, and showing the 95% confidence limits.

Species	Renewal sites	Renewal and trial sites	All sites
Light-bellied Brent Goose	1.2% (0.7%-1.6%)	4.1% (2.5%-5.7%)	8.1% (4.9%-11.2%)
Shelduck	2.1% (1.9%-2.4%)	7.4% (6.6%-8.2%)	14.5% (13%-16.1%)
Golden Plover	2.1% (1.5%-2.5%)	7.2% (5.4%-8.5%)	14% (10.5%-16.7%)
Grey Plover	2.1% (1.9%-2.3%)	7.3% (6.5%-8%)	14.2% (12.8%-15.7%)
Lapwing	1.1% (0.7%-1.5%)	3.9% (2.4%-5.3%)	7.5% (4.7%-10.4%)
Curlew	1.6% (1.5%-1.7%)	5.5% (5.2%-5.9%)	10.9% (10.1%-11.6%)
Black-tailed Godwit	2% (1.8%-2.2%)	7% (6.3%-7.8%)	13.8% (12.2%-15.3%)
Bar-tailed Godwit	2.1% (1.9%-2.4%)	7.3% (6.5%-8.2%)	14.4% (12.7%-16%)
Knot	2.1% (1.8%-2.4%)	7.4% (6.1%-8.5%)	14.6% (12%-16.7%)
Dunlin	1.9% (1.6%-2.2%)	6.7% (5.6%-7.7%)	13.1% (11%-15.1%)
Redshank	1.7% (1.5%-2%)	6.1% (5.4%-6.8%)	11.9% (10.5%-13.3%)

Species assessments

Light-bellied Brent Goose

4.3 The predicted displacement levels for Light-bellied Brent Goose were quite similar across all three scales of analysis, indicating potentially significant displacement levels under the renewal/trial sites scenario, and significant displacement levels under the all sites scenario.

4.4 Light-bellied Brent Goose showed a variable response pattern in the trestle study with neutral/positive patterns of association at some sites, and negative patterns at other sites. Light-bellied Brent Goose often feeds on the algae that attaches to the trestle bags and at some sites large numbers can be present on the trestles on the ebb/flood tides to exploit this food source. However, this behaviour appears to be rare at Bannow Bay. During the trestle study, only 1% of the birds were observed on trestles, compared to 12-53% of birds at the other three sites with significant numbers of this species. During site visits in February and March 2016, we made specific watches during the ebb/flood tides, but no Light-bellied Brent Goose were observed on trestles despite the presence of large flocks in the area. However, in the 2015/16 waterbird survey, around 75 Light-bellied Brent Goose were recorded feeding on trestles on one of the counts (Bird Survey Ireland, 2016).

4.5 Therefore, while there is some very limited evidence from the trestle study of a negative pattern of association with trestles at Bannow Bay, even if this is the case, the assumption made in the displacement calculations of complete exclusion from areas of trestles is not correct. This means that the displacement calculations represent conservative worst-case scenarios. Taking this into account, it is reasonable to conclude that only the full occupation of all sites scenario presents a risk of significant displacement impacts, and even this risk has a high level of uncertainty.

Shelduck

4.6 The predicted displacement levels for Shelduck increased strongly with the increasing scale of analysis. This reflects the fact that Shelduck mainly occurred in subsite 0O418, and to a lesser extent, subsite 0O416. In the 2009/10 surveys, Shelduck were almost completely absent from 0O413. While they showed higher occupancy levels in this subsite in the 2014/15-2015/16 surveys, the flock mapping data for 2014/15 indicates that the records for 2014/15, at least, refer to birds roosting on the sandflats in the western section of the subsite. These were likely to be birds that had been feeding in 0O418, but which had moved out onto the sandflats to roost.

4.7 Therefore, there is no evidence to indicate regular patterns of occupancy of the area around the aquaculture sites and we consider that potential for significant displacement impacts under any of the scenarios is very unlikely for Shelduck.

