Marine Institute Bird Studies (in support of Castlemaine Harbour Appropriate Assessment)

ATKINS

Castlemaine Waterbird Studies – I (Mussels)

Assessment of the potential effects of mussel ongrowing within the mussel order area and of the mussel seed fishery on the waterbird populations of Castlemaine Harbour

April 2011

Plan Design Enable

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18th April 2011

Notice

This report was produced by Atkins (Ecology) for the Marine Institute for the specific purpose of the Marine Institute Bird Studies (Castlemaine).

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Note: This report is an updated and expanded version of the *Castlemaine Waterbird Report* (Gittings and O'Donoghue, 2010).

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Executive Summary

The status and distribution of waterbirds in Castlemaine Harbour

We analysed the count data from the Irish Wetland Bird Survey (I-WeBS) between 1994/95 and 2008/09, and from the 2009/10 counts of Castlemaine Harbour carried out under the NPWS Baseline Waterbird Survey. We also used data from the transect counts carried out in the mussel nursery area in February and March 2010 (see below). We compared population levels recorded during the NPWS Baseline Waterbird Survey Programme with those recorded by the I-WeBS counts, and we assessed the importance of the count sectors containing the mussel nursery area and/or potentially affected by other mussel-related activities relative to other areas within Castlemaine Harbour.

The 2009/10 waterbird counts from the NPWS Baseline Waterbird Survey programme show apparent increases in many species compared to the recent I-WeBS counts. It is highly unlikely that so many waterbird species would show increased numbers in a single winter, and no species would show a significant decrease. Therefore, it seems likely that, given the acknowledged problems with coverage in the I-WeBS counts, I-WeBS counts in recent years have significantly underestimated the population of many species.

The fact that I-WeBS counts in the 1990s are generally closer to the 2009/10 count levels, suggest that either there has been a long-term decline (i.e., counts in the 1990s had a similar level of underestimation as those of more recent years) or counts in the 1990s were of higher quality.

For three of the waterbird species of Special Conservation Interest (Wigeon, Scaup and Common Scoter), the 2008/09 and 2009/10 data still show substantially lower numbers compared to those recorded in the mid-1990s. Wigeon has suffered a national decline but the decline in the Castlemaine Harbour population appears to have been considerably greater than the national trend. The decline in the Castlemaine Harbour Scaup population seems to be part of a decline in the regional population and may not reflect site-specific factors. I-WeBS data probably does not provide a reliable indication of the current status of Common Scoter at Castlemaine Harbour and numbers are considered to have remained stable.

Comparison of the mean daily maxima of the transect counts with the mean 2009/10 Castlemaine count indicates that the mussel nursery area was used by significant components of the Castlemaine populations of Light-bellied Brent, Little Egret, Sanderling, Dunlin, Bar-tailed Godwit, Curlew, Redshank, Turnstone and Herring Gull.

Comparison of the mean daily maxima of the transect counts the mean counts of the sectors overlapping the nursery area indicates that the mussel nursery area was used by representative proportions of the total Light-bellied Brent and most wader species in the local area. Ringed Plover and Grey Plover were very rare, or absent, during the transect counts despite occurring in significant numbers in the count sectors. Most ducks were very rare, or absent, during the transect counts despite occurring in significant numbers in these count sectors. This probably reflects their association with freshwater inflows and proximity to saltmarsh.

The main Common Scoter flock locations recorded during the 2009/10 waterbird count data were at least 1 km from the main seed mussel fishery, although a flock was recorded on one date close to this area. The distribution of the areas favoured by Common Scoter, based on the experience of a local naturalist over many years, also indicates that they mainly avoid the main seed mussel fishery.

The subtidal habitat that may be affected by boat activity during mussel ongrowing and harvesting operations (excluding seed mussel extraction) was not used by Common Scoter during the 2009/10 waterbird counts and was used by Cormorant, Red-throated Diver, Great Northern Diver and Red-breasted Merganser in numbers broadly corresponding to those expected if the birds were randomly distributed across the subtidal habitat covered by the survey.

No major high tide roosts were recorded in the vicinity of any areas affected by activity associated with the mussel seed fishery and mussel ongrowing in the mussel order area.

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.

Disturbance

During the transect counts in February and March 2010 (see above), counters recorded all human activity, and any impacts caused by these activities, and any other factors that caused disturbance to the birds in transects being counted. The area covered by this disturbance recording included the full extent of the mussel nursery area (apart from small areas that were not covered because of the failure of one counter to submit disturbance information) and the duration covered the entire low tide period during which the mussel nursery area was exposed. We used the observed alert and flight response distances and recovery times to calculate the amount of the habitat resource affected by all mussel-related disturbance activities.

Mussel-related disturbance activities occurred on four out of the five survey days and affected a mean of 6.8% of the available habitat resource, using the alert response distance, and 2.4% using the flight response distance.

These potential disturbance effects are overestimates of the actual disturbance impacts for a number of reasons. We consider that the actual mean disturbance impact per low tide period would be reduced by at least 50-75%, and probably lower than even the lower end of that range. Comparisons with relevant studies in the scientific literature show that these levels of disturbance intensity and impact are generally much lower than levels reported to affect survivorship.

