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Dundalk Waterbird Studies

Assessment of some potential impacts of cockle (*Cerastoderma edule*) harvesting on waterbirds

(Annex IV - Dundalk Bay Appropriate Assessment)

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(in support of Dundalk Bay Appropriate Assessment)

29th June 2011

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The 2009/10 count data for Dundalk Bay was collected as part of the 2009/10 Waterbird Survey Programme as undertaken by the National Parks & Wildlife Service, DoEHLG. We are grateful to NPWS for permission to use this data in this report.

The saltmarsh and muddy sand mapping data in Figure 3.1 are from an intertidal soft sediment survey carried out by the Aquatic Services Unit for NPWS.

1. Introduction

1.1 Atkins (Ecology) was commissioned by the Marine Institute to provide ornithological services in relation to the appropriate assessment of cockle fishing on the Dundalk Bay Special Protection Area (SPA).

1.2 As part of the work commissioned by the Marine Institute, Atkins designed, supervised and analysed studies of waterbird distribution and foraging behaviour. The objective of these studies was to examine the effect of cockle fishing on waterbird utilisation of intertidal habitat in Dundalk Bay.

1.3 The waterbird counts and focal observations, for these studies, were carried out by BirdWatch Ireland counters under the supervision of Atkins personnel.

1.4 Our brief for this report was to report on the waterbird distribution and foraging behaviour studies carried out in February and March 2010.

1.5 The data analysis and report writing was done by Tom Gittings; Paul O'Donoghue assisted with project design, document preparation and undertook document review. Data entry was carried out by Katie O'Hora.

1.6 Scientific names and British Trust for Ornithology (BTO) species codes of bird species mentioned in the text are listed in Appendix A.

Cockle fishing in Dundalk Bay

1.7 The most recent cockle fishing was carried out in the autumn of 2009. The area designated for fishing and the intensity of fishing activity is shown in Figure 1.1. The latter is shown as fishing effort in hours, as recorded by GPS trackers on the fishing vessels. These GPS trackers were continually recording, including during non-fishing periods, and the green dots outside the designated areas will mainly indicate vessel movements to/from fishing areas, rather than fishing activity.

Limitations to this study

1.8 The design of the waterbird distribution and foraging behaviour studies were constrained by the timing of the commissioning of this work, which did not allow much time for planning before counts had to begin.

1.9 The results of these studies provide data on waterbird usage and foraging behaviour in February and March 2010. The extent to which this data is representative of earlier in the winter and of previous years is not known.

1.10 See paragraphs 4.1-4.8 for further discussion of the limitations of the study.

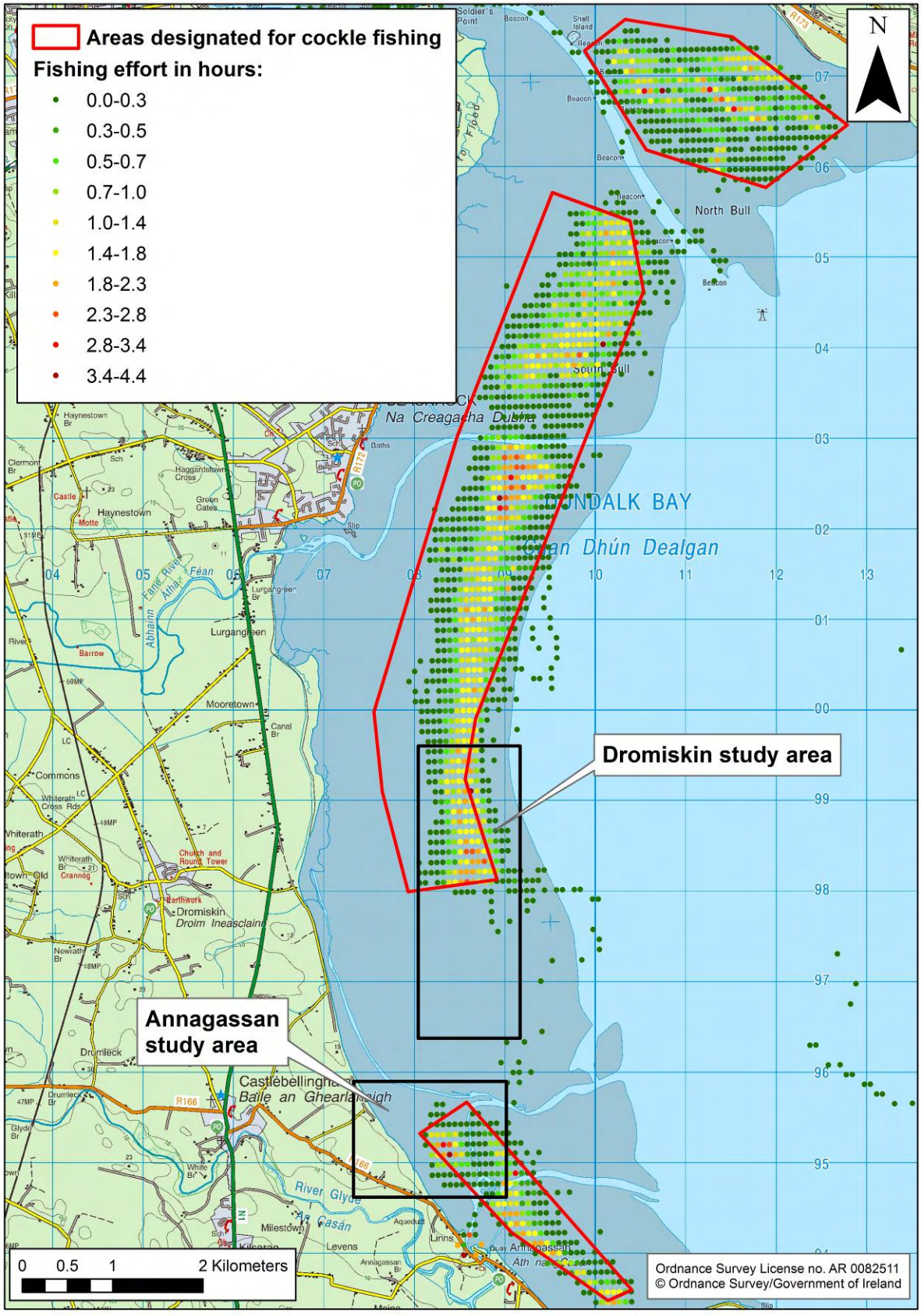

Figure 1.1 – Extent and intensity of cockle fishing in 2009 and general location of the waterbird study area.

2. Methods

Study area

2.1 The large, continuous blocks of habitat affected by cockle fishing made it difficult to identify comparable areas of control and impacted habitat. While several areas were checked during preliminary site visits, we only found one area with closely comparable control and impacted habitat.

2.2 The main study area was an approximately 2 km section of intertidal habitat at Dromiskin (Figure 1.1). This area was selected because it included an area with a high intensity of cockle fishing and an area of comparable control habitat. The latter was judged to be comparable during preliminary site visits because it occupies a similar lateral zone relative to the shoreline, has similar sediment type, lacks tidal creeks or other complicating factors, and the tideline moves through it in a similar way.

2.3 Some counts were also carried out in a second study area at Annagassan (Figure 1.1). This area had broadly similar zones of impacted and control habitat but comparisons were complicated by differing configurations of tidal creeks and intertidal habitat and the presence of a mussel bed in the impacted habitat zone.

Study design

2.4 The objective of this study was to examine the effect of cockle fishing on waterbird utilisation of intertidal habitat in Dundalk Bay. We examined the relationship between cockle fishing and bird distribution by carrying out a series of waterbird counts on six dates in February and March 2010 in areas that had been fished in the autumn of 2009 and in comparable unfished areas.

2.5 The first set of counts, on the first two count days, compared two pairs of large sectors (0.5-1 km wide). This approach was used because of problems with setting up the transects (our preferred approach).

2.6 The remaining sets of counts compared 10 transects through an area that had been fished in the autumn of 2009 and another 10 control transects in a comparable unfished area. The transect design was used to overcome some of the design problems associated with only having a single control-impact comparison. Transects were designed to address this issue by potentially allowing both detection of gradients in bird usage and analysis of the relationship between bird distribution and fishing intensity. However, other problems (see paragraph 4.5) prevented these types of analyses.

2.7 We also examined the relationship between cockle fishing and waterbird foraging behaviour by carrying out focal observations of Oystercatcher and Bar-tailed Godwit in subsets of the control and impact transects. The rationale for selecting these species is discussed in Appendix B.

2.8 We used the data to test the null hypotheses that waterbird distribution and feeding rates in the area surveyed are not related to cockle fishing.

Cockle fishing

2.9 Data on cockle fishing was provided by the Marine Institute. This data consists of hours fished recorded grid cells of approximately 100 x 100 m.

Waterbird distribution study

2.10 The waterbird counts in this study were carried out by counters from the NPWS Baseline Waterbird Survey Programme under the supervision of Atkins. Detailed guidelines were provided to the counters with instructions for how to carry out the counts and how to record the data.

2.11 Low tide times on the count days are shown in Table 2.1.

Table 2.1 – Low tide times at Dundalk (Soldier's Point) on the count days

Date	Time	Height	Sunrise	Sunset
10th February 2010	15:56:00	1.3	07:55	17:24
11th February 2010	16:47:00	1.1	07:53	17:26
24th February 2010	13:25:00	1.4	07:25	17:52
25th February 2010	14:49:00	1	07:23	17:54
11th March 2010	15:28:00	1.2	06:50	18:21
12th March 2010	16:16:00	1	06:47	18:23

Data source: Admiralty EasyTide (http://easytide.ukho.gov.uk/).

Sector counts

2.12 The sector counts were carried out on 10th and 11th February 2010.

2.13 The sectors were sections of shore at Dromiskin (DromN and DromS) and between Castlebellingham and Annagassan (AnnN and AnnS) (Figure 3.1).

2.14 The counts were carried out by counters positioned on the shoreline. The counters used compass bearings (45° for AnnN and AnnS; 90° for DromN and DromS) from fixed markers on the shoreline to identify the northern and southern boundaries of the sectors and moved along the shoreline as necessary to carry out the counts.

2.15 The Dromiskin sectors include the southernmost section of the main fishing area (DromN) and a comparable unfished area to the south (DromS). On the first count day, 1 km lengths of shoreline were used for each sector. Because counters found it difficult to complete the counts for a 1 km length of shoreline without bird movements affecting the counts, 0.5 km length of shoreline were used for the counts on the second count day. The sectors included the entire intertidal sand habitat as far as the tideline. The saltmarsh and muddy sand habitats in the upper shore were not included in the sectors. While the amount of the intertidal sand habitat varies between the control and impact sectors, the waterbirds mainly feed along or behind the tideline as it moves through the sectors. As the tideline is orientated more or less perpendicular to the sectors, the length of tideline in the control and impact sectors is similar. Therefore, the control and impact sectors can be taken as being equivalent in terms of their habitat availability for waterbirds.

