Annex VI

The relationship between intertidal mussel cover and the distribution of waterbirds in Casltmaine Harbour

Castlemaine Waterbird Report

[Working Document]

9th July 2010

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Contents

Executive Summary

Mussel cover and the distribution of waterbirds

We carried out a study to examine the effect of the mussel nursery area on waterbird utilisation of intertidal habitat in Castlemaine Harbour. We examined the relationship between mussel cover and bird distribution by carrying out a series of waterbird counts on five days in February and March 2010 in 20 transects across the mussel nursery area. Each transect was divided into three sectors and waterbird numbers were recorded separately for each sector. We quantified the mussel cover in 42 of these sectors (the other 28 sectors were dredged before we could survey them). We used the data to test the null hypothesis that waterbird distribution across the mussel nursery area is not related to mussel cover. The waterbird counts also recorded whether birds within each sector were on mussel beds or on areas of clear sand and we used this data to test whether species showed positive or negative associations with mussel beds at the within-sector scale.

In 2009/10, overall mussel cover within the mussel nursery area was less than 12% and the area directly affected by ongrowing of seed mussels was less than 4%.

Oystercatcher and Redshank were positively associated with mussel cover at both the within-sector and between-sector scales. Curlew showed no relationship with mussel cover at the between sector scale but were positively associated with mussel cover at the within-sector scale. There is some evidence to suggest that Light-bellied Brent, Turnstone and Herring Gull were also positively associated with mussel cover at the within-sector scale.

There is some evidence to suggest Sanderling, Dunlin and Bar-tailed Godwit were negatively associated with mussel cover at the within-sector scale. However, this does not necessarily mean that these species would be negatively associated with mussel cover at the between sector scale. The patterns of these associations are generally not unexpected from knowledge of the ecology of the species involved.

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The transect counts were carried out by Davey Farrar, Jen Fisher, Michael O'Clery, Pat Smiddy and Paul Troake as part of work contracted to Birdwatch Ireland under the 2009/10 Waterbird Survey Programme. Sineád Cummins (Birdwatch Ireland) helped in organising the scheduling of the counts and the mobilisation of the counters. Additional assistance in the field was provided by Ross Macklin and Eamonn Delaney, Atkins. Katie O'Hora assisted throughout with data management and project management.

I-WeBS data were supplied by the Irish Wetland Bird Survey (I-WeBS), a joint scheme of BirdWatch Ireland, the National Parks and Wildlife Service of the Department of the Environment and Local Government, and The Wildfowl & Wetlands Trust.

The 2009/10 count data for Castlemaine Harbour 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

Introduction

1.1 Atkins (Ecology) was commissioned by the Marine Institute to provide ornithological services in relation to the appropriate assessment of mussel fishing and ongrowing on the Castlemaine Harbour Special Protection Area (SPA).

1.2 As part of the work commissioned by the Marine Institute, Atkins designed, supervised and analysed a transect count study. The objective of this study was to examine the effect of the mussel nursery area on waterbird utilisation of intertidal habitat in Castlemaine Harbour and to collect data on potential disturbance impacts from mussel-related activity within the nursery area.

1.3 The transect counts were carried out by Birdwatch Ireland counters under the supervision of Atkins personnel. The mussel cover surveys were carried out by Atkins (Tom Gittings, Ross Macklin and Eammon Delaney).

1.4 Our brief for this report was to report on the transect count study carried out in February and March 2010.

1.5 The data analysis and report writing was done by Tom Gittings and was reviewed by Paul O'Donoghue. 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. The BTO species codes are also used in some of the figures included in this report.

Limitations to this study

1.7 The design of the transect count study was constrained by the timing of the commissioning of this work, which did not allow much time for planning before counts had to begin. In particular, it was not possible to visit the mussel nursery area during a spring low tide before beginning the transect count study.

1.8 The results of the transect count study provide data on waterbird usage of, and disturbance activities in the mussel nursery area 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

1.9 Very little dredging was carried out in the mussel nursery area in 2009 (because of the extended closure of the fishery in 2008, which resulted in little or no seed being fished in that year) and information on the extent and location of the areas that were dredged is not available. Therefore, our analysis of the transect count study does not consider any potential impacts from dredging in the mussel nursery area.

Mussel cover and the distribution of waterbirds

Methods

Study design

1.10 The objective of this study was to examine the effect of the mussel nursery area on waterbird utilisation of intertidal habitat in Castlemaine Harbour. We examined the relationship between mussel cover and bird distribution by carrying out a series of waterbird counts in 20 transects across the mussel nursery area. We used the data to test the null hypothesis that waterbird distribution across the mussel nursery area is not related to mussel cover.

1.11 In order to select appropriate transect locations we carried out an initial qualitative survey of mussel cover on 15 January 2010. Because of time constraints, our initial qualitative survey of mussel cover was carried out during neap low tide conditions when the lower part of the mussel nursery area was not exposed. We used the results of this survey to select transect locations so that each transect was positioned in areas where the mussel cover in the upper shore area was more or less uniform.

1.12 The transects covered most of the extent of the mussel nursery area as indicated in mapping data supplied by the Marine Institute (Figure 1). The northernmost section of the mapped area extended into a shallow channel that floods for a much longer period than the adjacent areas and was, therefore, not included in the transect survey.

1.13 Mussel cover extends over a much wider area than the mapped extent of the mussel nursery area. We extended the area covered by the bird survey transects slightly to the south of the mapped extent of the mussel nursery area in order to fit in 20 transects.

1.14 Each transect was 100 m wide and 360 m long and was divided into three 120 m long sectors (Figure. 2).

Mussel survey

1.15 We carried out mussel surveys in 14 of the 20 transects. The six transects that were not surveyed had been affected by mussel dredging operations before any surveys could be carried out.

1.16 We reviewed the relevant literature in an attempt to find an appropriate method of surveying mussel cover. The published methods of mussel surveys (e.g., McGrorty et al., 1990; Herlyn & Millat, 2000) appear to be designed for areas with discrete mussel beds with relatively low variation in mussel cover within the mussel beds. However, in the mussel nursery area at Castlemaine Harbour mussel cover is very heterogeneous with large areas where mussels occur in dispersed small patches of up to a few square metres. Therefore, we did not consider that the published methods would be appropriate and we devised a method designed for the particular circumstances in the mussel nursery area at Castlemaine Harbour.

1.17 We used a spatially stratified random sampling approach to survey mussel cover in each sector of the 14 transects that we surveyed. We divided each sector into a grid of 12 columns of 10 no. 10 x 10 m quadrats (Figure 3) and used random numbers to select one quadrat from each column. Therefore, in each sector we surveyed 12 no. 10 x 10 m quadrats, covering 10% of the total area of the sector.

1.18 In nine sectors we surveyed an additional six quadrats (making a total of 18) in order to examine the effect of increasing the survey effort on the estimate of mussel cover. These additional quadrats were selected, using random numbers, from the second, fourth, sixth, eight, tenth and twelfth columns.

1.19 In each quadrat we recorded the percentage mussel cover, the percentage attached seaweed cover and the presence of any seed mussels. The seed mussels were recorded using the following scoring system: 0 = no seed mussels present; 1 = some seed mussels present but with significant cover of older mussels; 2 = seed mussels dominant. Note that a quadrat could have low overall mussel cover but a seed mussel score of 2 if most of the mussels present were seed mussels. We took record photographs in each quadrat that can be used to provide data on mussel size distribution, if required. We also made notes on any unusual features, such as changes in the substrate type.

1.20 While we did not record the percentage seed mussel cover, we have used the seed mussel score to derive estimates of the percentage seed mussel cover, using the following formula:

*Seed mussel cover = mean % mussel cover*seed mussel score/24*

This formula will overestimate the seed mussel cover because not all of the quadrats with seed mussels dominant had 100% of the mussel cover consisting of seed mussels. Similarly, in most of the quadrats where the seed mussel score was one, less than 50% of the mussel cover consisted of seed mussels.

Waterbird counts

1.21 Waterbird counts were carried out by counters from the NPWS Baseline Waterbird Survey Programme under the supervision of Atkins.

1.22 Waterbird counts were carried out on five dates in February and March 2010, on days when the mussel nursery area was fully exposed at low tide (i.e., low tides of 0.9 m or less). Weather conditions were generally good during the counts. Visibility was good on all counts, except two counts on February 15 and three counts on February 16 for which visibility was moderate. An additional count was planned for a sixth day but had to be abandoned because of adverse weather conditions.

1.23 On each count day, a team of five counters was used. Counts were carried out over a 4-5 hour period, covering the period during which the transects were exposed at low tide. Each counter counted four adjacent transects in rotation, so each transect was counted four or five times with an interval of approximately one hour between each count. The counters counted different groups of transects on each count day (Table 2).

Table.1 – Details of transects counts timing and the low tide and weather conditions on transect counts.

Date	Low tide (Cromane)[1]		Count times		Weather		
	Time	Height	Start	Finish	Cloud cover[2,3]	Wind[2,4]	Rain[2,5]
03-Feb	14:18	0.5 m	12:30	17:15	1-2	SW-W 1-3	1
15-Feb	12:01	0.9 m	09:50	15:00	2-3	W 3-4	1-2
16-Feb	12:28	0.9 m	10:00	15:30	1-2	SW-W 2-3	1-2
04-Mar	13:49	0.4 m	11:30	16:45	1	NE-SE 1-3	1
05-Mar	14:33	0.7 m	12:00	17:15	1	Variable 0-1	1

[1] source: Admiralty EasyTide (http://easytide.ukho.gov.uk/)

[2] range of variation in parameter values occurring on 5% or more of the transect counts.

[3] 1 = 0-33%, 2 = 33-66%, 3 = 66-100%

[4] Beaufort scale and direction

[5] 1 = none, 2 = showers

Table.2 – Transects counted by each counter on each count day.

Date	Transect groups				
	1-4	5-8	9-12	13-16	17-20
03-Feb	PS	DF	MOC	JF	PT
15-Feb	DF	MOC	JF	PT	PS
16-Feb	MOC	JF	PT	PS	DF
04-Mar	JF	PT	PS	DF	MOC
05-Mar	PT	PS	DF	MOC	JF

DF = Davey Farrar; JF = Jen Fisher; MOC = Michael O'Clery; PS = Pat Smiddy; PT = Paul Troake

1.24 On each count, the number and activity (feeding or roosting) of all waterbird species in distance bands from the shoreline (i.e., the 120 m sectors) was recorded. Counters also recorded whether birds were on mussel beds or on patches of clear sand, and the position of the tideline. Counters also recorded the nature and location of any human activity within 200 m of the count sector.

1.25 Counters recorded waterbird count data directly onto standardised waterbird count forms (see Appendix C) in the field. Separate count forms were used for all counts.

Data processing

1.26 All count data was entered into Excel spreadsheets and tideline positions were digitised in ArcMap shapefiles. We double-checked the spreadsheet and shapefile data against the original count forms to pick up any errors in data entry. We also screened the data to identify any data entry errors in the raw data recorded on the count forms. For example, we reviewed the tideline position maps to check that the tideline positions recorded followed a logical sequence in relation to time before/after low tide. We checked any potential ambiguities or inconsistencies with the counters.

Data analysis

1.27 For clarity, the data analysis methods are described in the relevant parts of the Results section. All statistical analyses were carried out using R 2.10.1 (R Development Core Team, 2009).

Results

Mussel survey

1.28 The results of increasing sampling intensity are summarised in Figure. 3. While the estimates of mussel cover at all sampling intensities had high standard errors, the mean mussel cover per quadrat showed little variation between the three levels of sampling intensity. There was a mean change of 1.7% when the sampling intensity increased from 6 to 12 quadrats, and a mean change of 0.9% when the sampling intensity increased from 12 to 18 quadrats. The high variance in the mussel cover estimates were probably due to lateral bands of higher and lower mussel cover across the transects. The stratified sampling strategy matched this pattern of variation, so increasing the sampling intensity did not markedly affect the mussel cover estimates. Therefore, we consider that a sampling intensity of 12 quadrats per sector provides an adequate level of sampling intensity to reflect the overall variation in mussel cover between sectors.

1.29 The mean mussel cover estimates for each sector surveyed are presented in Table.3. The spatial pattern of variation in mussel cover across the mussel nursery area is shown in Figure 4.

1.30 The average mussel cover across the entire area surveyed was 12% with a maximum cover of 43% in Sector 11C. Only 12 of the 42 sectors surveyed had seed mussels and the average seed mussel cover across the entire area surveyed was 3% (which is likely to be an overestimate; see paragraph 1.20).

1.31 Mussel cover can vary significantly between sectors within the same transect. Therefore, we have used the individual sectors, rather than the transects, as the basic unit for the analysis of the waterbird count data.

Table.3 – Mean mussel cover for each sector surveyed, using data from 12 quadrats in each sector.