Acknowledgements

We are grateful to the Castlemaine Harbour Co-Operative Society Limited for giving permission to carry out survey work in the mussel nursery area. Ms. Catherine Butler (BIM) helped with the liaison with the Co-operative, while Joanne Gaffney (BIM) provided information on dredging in 2009. We would also like to thank Ms. Mary Cregg in the BIM library for sourcing historical data and Ms. Gráinne O'Brien (BIM) for assistance throughout.

Mr. Oliver Tully (Marine Institute), Dr. Lesley Lewis (NPWS) and Dr, David Tierney (NPWS) provided useful advice and comments during the design of the transect count study. Oliver Tully and George Smith (Atkins) provided useful comments on an earlier draft of this report. Thanks also to Francis Beirn and John Evans (Marine Institute) for assistance throughout.

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.

The *Zostera* mapping data in Figure 2.2 are from an intertidal soft sediment survey carried out by the Aquatic Services Unit for NPWS (Aquatic Services Unit, 2008).

1. 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 Only part of Castlemaine Harbour has been legally designated as a SPA, However, NPWS intend to extend the designation to cover the whole of Castlemaine Harbour and plan to advertise this extension in the near future (David Tierney, NPWS, pers. comm.). The appropriate assessment will have to consider the entirety of the area covered by the existing designation and the proposed extension.

1.3 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. We have also reviewed waterbird count data to assess the current status of waterbird species in Castlemaine Harbour and the distribution of waterbirds in relation to activities associated with mussel cultivation within the mussel order area.

1.4 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 Eamonn Delaney).

1.5 Our brief for this report was to: -

- Review the updated I-WeBS data series and the 2009/10 waterbird count data carried out under the NPWS Baseline Waterbird Survey Programme.
- Report on the transect count study carried out in February and March 2010.

1.6 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.

1.7 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.

1.8 This report is an updated and expanded version of the *Castlemaine Waterbird Report* (Gittings and O'Donoghue, 2010).

Mussel cultivation in Castlemaine Harbour

Current status

1.9 The current practise of mussel cultivation in Castlemaine Harbour involves the following stages:

- Fishing of seed mussel from seed mussel beds to the west of Inch Point.
- Relaying of the seed mussel onto the intertidal nursery area east of Inch Point, for ongrowing.

- Dredging of the ingrown seed mussel from the intertidal nursery area after 6-12 months.
- Relaying of the dredged mussels into subtidal plots along the northern side of Castlemaine Harbour and east of Cromane, for subtidal ongrowing.
- Harvesting (by dredging) the on grown mussels for sale after 12-18 months.

History

1.10 A mussel fishery appears to have existed in Castlemaine Harbour from the middle of the nineteenth century (Crowley, 1973; Lee, 1875). However, we understand that the seed mussel fishery west of Inch Point and intertidal relay on the nursery area only began within the last 20-30 years. Prior to this, the nursery area appears to have functioned mainly or entirely as a natural mussel bed: there are no references to relay of seed mussels to the nursery area in Crowley (1973) and Lee (1975), while CLAMS (2001) states that no intertidal relay of mussels occurred within the mussel nursery area prior to 1994. We understand that the collection and movement of seed mussel from west of Inch only became possible with the arrival of large dredgers in the bay; prior to this it was not possible to safely harvest seed mussel in this area with the boats in the harbour prior to the 1990's.

1.11 Relay of mussels from an area referred to as Banc Fluic (corresponding to the current nursery area) to subtidal areas appears to have occurred periodically at least as far back as 1950, such that some management of the fishery does seem to have been practices.. However, the evidence in Crowley (1973) and Lee (1975) indicates that the current subtidal relay plots are in areas where there have been mussel beds of, at least partly, natural origin for many decades. These documents also indicate the presence of an intertidal mussel bed at Banc Fluic, the site of the mussel order and the subject of this assessment.

1.12 Therefore, the baseline condition of the mussel nursery area is not an open sandflat with no mussel cover, but some undetermined level of mussel cover. Similarly, the baseline condition of the subtidal relay plots is also some undetermined level of mussel cover.

Limitations to this study

1.13 The data on bird distribution from the 2009/10 baseline waterbird survey programme is based on four low tide counts and one high tide count during one season. Species distribution patterns within Castlemaine Harbour may vary seasonally and between years. Furthermore, on each low tide count day only a single count was carried out in each count sector, and different sectors were counted at different stages of the tidal cycle (within an overall window of four hours centred on low tide). Spatial patterns of waterbird usage of intertidal habitat can vary significantly during the low tide period, although data recorded using the standard low tide count methodology (as used in the 2009/10 baseline waterbird survey programme) is considered to be representative of average usage in most cases (Burton, Musgrove & Rehfisch, 2004).

1.14 The estimated proportion of the Castlemaine Harbour population and of the local population (i.e., the count sectors overlapping the nursery area) that occurs within the nursery area was calculated from the mean daily maxima of transect counts within the nursery area across five days in Feb-Mar 2010, divided by the mean of the Castlemaine Harbour or local sector counts from 2009/10 baseline waterbird survey programme. These proportions should be interpreted with caution, as it is likely that for some species the mean Castlemaine Harbour or local sector counts from 2009/10 baseline waterbird survey programme are not representative of the numbers occurring in Castlemaine Harbour or the local sectors during the transect counts.

1.15 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.

1.16 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 (see paragraphs 3.37-3.39 for further discussion of this point).