Golden Plover

4.8 The predicted displacement levels for Golden Plover increased strongly with the increasing scale of analysis. This reflects the fact that Golden Plover mainly occurred in subsite 0O418 (2009/10) or subsite 0O416 (2015/15-2015/16). During the WSP counts, there was only a single count of 17 Golden Plover from subsite 0O413, while no Golden Plover were recorded from the sectors overlapping subsite 0O413 in the trestle study counts, and only a single bird was recorded on one date in 0O413 in the BSI counts.

4.9 Therefore, there is no evidence to indicate regular patterns of occupancy of the area around the aquaculture sites and we consider that potential for significant displacement impacts under any of the scenarios is very unlikely for Golden Plover.

Grey Plover

4.10 The predicted displacement levels for Grey Plover increased strongly with the increasing scale of analysis, with the largest scale analysis indicating significant displacement levels under the renewal/trial sites and all sites scenarios. The predicted displacement levels under the renewal sites scenario are measurable but non-significant. However, the upper confidence limits around these predicted levels are well below the significance threshold.

4.11 The distribution patterns of Grey Plover have showed a marked shift away from the mid zone to the upper zone in recent winters. This could be interpreted as reflecting displacement impacts from the expansion of the areas occupied by trestles during this period. However, while the decrease in the mid zone was most marked in 0O413, the data also indicates a shift from 0O418 to the upper zone. Therefore, the shift in distribution could reflect larger scale changes in habitat suitability within Bannow Bay unrelated to the expansion of trestles.

4.12 Given the potential for the expansion of trestles to have caused displacement of Grey Plover from 0O413, and the variability in distribution patterns across the three winters, we consider that the larger scale analyses are more likely to provide reliable predictions of displacement impacts for this species. The predicted displacement levels from the largest scale analysis have the tightest confidence intervals and may, therefore, be the most reliable.

Lapwing

4.13 The predicted displacement levels for Lapwing are very low under all scenarios for the smallest scale of analysis. The two larger scales indicate potentially significant displacement levels from full occupation of the renewal and trial sites, and significant displacement levels from full occupation of all sites.

4.14 Lapwing have occurred in consistently low numbers in 0O413 in all three of the winters covered by the WSP and BSI counts. Relatively higher numbers were recorded in 0O413 in the trestle study counts, but these birds were recorded in sector C3, which covers the area around the inlet at Taulaght. The overall distribution of Lapwing around Bannow Bay reflects the general association of this species in estuarine areas with upper shore areas and/or mixed sediment substrates. Therefore, we consider that the smallest scale of analysis is the most appropriate for assessing the potential displacement impact to this species.

Curlew

4.15 The predicted displacement levels for Curlew are low under all scenarios, with the the upper confidence limits well below the significance threshold, for the smallest scale of analysis. The two larger scales indicate significant displacement levels under the renewal/trial sites and all sites scenarios.

4.16 Curlew distribution patterns in Bannow Bay show only minor variability between winters across all the comparisons made. This reflects the typical widely dispersed distribution of this species in estuarine habitats, which means that it tends to occur at relatively uniform densities. However, the higher displacement levels recorded at the larger scales of analysis reflect the higher densities of Curlew that occur in 0O416 and 0O418. This, in turn, probably reflects the fact that around one-third of 0O413 is sandflat habitat of low suitability for Curlew.

4.17 The trestle study classified Curlew as having an overall neutral/positive pattern of association with oyster trestles. However, based on further analysis of the dataset we now consider that the response should be classified as variable (Gittings and O'Donoghue, 2016b). At Bannow Bay, Curlew showed a consistently negative pattern of association with oyster trestles. However, further data would be required to confirm this negative pattern of association and show that it is not just an artefact of the small sample size. Even, if the negative pattern of association at Bannow Bay is true, the assumption made in the displacement calculations of complete exclusion from areas of trestles is unlikely to be correct

4.18 It is likely that the recorded distribution patterns of Curlew in Bannow Bay reflect variation in habitat suitability. Therefore, on this basis, the smallest scale of analysis should provide the most reliable indication of the likely displacement impacts. The predicted displacement impact is likely to overestimate the actual displacement impact due to the assumption of complete exclusion.