Transect	Sector	Mean % mussel cover	SD	Seed mussel score	Seed mussel cover[1]
1	A	5.42	5.99	0	0.00
1	B	5.92	5.53	0	0.00
1	C	7.92	6.72	0	0.00
2	A	1.33	1.10	0	0.00
2	B	5.25	4.57	0	0.00
2	C	4.00	2.35	0	0.00
3	A	1.67	1.38	0	0.00
3	B	17.25	16.85	2	1.44
3	C	25.08	14.53	0	0.00
4	A	7.67	6.64	0	0.00
4	B	19.42	28.65	0	0.00
4	C	2.42	1.22	0	0.00

Transect	Sector	Mean % mussel cover	SD	Seed mussel score	Seed mussel cover[1]
5	A	5.92	6.08	0	0.00
5	B	5.92	4.29	7	1.73
5	C	8.00	16.05	0	0.00
6	A	6.00	5.67	6	1.50
6	B	8.67	7.27	12	4.33
6	C	8.08	5.76	4	1.35
7	A	4.64	2.39	0	0.00
7	B	3.36	1.38	0	0.00
7	C	8.00	4.92	0	0.00
8	A	2.92	1.67	0	0.00
8	B	3.90	3.38	0	0.00
8	C	3.92	4.21	0	0.00
10	A	21.58	20.78	0	0.00
10	B	13.75	16.63	0	0.00
10	C	2.75	2.90	0	0.00
11	A	21.17	9.29	2	1.76
11	B	21.08	17.88	0	0.00
11	C	42.58	30.47	0	0.00
13	A	30.08	18.23	22	27.58
13	B	23.75	13.99	18	17.81
13	C	12.92	11.70	19	10.23
14	A	19.08	13.84	24	19.08
14	B	28.00	17.67	24	28.00
14	C	7.75	3.71	14	4.52

[1] Seed mussel cover = mean % mussel cover*seed mussel score/24

Waterbird counts

1.32 A total of 454 unique transect counts were completed. As each count includes data for the three sectors of the transect, the dataset contains a total of 1362 counts.

1.33 A total of 22 species were recorded across all the counts. The most abundant species were Oystercatcher, Curlew, and Redshank (Table 4). These were also the most frequent and were recorded on 15-20% of the sector counts (Table.5). Most other species were recorded on very few counts: Common Gull and Herring Gull were recorded on 6-8% of the sector counts, and all other species on 3% or less. As the total number of sectors was 60, it can be seen from Table 4 that the mean count per sector was less than one for all species except Oystercatcher (3.0), Dunlin (1.1), Curlew (2.9) and Redshank (2.7).

Table 4 – Mean species counts per day for the entire study area.

	03-Feb	15-Feb	16-Feb	04-Mar	05-Mar	Overall mean
Light-bellied Brent Goose	53	16	52	32	17	34
Mallard	0	7	1	1	1	2
Little Egret	3	1	3	1	2	2
Oystercatcher	127	111	130	89	89	109
Knot	0	0	16	0	0	3
Sanderling	18	30	58	3	0	22
Dunlin	95	23	145	1	0	53
Bar-tailed Godwit	6	14	5	1	1	5
Curlew	87	109	134	84	99	103
Greenshank	1	3	1	0	0	1
Redshank	107	110	130	56	58	92
Turnstone	8	16	6	2	11	8
Black-headed Gull	1	1	1	5	1	2
Common Gull	11	30	13	27	20	20
Herring Gull	20	23	39	9	2	18

Note: This table contains the means of the four complete counts across all transects that were carried out on each survey day. Additional species recorded with an overall mean of < 0.5 were Wigeon, Pintail, Red-breasted Merganser, Great Northern Diver, Cormorant, Ringed Plover, Grey Plover, Black-tailed Godwit, Lesser Black-backed Gull and Great Black-backed Gull

Table.5 – Number of non-zero sector counts for each waterbird species.

	03-Feb	15-Feb	16-Feb	04-Mar	05-Mar	Total
Light-bellied Brent Goose	12	9	11	6	7	45
Mallard	0	4	2	3	2	11
Pintail	2	0	0	0	0	2
Red-breasted Merganser	0	0	4	3	0	7
Cormorant	2	3	4	4	3	16
Little Egret	10	6	8	8	10	42
Oystercatcher	55	57	65	53	55	285
Ringed Plover	0	0	2	0	0	2
Knot	0	2	3	0	0	5
Sanderling	8	8	12	2	0	30
Dunlin	16	8	9	3	0	36
Bar-tailed Godwit	8	6	8	4	4	30
Curlew	44	47	55	48	54	248
Greenshank	4	7	4	3	4	22

	03-Feb	15-Feb	16-Feb	04-Mar	05-Mar	Total
Redshank	58	38	48	32	37	213
Turnstone	12	16	12	7	10	57
Black-headed Gull	3	4	7	7	4	25
Common Gull	25	20	24	17	20	106
Lesser Black-backed Gull	2	0	**0**	0	0	2
Herring Gull	22	23	18	11	9	83
Great Black-backed Gull	0	0	2	2	2	6

1.34 Most non-zero counts occurred when the tideline was within the count sector, i.e., when the tideline position was between 0 and 120 m relative to the western end of the sector (Figure 8). While the occurrence of non-zero counts did not completely fall off until the tideline position was around 200 m, the proportion of zero counts is much higher (Table.6).

Table.6 – Non-zero waterbird sector counts in relation to tidal position

Tideline position/m		OC	CU	RK
0-120	No. of counts	189	189	189
	No. of non-zero counts	149	132	109
	% of non-zero counts	79%	69%	57%
120-160	No. of counts	32	32	32
	No. of non-zero counts	12	11	10
	% of non-zero counts	38%	34%	31%
160-200	No. of counts	38	38	38
	No. of non-zero counts	5	4	0
	% of non-zero counts	13%	11%	0%

1.35 Analysis of the composition of the total numbers recorded across all counts shows some apparent differences between species in their relative use of clear areas and mussel beds (Figure 9). Bar-tailed Godwit (BA), Black-headed Gull (BH), Dunlin (DN) and Sanderling (SS) mainly occurred in clear areas, Oystercatcher (OC) and Turnstone (TT) mainly on mussel beds, and the other species showed no particular association. The proportion of birds feeding was over 90% for most species, except Common Gull (CM), Herring Gull (HG), Light-bellied Brent (PB) and Sanderling (SS).

1.36 The analysis presented in Figure 9 is rather crude because it does not take account of the availability of mussel beds and clear areas. If birds are distributed randomly within sectors with respect to the habitat type then the percentage occurrence of birds on mussel beds in each sector will depend on the percentage mussel cover. Then the overall percentage occurrence of birds on mussel beds across all sectors would depend on the relative numbers of birds recorded in sectors with varying levels of mussel cover. Therefore, to test the null hypothesis that birds are distributed randomly within sectors with respect to the habitat type we used the summed totals of numbers recorded on mussel beds and clear areas across all counts in each sector. We compared the percentage of birds recorded on mussel beds with the percentage mussel cover in each sector where the total count was ten or more.

1.37 Because of the lack of mussel cover data for many sectors, most species had few qualifying sectors for this analysis (i.e., sectors with mussel cover data and a total count of ten or more).The within-sector distribution of Oystercatcher, Curlew and Redshank shows a clear preference for mussel beds (Figure 10-12). The within-sector distribution of Light-bellied Brent also indicates a preference of mussel beds (Figure 7) although the number of qualifying sectors is low. Other species with more than five qualifying sectors are shown in Table.7. Sanderling, Dunlin and Bar-tailed Godwit appear to show preferences for clear areas: the one non-zero percentage occurrence for any of these species was of 10% of a Bar-tailed Godwit count on mussel beds in a sector with 8% mussel cover. Turnstone and Herring Gull appear to show preferences for mussel beds with the percentage occurrence of these species on mussel beds higher than the mussel cover in all qualifying sectors.

Table.7 – Mussel cover and percentage occurrence of birds on mussel beds for qualifying sectors.

Species	Mussel cover	% of birds on mussel beds
Sanderling	0% (2), 4-8% (4)	0% (6)
Dunlin	0% (2), 3-8% (4)	0% (6)
Bar-tailed Godwit	2-8% (5)	0% (4), 10% (1)
Turnstone	1-6% (5), 19-25% (2)	79% (10, 100% (6)
Herring Gull	9% (1), 21-22% (3), 30% (1)	20% (1), 80% (1), 100% (3)

Note: Qualifying sectors are sectors with a total count of ten or more and with mussel cover data. Numbers in parentheses are numbers of sectors.

Waterbird numbers and mussel cover

Data analysis methods

1.38 Our objective was to test the hypothesis that waterbird numbers are affected by mussel cover. However, there are several other variables that could potentially affect waterbird numbers on any particular count. These include: tideline position, diurnal time, time relative to low tide, date, position of sector and disturbance.

1.39 The analysis presented above shows that waterbird occurrence in the transect sectors is very strongly affected by the tideline position: waterbirds generally only occur within a transect sector when the tideline is within that sector.

1.40 Because of the speed with which the tideline moves through the transects, and the variation between transects in its timing, the number and temporal distribution of counts where the tideline is within the sector is not balanced across the sectors. Therefore, the average count per sector is not an appropriate response variable because different sectors will have had different numbers and timings of counts where the tideline is within the sector on each count date. Instead the analysis needs to use the individual counts. Because separate counts from the same sector are not independent replicates, a mixed modelling approach is required.

1.41 We used Poisson Generalized Linear Mixed Modelling (GLMM) for the analysis. GLMM models for zero-inflated data are not well-developed (Zuur et al., 2009). Therefore, we restricted our analyses to counts where the tideline was within the count sector to avoid zero-inflation and high levels of overdispersion, and to species for which the above criteria produce a dataset that did not contain excessive numbers of zeros.

1.42 We only included counts from the 42 sectors for which we had estimates of mussel cover.

1.43 We did not use counts where the observer had recorded that the count had been affected by disturbance. One observer did not enter any disturbance information on any of his datasheets. Therefore, it is possible that some of his counts included in the analyses were affected by disturbance.

1.44 A total of 189 counts met the above criteria and were included in the GLMM analyses. These included 149 non-zero Oystercatcher counts, 132 non-zero Curlew counts and 109 non-zero Redshank counts.

1.45 The temporal distribution of the counts from each sector included in the GLMM analyses is shown in Appendix A. No more than two counts from any particular sector on the same day were included, and where two counts from the same day were included these were usually well separated in time.

1.46 The parameters that we used in our model building are defined in Table 8. We defined TDAY and TTIDE so that they represented time from sunset/sunrise and from low tide respectively. While we had already accounted for the major effects of tidal state by removing the counts with the tideline outside the sector, we included TTIDE because of the possibility that birds may sow larger-scale patterns in relation to tidal state (e.g., movement to/from high tide roost sites or favoured feeding areas elsewhere in Castlemaine Harbour). TRANS and TSEC were included as random factors, and the other parameters were included as fixed factors.

Table 8 – Variables used in GLMM model building.

Variable	Type	Description
sqrtMUSS	Quantitative	Average mussel cover/quadrat; square-root (x+1) transformed
DAY	Quantitative	Day number, where 1 January =1
TDAY	Quantitative	Diurnal time, calculated by the following formula: If $t_{count}<(t_{sunrise}-t_{sunset})/2$, TDAY = $t_{count}-t_{sunrise}$ If $t_{count}>(t_{sunrise}-t_{sunset})/2$, TDAY = $t_{sunset}-t_{count}$
TTIDE	Quantitative	Time relative to low tide, calculated by the following formula: If $t_{count}<t_{lowtide}$, TTIDE = $t_{lowtide}-t_{count}$ If $t_{count}>t_{lowtide}$, TTIDE = $t_{count}-t_{lowtide}$
TRANS	Categorical	Transect number
TSEC	Categorical	Transect-sector

1.47 There are a variety of approaches used to fit GLMM models in various statistical software packages and these approaches can sometimes give rather different results. Because our data has high levels of overdispersion, we used glmmPQL (MASS package; Venables & Ripley, 2002) procedure in R 2.10.1, as this automatically estimates overdispersion. This procedure is unreliable for Poisson responses with means less than five (Bolker et al., 2009) but the mean counts per sector in our datasets exceeded five in all cases.

1.48 The other widely used procedure in R is glmer (lme4 package; Bates & Maechler, 2010). However, with overdispersed data this procedure requires a quasilikelihood, which may be unreliable in lme4 (http://glmm.wikidot.com/faq).

1.49 Before beginning the analyses we used Cleveland dotplots to inspect each dataset for outliers. Based on this, we used a square-root (x+1) transformation on the mussel cover data. We also noted the presence of an outlier in the Redshank dataset. However, we found that excluding this outlier did not significantly change the analysis.

1.50 We calculated Variance Inflation Factors (VIF) using corvif (AED package) to detect collinearity between our explanatory variables. There was not any significant collinearity between our explanatory variables.

1.51 We used backward selection with the significance of the t-value as the criterion.

1.52 To validate the final model we plotted graphs of the residuals against the fitted values and against the explanatory variables (including those not selected in the final model). We used semi-variograms, created by Vario1 (gstat package; Pebesma, 2004), using the x y co-ordinates of the sectors, to check for spatial correlation in the final model.

1.53 We have not formally analysed potential temporal auto-correlation within days in our dataset: i.e., are counts that were closer together in time more similar. However, visual inspections of time series plots of each species on each day in each count sector did not show any obvious signs of temporal auto-correlation.

Analysis results

1.54 The results of the GLMM analyses are summarised in Table 9. Oystercatcher and Redshank numbers showed a positive relationship with mussel cover. Curlew numbers did not show any significant relationship with mussel cover, but showed a positive relationship with time of day, indicating that higher numbers of this species tended to occur in the middle of the day.

Table 9 – Summary output of generalised linear mixed models with poisson errors, modelling Oystercatcher (OC), Curlew (CU) and Redshank (RK) numbers.