1.17 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.

2. Literature review

2.1 There is little published information available on the effects of intertidal aquaculture on waterbird populations in Ireland. Hilgerloh *et al*. (2001) undertook a preliminary investigation of the effect of oyster trestles on intertidal birds at a site in Cork Harbour, while Roycroft *et al*. (2004) examined the impact of suspension culture of mussels on birds and seals in Bantry Bay, a non-seaduck area in the southwest of Ireland. There have, however, been no studies looking at the relationship between the intertidal culture of mussels (*Mytilus edulis*) and intertidal birds in Ireland.

2.2 This trend is repeated aboard with few detailed studies of effects of intertidal aquaculture on waterbird populations having being published in the peer reviewed literature. A number of significant exceptions include studies of intertidal mussel cultivation (Caldow *et al*., 2003), oyster trestles (Kelly *et al*., 1996; Hilgerloh *et al*., 2001) and intertidal clam cultivation (Godet *et al*., 2009).

Caldow *et al*. (2003)

2.3 With respect to mussels, Caldow *et al*. (2003) carried out a BACI[1] manipulation study on the effects of intertidal mussel culture on habitat use by waterbirds in Wales. They examined waterbird distribution within a latin square grid of 16 no. 20 x 20 m cells with varying initial mussel densities, and between this grid and another seeded plot and two control plots. The study lasted for three seasons: one pre-impact and two post-impact. The data was analysed using the two impact and two control plots to examine variation in waterbird assemblages, but using each cell of the latin square as replicate, in combination with the other three lots, to examine the relationship between mussel presence and waterbird numbers.

2.4 Before seeding of the impact plots, the waterbird assemblages in the four plots were similar. Following seeding, the waterbird assemblages in the impact plots diverged from those in the control plots, although they did not lose any species. This divergence was mainly due to changes in relative abundances of Oystercatcher, Curlew, Redshank, Black-headed Gull and Herring Gull. Curlew and Redshank showed higher densities in the impact plots. However, within the cells of the latin square, Oystercatcher and Redshank showed negative associations with mussel density.

2.5 The authors suggest that the increase in Curlew and Redshank density on the impact plots may have been due to an increase in potential prey species (recorded in a related study; Beadman *et al*., 2004). Alternatively, they suggest that the mussel matrix provides a refuge for invertebrates from water movement and desiccation, allowing them to remain active closer to the surface during low tide. The negative association with high mussel density reflected the fact that the cells with high mussel density “were covered in a solid mat of mussels”, which would have had negative effects on prey density. However, the authors suggest that these areas of high mussel density may have helped increase the suitability of the areas of low density because the areas of high density became elevated over time and “water draining off the higher-level mudflats tended to flow around such elevated areas, so that cells with lower densities of mussels more often contained small pools and creeks at low tide”.

2.6 This work provides some useful data on two of the waterbird species of Special Conservation Interest at Castlemaine Harbour (Oystercatcher and Redshank). However, there are another 14 species that are not covered by this study. Also, the study does not consider the potential impact of disturbance from mussel husbandry. The comparison between mussel presence and absence

[1] BACI: Before – After Control Impact Study.

was based on a rather curious design which combined 20 x 20 m plots and much larger-scale plots and only included two control plots.

2.7 The mussel densities in this study cannot be directly compared to our survey of the mussel cover in the nursery area at Castlemaine, because of differences in the survey methods. However, the highest level of mussel cover in this study is described as resulting in cells that “were covered in a solid mat of mussels”, implying a mussel cover of close to 100%. This is a much higher level of mussel cover than occurred in any of the 120 x 100 m sectors that we surveyed in the mussel nursery area.

3. The status and distribution of waterbirds in Castlemaine Harbour

Introduction

3.1 The Irish Wetland Bird Survey (I-WeBS) has been monitoring waterbirds at Castlemaine Harbour since the winter of 1994/95. The results of this monitoring have recently been reviewed (I-WeBS Office, 2009).

3.2 The NPWS Baseline Waterbird Survey Programme completed a series of five counts in Castlemaine Harbour between October 2009 and January 2010.

3.3 We have analysed the count data to: (i) compare population levels recorded during the NPWS Baseline Waterbird Survey Programme with those recorded by the I-WeBS counts; and to (ii) determine the importance of the count sectors containing the mussel nursery area and/or potentially affected by other mussel-related activities relative to other areas within Castlemaine Harbour.

Data sources

Irish Wetland Bird Survey (I-WeBS)

3.4 The methodology used by the Irish Wetland Bird Survey (I-WeBS) is described by Crowe (2005) and specific details of the counting methodology used at Castlemaine Harbour is described by I-WeBS Office (2009).

NPWS Baseline Waterbird Survey Programme

3.5 The methodology used in the NPWS Baseline Waterbird Survey Programme is described in *Baseline Waterbird Surveys within Irish Coastal Special Protection Areas – Draft Survey Methods and Guidance Notes* (National Parks and Wildlife Service, 2009). Details of the results of the counts and any constraints/limitations experienced are described in *Collection of baseline waterbird data for Irish Coastal Special Protection Areas 1: Castlemaine Harbour, Tralee Bay, Lough Gill & Akeragh Lough, Dundalk Bay, Bannow Bay, Dungarvan Harbour & Blackwater Estuary* (Cummins & Crowe, 2010).