Black-tailed Godwit

4.19 The upper confidence limits of the predicted displacement levels for Black-tailed Godwit are well below the significance threshold for the renewal site scenario at all the scales of analysis. For the two other scenarios, significant displacement levels are indicated at the two larger scales of analysis.

4.20 Black-tailed Godwit have shown variable distribution patterns in Bannow Bay across the winters that we have compared. Mean occupancy levels in the mid zone show an increase across recent winters, but this appears to be mainly due to increased numbers in 00418.

4.21 Given the high variability in distribution patterns across the three winters, we consider that the larger scale analyses are more likely to provide reliable predictions of displacement impacts for this species. The predicted displacement levels from the largest scale analysis have the tightest confidence intervals and may, therefore, be the most reliable.

Bar-tailed Godwit

4.22 The upper confidence limits of the predicted displacement levels for Bar-tailed Godwit are well below the significance threshold for the renewal site scenario at all the scales of analysis. For the two other scenarios, significant displacement levels are indicated at all the scales of analysis.

4.23 The distribution patterns of Bar-tailed Godwit have showed an apparent shift away from the mid zone to the upper zone in recent winters. This could be interpreted as reflecting displacement impacts from the expansion of the areas occupied by trestles during this period.

4.24 Given the potential for the expansion of trestles to have caused displacement of Bar-tailed Godwit from 00413, and the variability in distribution patterns across the three winters, we consider that the larger scale analyses are more likely to provide reliable predictions of displacement impacts for this species. The predicted displacement levels from the largest scale analysis have the tightest confidence intervals and may, therefore, be the most reliable.

Knot

4.25 The upper confidence limits of the predicted displacement levels for Knot are well below the significance threshold for renewal site scenario at all the scales of analysis. For the renewals and trials scenario, significant displacement levels are indicated at the two larger scale of analysis, while for the all sites scenario, significant displacement levels are indicated at all the scales of analysis.

4.26 The recorded Knot distribution patterns have been highly variable in recent winters. This variability reflects the highly mobile nature of this species and four counts per winter is unlikely to provide an adequate sample for analysing changes in distribution between winters. There is no evidence in the data that displacement impacts from the expansion of the areas occupied by trestles during this period have affected distribution patterns, but any such impact, if it exists, may have been obscured by the high variability of the data.

4.27 Due to the variability in distribution patterns across the three winters, we consider that the larger scale analyses are more likely to provide reliable predictions of displacement impacts for this species. The predicted displacement levels from the largest scale analysis have the tightest confidence intervals and may, therefore, be the most reliable.

Dunlin

4.28 The upper confidence limits of the predicted displacement levels for Dunlin are well below the significance threshold for renewal site scenario at all the scales of analysis. For the renewal/trial sites scenario, significant displacement levels are indicated at the two larger scale of analysis, while for the all sites scenario, significant displacement levels are indicated at all the scales of analysis.

4.29 The recorded Dunlin distribution patterns have been rather variable in recent winters but with some indication of a decrease in occupancy levels in 0O413. This variability reflects the highly mobile nature of this species and four counts per winter is unlikely to provide an adequate sample for analysing changes in distribution between winters. However, it is possible that displacement impacts from the expansion of the areas occupied by trestles during this period have affected distribution patterns.

4.30 Given the potential for the expansion of trestles to have caused displacement of Dunlin from 0O413, and the variability in distribution patterns across the three winters, we consider that the larger scale analyses are more likely to provide reliable predictions of displacement impacts for this species. The predicted displacement levels from the largest scale analysis have the tightest confidence intervals and may, therefore, be the most reliable.

Redshank

4.31 The upper confidence limits of the predicted displacement levels for Redshank are well below the significance threshold for the renewal site scenario at all the scales of analysis. For the renewal/trial sites scenario, potentially significant, or significant, displacement levels are indicated at the two larger scale of analysis, while for the all sites scenario, potentially significant, or significant, displacement levels are indicated at all the scales of analysis.