2.16 The Castlebellingham-Annagassan sectors include the northernmost section of the fishing area at Annagassan (AnnS) and a comparable unfished area to the north (AnnN). Each sector comprised a 500 m length of shoreline from the upper shore to the tidal channel that runs approximately NW-SE across the sectors, 0.5-1 km downshore. Because of the form of the tidal channel, there is a larger amount of intertidal habitat and a longer length of tidal channel in the impact sector (AnnS) compared to the control sector (AnnN). From the Ordnance Survey Discovery series map, there is 41 ha of intertidal habitat in AnnS compared to 26 ha in Ann N and 1.13 compared to 0.56 km of

tidal channel. However, the form of the tidal channel in the Discovery series map appears to be based on the Ordnance Survey 6 inch maps. The latter date back to the 1930s and it is likely that the form of the tidal channel has changed since then. Because waterbirds feed throughout these sectors, the differences in both the amount of intertidal habitat and length of tidal channel may affect waterbirds numbers in the sectors. The two sectors also differ in the presence of a mussel bed in the upper shore section of AnnS.

Transect counts

2.17 Transects consisted of two blocks of 10 contiguous 100 x 800 m transects with a 200 m wide gap between the two blocks (Figure 3.2). The width of the gap separating the blocks was constrained by the need to have contiguous blocks of transects (for logistical reasons; see paragraph 4.3), the objective of including areas with high fishing intensity in the impact zone transects, and the need to avoid the influence of the Castlebellingham tidal creek at the southern end of the control zone transects.

2.18 Transects were marked with coloured buoys at their corners and the midpoints of their northern and southern sides. The midpoint buoys divided each 100 x 800 m transect into two 100 x 400 m sectors.

2.19 Waterbird counts were carried out on 24th and 25th February and the 11th and 12th March 2010, on days when the timing of the low tide was suitable.

2.20 On each count day, a team of four counters was used. Counts were carried out over a 4-5 hour period, from around four hours before low tide to one hour after low tide. Each counter counted five adjacent transects in rotation, so each transect was counted four or five times with an interval of approximately one hour between each count.

2.21 On each count, the number and activity (feeding or roosting) of all waterbird species was recorded. Counters also recorded whether birds were on the tideline or on intertidal habitat away from the tideline. These data were recorded separately for each sector within the transect being counted. Counters also recorded the position of the tideline and whether counts were affected by disturbance.

Foraging behaviour study

2.22 The focal observations in this study were carried out by a counter from the NPWS Baseline Waterbird Survey Programme under the supervision of Atkins. Detailed guidelines were provided to the counter with instructions for how to carry out the focal observations and how to record the data.

2.23 Focal observations were carried out on 24th and 25th February and the 11th and 12th March 2010, on days when the timing of the low tide was suitable. Observations were carried out from four hours before low tide to one hour after low tide. The surveyor was positioned no closer than 400 m to the nearest bird activity within nearby transects.

2.24 The surveyor carried out focal observations continuously throughout the survey period in transects 08-10 (impact zone) and 11-14 (control zone). The selected transects in the impact zone include some of the most intensive areas of cockle fishing activity (see Figure 3.2) and were deliberately selected to be close to each other to minimise time wasted through movement between transects. Designation of specified transects for the study was designed to ensure that the focal observations were spatially segregated. We also intended to analyse the results in relation to the

recorded fishing intensity within the impact transects but the number of replicates achieved was not sufficient to do this (due to various logistical issues; see paragraph 4.8).

2.25 The survey generally followed the following sequence: T08 → T11 → T09 → T12 → T10 → T13 (i.e., an alternating sequence of impact and control transects). However, this sequence had to be modified when the target species were not present in the designated transect.

2.26 The focal observations were carried out in transects 8-10 (impact zone) and 11-14 (control zone).

2.27 In each transect, the surveyor made focal observations of two Oystercatchers and two Bar-tailed Godwits. Each focal observation lasted for five minutes (Oystercatchers) or two minutes (Bar-tailed Godwit). These durations were based on a literature review of the methodologies use in comparable studies and reflect the generally lower capture rate of Oystercatchers.

2.28 Where possible, birds selected for focal observations were birds feeding around the tideline.

2.29 During each focal observation, the selected bird was watched continuously for the required period. A countdown timer that beeps at the end of the timed period was used. The following bird activity was recorded using a dictaphone: peck = peck at the surface of the sediment; short probe = probe up to half the bill length in the sediment; full probe = the whole length of the bill probed into the sediment; swallow = successful capture and ingestion of prey.

2.30 Where possible, the identity of the prey item was recorded. However, because of the distance at which observations needed to be carried out, this was not often possible.

2.31 If the bird engaged in kleptoparasitism or aggressive/territorial behaviour, showed an alert response to disturbance, or displayed any non-feeding behaviour, during the focal observation, this was also recorded.

2.32 After completing the focal observations in each transect, the surveyor carried out a count of the birds in the transect.

Data analysis

2.33 For clarity, data analysis methods are described in the relevant sections of the results.

2.34 We designed the transect study with the intention of using Generalised Linear Mixed Modelling (GLMM) techniques (see Zuur *et al.*, 2009) to analyse the results. However, for various reasons, the data was not suitable for this type of analysis (see paragraphs 4.6-4.7).

3. Results

Sector counts

3.1 Six counts were carried out in the Dromiskin sectors: two on 10 February and four on 11 February. However, one of the counts on 10th February only had incomplete coverage of the DromN sector and has been excluded from the analyses. Nine counts were carried out in the Annagassan sectors: five on 10th February and four on 11th February. However, two of the counts on 10th February and one of the counts on 11th February were significantly affected by disturbance and have been excluded from the analyses.

3.2 A total of 17 species were recorded on the counts in the Dromiskin sectors. Seven of the eight species that occurred in sufficient numbers for analysis were more abundant in DromS (Control) sector (Table 3.1). The difference was particularly notable for Knot and Bar-tailed Godwit, which occurred in large numbers in the DromS (Control) sector but which were absent or very rare in DromN (Impact) sector.

Table 3.1 – Results of the Dromiskin sector counts.

Species	Sector[1]	10 Feb	11 Feb				Mean	S.D.
			Count 1	Count 2	Count 3	Count 4		
Mallard	DromN	20	50	2	6	30	22	19
	DromS	0	61	25	34	44	33	23
Oystercatcher	DromN	96	22	83	90	157	90	48
	DromS	63	90	82	108	306	130	100
Knot	DromN	0	0	0	35	2	7	15
	DromS	2370	2870	660	0	2195	1619	1225
Black-tailed Godwit	DromN	45	0	0	2	21	14	20
	DromS	0	0	0	8	10	4	5
Bar-tailed Godwit	DromN	0	0	0	0	0	0	0
	DromS	609	366	15	1015	1448	691	558
Curlew	DromN	48	28	20	17	17	26	13
	DromS	21	69	22	39	69	44	24
Common Gull	DromN	35	38	34	18	95	44	30
	DromS	14	46	27	40	240	73	94
Herring Gull	DromN	4	0	0	0	0	1	2
	DromS	7	18	5	9	14	11	5

[1] DromN = Impact zone; DromS = Control zone.

3.3 A total of 22 species were recorded on the counts in the Annagassan sectors, of which 15 occurred in sufficient numbers for analysis (Table 3.2). Most species showed quite variable distribution patterns between the two days: e.g., Knot were more abundant in the AnnN (Control) sector on 10 February but were more abundant in the AnnS (Impact) sector on the following day. Oystercatcher, Dunlin and Turnstone did show more or less consistent distribution patterns, being

more abundant in the AnnS (Impact) sector on five (Oystercatcher and Dunlin) or six (Turnstone) out of the six counts. In the case of Oystercatcher and Turnstone this difference probably was due to the presence of the mussel bed in the AnnS sector, with which they showed a strong association.

Table 3.2 - Results of the Annagassan sector counts.

Species	Sector[1]	10-Feb		11-Feb		Overall		% on mussel bed
		Mean	SD	Mean	SD	Mean	SD	
Wigeon	Ann N	1	1	74	78	37	63	0%
	Ann S	4	5	0	0	2	4	0%
Mallard	Ann N	0	0	72	63	36	56	0%
	Ann S	0	0	2	3	1	2	73%
Oystercatcher	Ann N	187	114	239	45	213	82	5%
	Ann S	369	104	284	116	327	109	49%
Ringed Plover	Ann N	0	0	1	1	1	1	0%
	Ann S	2	1	2	2	2	1	76%
Grey Plover	Ann N	44	18	22	10	33	18	2%
	Ann S	43	37	15	15	29	30	1%
Knot	Ann N	94	137	73	110	84	111	6%
	Ann S	26	37	419	520	222	394	99%
Dunlin	Ann N	165	227	296	164	231	191	0%
	Ann S	491	284	1087	878	789	669	0%
Black-tailed Godwit	Ann N	34	59	0	0	17	42	0%
	Ann S	8	11	1	2	4	8	0%
Bar-tailed Godwit	Ann N	9	16	20	18	15	16	0%
	Ann S	1	1	6	10	3	7	14%
Curlew	Ann N	13	8	10	10	11	8	0%
	Ann S	14	8	5	1	9	7	3%
Redshank	Ann N	16	10	54	41	35	34	0%
	Ann S	25	1	19	12	22	8	70%
Turnstone	Ann N	0	0	3	5	1	3	0%
	Ann S	3	4	6	5	5	4	100%
Black-headed Gull	Ann N	2	2	20	20	11	16	0%
	Ann S	0	1	1	1	1	1	50%
Common Gull	Ann N	12	16	10	9	11	11	0%
	Ann S	4	2	19	26	12	18	8%
Herring Gull	Ann N	3	3	1	2	2	3	0%
	Ann S	0	1	10	13	5	10	5%

[1] AnnN = Control sector; AnnS = Impact sector.

Transect counts

Tideline behaviour

3.4 Figure 3.3 to Figure 3.6 show the movement of the tideline through the transects on each of the four transect count days.

3.5 The tideline remained in the transects for a longer period during the February counts compared to the March counts.

Date	Number of counts with	
	tideline inside transect	tideline outside transect
24th February 2010	65	4
25th February 2010	54	26
11th March 2010	39	41
12th March 2010	23	57

3.6 During the March counts, the tideline moved more rapidly through the control transects (transects 11-20) compared to the impact transects (transects 1-10) (see Figure 3.5 and Figure 3.6).

Waterbird counts

3.7 A total of 309 unique transect counts were completed.

3.8 A total of 20 species were recorded across all the counts. The most abundant species was Knot, followed by Bar-tailed Godwit, Oystercatcher, Dunlin and Common Gull (Table 3.3). However, the most frequent species were Oystercatcher, Common Gull and Curlew, which were recorded on 45-60% of the transect counts (Table 3.4). Bar-tailed Godwit, Dunlin, Great Black-backed Gull, Herring Gull and Knot were recorded on 20-30% of the transect counts, and the remaining species were recorded on less than 10% of the counts. Most species were recorded less frequently in the March counts compared to the February counts, with the exception of Curlew and some of the very infrequent species.

3.9 Most species were recorded more frequently on counts with the tideline inside the transect, compared to counts with the tideline outside the transect (Figure 3.7).