3.6 Four low tide counts and one high tide count were completed at Castlemaine Harbour under the NPWS Baseline Waterbird Survey Programme (Table 3.1). The count data was supplied to us by NPWS in spreadsheet format.

Table 3.1 – NPWS counts at Castlemaine Harbour.

Date	Tide	Tide time (Cromane)[1]	Tide height (Cromane)[1]
5th October 2009	Low	12:24	0.7 m
21st November 2009	Low	13:40	1.4 m
4th January 2010	Low	13:55	0.7 m
25th January 2010	High	12:05	3.7 m
1st February 2010	Low	12:48	0.3 m

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

3.7 The NPWS Baseline Waterbird Survey also included recording the location of major flocks of foraging and/or roosting birds on field maps (National Parks and Wildlife Service, 2009). The raw field maps were provided to us and we have processed the data from these maps for the area of Castlemaine Harbour relevant to this report.

3.8 In addition to the above counts, a high tide roost survey was carried out on 26th February 2010 and a dedicated seaduck/diver survey was carried out in the outer part of Castlemaine Harbour (i.e., west of Inch) on 8th March 2010.

Habitat areas

3.9 The area of intertidal littoral sediment[2] habitat in Castlemaine Harbour has been defined in the conservation objectives (National Parks and Wildlife Service, 2010) as 3983 ha. This area appears to be based on the Ordnance Survey Discovery Series mapping, which, from comparison with recent aerial photography, is out of date. However, in the absence of any other information, this figure has been used in this report.

3.10 There are two biotope maps for Castlemaine Harbour. The ASU map (Aquatic Services Unit, 2008) shows the extent of subtidal habitats, but, again, this appears to be derived from the Ordnance Survey Discovery Series mapping. The biotope mapping in the Conservation Objectives (National Parks and Wildlife Service, 2010) does not explicitly differentiate between intertidal and subtidal habitats.

3.11 Therefore, because of the lack of detailed up to date mapping of the extent of intertidal habitats in Castlemaine Harbour, the figure of 3983 ha has been used for the total extent of intertidal habitat, and the Discovery Series mapping has been used to calculate habitat areas in individual count sectors.

3.12 Similarly, the figure of 7471 ha has been used for the total extent of subtidal habitat. For some purposes, the area of subtidal habitat in the inner part of Castlemaine Harbour has been calculated. For this purposes the inner part of Castlemaine Harbour was defined as extending from the upstream boundary of OK445 to the downstream boundary of OK458. This gives a figure of 1510 ha.

[2] The conservation objectives refer to *intertidal habitat* without any qualification. However, areas of saltmarsh habitat are included in the *supratidal habitat* category (although saltmarsh is an intertidal habitat). Therefore, the conservation objectives' *intertidal habitat* category appears to refer to intertidal littoral sediment habitat.

Status of waterbird species in Castlemaine Harbour

3.13 We have used I-WeBS data from 1994/95-2008/09 and NPWS Baseline Waterbird Survey data from 2009/10 to assess the status of waterbird species in Castlemaine Harbour.

Irish Wetland Bird Survey (I-WeBS) data for Castlemaine Harbour

3.14 I-WeBS data is used to assess the status of waterbird populations at individual sites by taking the mean of the annual maximum count of each species over a five year period (Crowe, 2005). Published five year means for Castlemaine Harbour are shown in Table 3.2.

Table 3.2 – Published 5 year means for Castlemaine Harbour of species that occurred in internationally or nationally important numbers during at least one of the periods.

Species	94-98[1]	95-99[1]	96-00[1]	02-06[2]
Light-bellied Brent Goose	614	633	539	232
Wigeon	7513	6819	6811	1434
Pintail	160	145	117	5
Scaup	143	123	79	1
Common Scoter	4587	3651	2423	-
Red-throated Diver	63	75	19	-
Great Northern Diver	24	23	20	-
Cormorant	145	136	118	58
Oystercatcher	1255	1035	895	408
Ringed Plover	229	206	214	89
Grey Plover	76	46	45	0
Sanderling	299	335	349	338
Bar-tailed Godwit	371	397	398	83
Redshank	366	341	344	226
Turnstone	166	144	110	35

Sources: [1] (Crowe, 2005); [2] (I-WeBS Office, 2009).

3.15 I-WeBS Office (2009) discuss the quality of the I-WeBS count data at Castlemaine Harbour. Fully co-ordinated counts were not carried out in 2003/04 while coverage in the 2004/05 season was incomplete. The 2003/04 counts appear not to have been included in the published 02-06 mean, while this mean also includes the incomplete counts from 2004/05. Therefore, the 02-06 5-year means are not fully comparable to the other 5-year means.