4.32 Redshank recorded distribution patterns in Bannow Bay show little variability between winters (apart from in the comparisons with the bird usage dataset). This reflects the typical widely dispersed distribution of this species in estuarine habitats, which means that it tends to occur at relatively uniform densities. However, the higher displacement levels recorded at the larger scales of analysis reflect the higher densities of Redshank that occur in 0O416 and 0O418. This, in turn, probably reflects the fact that around one-third of 0O413 is sandflat habitat of low suitability for Redshank.

4.33 The trestle study classified Redshank as having an overall neutral/positive pattern of association with oyster trestles. Redshank has been included in this assessment because Bannow Bay was the one site where Redshank appeared to show a negative pattern of association with oyster trestles. However, further data would be required to confirm this negative pattern of association and show that it is not just an artefact of the small sample size. Even, if the negative pattern of association at Bannow Bay is true, the assumption made in the displacement calculations of complete exclusion from areas of trestles is unlikely to be correct

4.34 It is likely that the recorded distribution patterns of Redshank in Bannow Bay reflect variation in habitat suitability. Therefore, on this basis, the smallest scale of analysis should provide the most reliable indication of the likely displacement impacts. The predicted displacement impact is likely to overestimate the actual displacement impact due to the assumption of complete exclusion.

Discussion

Subsite definition

4.35 The aquaculture areas occupy a transitional zone between the muddier sediments in the upper estuary that hold high densities of most species and the sandier sediments in the middle zone of the estuary that hold low densities of most species. The analyses of waterbird distribution across the count sectors used for the trestle study (see Table 8.2 in the AA Report) show a gradient from high densities in the muddy upper estuary to low densities in the sandy habitat to the south of the aquaculture areas. This creates problems for the definition of a suitable habitat unit to use for the displacement assessments. Therefore, assessment of potential displacement impacts at Bannow Bay is more difficult than at other sites (such as Ballymacoda Bay and Dungarvan Harbour) where the aquaculture areas occur in a well-defined area of relatively homogeneous habitat.

4.36 The subsite divisions used for the WSP and BSI counts compound the difficulty. These subsites were defined for the purposes of monitoring broad patterns of waterbird distribution, not for analysing species distribution in relation to aquaculture activity. The subsite containing the aquaculture area (0O413) is divided by the main tidal channel with contrasting habitat conditions either side of the tidal channel: the southern side holds sandbanks that rapidly dry out as the tide recedes and appear to support very low numbers of birds, while the northern side (where the aquaculture areas are) hold muddier sediments (albeit transitioning to sandbank habitat at their western end). Furthermore, our limited observations of waterbird movement patterns suggest that the birds that do use the southern part of 0O413 move out from 0O418, rather than across the tidal channel from the northern part of 0O413. Therefore, the southern part of 0O413 may be more naturally grouped with 0O418, than with the rest of 0O413.

4.37 Division of this subsite into separate count units either side of the tidal channel for any future monitoring would allow more accurate monitoring and assessment of potential displacement impacts from aquaculture activity. In fact, it may be possible to retrospectively make this division as the flock mapping data indicates that on most/all of the WSP and BSI counts, 0O413 was counted by two observers, with the division between the areas counted appearing to correspond to the tidal channel. Therefore, the original datasheets, if available, might allow the counts for 0O413 to be divided into these two sections.

Waterbird distribution patterns

4.38 The BSI counts have provided valuable additional data on waterbird distribution patterns in Bannow Bay, and the combined WSP/BSI dataset now contains a sufficient number of low tide counts for meaningful patterns to be expected to emerge. For some species (e.g., OC, Curlew and Redshank), distribution patterns are relatively consistent across the three winters covered by the combined dataset, reflecting the ecology of these species. For other species, distribution patterns were much more variable.

4.39 Species that are highly mobile (Knot and Dunlin) are likely to show very variable patterns between individual counts and four counts per winter are unlikely to be enough to allow detection of reliable patterns of species distribution. However, some species did appear to show consistent changes in distribution patterns between 2009/10 and 2014/15-2015/16.