Table 3.3 – Mean species counts per day for the entire study area.

Species	24-Feb	25-Feb	11-Mar	12-Mar	Overall mean
Light-bellied Brent Goose	75	0	3	0	20
Mallard	0	0	0	0	0
Oystercatcher	499	408	81	32	255
Golden Plover	2	0	0	0	1
Grey Plover	6	2	1	2	3
Knot	3605	2551	728	2240	2281
Dunlin	96	254	85	579	253
Black-tailed Godwit	8	354	18	25	101
Bar-tailed Godwit	251	1091	11	2	339
Curlew	61	346	24	27	114
Redshank	53	4	0	0	14
Black-headed Gull	58	1	3	1	16
Common Gull	415	262	78	26	195
Lesser Black-backed Gull	1	0	0	0	0
Herring Gull	155	56	1	5	54
Great Black-backed Gull	64	45	3	11	30

This table contains the mean of the second and third counts carried out each day. The first and fourth counts were excluded because they were incomplete on 24 February. Four additional species were recorded (CX, RP, SV and WN) on single counts only.

Table 3.4 – Number of non-zero transect counts for each waterbird species.

Species	24-Feb	25-Feb	11-Mar	12-Mar	Total
Light-bellied Brent Goose	17	0	1	1	19
Mallard	3	2	0	0	5
Oystercatcher	63	69	33	10	175
Golden Plover	5	0	1	0	6
Grey Plover	12	8	2	5	27
Knot	49	22	5	9	85
Dunlin	33	24	6	2	65
Black-tailed Godwit	7	10	6	5	28
Bar-tailed Godwit	41	28	6	2	77
Curlew	27	34	37	45	143
Redshank	13	3	0	0	16
Black-headed Gull	10	1	4	4	19

Species	24-Feb	25-Feb	11-Mar	12-Mar	Total
Common Gull	51	70	35	30	186
Lesser Black-backed Gull	2	0	1	1	4
Herring Gull	49	27	6	7	89
Great Black-backed Gull	35	30	6	3	74
Total no. of counts	69	80	80	80	309

3.10 Over 80% of Bar-tailed Godwit, Black-headed Gull, Herring Gull, Great Black-backed Gull and Pale-bellied Brent counts were on the tideline, while other species tended to show a more even distribution between tideline and intertidal counts (Figure 3.8). The proportion of counts of feeding birds was over 90% for all waders, except Oystercatcher, but was only 48-70% for the four gull species (Figure 3.8).

3.11 The total numbers recorded in the transects in the control and impact zones on each count day are shown in Table 3.5. On three out of the four count days, higher numbers of Knot were recorded in the control zone, with the difference being very marked on the March count days. On the two count days when significant numbers were recorded, higher numbers of Bar-tailed Godwits were recorded in the impact zone. The small numbers of Grey Plovers recorded were almost all in the control zone. None of the other species showed consistent differences between the control and impact zones.

Waterbird numbers and cockle fishing

3.12 The Dromiskin sector counts and the transect counts covered roughly the same area. The proportion of birds in the impact zones across both of these sets of counts are shown in Table 3.6.

3.13 Significantly higher numbers of Knot occurred in the control zone (one-tailed paired t-test, $t = 2.11$, $p = 0.026$, d.f. = 15). The pattern of distribution of Knot between the transects shows high variability between counts and does not indicate a response to a gradient in habitat quality (Figure 3.9).

3.14 The proportions of the counts of the other species in the impact zone were all close to 50% and paired t-tests did not indicate significant differences in numbers between the control and impact zones.

Foraging behaviour study

3.15 During the March counts, the low numbers of Bar-tailed Godwit and the short duration of the period with the tideline within the transects limited the number of focal observations that it was possible to complete.

3.16 A total of 46 focal observations of Oystercatcher (20 in the control zone and 26 in the impact zone), 11 of Bar-tailed Godwit (four in the control zone and seven in the impact zone), and two of Black-tailed Godwit (one each in the control and impact zones) were completed.

3.17 Twelve of the Oystercatcher focal observations (six each in the control and impact zones) were of birds outside the transects (because no birds were present within the transects at the times of those observations) and have been excluded from the main analysis.

3.18 Comparisons of the position of the tideline during each focal observation (as indicated by the tideline maps from the waterbird distribution study; see Figure 3.3-Figure 3.6) to the fishing effort map indicated that a further four Oystercatcher and two Bar-tailed Godwit focal observations from the impact zone transects were outside the area actually affected by cockle fishing. These focal observations were also excluded from the main analyses.

3.19 The foraging behaviour of Oystercatcher and Bar-tailed Godwit in the control and impact zones was generally very similar (Figure 3.10) and there were no statistically significant differences in any of the Oystercatcher feeding rate parameters between the control and impact zones.

3.20 The number of swallows per Bar-tailed Godwit focal observation was almost twice as high in the control compared to the impact zone (6.3 compared to 3.8). However, the sample size is too small for meaningful statistical analysis. Furthermore, the four focal observations in the control zone and four of the five focal observations in the impact zone involved two pairs of consecutive observations of birds in the same transect.

3.21 There were some apparent differences in the foraging behaviour of Oystercatchers outside the transects compared to Oystercatchers within the transects (Figure 3.11). In particular, the number of swallows per Bar-tailed Godwit focal observation was over four times as high in the transects compared to the outside the transects (5.8 compared to 1.3) and this difference was significant ($t = 4.49$, $p < 0.001$, $d.f = 38$). While the number of observations of Oystercatchers outside the transects was relatively small, these observations were well distributed spatially (across areas downshore of four of the five transects used) and temporally (across three of the four study days).

3.22 Oystercatchers were recorded preening during nine focal observations in total, six of which are included in the analysis presented in Figure 3.10. The duration of preening in these observations varied from 4-8 seconds. Other activities, such as aggressive interactions and handling time for birds feeding on cockles, affected up to 34 seconds of Oystercatcher focal observations. However, when the foraging rate parameters were corrected for the reduced period of active foraging in these focal observations, the mean values changed by 2.5% or less. Therefore, these activities did not bias the comparisons in Figure 3.10.

3.23 Prey items were recorded during nine focal observations of Oystercatchers: annelids (three observations), cockles (three observations), razor shells (two observations) and a small bivalve (one observation). The three observations of predation on cockles involved handling times of 19, 30 and 32 seconds. There was a single observation of Bar-tailed Godwit predating annelids.

3.24 Aggressive interactions were recorded during six focal observations of Oystercatchers, with: other Oystercatchers (three observations), Common Gulls (two observations) and a Black-headed Gull (one observation).

Table 3.5 – Total counts in the control (transects 11-20) and impact (transects 1-10) sections of the transect count study area.

Species	Date	24-Feb		25-Feb				11-Mar				12-Mar			
	Count	2	3	1	2	3	4	1	2	3	4	1	2	3	4
Light-bellied Brent Goose	Control	7	120	0	0	0	0	0	0	0	0	4	0	0	0
	Impact	6	17	0	0	0	0	0	0	6	0	0	0	0	0
Mallard	Control	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Impact	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Oystercatcher	Control	184	313	183	136	297	273	69	17	0	20	33	0	50	11
	Impact	289	211	93	247	136	204	41	78	66	0	0	14	0	0
Golden Plover	Control	0	4	0	0	0	0	0	0	0	11	0	0	0	0
	Impact	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grey Plover	Control	7	5	4	0	4	10	0	0	0	1	0	0	4	9
	Impact	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Knot	Control	2390	1852	18	50	157	585	0	265	1100	634	2000	4280	200	5935
	Impact	1861	1107	0	710	4184	858	0	0	90	0	0	0	0	0
Dunlin	Control	41	67	2	0	81	178	0	18	80	0	0	1158	0	0
	Impact	56	28	0	71	355	190	0	0	71	0	0	0	0	0
Black-tailed Godwit	Control	0	7	273	580	0	0	0	35	0	6	9	50	0	30
	Impact	9	0	0	120	7	113	11	0	0	0	0	0	0	0
Bar-tailed Godwit	Control	21	58	0	165	2	142	23	3	0	0	0	0	0	0
	Impact	165	258	24	723	1292	965	0	0	18	0	2	4	0	0
Curlew	Control	27	20	13	10	4	28	6	16	4	31	25	28	11	33
	Impact	47	27	3	29	648	29	6	22	6	17	39	14	0	27

Species	Date	24-Feb		25-Feb				11-Mar				12-Mar			
	Count	2	3	1	2	3	4	1	2	3	4	1	2	3	4
Redshank	Control	43	49	0	1	0	0	0	0	0	0	0	0	0	0
	Impact	14	0	0	0	7	0	0	0	0	0	0	0	0	0
Black-headed Gull	Control	7	2	0	0	0	0	0	0	0	0	0	0	0	0
	Impact	102	5	0	2	0	0	0	4	1	0	3	1	0	0
Common Gull	Control	309	125	177	62	33	156	10	53	15	12	18	0	0	0
	Impact	259	136	81	167	262	167	24	45	43	15	54	48	3	12
Lesser Black-backed Gull	Control	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Impact	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Herring Gull	Control	80	62	38	24	0	3	1	0	0	0	11	9	0	0
	Impact	128	39	36	47	41	0	2	2	0	1	1	0	0	0
Great Black-backed Gull	Control	80	30	20	21	1	0	0	2	0	1	0	20	0	0
	Impact	11	6	15	40	28	0	0	1	2	0	0	0	1	0

Count series 1, 4 and 5 from 24 February are not included as these count series were incomplete.

Four additional species (Wigeon, Shoveler, Common Scoter and Ringed Plover) were recorded on single counts only.

Table 3.6 – Proportion of birds in the Impact zone in the Dromiskin sector counts and the transect counts.

Date	Count	Oystercatcher	Knot	Dunlin	Bar-tailed Godwit	Curlew	Common Gull
10-Feb	1	60%	0%		0%	70%	
11-Feb	1	20%	0%		0%	29%	45%
	2	50%	0%				56%
	3	45%			0%	30%	31%
	4	34%	0%	0%	0%	20%	28%
24-Feb	2	61%	44%	58%	89%	64%	46%
	3	40%	37%	29%	82%		52%
25-Feb	1	34%					31%
	2	64%	93%	100%	81%		73%
	3	31%	96%	81%	100%	99%	89%
	4	43%	59%	52%	87%	51%	52%
11-Mar	1	37%					
	2	82%	0%				46%
	3	100%	8%	47%			74%
	4		0%				
12-Mar	1		0%			61%	75%
	2		0%	0%			
	3	0%	0%				
	4		0%			45%	
Mean		47%	21%	46%	49%	52%	54%
SD		25%	37%	33%	7%	21%	19%

Only counts with total numbers of 50 or more birds are included and only species with five or more qualifying counts are included.