3.16 The discussion in I-WeBS Office (2009) also indicates that there are significant additional issues with the quality of all of the I-WeBS counts throughout the period under review, due to access problems. As a result, most of the area along the eastern side of Inch dunes received poor quality coverage (the area broadly corresponding to the NPWS Baseline Waterbird Survey sector 0K446), or no coverage at all (the area broadly corresponding to the NPWS Baseline Waterbird Survey sector 0K444 and OK445). From information provided by BWI (email from Siobhán Egan to Tom Gittings, dated 19/08/2010), it appears that the coverage of the area corresponding to OK446 may have better before 2000/01. In the 2008/09 season, additional efforts were made to achieve better coverage of the area corresponding to OK446 (I-WeBS Office, 2009). The I-WeBS counts for that season are, therefore, potentially of higher quality than the preceding seasons, although the areas corresponding to OK444 and 445 were again not covered in that season (I-

WeBS Office, 2009). The areas behind Inch dunes with poor or no coverage during the I-WeBS counts held significant numbers of waterbirds during the high tide counts carried out in 2009/10 for the NPWS Baseline Waterbird Survey (Table 3.3 and Table 3.4).

Table 3.3 – Numbers recorded in the high tide count on 26th February 2010, as percentages of the total Castlemaine Harbour count, in the area behind Inch dunes, corresponding to areas with poor or no coverage during I-WeBS.

Species	Poor coverage (OK446)	No coverage (OK444 and 445)	Total Castlemaine Harbour count
Mute Swan	0%	63%	16
Light-bellied Brent Goose	5%	49%	819
Shelduck	62%	12%	189
Wigeon	1%	55%	567
Teal	0%	24%	225
Mallard	0%	51%	380
Pintail	0%	29%	49
Little Egret	0%	33%	15
Oystercatcher	1%	14%	1049
Ringed Plover	32%	0%	205
Grey Plover	65%	3%	99
Lapwing	0%	4%	1211
Sanderling	7%	0%	428
Dunlin	56%	3%	2530
Snipe	0%	38%	29
Curlew	3%	28%	690
Greenshank	2%	9%	47
Redshank	2%	18%	822
Turnstone	2%	3%	147
Black-headed Gull	0%	4%	657
Common Gull	0%	17%	125

Table 3.4 – Counts from the high tide roost survey on 26th February 2010 in the area behind Inch dunes, corresponding to areas with poor or no coverage during I-WeBS.

Species	Poor coverage (OK446)	No coverage (OK444 and 445)
Mute Swan		7
Light-bellied Brent Goose		953
Shelduck		44
Wigeon	315	95
Teal	300	105
Mallard	269	62
Pintail	13	
Oystercatcher		14
Grey Plover		45
Lapwing	85	
Knot		60
Bar-tailed Godwit		314
Curlew	51	390
Greenshank	14	21
Redshank	226	231
Turnstone	20	
Black-headed Gull	20	
Herring Gull	15	
Great Black-backed Gull	24	3

Note: These are summed totals from individual roosts. The data is not expressed as percentages of the total Castlemaine Harbour count, because the purpose of the survey was to locate roost sites, rather than to achieve a co-ordinated count.

3.17 There are two other areas, covered by the NPWS Baseline Waterbird survey programme: the Lower River Maine (sector OK456) and Caragh Creek, which is part of the Rossbehy Creek sector (sector OK475). The Lower River Maine held significant numbers of Teal, Dunlin, Redshank, Greenshank and Black-headed Gull during the high tide count on 25th January 2010, although few birds were recorded in roosts here during the roost count on 26th February 2010 (Table 3.5). Caragh Creek was not counted separately during the NPWS Baseline Waterbird survey high tide count, but no roosts were recorded here during the roost count.

Table 3.5 – Counts from the NPWS Baseline Waterbird survey programme in the Lower River Maine (Sector OK456), an area not covered during I-WeBS.

	25/01/2010		26/02/2010
Species	**% in OK456**	**Total Castlemaine Harbour count**	**Roost count in 0K456**
Shelduck	2%	189	15
Wigeon	2%	567	
Teal	17%	225	
Mallard		380	5
Cormorant	4%	48	
Lapwing	5%	1211	
Dunlin	12%	2530	
Snipe	48%	29	
Curlew		690	2
Redshank	23%	822	
Greenshank	11%	47	
Black-headed Gull	45%	657	75

Analysis of trends in waterbird numbers

3.18 Trends in waterbird numbers in Castlemaine Harbour are shown in Table 3.2. In order to allow analysis of trends using comparable data, we have calculated 3 year means and have excluded the data from 2003/04 and 2004/05. Therefore, we present 3-year means from the periods 94-96, 97-99, 00-02 and 05-07. We present the I-WeBS data from the 2008/09 season and the NPWS Baseline Waterbird Survey data from the 2009/10 season separately, as the coverage for these seasons is not comparable to the preceding periods.

3.19 Castlemaine Harbour is described as being internationally important for one species and nationally important for up to another 15 species by Crowe (2005) and these are the species that are listed as Special Conservation Interests in the draft conservation objectives for the SPA (National Parks and Wildlife Service, 2010). In 2009/10, one of the nationally important species (Ringed Plover) listed by Crowe (2005) was recorded in internationally important numbers, another (Scaup) was not recorded in nationally important numbers, while an additional eight species were recorded in nationally important numbers (Shelduck, Teal, Red-breasted Merganser, Grey Heron, Knot, Dunlin, Black-tailed Godwit and Curlew).

3.20 For 15 of the 26 species, the 2008/09 peak count was higher than the 05-07 3-year mean, while for 25 of the 26 species; the 2009/10 peak count was higher than the 05-07 3-year mean. Furthermore, for 25 of the 26 species, the 2009/10 peak count was higher than the maximum count for the 05-07 period. For many species, the increase in numbers between 05-07 and 2009/10 is very dramatic: e.g., from 166 to 1374 for Light-bellied Brent Goose and from 126 to 2530 for Dunlin. The exception was Sanderling, for which peak counts of 554 and 570 were recorded in 2005/06 and 2006/07, respectively. However, this species may have been misidentified in some of the I-WeBS counts during this period (I-WeBS Office, 2009).