4.40 It is notable that the two species (Grey Plover and Bar-tailed Godwit) that showed a marked shift in distribution from the mid zone to the upper zone are both species that show strongly negative responses to the presence of trestles. Therefore, the expansion in trestle occupancy over this period is a possible explanation for the decreased occupancy of the mid zone. However, the scale of the expansion in trestle occupancy would only be expected to cause displacement levels around 10-20% of the observed decrease in occupancy levels in 0O413, based on the method used to calculate displacement impacts in this report. This discrepancy raises the possibility that this method significantly underestimates the potential displacement impacts.

4.41 The methods used to calculate displacement impacts in this report assume that the displacement only occurs from the areas occupied by trestles. However, it is possible that additional displacement occurs outside the areas occupied by trestles, due to fragmentation of habitat and/or disturbance. This is may well have been an issue at Bannow Bay due to the pattern of trestle expansion, which has involved the development of scattered trestle blocks over a wide area of intertidal habitat. This is less likely to be an issue with the calculations of predicted displacement impacts under the scenarios considered in this report, as these scenarios assume complete occupation of the aquaculture sites, rather than the fragmentary pattern of trestle expansion discussed above.

4.42 An alternative explanation for the discrepancy between the predicted displacement due to expansion in trestle occupancy and the observed decrease in occupancy levels in 0O413 is that the habitat in 0O413 is of variable quality for these species and that the trestle expansion happened to affect the highest quality areas of habitat. As discussed above, there is a large area of unfavourable sandbank habitat in the southern part of 0O413, while the trestle expansion occurred in the northern part of the subsite, which has more favourable habitat. Exclusion of the unfavourable sandbank habitat would only increase the predicted displacement levels to around 15-30% of the observed decrease in occupancy levels. However, there may be more subtle additional variations in habitat quality that we are not able to account for, and which may further reduce the discrepancy.

4.43 Shifts in distribution patterns may also occur due to habitat changes that are unrelated to the expansion of the trestles. The erosion of the sandbar at the mouth of the bay has presumably caused changes in the distribution of sediments within the bay and the comparison with the 1998/99 dataset indicates that there have been some long-term changes in waterbird distribution patterns within Bannow Bay. In the case of Grey Plover, the shift in distribution from the mid zone to the upper zone included decreases in occupancy levels in both subsites within the mid zone, and a dramatic increase in occupancy levels in the upper zone. If the change in distribution patterns was solely due to the expansion in trestle occupancy, the shift in distribution would have been expected to have been from 0O413 to 0O418. Instead, the changes in Grey Plover distribution indicate a wider scale decrease in habitat suitability within the mid zone, and/or increased habitat suitability in the upper zone.

Displacement predictions

4.44 The reliability of the predictions from the displacement calculations are clearly dependent upon the accuracy of the occupancy data, and of our knowledge of the nature of the species' responses to the presence of trestles.

4.45 The confidence intervals for the displacement predictions are relatively tight, which might be interpreted as indicating high reliability. However, if the data are biased, these confidence intervals will not be valid. One possible bias to the data would result from counts that do not accurately record species distributions. Some species showed high levels of variability in total numbers between counts within the same winters. In some cases, this variation is expected and may reflect seasonal patterns (e.g., Shelduck) or birds leaving the estuary to feed in fields (e.g., Light-bellied Brent Goose, Curlew and Black-tailed Godwit). However, it is noticeable that, in two of the three winters, the high tide counts of Grey Plover and Bar-tailed Godwit were much higher than the peak low tide count. Carrying out low tide counts of waterbirds in complex estuarine habitats is a challenging task and, without a team of observers large enough to allow continuous monitoring of all the main habitats, a degree of error will be inevitable due to bird movements during the count and/or birds being hidden in tidal channels at low tide.

4.46 The bird occupancy data that we have used to calculate the displacement impacts is potentially affected by any displacement impacts that are already occurring due to the existing levels of trestle occupancy at the times that the bird surveys were carried out. The adjustments that we have made to correct for this factor assume that all the birds displaced have left the area used to calculate the occupancy levels. This assumption is likely to become less reasonable as the scale of the analysis increases. However, the increase in predicted displacement levels caused by these adjustments are minor and would not affect the overall assessment of the potential significance of the predicted displacement impacts.