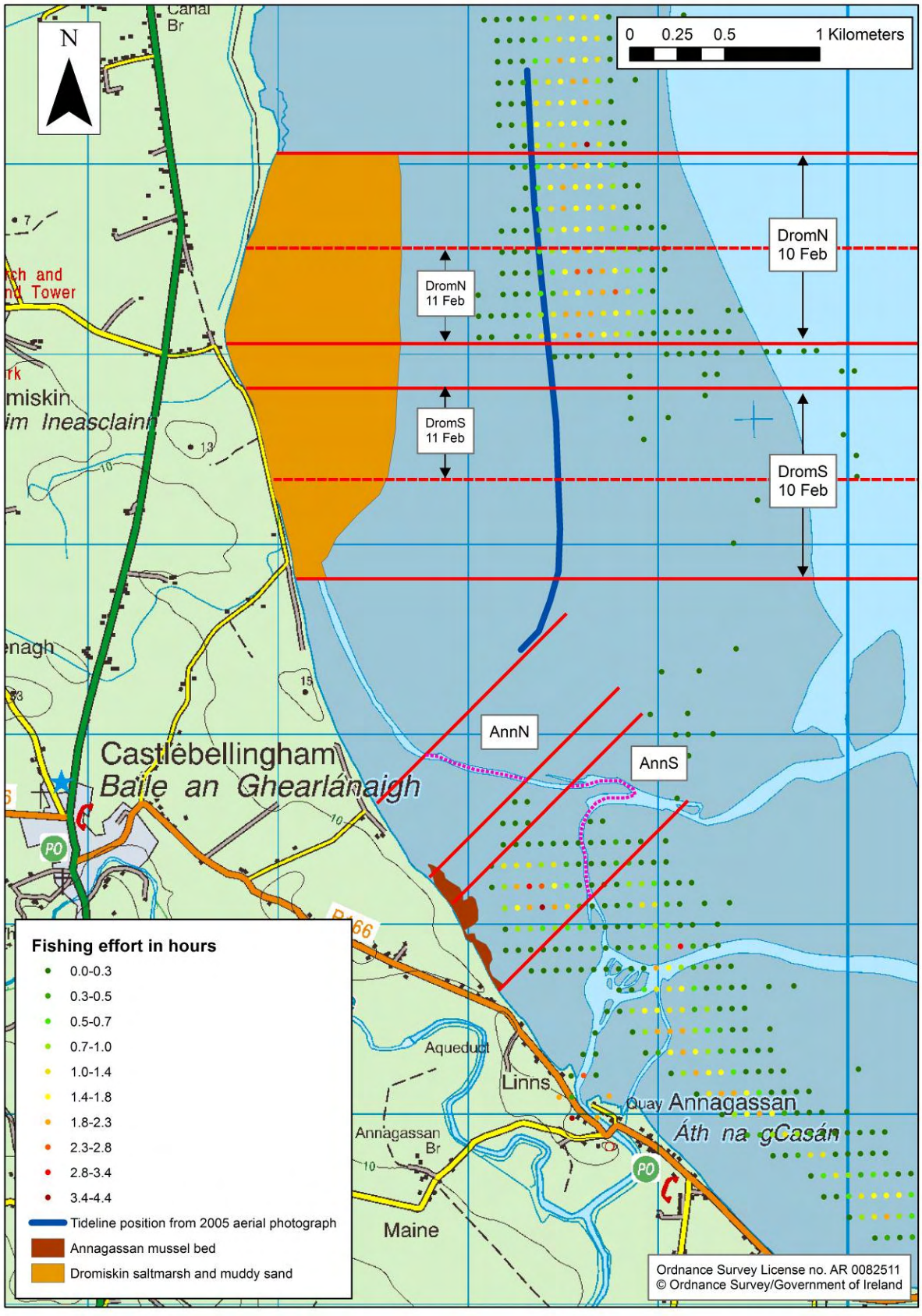

Figure 3.1 – Count sectors used in the waterbird counts on 10 and 11 February 2010.

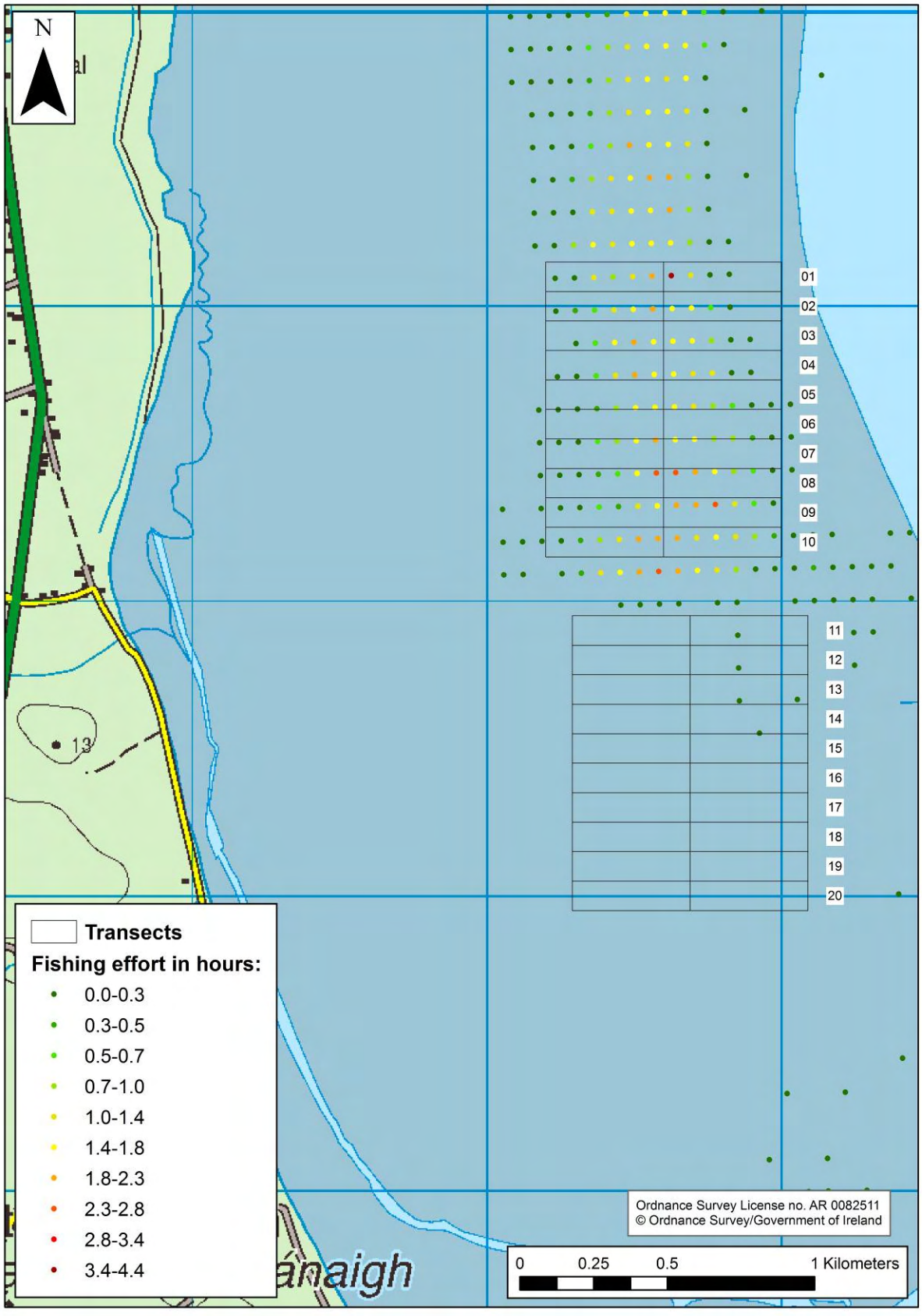

Figure 3.2 – Transects used in the waterbird counts on 24-25 February and 11-12 March 2010.

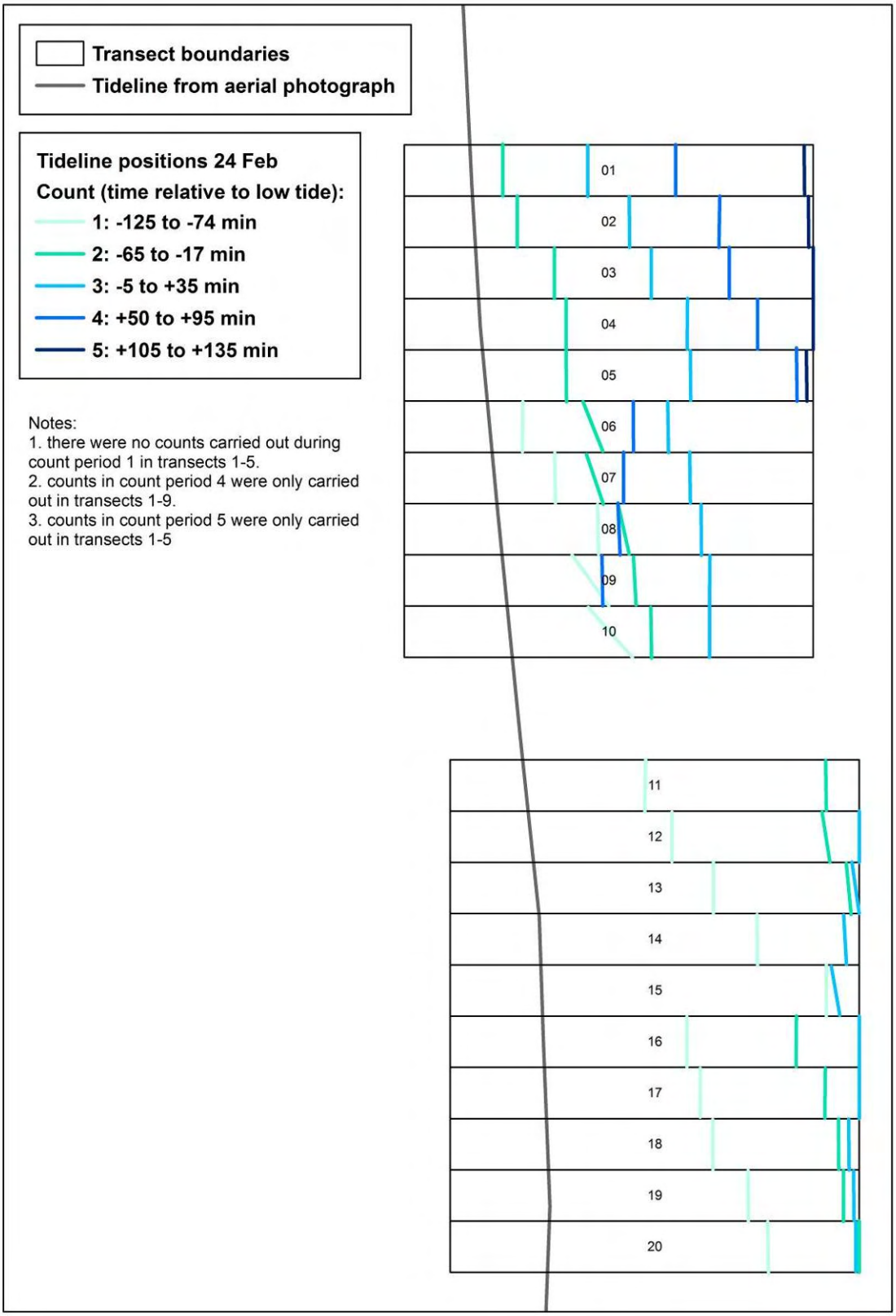

Figure 3.3 – Tideline positions recorded during transect counts on 24 February 2010.