Model	Random effect	S.D. of random effect	Fixed effect	Estimate (± S.E.)	t-value	D.F.	*p*
OC	TRANS	0.3102	Intercept	1.494 ± 0.236	6.34	145	< 0.0001
	TSEC	0.1551	sqrtMUSS	0.150 ± 0.068	2.21	27	0.0359
CU	TRANS	0.483	Intercept	1.075 ± 0.274	3.929	146	0.0001
	TSEC	0.1729	TDAY	0.003 ± 0.001	3.33	146	0.0011
RK	TRANS	0.541	Intercept	0.520 ± 0.389	1.332	147	0.1850
	TSEC	0.401	sqrtMUSS	0.275 ± 0.107	2.563	27	0.0163

The dispersion parameter ϕ was 2.37 for the Oystercatcher model, 2.47 for the Curlew model and 2.40 for the Redshank model.

1.55 We did not find a significant relationship between mussel cover and Curlew numbers. However, this could be due to weak statistical power, rather than the absence of a relationship. In order to examine this possibility, we added mussel cover to the Curlew GLMM model and examined the confidence interval of the estimated effect (see Steidl, Hayes & Schauber, 1997). By definition, a non-significant effect will have a confidence interval that includes both positive and negative values. The lower limit of the confidence interval of the estimated effect of mussel cover can, therefore, be used to predict the maximum strength of the negative effect that is included within the confidence interval. However, the form of the relationship predicted by a model including the lower limit of the confidence interval of the estimated effect of mussel cover is biologically implausible: it predicts a 14% decrease in Curlew numbers when mussel cover increases from 0% to 1%. Therefore, we did not consider that this model was meaningful.

Model validation

1.56 Our model validation did not indicate major patterns in the residuals from our GLMM models, apart from some evidence of heterogeneity discussed below. The semi-variograms did not show any evidence of spatial correlation in the final models.

1.57 The distribution of residuals in relation to TRANS and TSEC do show heterogeneity (Figure.8 and Figure.9). This is particularly strong in the latter case, where it may reflect the small sample sizes of some of the sectors.

1.58 The distribution of residuals in relation to DAY in the final Oystercatcher model also shows heterogeneity, with a much wider spread at day 34 compared to the other days (Figure.10). It could be argued that DAY should have been treated as a random factor. However, DAY has only five levels. Random factors need to have at least six levels for GLMM analyses and factors with less than six levels should be treated as fixed factors (Zuur et al., 2009). We also found that when we added DAY as a random factor to the models, its standard deviation was very low (< 0.001).

Waterbird assemblages

Data analysis methods

1.59 Our objective was to test the hypothesis that the composition of the waterbird assemblage is affected by mussel cover. We used Canonical Correspondence Analysis (CCA) to test whether mussel cover explained a significant component of assemblage variation. We used cca (vegan package; Oksanen et al., 2010) to carry out the analysis.

1.60 There were 179 non-zero counts in sectors with mussel cover estimates. Therefore, we only included species that occurred in nine or more counts (i.e., > 5% of counts). We used log (x+1) transformed species abundance data.

1.61 We developed CCA models using stepwise selection procedures with Akaike's Information Criterion (AIC) as the primary selection criterion. The AIC measures goodness-of-fit derived from the residual (unconstrained) inertia penalized by the rank of the constraints. Because the AIC used in model building in the CCA analysis in vegan is not based on a firm theory and should only be used as an aid to model building (Oksanen, 2006) we also considered the results of permutation tests at each step, which tested the additional variance each variable explains and its significance when added to the model. The CCA analyses used biplot scaling optimising sites and ordination diagrams use weighted average scores.

1.62 We used the same environmental parameters as included in the GLMM analyses (Table 8), with the addition of the x and y co-ordinates of the transect sectors.

Analysis results

1.63 The final CCA model included mussel cover, day and the x and y co-ordinates as explanatory variables (Table.8). These parameters all improved the fit of the model (as measured by the AIC) and explained a significant component of additional variation (as measured by the permutation test) when added to the model. The sqrtMUSS*DAY interaction term was also selected in the initial model building. However, the model including this term had high variance inflation factors for both sqrtMUSS and sqrtMUSS*DAY, while the sqrtMUSS and sqrtMUSS*DAY vectors were very similar in scale and orientation. Therefore, the sqrtMUSS*DAY interaction term was dropped from the final model. The TRANS and TSEC parameters both explained significant components of additional variation (as measured by the permutation test) when added to the model but did not improve the fit (due to their high degrees of freedom) and had high variance inflation factors. Therefore, these parameters were not included in the model.

1.64 The eigenvalues of the ordination axes are low and the species-environment correlations are low (Table.8) indicating that there is alot of assemblage variation which is not explained by the CCA model.

1.65 The CCA triplot (Figure.11) shows a wide spread of counts along axis 2 with two possible outliers. However, repeating the analysis with these outliers excluded produced very similar results.

1.66 The vectors for sqrtMUSS and DAY represent very similar gradient of assemblage variation. Therefore, the position of species along this gradient (Figure.12) represents an interaction between these two parameters and cannot be simply used to indicate associations with high or low levels of mussel cover.

Table.8 – Summary of the final CCA model.

	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.105	0.074	0.027	0.010
Variance explained	5.1%	3.6%	1.3%	0.5%
Species-environment correlations	0.66	0.49	0.33	0.23

Discussion

Mussel cover

1.67 Our mussel survey showed that the actual level of mussel cover in the nursery area in Castlemaine Harbour is quite low. The average mussel cover in the areas we surveyed was only 11.6%, while seed mussel cover was under 4%.

1.68 We did not survey the entire mapped extent of the nursery area. However, from other observations, at least 60% of the unsurveyed area probably held less than 10% mussel cover. Therefore, it is unlikely that the overall level of mussel cover in the mapped extent of the nursery area is significantly higher than our estimate.

1.69 The low level of seed mussel cover is notable. If this level is typical of most years it suggests that the physical impact of mussel ongrowing in any one year, in terms of the extent of the area directly affected, is low.

1.70 There are also extensive areas of mussel beds outside the mapped extent of the nursery area. However, these appear to be largely, or entirely, older mussels. We did not observe any significant areas of seed mussels outside the mapped extent of the nursery area, but we did not search for these.

Within-sector distribution

1.71 In our analysis of the within-sector distribution of waterbird species, Oystercatcher, Curlew and Redshank showed strong positive associations with mussel beds. Only limited suitable data was available for other species, but Light-bellied Brent, Turnstone and Herring Gull appear to show positive associations with mussel beds, while Sanderling, Dunlin and Bar-tailed Godwit appear to show negative associations with mussel beds. The patterns of these associations are generally not unexpected from knowledge of the ecology of the species involved.

1.72 Species that show a positive association with clear areas in their within sector distribution are not necessarily negatively associated with mussel cover at the between-sector scale. A species could be associated with areas of higher mussel cover but could preferentially feed in clear patches within these areas because the mussel beds may create more suitable habitat conditions in the clear areas between the mussel beds, compared to areas without mussel beds (cf. Caldow et al., 2003). However, the converse scenario, where a species has a positive association with mussel beds in their within-sector distribution but has a negative association with mussel cover at the between-sector scale seems more unlikely because there is not any obvious ecological mechanism to explain such a scenario.

1.73 It should be noted that for several species, sectors with zero or very low recorded mussel cover had high recorded percentages of birds on mussel beds. We recorded mussel cover to the nearest integer percentage value, so sectors with zero recorded mussel cover had less than 0.5% mussel cover. Therefore, these sectors could have had up to 60 m^2 of mussel cover. However, the counters noted that, in some sectors, it could be difficult to decide whether birds were on mussel beds or clear areas. We also noted that mussel cover appears higher when viewed from a distance due to perspective and foreshortening. Therefore, it is likely that there was a tendency to overestimate the percentage occurrence of birds on mussel beds.

Waterbird numbers and mussel cover

1.74 We only had sufficient data to test relationships between waterbird numbers and mussel cover for three species: Oystercatcher, Curlew and Redshank.

1.75 There were positive relationships between mussel cover and Oystercatcher and Redshank numbers. These positive relationships are supported by the apparent positive association with mussel beds shown by these species in the analysis of their within-sector distribution

1.76 We did not find any significant relationship between mussel cover and Curlew numbers. However, in conservation biology the avoidance of Type II errors is as important as the avoidance of Type I errors (Steidl, Hayes & Schauber, 1997). Therefore, the possibility of a Type II error obscuring a significant relationship between mussel cover and Curlew numbers needs to be considered. However, the positive association with mussel beds shown Curlew in the analysis of its within-sector distribution suggests that a negative relationship between mussel cover and Curlew numbers at the between sector scale is very unlikely.

Waterbird assemblages and mussel cover

1.77 We had sufficient data to test the relationship between mussel cover and the structure of an assemblage containing the following waterbird species: Little Egret, Light-bellied Brent, Oystercatcher, Dunlin, Bar-tailed Godwit, Curlew, Greenshank, Redshank, Turnstone, Black-headed Gull, Common Gull and Herring Gull.

1.78 The eigenvalues of the ordination axes are low and the species-environment correlations in the CCA model were low. This probably reflects the fact that the dataset contained a large number of zero values and a large component of these zero values were due to random error: i.e., zero counts were recorded because birds happened not to visit a particular sector at the time that it was being counted, not because the sector was unsuitable for the birds. Therefore, the actual amount of variation in the dataset that is potentially explainable is probably quite low.

1.79 The CCA model indicates that mussel cover explains a significant component of the assemblage variation. However, the vector for mussel cover represents a very similar gradient of assemblage variation to that represented by the vector for count day. Therefore, the position of species along this gradient represents an interaction between these two parameters and cannot be simply used to indicate associations with high or low levels of mussel cover.

Conclusions

1.80 In 2009/10, overall mussel cover within the mussel nursery area was less than 12% and the area directly affected by ongrowing of seed mussels was less than 4%.

1.81 Oystercatcher and Redshank are positively associated with mussel cover at both the within-sector and between-sector scales. Curlew show no relationship with mussel cover at the between sector scale but were positively associated with mussel cover at the within-sector scale. There is some evidence to suggest that Light-bellied Brent, Turnstone and Herring Gull are also positively associated with mussel cover at the within-sector scale.

1.82 There is some evidence to suggest Sanderling, Dunlin and Bar-tailed Godwit are negatively associated with mussel cover at the within-sector scale. However, this does not necessarily mean that these species would be negatively associated with mussel cover at the between sector scale.

ATKINS

Figure 1 – Location of bird survey transects in Castlemaine Harbour.

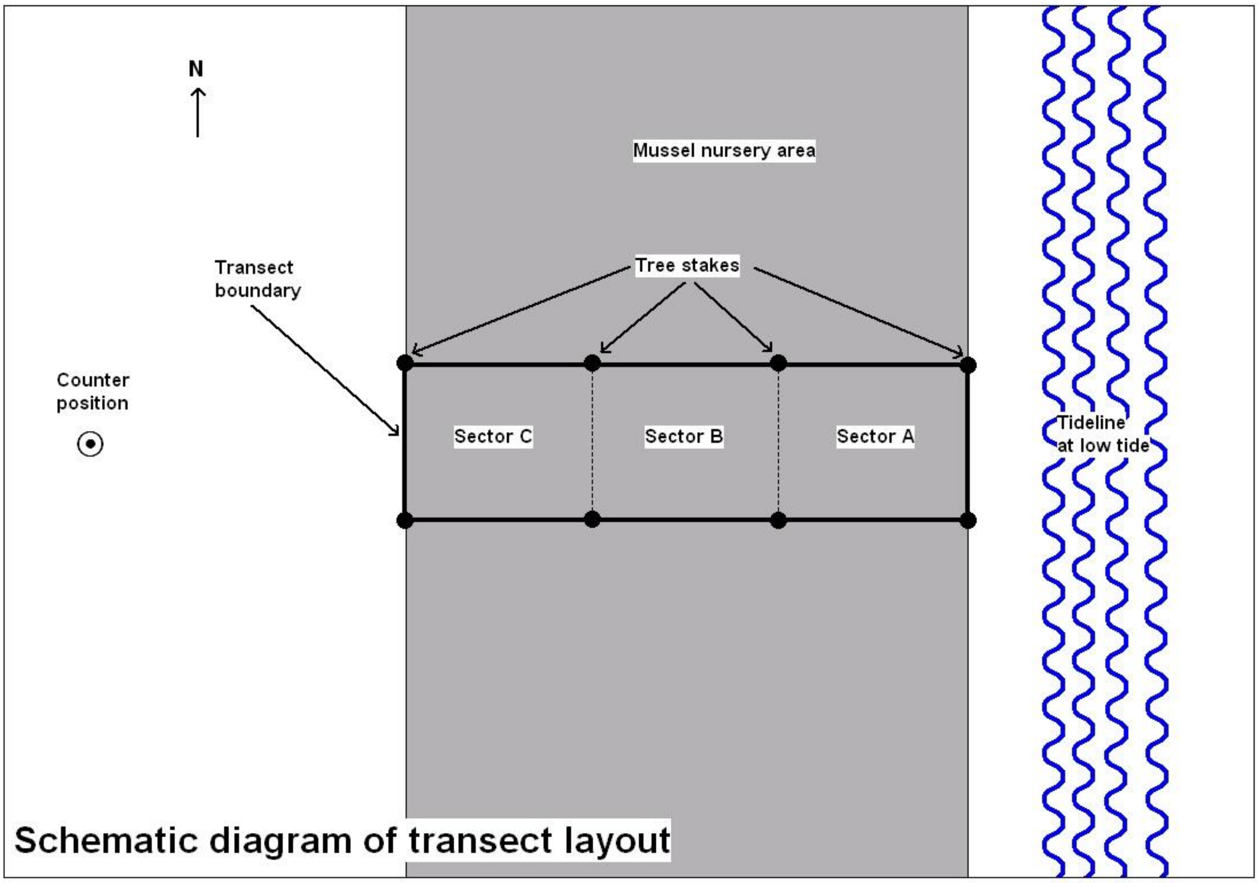

Figure. 2 – Schematic diagram of the layout of the transects used for the waterbird counts.