3.21 The apparent increases in the 2009/10 season could reflect real increases in populations at Castlemaine Harbour, or could reflect seasonal cold weather movements due to the exceptional weather conditions of the 2009/10 winter, or could reflect the much improved coverage achieved by the NPWS Baseline Waterbird Survey programme.

3.22 Examination of the pattern of the totals for the individual counts from the 2009/10 season (Table 3.7) does not indicate that seasonal cold weather movements were an important contributing factor. While several species show increased numbers in the January counts following the onset of the cold weather, the increases are generally not dramatic and are consistent with the typical mid-winter peak that would be expected in a normal winter. Furthermore, some of the species showing dramatic increases between 05-07 and 2009/10 had peak counts in October or November, before the onset of cold weather.

3.23 It is not possible to rule out population increases as the explanation for the increased counts in all cases. However, it is highly unlikely that so many waterbird species would show increased numbers in a single winter, and no species would show a significant decrease. Therefore, it seems likely that, given the acknowledged problems with coverage in the I-WeBS counts, I-WeBS counts in recent years have significantly underestimated the population of many species.

3.24 I-WeBS counts in the 1990s are generally closer to the 2009/10 count levels. If counts in the 1990s had a similar level of underestimation as those of more recent years, this would suggest that there has been a long-term decline in actual population sizes. Alternatively, if counts in the 1990s were of higher quality compared to more recent I-WeBS counts, then the apparent declines in recent years may be artefacts of the counting methodologies, rather than representing real changes in population sizes.

Table 3.6 – 3-year I-WeBS means between 1994 and 2007 and 2008/09 and 2009/10 peak counts for species recorded in internationally or nationally important numbers during this period.

Species	Importance thresholds		3-year means				Individual seasons		08/09 status
	N	I	94-96	97-99	00-02	05-07	08/09	09/10	
Special Conservation Interests									
Light-bellied Brent Goose	220	260	619	538	559	166	835	1374	I
Wigeon	820	15000	3430	8023	5279	185	443	1590	N
Mallard	380	20000	386	492	511	64	189	1401	N
Pintail	20	600	167	107	16	0	61	105	N
Scaup	45	3100	207	79	2	10	22	14	
Common Scoter	230	16000	7393	335	524	279	146	1892	N
Red-throated Diver	20	3000	96	2	9	1	0	33	N
Cormorant	140	1200	185	91	52	61	23	141	N
Oystercatcher	680	10200	1473	823	473	481	711	1843	N
Ringed Plover	150	730	320	79	208	166	59	731	I
Sanderling	65	1200	207	378	140	415	130	428	N
Bar-tailed Godwit	160	1200	211	475	99	96	211	318	N
Redshank	310	3900	270	388	143	413	312	1170	N
Greenshank	20	2300	26	55	19	15	12	77	N
Turnstone	120	1500	183	124	60	36	53	147	N
Other species									
Great Northern Diver	20	50	26	15	8	14	20	33	N
Shelduck	150	3000	124	71	178	52	108	235	N
Teal	450	5000	270	275	215	86	168	557	N
Red-breasted Merganser	35	1700	43	23	22	7	8	49	N
Grey Heron	30	2700	12	17	6	7	5	62	N
Grey Plover	65	2500	122	5	20	0	0	99	N
Knot	190	4500	323	170	435	240	24	616	N
Dunlin	880	13300	1335	671	295	126	789	2530	N
Black-tailed Godwit	140	470	37	31	12	2	0	366	N
Curlew	550	8500	541	398	286	288	381	1502	N

Table 3.7 – Individual count data for the species recorded in internationally or nationally important numbers during the NPWS Baseline Waterbird Survey counts of Castlemaine Harbour.

Species	05/10/09	21/11/09	04/01/10	25/01/10	01/02/10
Special Conservation Interests					
Light-bellied Brent Goose	1063	1374	654	819	777
Wigeon	1590	131	528	567	644
Mallard	1401	203	721	380	594
Pintail	4	16	36	49	105
Common Scoter	1892	912	560	979	1121
Red-throated Diver	3	3	5	2	33
Cormorant	141	63	34	48	64
Oystercatcher	1712	1843	1673	1049	1839
Ringed Plover	16	46	731	205	276
Sanderling	4	325	203	428	324
Bar-tailed Godwit	52	186	158	318	284
Redshank	1170	1133	1135	822	1026
Greenshank	59	44	76	47	77
Turnstone	77	94	97	147	136
Other species					
Shelduck	0	17	170	189	235
Teal	222	142	557	225	381
Red-breasted Merganser	42	18	34	20	49
Great Northern Diver	0	11	18	16	33
Grey Heron	62	23	32	10	28
Grey Plover	0	16	87	99	75
Knot	103	19	39	190	616
Dunlin	143	1360	1823	2530	1777
Black-tailed Godwit	76	2	236	175	366
Curlew	1502	744	1071	690	1133

Note: Additional species recorded: Mute Swan, American Wigeon, Shoveler, Scaup, Eider, Goldeneye, Great Crested Grebe, Shag, Little Egret, Spoonbill, Water Rail, Moorhen, Golden Plover, Lapwing, Ruff, Snipe, Whimbrel, Spotted Redshank, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull, Kingfisher.