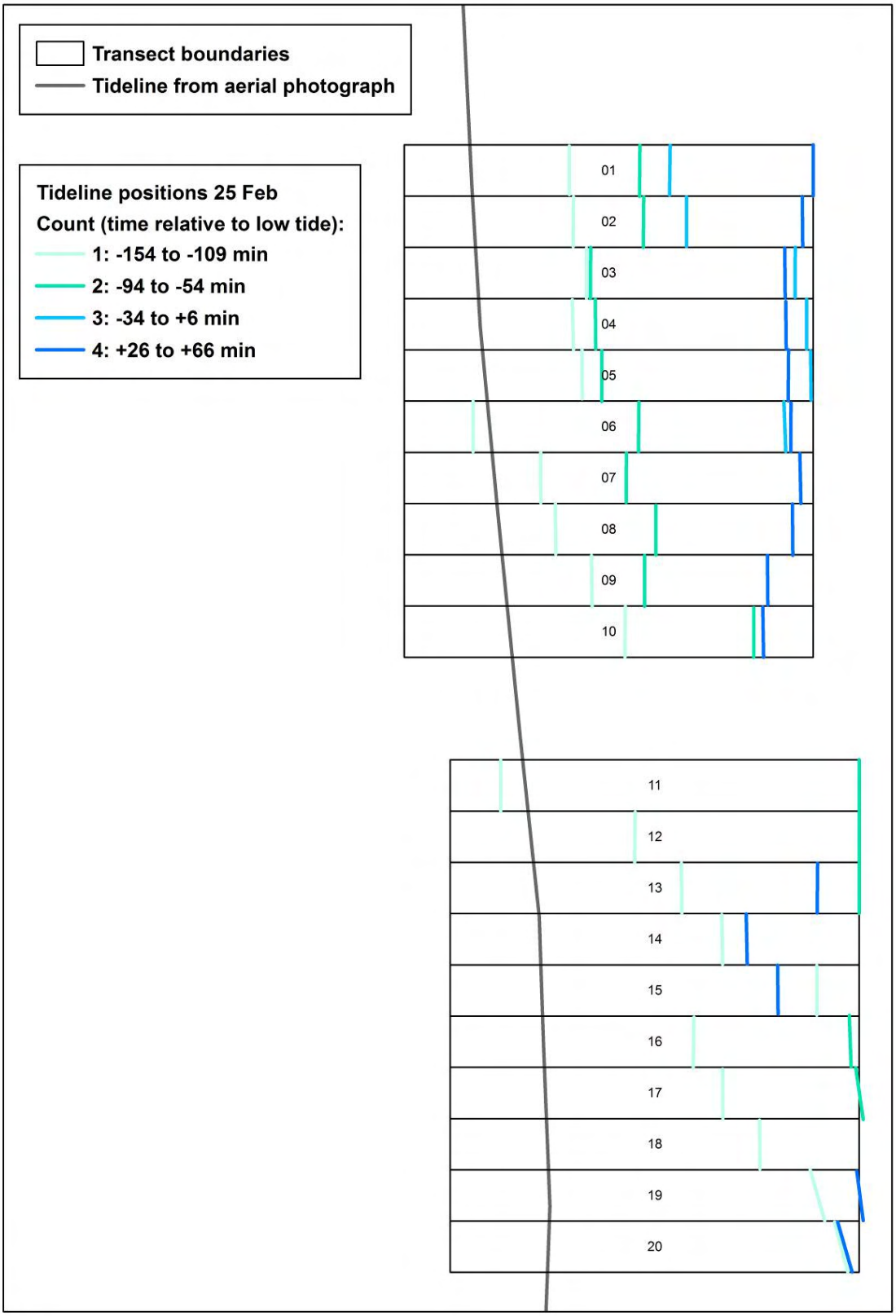

Figure 3.4 – Tideline positions recorded during transect counts on 25 February 2010.

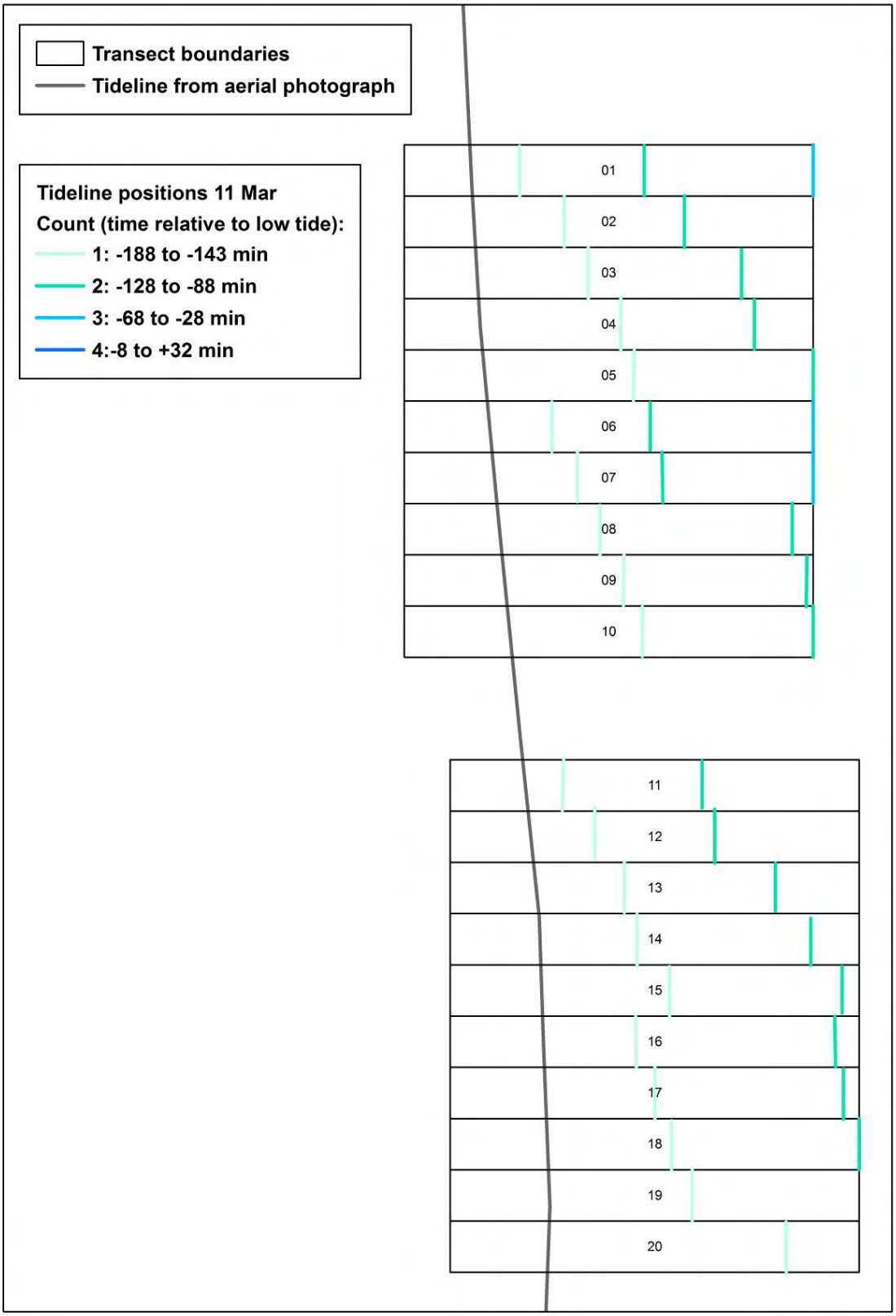

Figure 3.5 – Tideline positions recorded during transect counts on 11 March 2010.

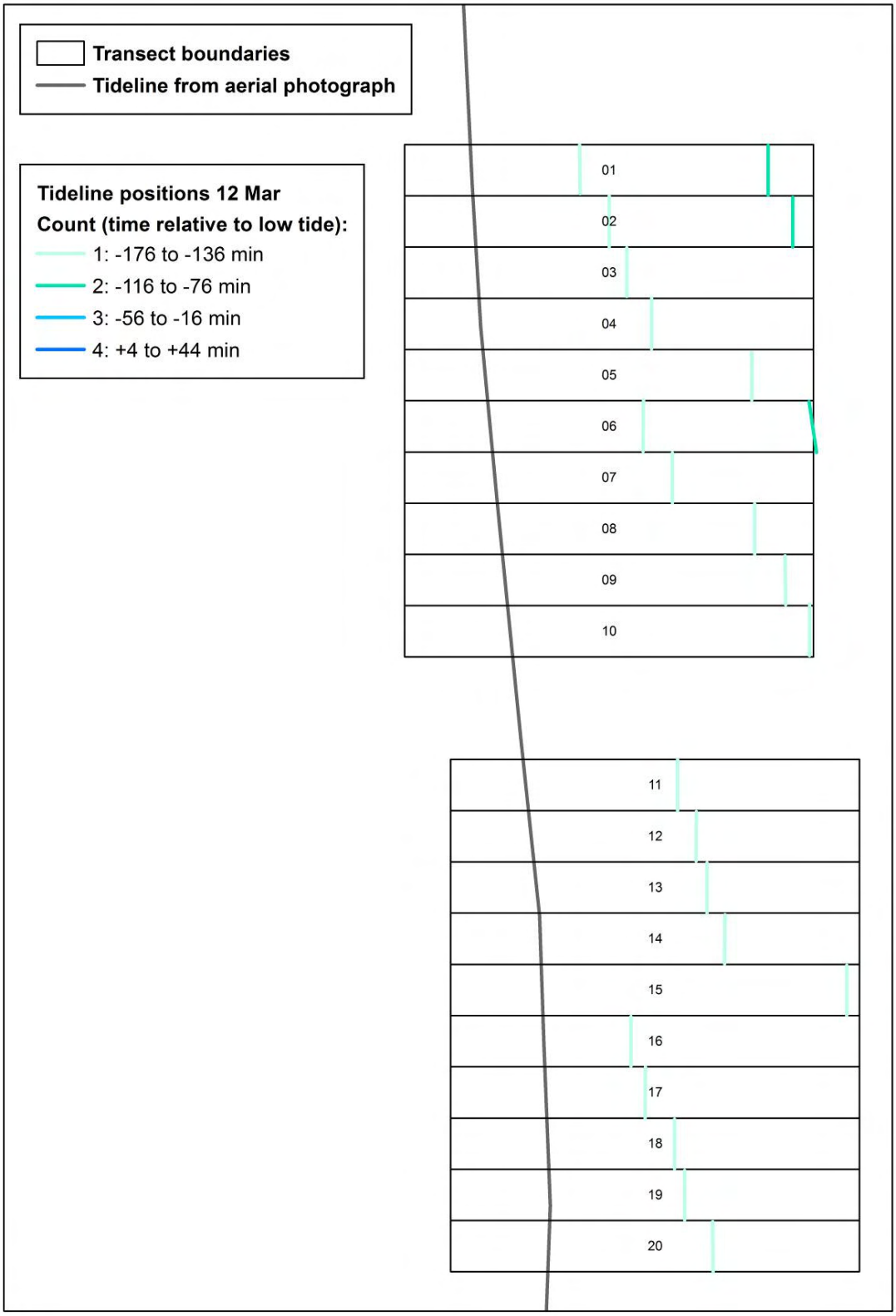

Figure 3.6 – Tideline positions recorded during transect counts on 12 March 2010.