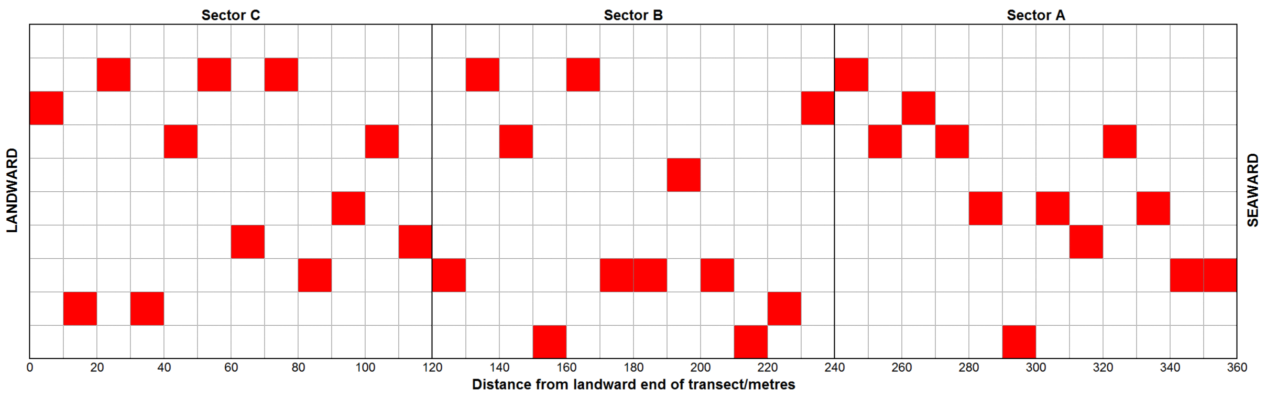

Figure 3 – Arrangement of quadrat grid used for the mussel surveys, with an example of randomly selected quadrats.

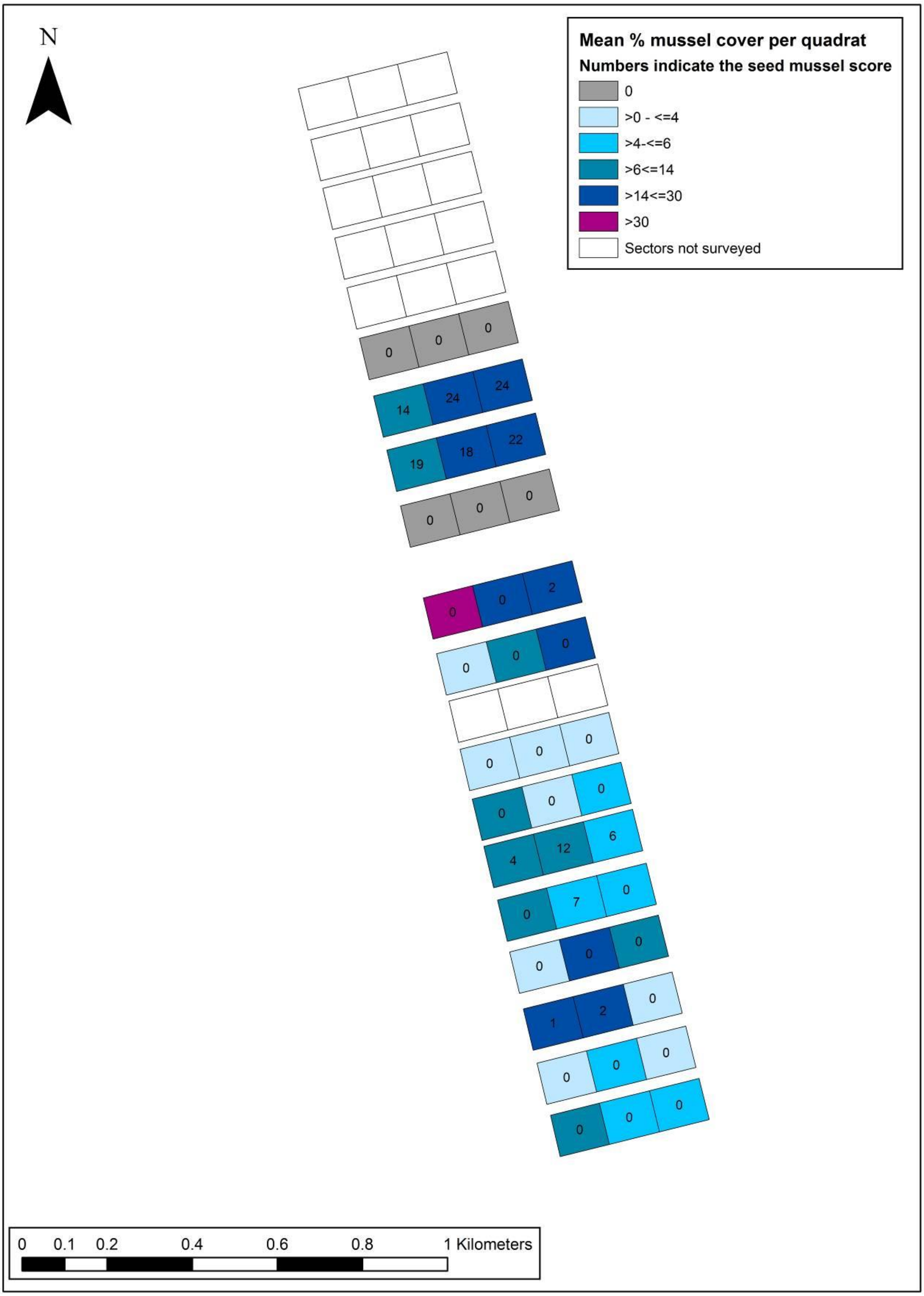

Figure 4 – Mussel cover in the transect sectors.

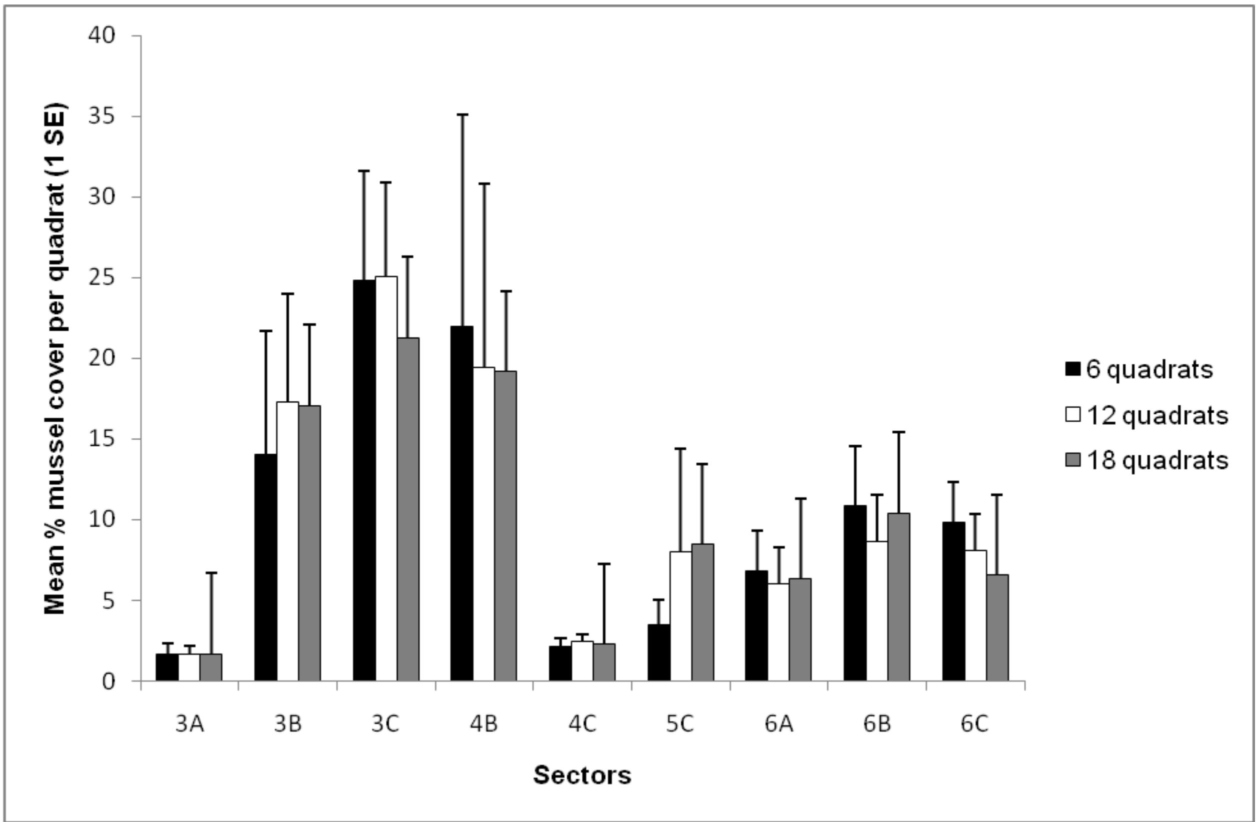

Figure. 3 – Relationship between mussel cover and increasing sampling intensity.

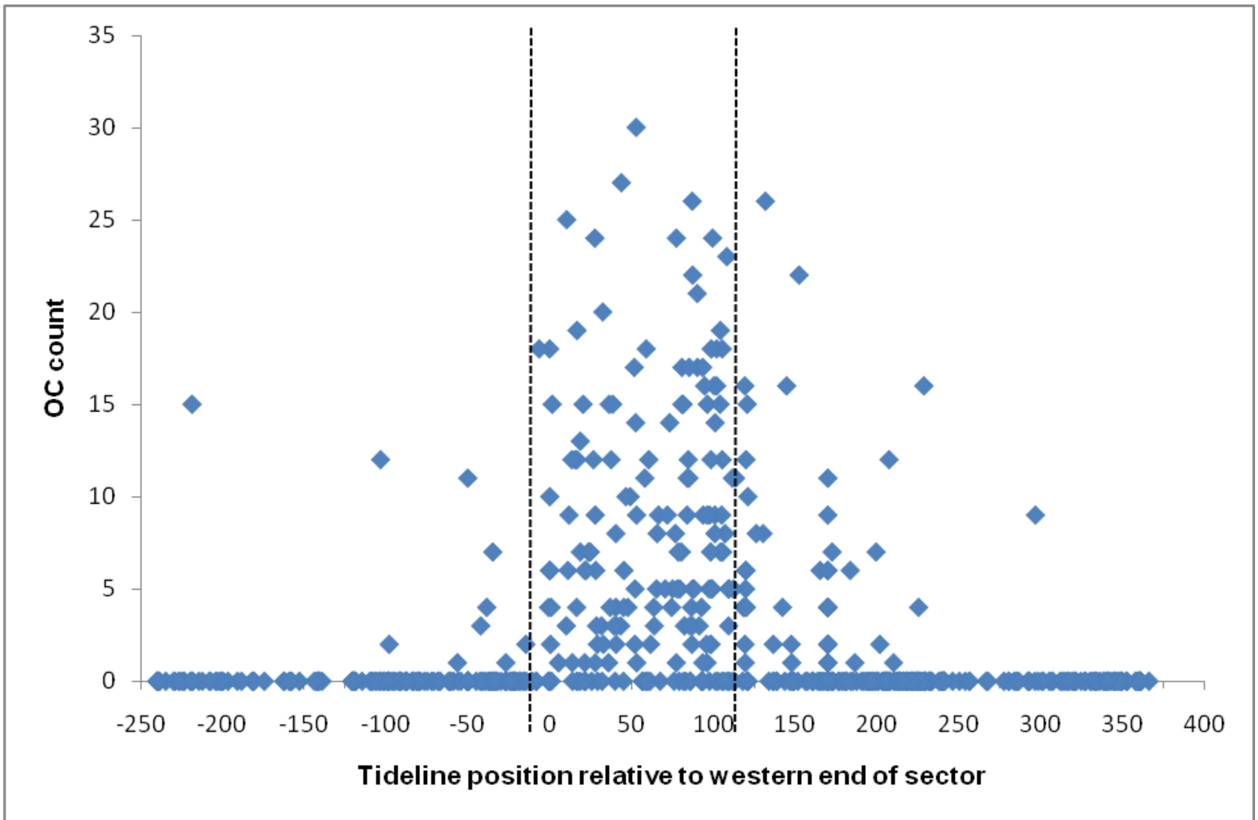

Figure. 4 – Oystercatcher sector counts in relation to tideline position.