4.47 As discussed above, the occupancy data that we have used to calculate the displacement impacts is likely to be biased by the inclusion of a large area of unfavourable sandbank habitat in 0O413. If the area of this habitat is excluded from the calculations of occupancy levels, the predicted displacement impacts would increase by factors of around 1.2-1.5, depending upon the scale of the analysis.

4.48 The displacement predictions assume that all the birds will be displaced from the areas occupied by the trestles. This is a reasonable assumption for Grey Plover and Knot, based on the results of the trestle study and on further monitoring at Dungarvan Harbour. For Bar-tailed Godwit and Dunlin, we know that complete exclusion does not occur. The results of the trestle study suggest correction factors of 6/7 (Bar-tailed Godwit) and 7/8 (Dunlin) to the predicted displacement levels to allow for incomplete exclusion. For Light-bellied Brent Goose, Curlew and Redshank, it is not certain that birds will be displaced by the trestles and, even if they are, the displacement will not cause complete exclusion. Therefore, the predicted displacement levels for these species are extreme worst-case scenarios.

4.49 The displacement predictions do not tell us what the population-level consequences of the displacement impacts will be. Development of an individual-based model (Stillman and Goss-Custard, 2010) would allow assessment of population-level consequences of the displacement impacts from aquaculture activities in Bannow Bay.

Habitat quality

4.50 The methods used for the displacement calculations are very simplistic and assume that, on average, waterbirds distribute themselves more or less uniformly across suitable habitat. This assumption may not be correct. For example, it is possible that as waterbird numbers build up they progressively occupy less favourable habitat. This would mean that the occupancy levels (as measured by the percentage of the total population) of the most favourable areas would decline as the total numbers increased. Birds may occur in higher densities in the most favourable areas, which will mean that the assumption of uniform distribution is not correct. Also, the actual significance of any displacement impacts will depend on the quality of the habitat from which the birds are displaced, as well as the numbers of birds that are displaced. Without data on habitat quality (i.e., benthic prey resources) it is not possible to factor habitat quality into the assessment, beyond simple factors such as substrate type.

4.51 As discussed above, long-term changes in habitat quality may be driving some of the changes in waterbird distribution patterns identified in this report. There may also be short-term, more or less random, changes in prey availability that affect waterbird distribution between winters.

4.52 Inclusion of more detailed information on habitat quality, and changes in habitat quality over time, would allow more reliable predictions of displacement impacts, and would also allow more reliable assessment as to whether observed changes in waterbird distribution patterns are related to aquaculture activities. The transitional nature of the habitat occupied by the aquaculture sites makes this a particularly important issue at Bannow Bay, compared to some of the other sites where we have carried out assessments of displacement impacts from intertidal oyster cultivation,

4.53 Development of an individual-based model (Stillman and Goss-Custard, 2010) would allow information on habitat quality to be taken into account in the prediction of displacement impacts from aquaculture activities in Bannow Bay.

Conclusions

4.54 Our best estimates of the predicted displacement impacts are shown in Table 4.4.

4.55 Under the renewal sites scenario, the upper 95% confidence limit of the predicted displacement levels for all species are well below the 5% significance threshold. This remains the case even allowing for the potential increase in predicted displacement levels that might result from allowing for the unsuitability of the sandbank habitat in 0O413.

4.56 The renewal/trial sites and all sites scenarios are predicted to have significant, or near-significant, displacement impacts on Light-bellied Brent Goose, Grey Plover, Curlew (all sites scenario only), Black-tailed Godwit, Bar-tailed Godwit, Knot, Dunlin and Redshank (all sites scenario only). However, in the case of Light-bellied Brent Goose, Curlew and Redshank the probability of a negative response to the presence of trestles is low as these species can all show neutral/positive responses to trestles at other sites.

4.57 Further analysis of the WSP and BSI datasets, using the original count datasheets (if available) to subdivide the count data for 0O413, would allow the predicted displacement levels to be refined.