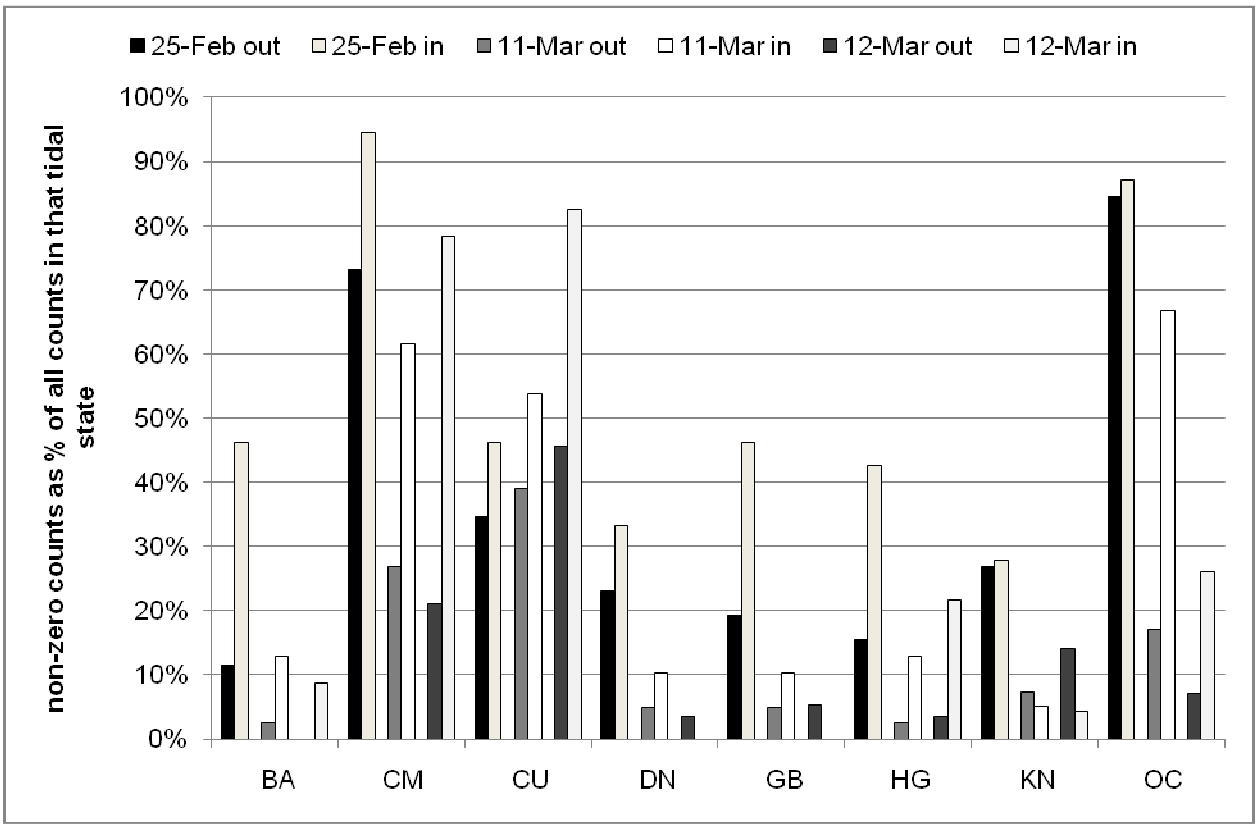

Figure 3.7 - Non-zero waterbird counts in relation to tidal position. The number of counts with the tideline outside the transect was 26 on 25th February, 41 on 11th March and 57 on 12th March. There were only five counts with the tideline outside the transect on 24th Feb so data from that day is not included in this graph.

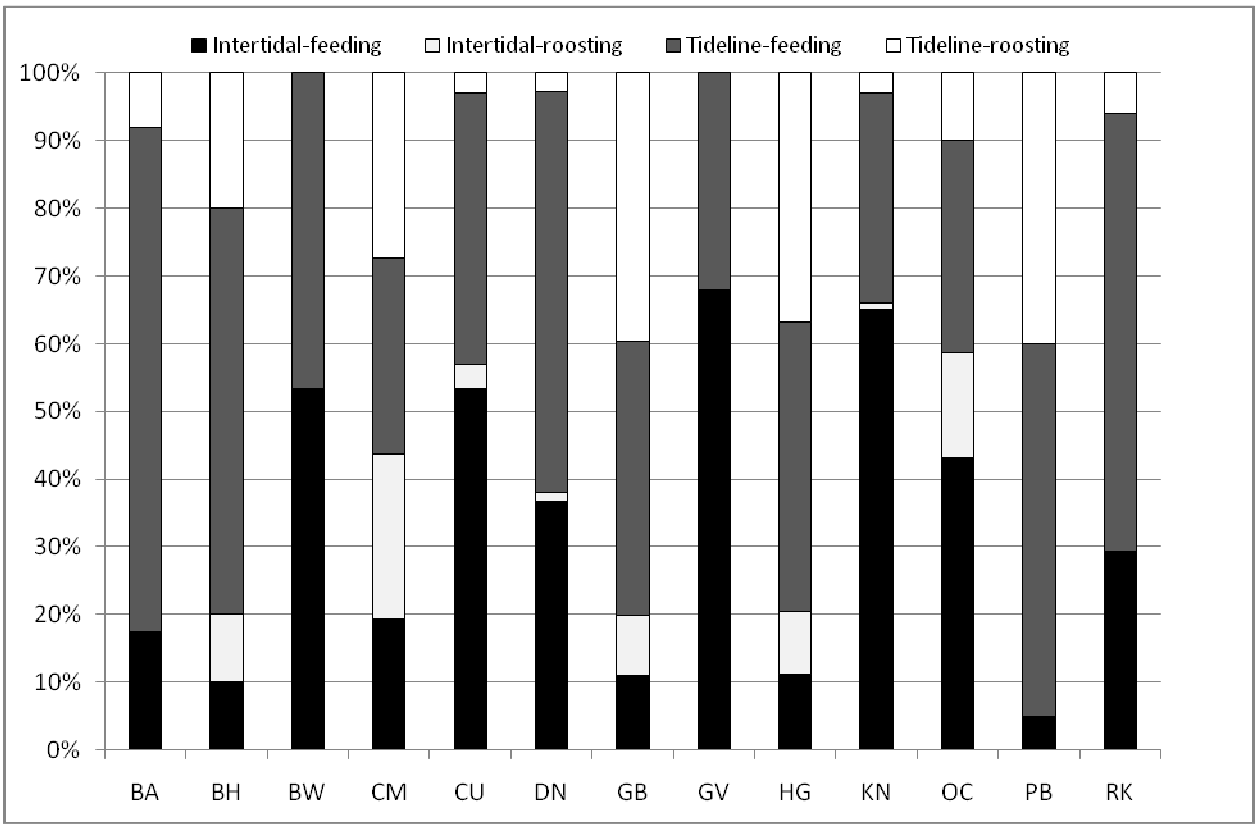

Figure 3.8 – Percentage frequency of counts by location and activity of waterbird species recorded in the transect counts.

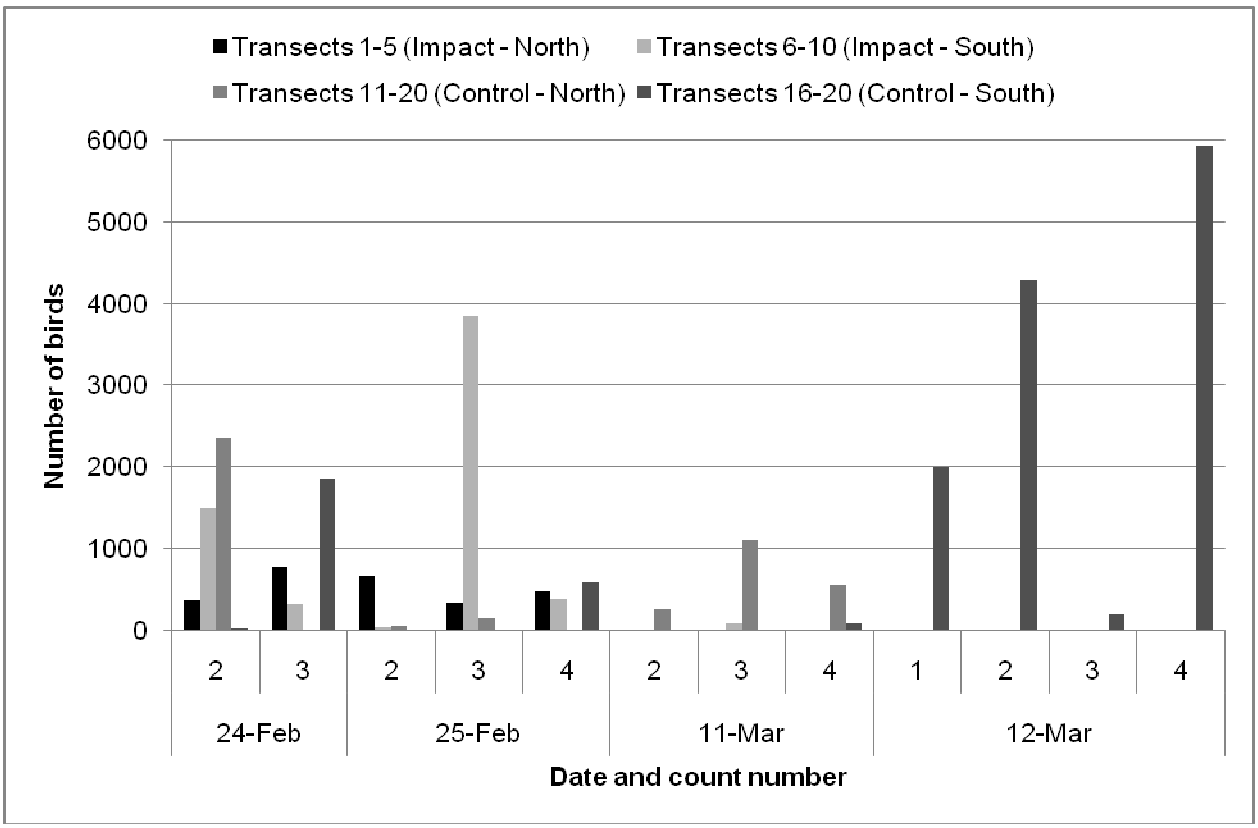

Figure 3.9 – Distribution of Knot between transect groups on each count.