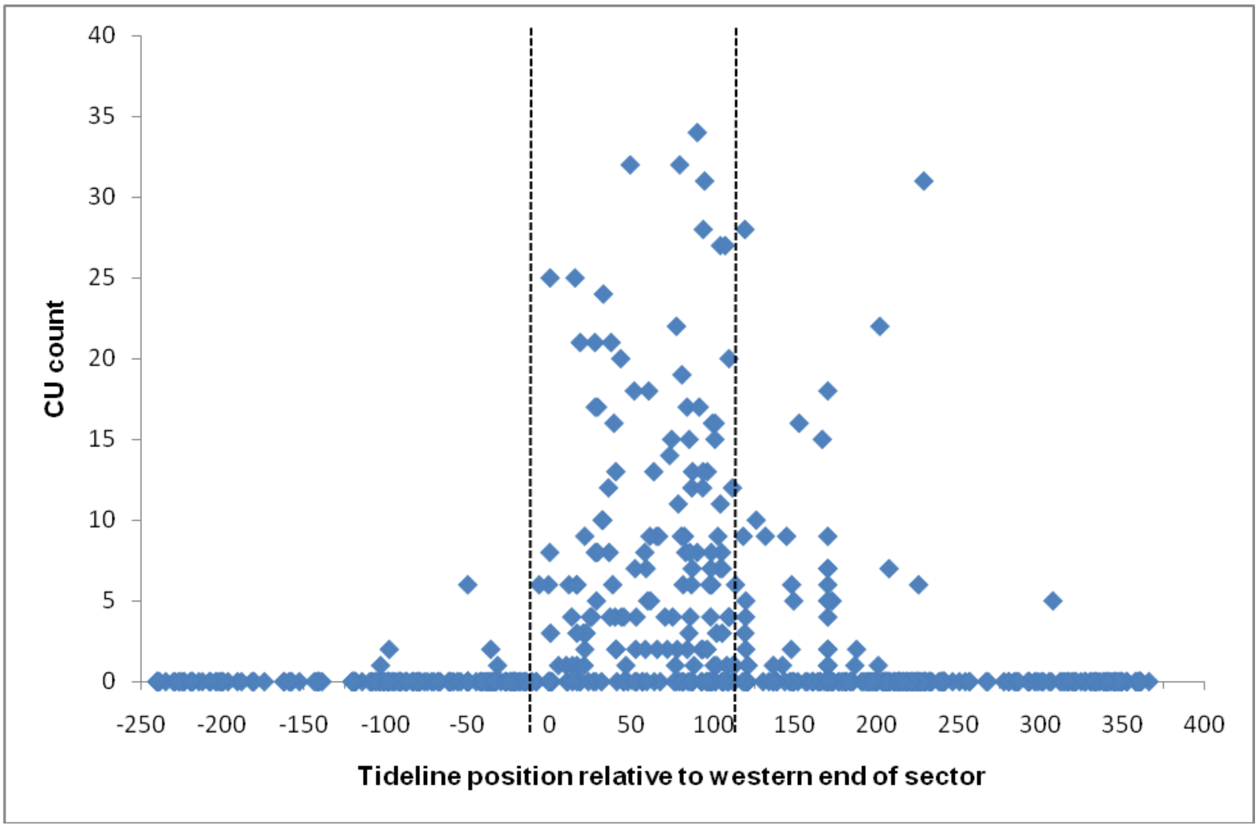

Figure 7 – Curlew sector counts in relation to tideline position.

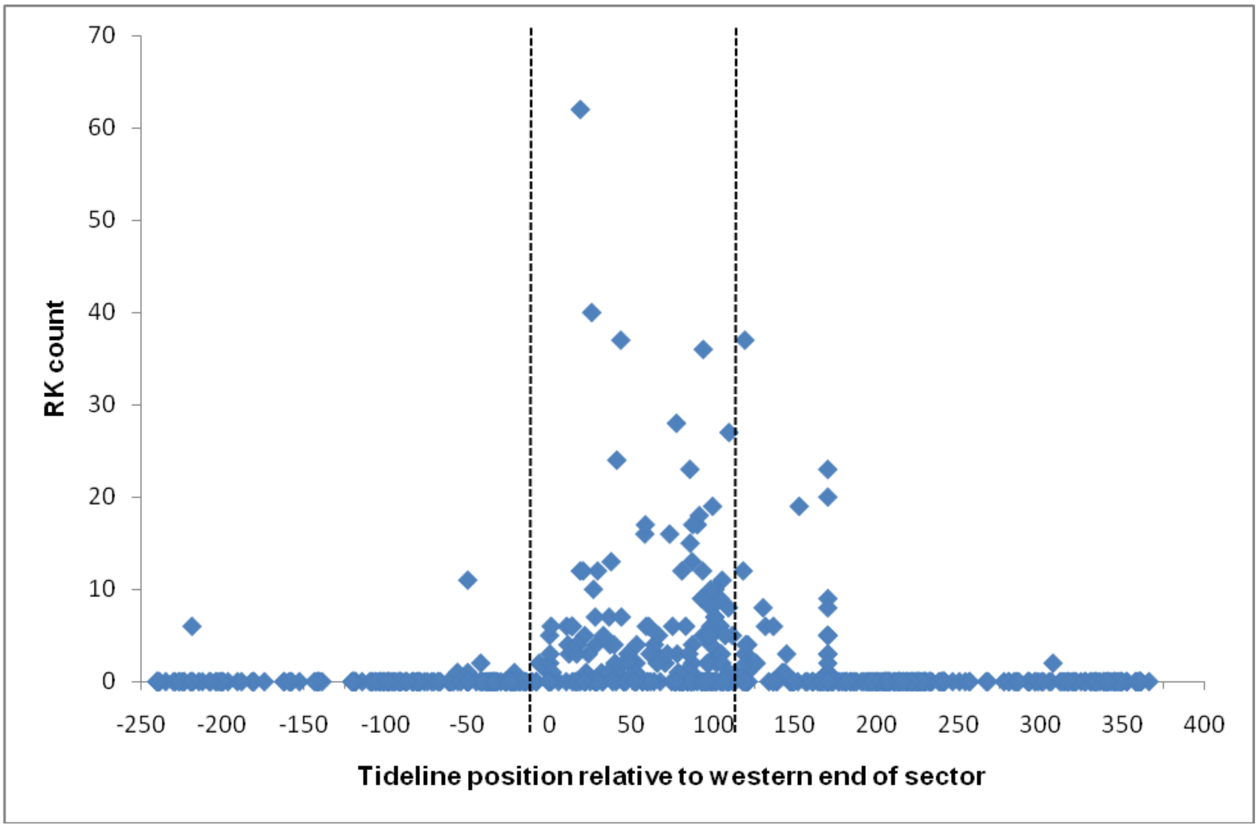

Figure 5 – Redshank sector counts in relation to tideline position.

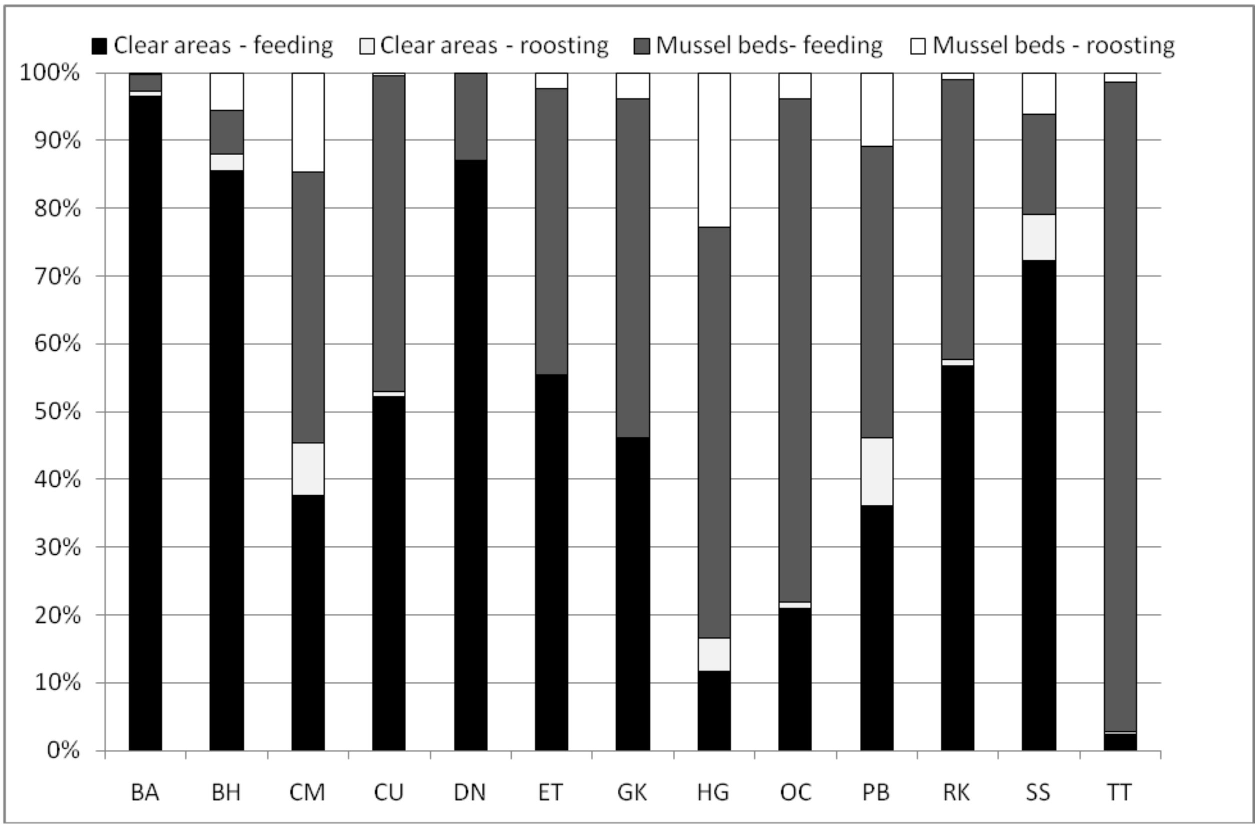

Figure 9– Percentage composition of total count by location and activity of waterbird species recorded in the transect counts.

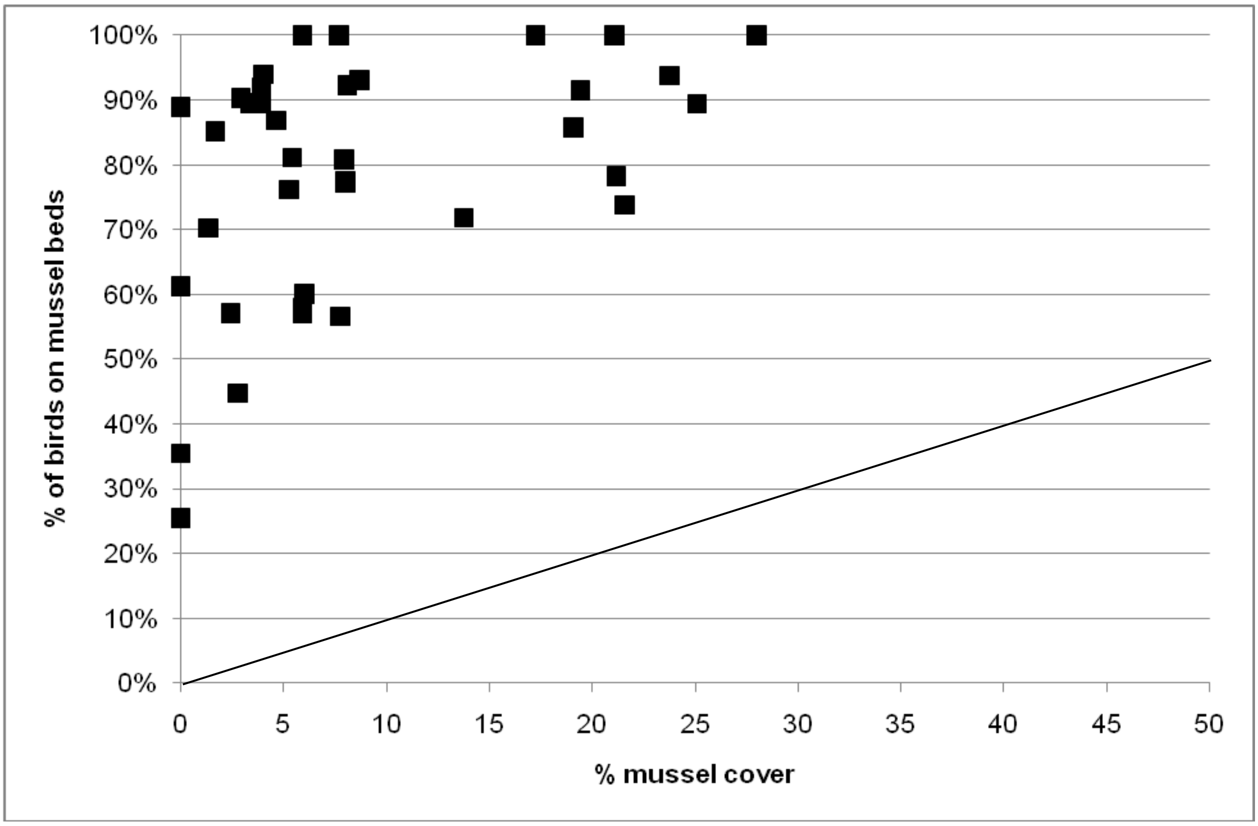

Figure 10 – Mussel cover and percentage occurrence of Oystercatcher on mussel beds for sectors with a total count of ten or more.