4.58 The aquaculture area is located in a transitional zone between the muddy upper estuary (with high waterbird densities) and sandflats to the south (with low waterbird densities). Starting *de novo*, development of aquaculture sites in the sandflat area would have been likely to have lower displacement impacts, compared to development of aquaculture sites in the existing aquaculture area. While the current situation is more complex, there may be scope for rationalising the footprint of the existing aquaculture sites in the existing aquaculture area, and focussing any further expansion of aquaculture in the sandbank area. However, this strategy would require further review and analysis of the existing data (particularly flock map data), and additional targeted surveys, to confirm low waterbird occupancy of the sandbank area.

4.59 If development of the trial and application sites is to go ahead, targeted waterbird surveys should be carried out to monitor the impact of this development on waterbird populations. This monitoring should use customised count sectors (rather than the WSP subsites) that are designed to reflect the boundaries of the aquaculture sites and to reflect variations in substrate type. Bimonthly counts throughout the winter would be required to provide sufficient data to allow for the inherent variability in waterbird distribution patterns. At least one winter of pre-development counts would be required to provide a baseline against which impacts could be assessed.

4.60 Development of an individual-based model (Stillman and Goss-Custard, 2010) would allow information on habitat quality to be taken into account in the prediction of displacement impacts from aquaculture activities in Bannow Bay, and would also population-level consequences of the displacement impacts to be assessed. This would provide a more comprehensive and robust method of assessing impacts than the monitoring programme described above.

Table 4.4 - Summary of predicted displacement impacts.

Species	Scale of assessment	Probability of negative response	Correction factor for sandbank	Predicted displacement levels		
				Renewal sites	Renewal and trial sites	All sites
Light-bellied Brent Goose	2	low	1.2	0.8% (0.3%-1.2%)	2.7% (1.1%-4.2%)	5.2% (2.1%-8.3%)
Shelduck	1	moderate	n/a	negligible		
Golden Plover	1	moderate	1.2	0% (0%-0%)	0% (0%-0%)	0% (0%-0.1%)
Grey Plover	3	very high	1.2	2.1% (1.9%-2.3%)	7.3% (6.5%-8%)	14.2% (12.8%-15.7%)
Lapwing	1	mod	1.5	0.1% (0%-0.2%)	0.4% (0.2%-0.7%)	0.9% (0.3%-1.4%)
Curlew	1	low	1.5	0.7% (0.5%-0.9%)	2.4% (1.6%-3.1%)	4.6% (3.1%-6.1%)
Black-tailed Godwit	3	moderate	1.2	2% (1.8%-2.2%)	7% (6.3%-7.8%)	13.8% (12.2%-15.3%)
Bar-tailed Godwit	3	high	1.2	1.8% (1.6%-2%)	6.3% (5.6%-7%)	12.3% (10.9%-13.8%)
Knot	3	very high	1.2	2.1% (1.8%-2.4%)	7.4% (6.1%-8.5%)	14.6% (12%-16.7%)
Dunlin	3	high	1.2	1.7% (1.4%-1.9%)	5.8% (4.9%-6.8%)	11.4% (9.6%-13.2%)
Redshank	1	low	1.5	0.7% (0.5%-1%)	2.5% (1.7%-3.4%)	5% (3.3%-6.6%)

Scale of assessment: 1 = using occupancy levels for 0O413; 2 = using occupancy levels for 0O413 and 0O416 combined; 3 = using occupancy levels for 0O413, 0O416 and 0O418.

Probability of negative response: low = species may have neutral/positive response to trestles; moderate = species likely to have negative response to trestles but evidence for this is weak; high = strong evidence that species has negative response to trestles; very high = strong evidence that species is excluded by the presence of trestles.

Correction factor for sandbank indicates the potential increase in the predicted displacement levels that would occur if birds are assumed not to use the sandbank habitat to the south of the main tidal channel in 0O413.

The predicted displacement levels for Shelduck are given as negligible for all scenarios, as the calculated displacement levels are likely to be biased by inclusion of large roosting flocks in the sandbank habitat to the south of the main tidal channel.

The predicted displacement levels for Bar-tailed Godwit and Dunlin have been corrected by factors of 6/7 and 7/8, respectively, to reflect the fact that displacement does not cause complete exclusion of these species from areas of oyster trestles.

5. References

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