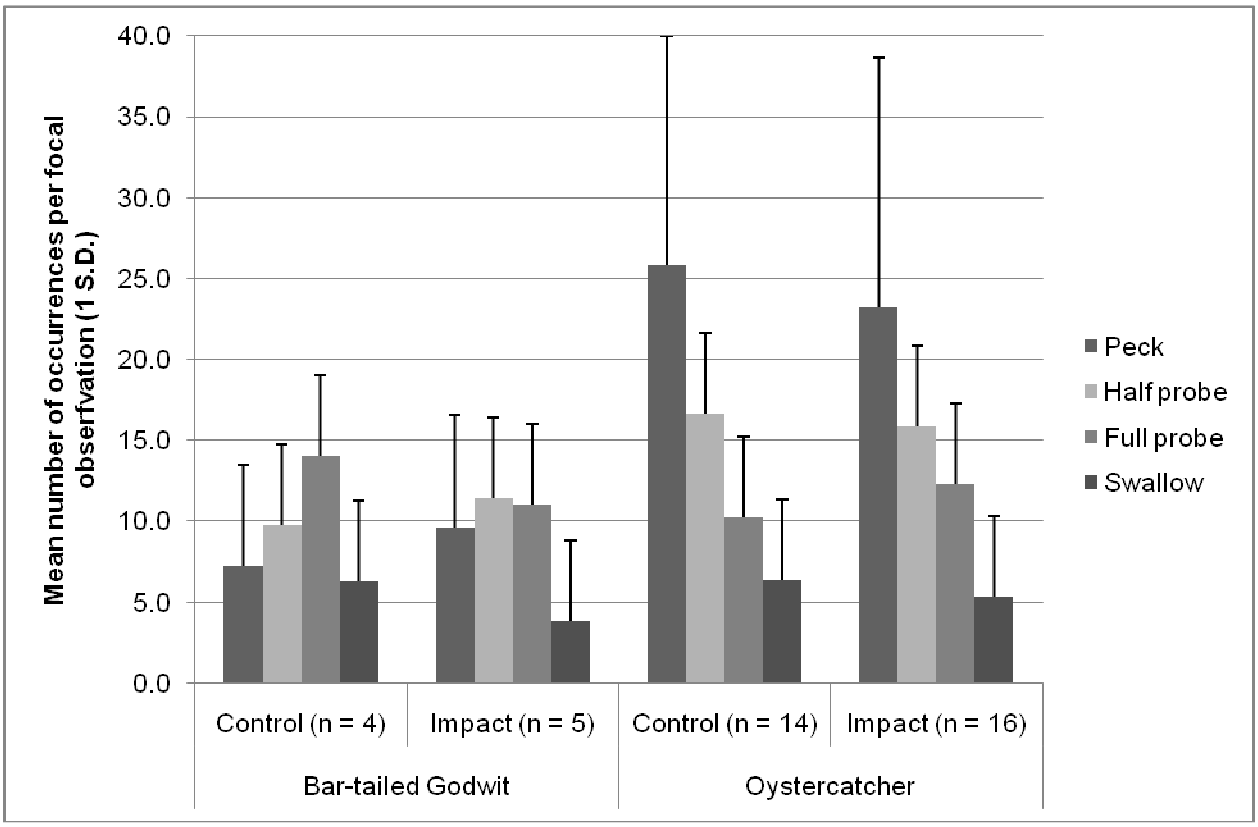

Figure 3.10 - Foraging behaviour recorded in focal observations of Oystercatcher and Bar-tailed Godwit: comparison of birds in control and impact zones.

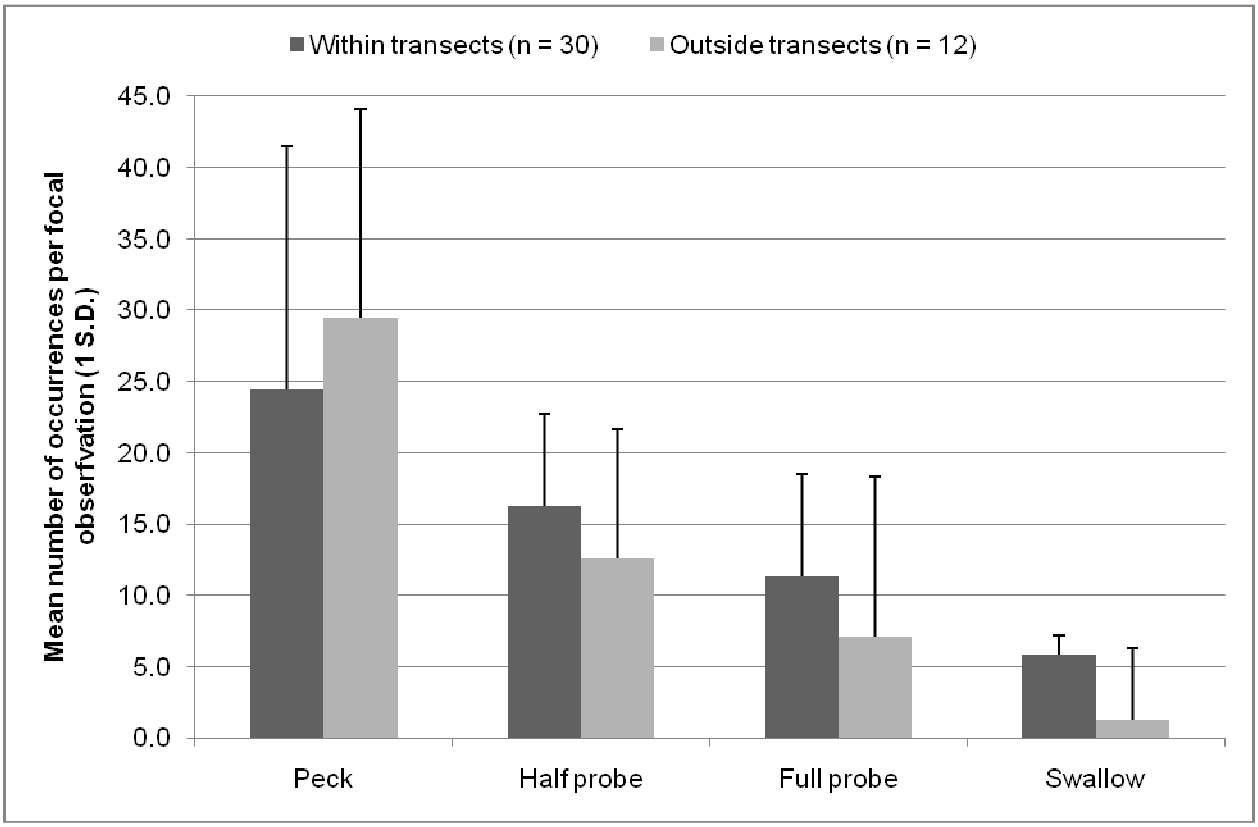

Figure 3.11 - Foraging behaviour recorded in focal observations of Oystercatcher: comparison of birds within and outside transects.

4. Discussion

Limitations

4.1 Several factors affected the quality of data produced by the studies described in this report. There were considerable practical difficulties in designing and carrying out the study, while the late start to the study affected the results of the study.

4.2 The large, continuous blocks of habitat affected by cockle fishing made it difficult to identify comparable areas of control and impacted habitat. It was only possible to identify one area with sizeable areas of control and impacted habitat at similar shore positions relative to the tideline, with similar sediment types and without tidal channels, etc. This meant that the study was effectively unreplicated. The transects were designed to address this issue by potentially allowing both detection of gradients in bird usage and analysis of the relationship between bird distribution and fishing intensity. However, other problems (see paragraph 4.5) prevented these types of analyses.

4.3 There were major logistical difficulties in marking transect boundaries, due to the exposed nature of the site and the mobile sediment. The first attempt (using wooden stakes) was unsuccessful. While the later attempts (using buoys) were successful, the logistical issues meant that transects had to be contiguous, and the number of sub-divisions of the transects had to be limited.

4.4 There were also issues with safe access for counters out onto the sandflats to suitable vantage points in time to catch the tideline beginning to move through the upper edge of the transects.

4.5 The late start to the study, the problems with marking transect boundaries, and the fact that count dates were constrained by tidal conditions and the availability of counters, meant that the number of transect count days was reduced. Furthermore, these issues also resulted in the third and fourth count days, in early March, taking pace when numbers of most species were significantly reduced. As a result, the number of non-zero transect counts on the March count days were low for all species.

4.6 Our intention had been to use Generalised Linear Mixed Modelling (GLMM) techniques to analyse the relationship between waterbird distribution and cockle fishing intensity (see Gittings and O'Donoghue, 2011 for a comparable example of the use of these techniques). However, the high number of non-zero counts meant that the species datasets were all highly zero-inflated. GLMM models for zero-inflated data are not well-developed (Zuur *et al.*, 2009) and we considered that the resources required to try and develop suitable models for dealing with the data would not be likely to be justified given the limited nature of the dataset.

4.7 We did try some GLMM analyses on subsets of the data that had relatively low levels of zero – inflation. However, these analyses were not robust: the models often failed to converge and/or were very sensitive to small changes in the model building procedure.

4.8 The foraging behaviour study was also affected by some of the above issues. The late start to the study meant that one of the target species (Bar-tailed Godwit) was very rare during the March observation days. Therefore, the number of focal observations of Bar-tailed Godwit were very limited. The access issues (see paragraph 4.4) and rapid movement of the tideline through the transects also limited the number of focal observations that were possible of birds within the designated impact and control zones.

Waterbird distribution

4.9 Most species did not show consistent patterns of distribution between the control and impact sectors in the Annagassan sector counts. For two of the three species that did, the difference was related to the presence of the mussel bed in the AnnS (Impact) sector.

4.10 For most species, the spatial distribution of waterbirds between the control and impact zones across the Dromiskin sector counts and transect counts was quite variable. For example, Bar-tailed Godwit occurred exclusively in the control zone during the Dromiskin sector counts but was consistently more abundant in the impact zone during the transect counts.

4.11 Overall, for Oystercatcher, Dunlin, Bar-tailed Godwit, Curlew and Common Gull, the mean proportion of birds in the impact zone across the Dromiskin sector counts and transect counts was close to 50%. Therefore, if cockle fishing in the autumn of 2009 caused habitat differences between the control and impact zones, any such habitat differences were not having detectable effects on the distribution of these species, in this part of Dundalk Bay, in February and March 2010.

4.12 Significantly higher numbers of Knot occurred in the control zone across the Dromiskin sector counts and transect counts, indicating a possibility that habitat differences exist between the control and impact zone and that these habitat differences affected Knot distribution. However, because of the lack of effective replication, it is not possible to say whether any such habitat differences were due to cockle fishing or to other causes, such as underlying habitat differences, or the effects of prey depletion earlier in the winter.

4.13 Furthermore on one of the four count days the main Knot flock occurred in the impact zone. Because Knot tend to feed in a few large flocks, they have a highly aggregated distribution. At the relatively small spatial scales considered in this study, random factors may have a major influence on the distribution of Knot between the control and impact zones. Therefore, the apparent difference in Knot numbers between the control and impact zones does not necessarily mean that there were any habitat differences between these zones.