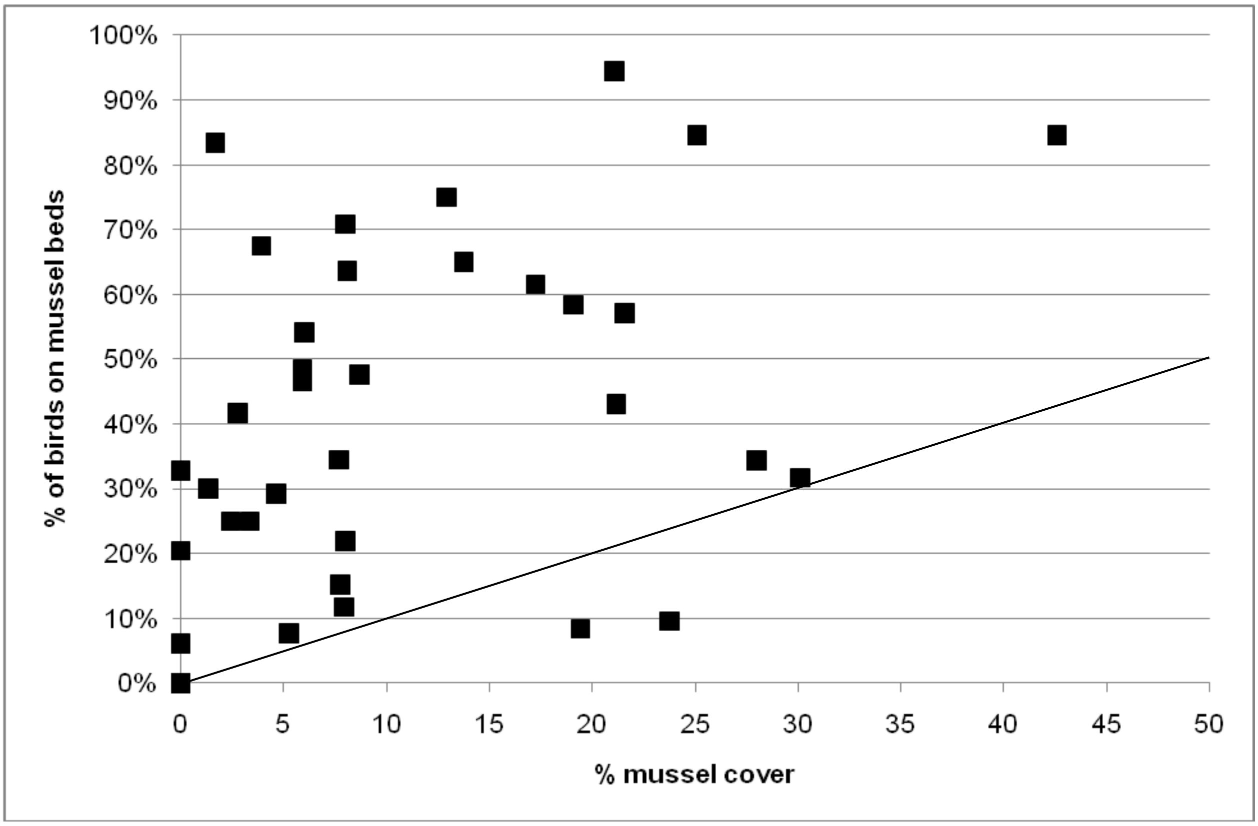

Figure 6 – Mussel cover and percentage occurrence of Curlew on mussel beds for sectors with a total count of ten or more.

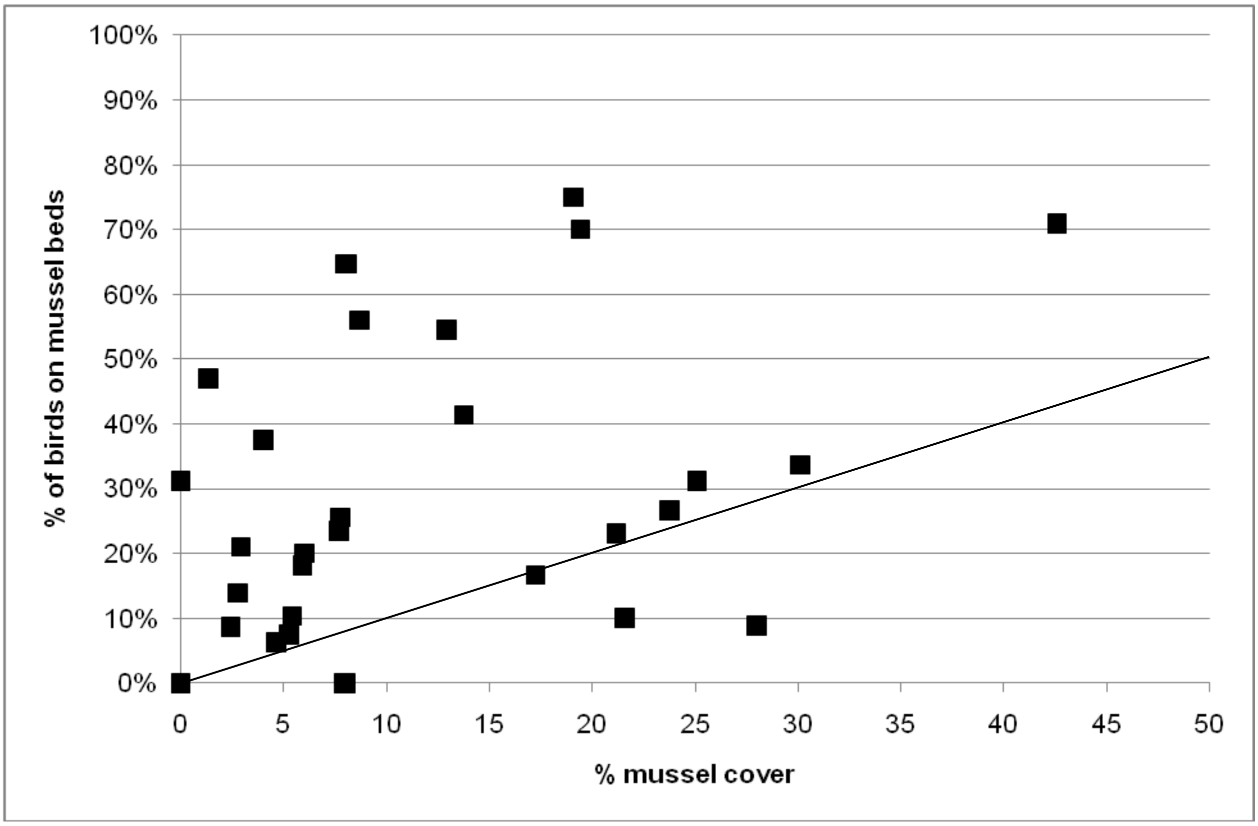

Figure 12 – Mussel cover and percentage occurrence of Redshank on mussel beds for sectors with a total count of ten or more.

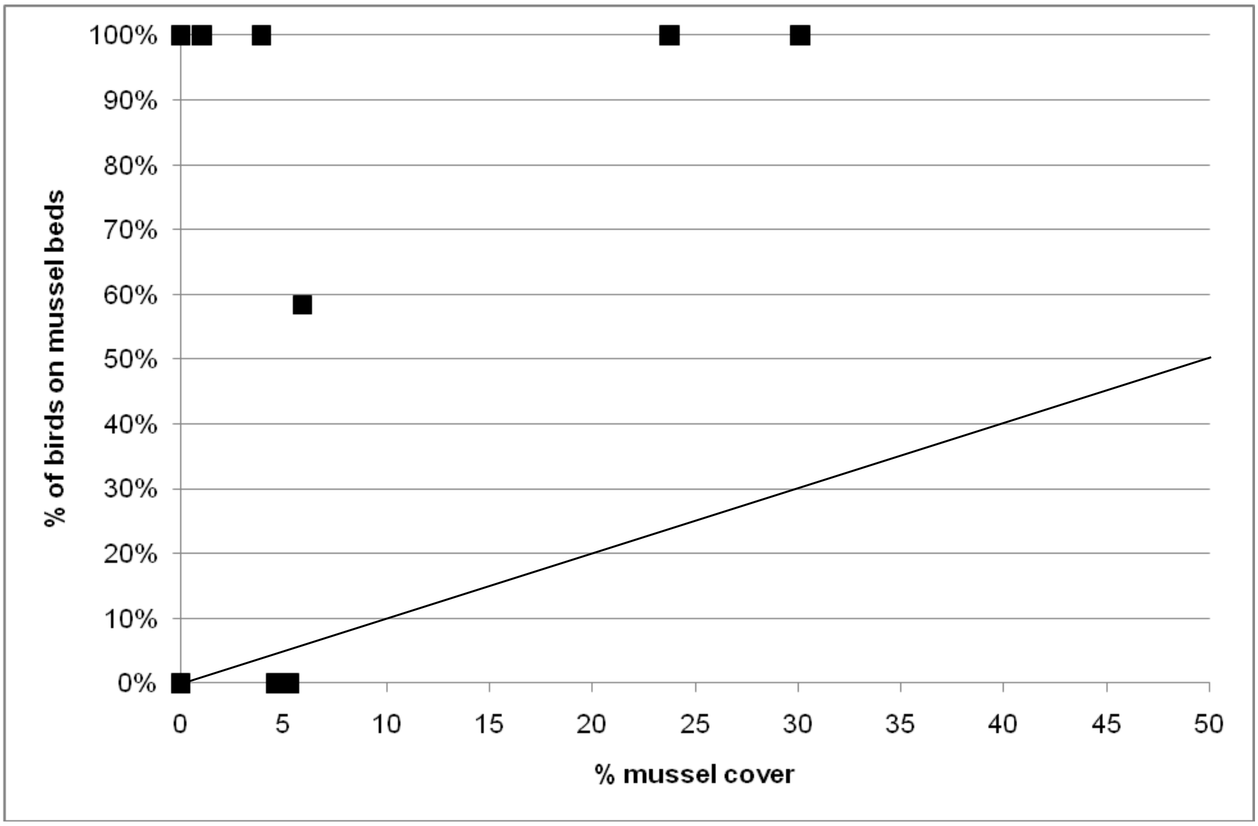

Figure 7 – Mussel cover and percentage occurrence of Light-bellied Brent on mussel beds for sectors with a total count of ten or more.

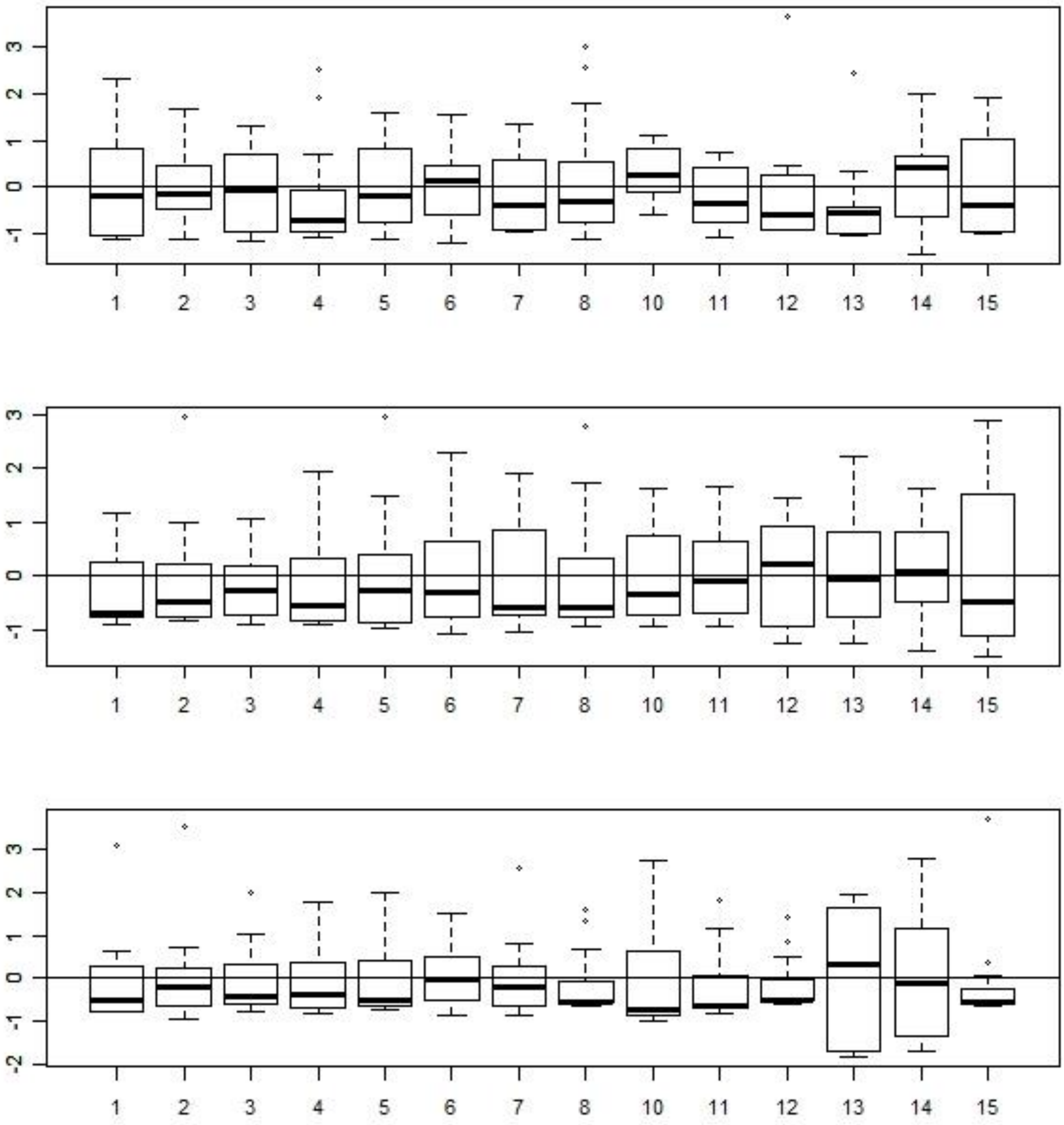

Figure.8 – Boxplot of Pearsons residuals from GLMM Oystercatcher (upper), Curlew (middle) and Redshank (lower) models against TRANS.