Comparison with national and regional trends

3.25 For three of the waterbird species of Special Conservation Interest (Wigeon, Scaup and Common Scoter), the 2008/09 and 2009/10 data still show substantially lower numbers compared to those recorded in the mid-1990s. The following sections review the national and regional trends in the status of these species. The national trends are taken from Crowe *et al*. (2004). The regional trends are analysed using I-WeBs data for sites in the Munster region with nationally important populations.

Wigeon

3.26 At a national level, the Irish Wigeon population experienced an annual decline of -2.9% between 1994/95 and 2003/04 (Crowe *et al*., 2008). This amounts to a 23% decline over that period. Between 1999/2000 and 2003/04, the Castlemaine Harbour population declined by over 50% (from the GAM analysis in NPWS, 2011). Therefore, the decline in the Castlemaine Harbour population appears to have been considerably greater than the national trend.

3.27 Comparison of sites with important populations of Wigeon in the Munster region does not show a consistent pattern of trends across the sites (Figure 3.3). The absolute scale of the decline in Castlemaine Harbour in 1995/96-2002/03 is much greater than the fluctuations in any of the other sites, but this reflects the much larger size of the peak population here (Table 3.8). However, several other sites show comparable relative fluctuations in population size (Figure 3.3).

3.28 These comparisons are complicated by limited coverage in many of the sites. Even in Cork Harbour, a site with apparently complete coverage, a detailed analysis of coverage found that between 1994/95 and 2002/03, full coverage of count sectors was only achieved in 9 of the 62 months (Gittings, 2006). The apparent dip in Wigeon numbers between 1997/98 and 2002/03 reflects the poor coverage of count sectors within those winters (see Gittings, 2006), while the low numbers from 2006/07-2008/09 probably reflects late submission of count data for those winters.

Table 3.8 – Peak I-WeBS counts at sites in Munster with nationally important populations of Wigeon.

Site	Peak count	Season of peak count
Ballyallia Lake	2200	1998/99
Blackwater Callows	2750	1996/97
Castlemaine Harbour & Rossbehy	10024	1997/98-1998/99
Cork Harbour	2926	2003/04
Corofin Wetlands	5170	1996/97
Kells (Corofin)	2000	1999/00
Shannon & Fergus Estuary	5481	1995/96
Shannon & Fergus Estuary Aerial	5799	1996/97
Tralee Bay, Lough Gill & Akeragh Lough	4800	1999/00

Scaup

3.29 At a national level, the Irish Scaup population experienced an annual decline of -4.3% between 1994/95 and 2003/04 (Crowe *et al.*, 2008). This amounts to a 33% decline over that period. Over this period, the limited data indicates a decline in the Castlemaine Harbour population of nearly 100% (Figure 3.4). Therefore, the decline in the Castlemaine Harbour population may have been considerably greater than the national trend.

3.30 There are two other sites with important populations of Scaup in the Munster region (the Shannon & Fergus Estuary and Tralee Bay). At both of these sites, the Scaup populations show similar trends and relative decline to the Castlemaine Harbour population[3] (Figure 3.4). Therefore, the decline in the Castlemaine Harbour population seems to be part of a decline in the regional population and may not reflect site-specific factors. Given that the peak Castlemaine Harbour population was around 10% of the peak Tralee Bay population (Table 3.9), the Castlemaine Harbour population may have been an overspill from the latter.

Table 3.9 – Peak I-WeBS counts at sites in Munster with nationally important populations of Scaup

Site	Peak count	Season of peak count
Shannon & Fergus Estuary	148	1994/95
Shannon & Fergus Estuary Aerial	129	1996/97
Tralee Bay, Lough Gill & Akeragh Lough	1865	1996/97
Castlemaine Harbour & Rossbehy	210	1995/96

Common Scoter

3.31 National trends in Common Scoter numbers were not analysed by Crowe *et al.* (2008) because of the low number of sites and problems with data consistency.

3.32 Comparison of trends across sites with important populations of Common Scoter in the Munster region is difficult because data series for most sites are very patchy (Figure 3.5). However, the peak counts at all the sites occurred in the mid-1990s (Table 3.10). Numbers at Ballinskelligs Bay showed a very similar trend to Castlemaine Harbour, with a similar relative decline, between 1994/95 and 1999/00. Numbers in Brandon Bay were at relatively high between 2002/03 and 2006/07, at a time when number counted at Castlemaine Harbour were very low. However, comparison of peak counts shows that this cannot be accounted for simply by moving of birds between sites.

Table 3.10 – Peak I-WeBS counts at sites in Munster with nationally important populations of Common Scoter.

Site	Peak count	Season of peak count
Ballinskelligs Bay	1210	1996/97
Brandon Bay - Inner Brandon Bay	2200	1996/97
Liscannor Bay (Liscannor - Rinanoughter)	650	1997/98
Tralee Bay, Lough Gill & Akeragh Lough	620	1994/95
Castlemaine Harbour & Rossbehy	10110	1996/97

[3] The low count at Tralee Bay in 1995/96 reflects very poor coverage during that winter.