Waterbird foraging behaviour

4.14 The foraging behaviour of Oystercatcher and Bar-tailed Godwit in the control and impact zones was generally very similar and there were no statistically significant differences in any of the Oystercatcher feeding rate parameters between the control and impact zones. The number of swallows per Bar-tailed Godwit focal observation was almost twice as high in the control compared to the impact zone but the ecological significance of this result is unclear due to the very small sample size. Therefore, overall, this study did not provide any clear evidence that cockle fishing in the autumn of 2009 affected the foraging behaviour of these species in this part of Dundalk Bay in February and March 2010.

4.15 While the sample size is quite small, there did appear to be a difference in the foraging behaviour of Oystercatchers in lower shore habitat outside the transects, compared to birds within the transects. This may indicate habitat differences between the lateral zone occupied by the transects and the lateral zone below the transects. This result supports the importance attached in the design of these studies to having control and impact areas within the same lateral zone of the shoreline.

4.16 Oystercatcher prey capture rates reported in the literature are highly variable, ranging from 0.1-0.2 items per min (for Oystercatchers predating mussels; Sitters, 2000) to 2.7-7.5 items per min for (Oystercatchers predating cockles using the stabbing method; Meire, 1996). However, the prey

capture rates are not solely determined by prey type as another study (Sutherland, 1982) found a low prey capture rate (0.4-0.6 items per min) for Oystercatchers predating cockles. The prey capture rates in this study (1.1 items per min in the transects and 0.2 items per min outside the transects) are towards the lower end of the reported range. While the observations indicated that the handling time for cockles could be relatively lengthy, this factor did not affect the overall prey capture rates due to the low incidences of such events.

4.17 The handling time for Oystercatchers predating cockles increases with the size of the cockles (Zwarts *et al*., 1996). The handling times observed in this study of 19-32 seconds would correspond to shell lengths of approximately 20-35 mm according to the relationship reported by Zwarts *et al* (1996). However, small cockles, requiring handling times of a few seconds, may have been consumed without the prey type being detected.

4.18 The overall composition of the Oystercatcher diet could not be recorded during this study due to the distance at which it was necessary to carry out observations. However, given the lengthy handling times required for large cockles it is likely that all captures of large cockles were recorded. Therefore, Oystercatchers had very low capture rates of large cockles during this study.

4.19 The prey capture rate recorded for Bar-tailed Godwit in this study (2.1 items per min; combined control and impact zones data) is comparable to rates reported in the literature: 1.9 items/min (Smith and Evans, 1973); 2.1-2.8 items per min (Smit and Wolff, 1982); 2.7-4.7 items per min (Zharikov and Skilleter, 2003); and 2.6-3.0 items per min (Granadeiro *et al*., 2006).

4.20 The internal consistency of the results reported in this study and the comparisons with the literature indicate that the methodology used was appropriate and that this methodology, if extended over large spatial and temporal scales, could provide useful information on the impact of cockle fishing. However, a deficiency in this methodology is that, because of the distances involved, it is difficult to identify prey species and prey size. Differences in prey species/size may confound comparison of foraging behaviour parameters: for example, lower prey capture rates could reflect capture of larger/more valuable prey.

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Appendix A
Scientific names of bird species mentioned in the text

A.1.1 Scientific names of bird species mentioned in the text.

Common Name	Scientific Name
Black-headed Gull	*Chroicocephalus ridibundus*
Bar-tailed Godwit	*Limosa lapponica*
Black-tailed Godwit	*Limosa limosa*
Common Gull	*Larus canus*
Common Scoter	*Melanitta nigra*
Cormorant	*Phalacrocorax carbo*
Curlew	*Numenius arquata*
Dunlin	*Calidris alpina*
Gadwall	*Anas strepera*
Goldeneye	*Bucephala clangula*
Golden Plover	*Pluvialis apricaria*
Great Crested Grebe	*Podiceps cristatus*
Greylag Goose	*Anser anser*
Grey Heron	*Ardea cinerea*
Grey Plover	*Pluvialis squatarola*
Great Black-backed Gull	*Larus marinus*
Greenshank	*Tringa nebularia*
Herring Gull	*Larus argentatus*
Lapwing	*Vanellus vanellus*
Lesser Black-backed Gull	*Larus fuscus*
Light-bellied Brent Goose	*Branta bernicla hrota*
Little Egret	*Egretta garzetta*
Little Grebe	*Tachybaptus ruficollis*
Knot	*Calidris canutus*
Mallard	*Anas platyrhynchus*
Mute Swan	*Cygnus olor*
Oystercatcher	*Haematopus ostralegus*
Pintail	*Anas acuta*
Red-breasted Merganser	*Mergus serrator*
Redshank	*Tringa totanus*
Ringed Plover	*Charadrius hiaticula*
Ruff	*Philomachus pugnax)*
Sanderling	*Calidris alba*
Shelduck	*Tadorna tadorna*
Shoveler	*Anas clypeata*

Snipe	*Gallinago gallinago*
Spotted Redshank	*Tringa erythropus*
Teal	*Anas crecca*
Turnstone	*Arenaria interpres*
Wigeon	*Anas penelope*

Appendix B

Rationale for selection of focal species for feeding rate study

B.1 Species numbers

B.1.1 Irish Wetland Bird Survey high tide count data for the Lurgangreen South subsite, which contains most of the study area (see Figure B.1), are summarised in Table B.1. However, not all of the species listed utilise the lower shore sandflat habitat in which the impact and control areas are located. The geese mainly occur in fields above the shoreline, seaduck and grebes occur in subtidal habitat and dabbling duck and some waders (e.g., Black-tailed Godwit and Redshank) mainly occur in muddy upper shore sediments (based on observations in January-February 2010 and discussions with the low tide counters).

B.1.2 The species that occur in significant numbers on intertidal habitat within the impact and control areas are: Oystercatcher, Knot, Dunlin, Bar-tailed Godwit and Curlew.

B.1.3 Overall numbers of Knot and Bar-tailed Godwit in Dundalk Bay are of international importance (Crowe, 2005), while Oystercatcher, Dunlin and Curlew occur in nationally important numbers. Dundalk Bay is the most important site in Ireland for Oystercatcher, Knot and Bar-tailed Godwit.

B.2 Foraging behaviour

B.2.1 Waders feeding in intertidal habitat utilise a wide range of prey and the same species may have quite different diets in different sites and/or at different seasons. However, Oystercatchers are specialists on bivalve molluscs.

B.2.2 The available prey for any species is constrained by its bill length, so species with longer bills (e.g., Oystercatcher, Bar-tailed Godwit and Curlew) can reach deeper prey than species with shorter bills (e.g., Knot and Dunlin). However, species will not necessarily always use their full bill length when foraging.

B.2.3 While all species utilise a range of foraging methods, the smaller calidrids (e.g., Dunlin) generally have a rapid feeding action with pecks and shallow probes interspersed with short runs and often swallow their prey without raising their head. The larger species such as Bar-tailed Godwit and Curlew have a slower, more deliberate feeding action.

B.3 Selection of study species

B.3.1 Waterbirds on the sandflats in the impact and control areas appear to be very sensitive to disturbance, showing responses at distances of up to 300 m. Therefore, observations for the intake rate study will need to be made at a long distance (c. 400 m). This means that the foraging behaviour of the smaller species (Knot and Dunlin) would be difficult to observe accurately, because of their more rapid feeding action.

B.3.2 The smaller species are also likely to obtain a higher proportion of their diet from surface pecks. As the sediments in Dundalk Bay are highly mobile, there is likely to have been a lot of redistribution of prey in the surface layers in the months since the cockle fishing. Any remaining impact of cockle fishing on prey availability is more likely to occur in the deeper layers of the sediment.

B.3.3 Of the larger species, the populations of Oystercatcher and Bar-tailed Godwit at Dundalk Bay are more significant. Therefore, we have selected Oystercatcher and Bar-tailed Godwit as the target species for this study.

Table B.1 – I-WeBs data for the Lurgangreen sub-site.

Species	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	Mean
Mute Swan					1			1
Greylag Goose	14	75	3		205	3	22	54
Light-bellied Brent Goose	108	86	145		1	178	95	102
Shelduck	166	54	184	111	153	148	123	134
Wigeon	156	185	174	112	211	50	290	168
Gadwall							2	2
Teal	340	80	455	20	207	37	167	187
Mallard	325	351	447	241	562	864	781	510
Pintail		3	2		1	22	26	11
Goldeneye	7	2		3		8	2	4
Red-breasted Merganser		2	2	1	36	9	2	9
Little Grebe						2		2
Great Crested Grebe	2	1	175		3	2	43	38
Cormorant	10	3	2		9		16	8
Little Egret					1	1	8	3
Grey Heron	2	2	3		2	5	5	3
Oystercatcher	2385	2440	1750	2770	2633	3140	2560	2525
Ringed Plover	75	42	9	8	54	15	119	46
Golden Plover	1255	70	740	840	2700	2565	490	1237
Grey Plover	52	115	4	3	6	33	9	32
Lapwing	1001	2525	1090	1035	1141	610	816	1174
Knot	4905	3625	1490	4780	2480	1860	2675	3116
Sanderling					6	8		7
Dunlin	3600	4650	1264	1470	6450	566	5180	3311
Ruff		1						1
Snipe	3		1		2		3	2
Black-tailed Godwit	105	208	121	35	88	1740	96	342
Bar-tailed Godwit	1380	1760	780	430	360	368	780	837
Curlew	510	515	975	285	550	381	335	507
Spotted Redshank			1					1
Greenshank	5	5	11	3	6	14	28	10

Species	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	Mean
Redshank	195	280	555	165	409	573	762	420
Turnstone		1			4	5		3
Black-headed Gull	830	1600	1080	135	510	1820	1414	1056
Common Gull	15	35	25	36	105	90	81	55
Lesser Black-backed Gull		7			6	17		10
Herring Gull	40	40	55	5	88	22	62	45
Great Black-backed Gull	9	72	25		14	10	55	31

Figure B.1 - Location of study area in relation to I-WeBS count sectors.

Atkins is one of the world's leading providers of professional, technology based consultancy services. With over 15,600 staff worldwide, Atkins has expanded in recent years from its historical base in traditional engineering into related technological consultancy services. In Ireland, Atkins can deliver the full range of services to clients in both the public and private sector.

Our clients are varied and include governments, local and regional authorities, funding agencies and commercial and industrial enterprises. We help our clients to realise their objectives by developing and delivering practical solutions, adding value to their businesses through the application of our experience, innovative thinking and state-of-the-art technology. Atkins in Ireland is an integral part of WS Atkins plc and employs over 170 staff at its offices in Dublin, Cork, Galway and Belfast. In addition, it is able to draw on the expertise of other Atkins divisions in the UK to provide appropriate staff on a project by project basis.

Atkins in Ireland provides a wide range of engineering, architectural, technical support and management services in the following key areas:-

- Roads (Highways & Bridges)
- Transportation & Planning Services
- Rail
- Water
- Architecture & Design
- Engineering
- Environment & Landscape
- Cost Management and Quantity Surveying

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