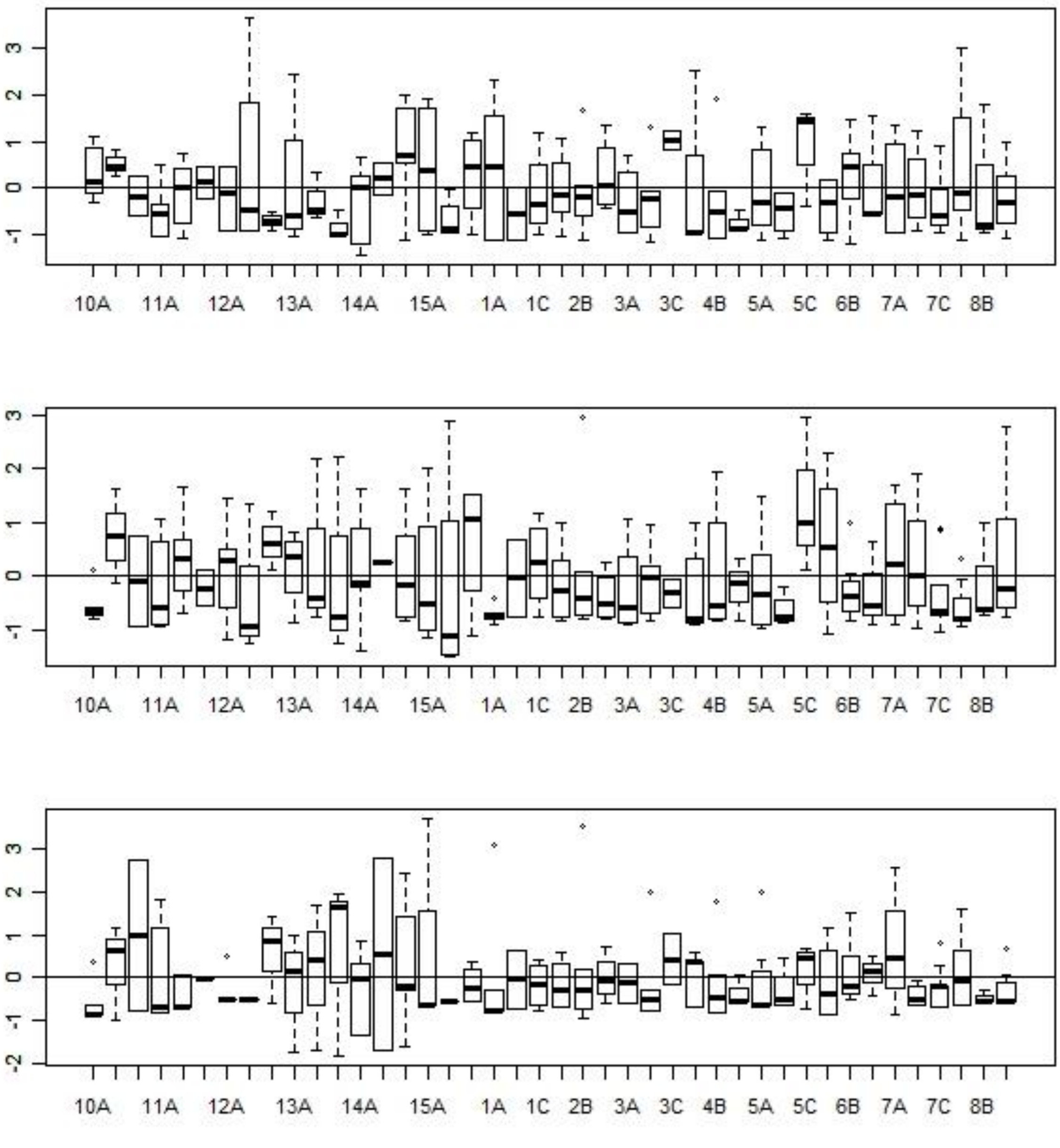

Figure.9 – Boxplot of Pearsons residuals from GLMM Oystercatcher (upper), Curlew (middle) and Redshank (lower) models against TSEC

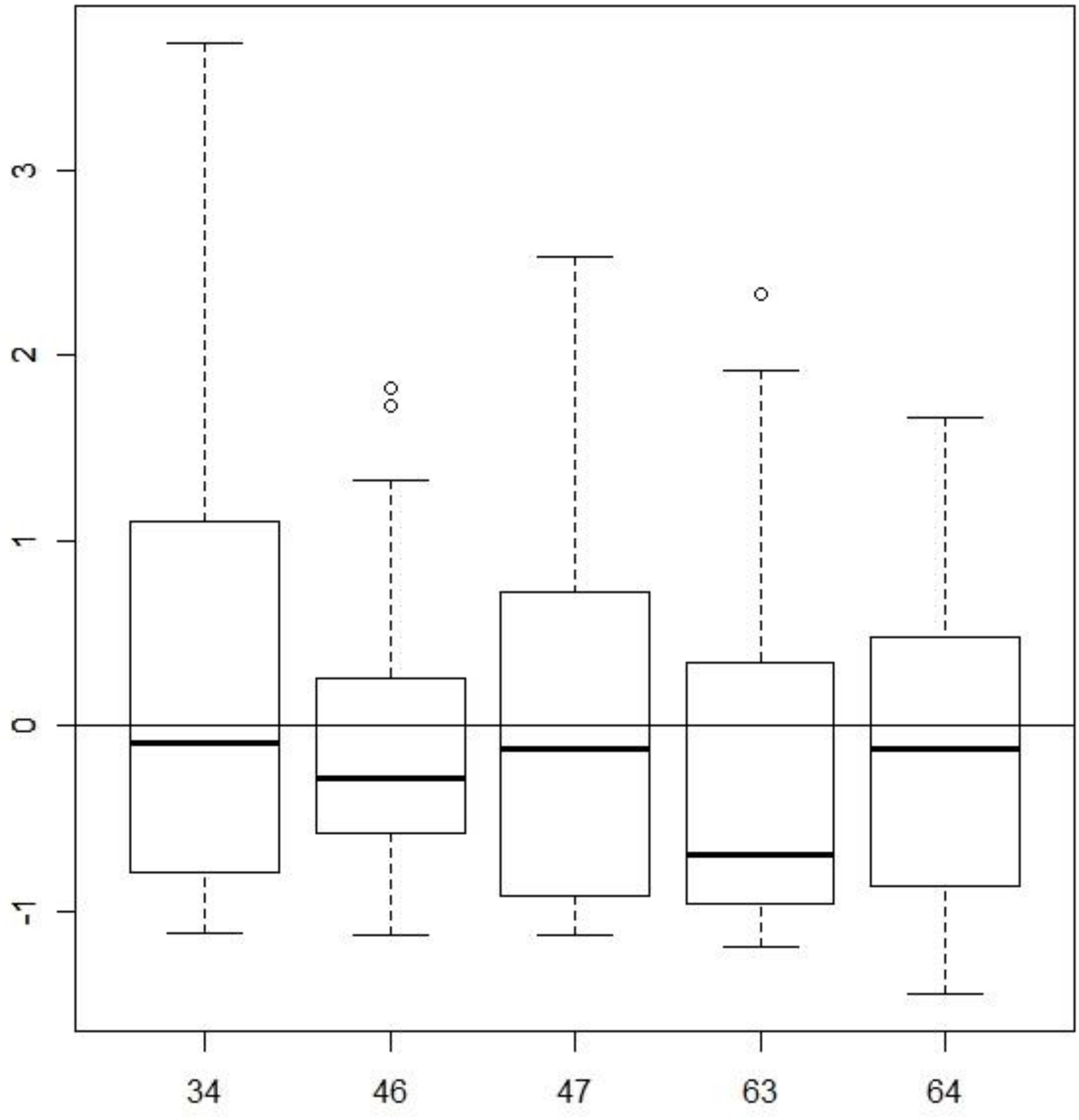

Figure.10 – Boxplot of Pearsons residuals from the GLMM Oystercatcher model against DAY.

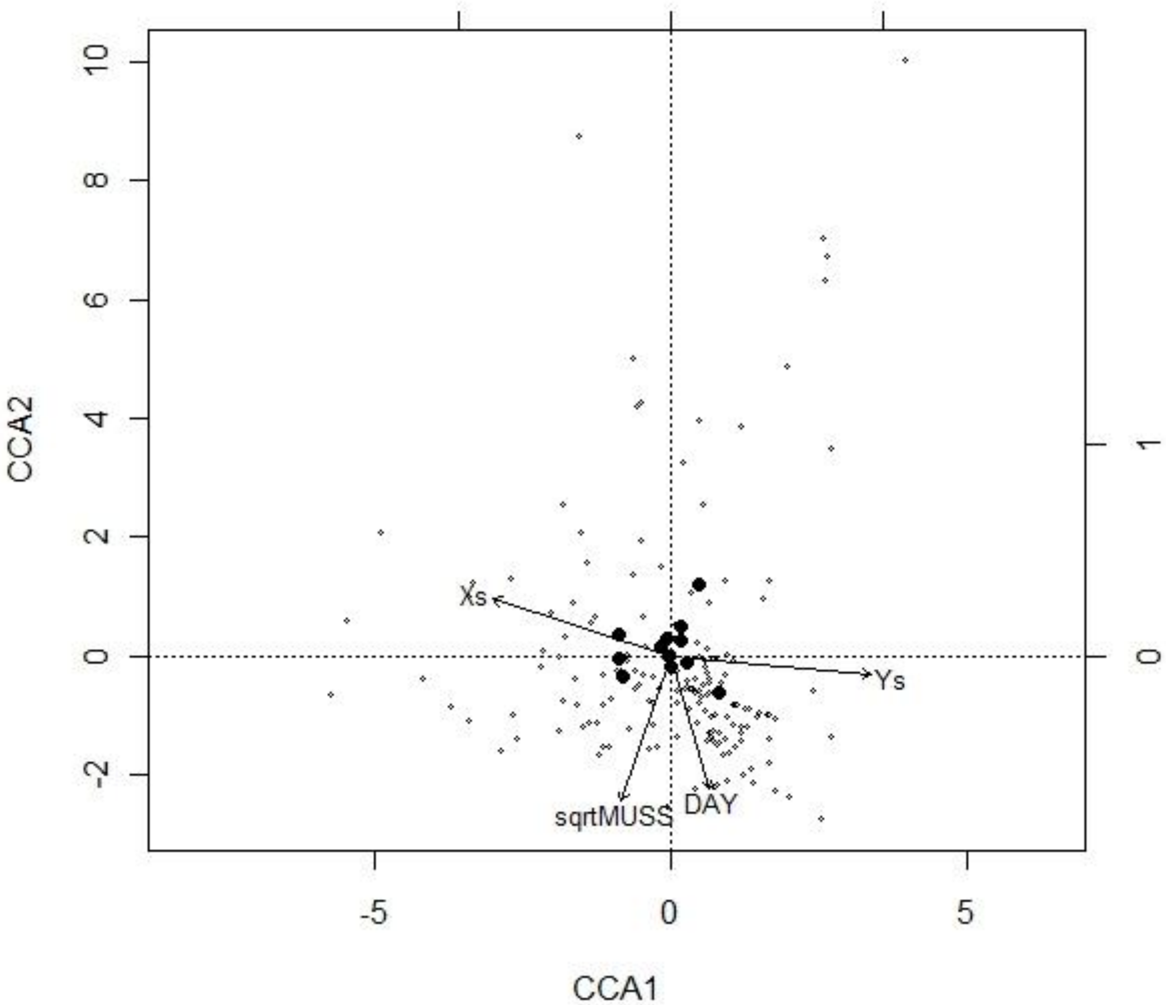

Figure.11 – CCA triplot of waterbird species assemblages recorded on the transect counts with counts shown as small open circles and species shown as large solid circles.

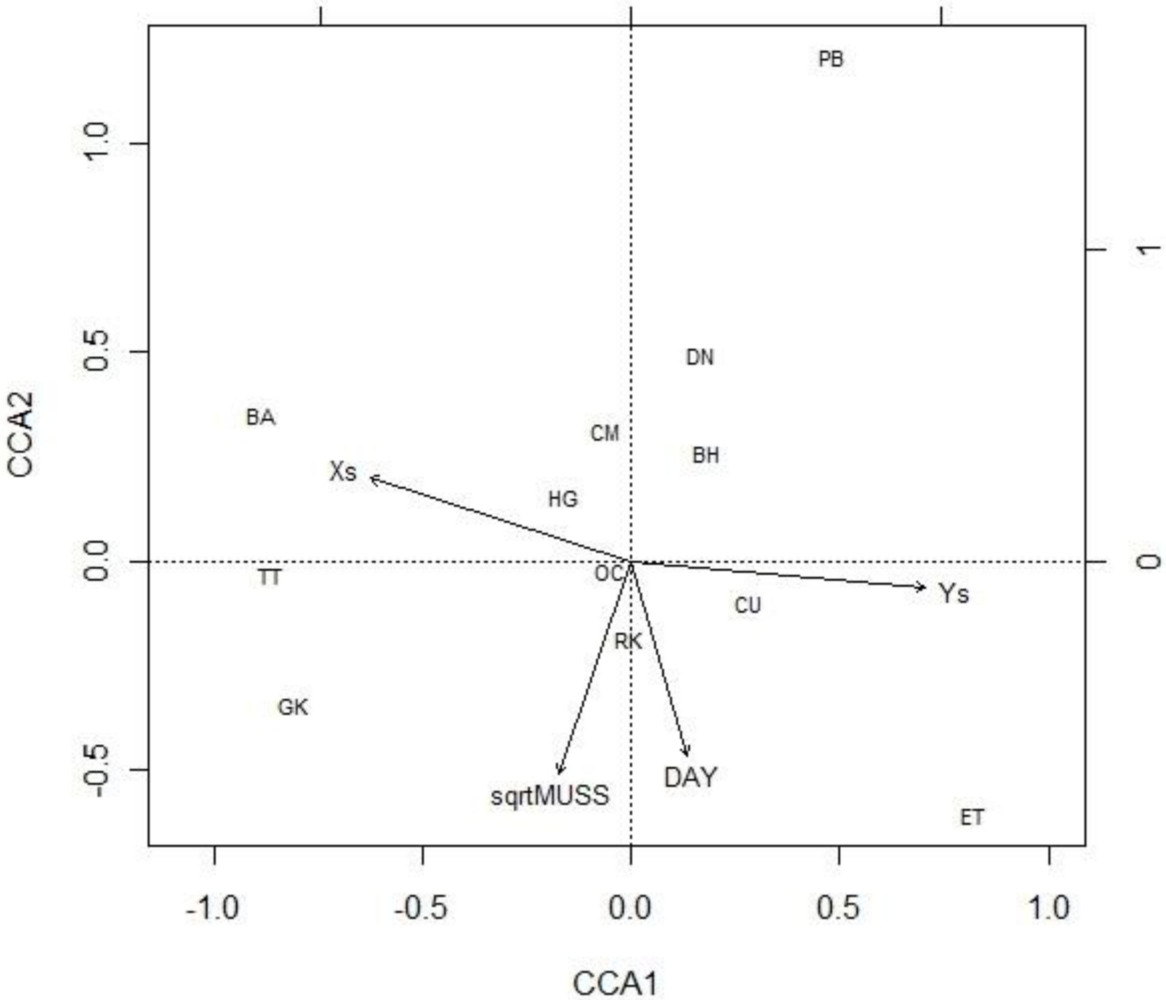

Figure.12 – CCA biplot showing the ordination of waterbird species recorded on the transect counts in relation to the environmental variables.

Appendix A – Species codes and scientific names of bird species mentioned in the text.

A.1.1 The following table lists the BTO species codes and the scientific names of the bird species mentioned in the text. The nomenclature follows Cramp & Simmons (2004).

Code	Name	Scientific name
MS	Mute Swan	*Cygnus olor*
GJ	Greylag Goose	*Anser anser*
PB	Light-bellied Brent Goose	*Branta bernicla hrota*
SU	Shelduck	*Tadorna tadorna*
WN	Wigeon	*Anas penelope*
AW	American Wigeon	*Anas americana*
T.	Teal	*Anas crecca*
MA	Mallard	*Anas platyrhynchos*
PT	Pintail	*Anas acuta*
SV	Shoveler	*Anas clypeata*
SP	Scaup	*Athya marila*
E.	Eider	*Somateria mollissima*
CX	Common Scoter	*Melanitta nigra*
GN	Goldeneye	*Bucephala clangula*
RM	Red-breasted Merganser	*Mergus serrator*
RH	Red-throated Diver	*Gavia stellata*
ND	Great Northern Diver	*Gavia immer*
GG	Great Crested Grebe	*Podiceps cristatus*
CA	Cormorant	*Phalacrocorax carbo*
SA	Shag	*Phalacrocorax aristotelis*
ET	Little Egret	*Egretta garzetta*
H.	Grey Heron	*Ardea cinerea*
NB	Spoonbill	*Platalea leucorodia*
WA	Water Rail	*Rallus aquaticus*
MH	Moorhen	*Gallinula chloropus*
OC	Oystercatcher	*Haematopus ostralegus*
RP	Ringed Plover	*Charadrius hiaticula*
GP	Golden Plover	*Pluvialis apricaria*
GV	Grey Plover	*Pluvialis squatarola*
L.	Lapwing	*Vanellus vanellus*
KN	Knot	*Calidris canutus*
SS	Sanderling	*Calidris alba*
DN	Dunlin	*Calidris alpina*
RU	Ruff	*Philomachus pugnax*
SN	Snipe	*Gallinago gallinao*
BW	Black-tailed Godwit	*Limosa limosa*
BA	Bar-tailed Godwit	*Limosa lapponica*
WM	Whimbrel	*Numenius phaeopus*
CU	Curlew	*Numenius arquata*
DR	Spotted Redshank	*Tringa erythropus*

Code	Name	Scientific name
GK	Greenshank	*Tringa nebularia*
RK	Redshank	*Tringa totanus*
TT	Turnstone	*Arenaria interpres*
BH	Black-headed Gull	*Larus ridibundus*
CM	Common Gull	*Larus canus*
LB	Lesser Black-backed Gull	*Larus fuscus*
HG	Herring Gull	*Larus argentatus*
GB	Great Black-backed Gull	*Larus marinus*
KF	Kingfisher	*Alcedo atthis*

Appendix B - Distribution of counts included in the GLMM analyses.

B.1.1 The following tables show the distribution of the counts from each sector that were included in the GLMM analyses by the count date and the count sequence. Under each date, the numbers indicate the sequence of count series by time of day. Each count series comprised co-ordinated counts across transects over a period of approximately one hour. Most count series included all transects. However, on some dates, the first and/or last count series did not include all transects because of differences between transects in their exposure time and/or for logistical reasons.

	03-Feb					15-Feb					
Sector	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**6**
1A							1				
1B						1		1			
1C				1					1		
2A			1				1				
2B				1		1		1			
2C									1		
3A							1				
3B				1		1			1		
3C					1						
4A							1				
4B				1		1			1		
4C					1						
5A	1	1					1		1		
5B				1		1					
5C					1					1	
6A		1					1				
6B	1			1							
6C						1				1	
7A	1		1								
7B				1			1			1	
7C					1	1					1
8A	1			1						1	
8B					1		1				
8C						1					1
10A				1		1			1		
10B											
10C										1	
11A	1			1		1			1		
11B					1					1	
11C											
12A				1							
12B	1				1	1				1	
12C											

Sector	03-Feb					15-Feb					
	1	2	3	4	5	1	2	3	4	5	6
13A	1							1			
13B											
13C				1					1		
14A	1					1					
14B				1							
14C									1		
15A				1							
15B	1					1			1		
15C											
Total	9	2	2	14	7	13	8	3	10	7	2

Sector	16-Feb						04-Mar			
	1	2	3	4	5	6	1	2	4	5
1A		1							1	
1B										
1C	1				1					
2A		1					1		1	
2B					1					
2C	1					1				1
3A		1			1					
3B	1						1			1
3C						1				
4A		1			1					1
4B							1			
4C	1					1				
5A		1		1			1			
5B					1				1	
5C										
6A										
6B		1			1		1		1	
6C										
7A									1	
7B					1					
7C		1				1	1			1
8A			1		1			1		
8B										
8C		1				1	1			1
10A		1					1			

Sector	16-Feb						04-Mar			
	1	2	3	4	5	6	1	2	4	5
10B				1						
10C										1
11A		1								
11B				1	1		1			1
11C										
12A				1				1		1
12B										
12C		1					1			
13A							1			
13B		1							1	
13C					1					
14A									1	
14B							1			
14C		1			1					
15A			1						1	
15B					1					
15C		1					1			
Total	4	14	2	4	12	5	13	2	8	8

Sector	05-Mar					Overall total
	1	2	4	5	6	
1A	1		1			5
1B						2
1C						4
2A			1			6
2B	1			1		6
2C						4
3A		1				4
3B	1			1		8
3C						2
4A		1				5
4B	1			1		6
4C						3
5A	1		1			9
5B						4
5C				1		3
6A		1	1			4
6B	1					7

Sector	05-Mar					Overall total
	1	2	4	5	6	
6C				1		3
7A		1				4
7B						4
7C	1			1		9
8A		1				7
8B				1		3
8C	1					7
10A						5
10B	1			1		3
10C						2
11A				1		6
11B						6
11C	1				1	2
12A		1				5
12B						4
12C	1					3
13A			1			4
13B	1					3
13C						3
14A		1	1			5
14B						2
14C	1			1		5
15A		1				4
15B						4
15C	1			1		4
Total	14	8	6	11	1	189

Appendix C - Instructions given to counters for completing the waterbird count form.

C.1.1 **Counter:** enter counter name in this space.

C.1.2 **Date:** enter the date in the format dd/mm/yy.

C.1.3 **Transect number:** enter the transect number in this space. Transect numbers are shown on the map of the plot locations.

C.1.4 **Time:** enter the start and finish time in the format hh:mm-hh:mm.

C.1.5 **Count affected by disturbance:** enter yes if birds in the transect were affected by a disturbance event during the count, or if a disturbance event prior to the count is considered to have affected the number of birds recorded. Enter the event reference (see instructions for disturbance amps and forms), details of the disturbance event and its effects on birds in the *Notes* section of the form. If disturbance is not considered to have affected the birds in the transect, enter no in this space.

C.1.6 **Time since last disturbance event:** a disturbance event includes any event that is known to have caused disturbance of birds, as well as any human activity within 200 m of the transect, whether or not it is known to have caused disturbance. If no disturbance event has occurred on this count day, enter N/A. Information entered in this box should correspond to the information entered on the disturbance map and forms.

C.1.7 **Distance from transect of last disturbance event:** see above for definition of what counts as a disturbance event. Enter distance in metres. If no disturbance event has occurred on this count day, enter N/A. Information entered in this box should correspond to the information entered on the disturbance map and forms.

C.1.8 **Sketch position of tideline:** indicate the approximate position of the tideline at the time of the count by drawing a line across the diagram of the transect. This section must be completed for every count. Any uncertainties in estimating the tideline position can be mentioned in the *Notes* section of the form.

C.1.9 **Weather:** weather conditions should be recorded using the same methodology and criteria as used for the *Baseline Waterbird Surveys within Irish Coastal Special Protection Areas 2009/10 Waterbird Count Form*, with the exception of wind. Wind speed and direction should be recorded using a compass direction and the Beaufort scale (e.g., NW5). The Beaufort scale is defined below (source: http://en.wikipedia.org/wiki/Beaufort_scale).

Beaufort scale	Sea conditions	Land conditions
0	Flat	Calm. Smoke rises vertically.
1	Ripples with crests	Wind motion visible in smoke.
2	Small wavelets. Crests of glassy appearance, not breaking	Wind felt on exposed skin. Leaves rustle.
3	Large wavelets. Crests begin to break; scattered whitecaps	Leaves and smaller twigs in constant motion.
4	Small waves with breaking crests. Fairly frequent white horses.	Dust and loose paper raised. Small branches begin to move.
5	Moderate waves of some length. Many white horses. Small amounts of spray.	Branches of a moderate size move. Small trees begin to sway.
6	Long waves begin to form. White foam crests are very frequent. Some airborne spray is present.	Large branches in motion. Whistling heard in overhead wires. Umbrella use becomes difficult. Empty plastic garbage cans tip over.
7	Sea heaps up. Some foam from breaking waves is blown into streaks along wind direction. Moderate amounts of airborne spray.	Whole trees in motion. Effort needed to walk against the wind. Swaying of skyscrapers may be felt, especially by people on upper floors.

C.1.10 **Bird counts:** enter the number of waterbird species recorded in appropriate columns with regards to their position in the transect (sector number), their location (on mussel bed or on clear area) and their behaviour (feeding or roosting/other).

- Birds within/on top of mussel patches should be recorded as *On mussel bed*. Birds feeding in gaps between the mussel patches or on large areas of clear sand should be recorded as *On clear area*. The location should be recorded based on the birds' position when first seen, so birds that move from a mussel bed to a clear area should be recorded as *On mussel bed*. There may be difficulty in judging the location of more distant birds in areas with closely spaced mussel patches; in these cases record your first impression and do not spend too much time trying to work out the exact location.

- Birds should be assigned to behaviour categories (feeding and roosting/other) following the same guidelines and criteria as used for the *Baseline Waterbird Surveys within Irish Coastal Special Protection Areas 2009/10*.

C.1.11 **Notes:** use this section to enter details of any disturbance events that affected the count, details of any other factors that affected the data recording, and any other miscellaneous observations of interest

C.1.12 A copy of the waterbird count form is provided on the next page.

Castlemaine aquaculture impact study: Waterbird count form

Counter:	
Date:	
Transect:	
Time:	

Count affected by disturbance?	
Time since last disturbance event:	
Distance from transect of last disturbance event:	

Weather (circle as appropriate)			
Cloud cover:	1 0-33%	2 33-66%	3 66-100%
Rain:	1 none	2 showers	3 drizzle
Wind speed (Beaufort scale) and direction :			
Visibility	1 good	2 moderate	3 poor

Sketch position of tideline:

seaward			landward
	Sector A	Sector B	Sector C
0 m	120 m	240 m	360 m

	Sector A				Sector B				Sector C			
	On mussel bed		On clear area		On mussel bed		On clear area		On mussel bed		On clear area	
Species	F	R	F	R	F	R	F	R	F	R	F	R

Notes:

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