3.33 However, I-WeBS counts may not provide a reliable indication of trends in Common Scoter numbers at Castlemaine Harbour. For example, a flock of 5,600 was recorded on September 10 2007 (O'Clery, 2011), while the peak I-WeBS count for that winter was only 239. The opinion of a local naturalist with experience of Castlemaine Harbour over many years is as follows:

> "*If I had to say, I'd say numbers have remained stable. I think large counts, or rather the perfect weather opportunities for large counts, are being missed. I wouldn't be at all surprised if 5000+ counts were found to be regular. However, I'd temper that by saying, from my experience at Brandon and Waterville, that numbers did seem to vary over the years there, rising and falling over maybe 3-5 years*". (O'Clery, 2011)

Distribution of waterbird species in Castlemaine Harbour

Waterbirds in the mussel nursery area

Waterbird usage of the nursery area in a whole site context

3.34 Three of the NPWS Baseline Waterbird Survey count sectors overlap the mussel nursery area (Figure 3.1). These sectors contain 515 ha of intertidal habitat, which amount to 13% of the total extent of intertidal habitat in Castlemaine Harbour, as mapped by the NPWS habitat survey. During the NPWS Baseline Waterbird Survey low tide counts these sectors held well over 13% of the Castlemaine Harbour populations of all the waterbird species that use intertidal habitat, except Black-tailed Godwit (Table 3.11). The sectors were particularly important for Light-bellied Brent, Shelduck, Pintail, Grey Plover, Common Gull, Herring Gull and Great Black-backed Gull, holding 50% or more of the Castlemaine Harbour populations of these species.

3.35 The dabbling ducks showed consistently higher numbers in sector OK447 during the low tide counts compared to the other two sectors that overlap the mussel nursery area.

Table 3.11 – Percentage of the total Castlemaine Harbour population of various waterbird species recorded in sectors OK444, OK445 and OK447 during the NPWS Baseline Waterbird Survey counts.

Species	Low tide counts (n = 4)		High tide count
	Mean	s.d.	
Special Conservation Interests			
Light-bellied Brent Goose	55%	34%	61%
Wigeon	40%	22%	65%
Mallard	51%	18%	52%
Pintail	74%	19%	94%
Common Scoter	0%	0%	0%
Red-throated Diver	0%	0%	0%
Cormorant	23%	12%	0%
Oystercatcher	34%	15%	33%
Ringed Plover	47%	27%	37%
Sanderling	28%	26%	7%
Bar-tailed Godwit	26%	26%	0%
Redshank	19%	18%	37%
Greenshank	18%	15%	18%
Turnstone	16%	19%	40%
Other species			
Shelduck	56%	41%	76%
Teal	26%	16%	35%
Red-breasted Merganser	23%	13%	0%
Great Northern Diver	2%	3%	0%
Little Egret	43%	12%	43%
Grey Heron	20%	12%	50%
Grey Plover	60%	43%	67%
Knot	25%	50%	0%
Dunlin	36%	20%	60%
Black-tailed Godwit	0%	0%	0%
Curlew	41%	7%	30%
Black-headed Gull	22%	12%	5%
Common Gull	50%	20%	25%
Lesser Black-backed Gull	11%	16%	0%
Herring Gull	52%	17%	0%
Great Black-backed Gull	50%	31%	0%

3.36 The three count sectors that overlap the mussel nursery area hold large areas of intertidal habitat outside the mussel nursery area. Therefore, the percentages in Table 3.11 will overestimate the usage of the mussel nursery area. The transect counts carried out in the mussel nursery area in February and March 2010 provide a more precise estimate of the usage of the mussel nursery area. Comparison of the mean daily maxima of these counts with the mean Castlemaine count (Table 3.12) indicates that the mussel nursery area is used by significant components of the Castlemaine populations of Light-bellied Brent, Little Egret, Sanderling, Dunlin, Bar-tailed Godwit, Curlew, Redshank, Turnstone and Herring Gull. The proportions of the populations of these species that occur in the mussel nursery area are much greater than would be predicted from the 2.4% of intertidal habitat in Castlemaine Harbour that it occupies.

Table 3.12 – Transect counts of waterbirds in the mussel nursery area compared to 2009/10 counts for the whole of Castlemaine Harbour.

Species	Daily maxima of transect counts[1]		Mean Castlemaine count[2]	Nursery area count as % of Castlemaine count[3]
	Mean	s.d.		
Special Conservation Interests				
Light-bellied Brent Goose	73	71	937	10%
Cormorant	1	0.4	70	2%
Oystercatcher	126	36	1623	10%
Sanderling	16	18	320	6%
Bar-tailed Godwit	20	10	200	13%
Redshank	96	16	1059	12%
Greenshank	2	0.9	61	3%
Turnstone	18	10	110	22%
Other species				
Little Egret	4	2.4	30	19%
Knot	1	1.3	193	1%
Dunlin	133	107	1873	9%
Curlew	129	21	1028	16%
Black-headed Gull	3	1.9	635	1%
Common Gull	7	3.5	349	3%
Herring Gull	22	14	195	15%
Great Black-backed Gull	1	1.1	47	2%

[1] The transect counts for all 20 transects on each complete series of counts (n = 4 per day) were summed to provide a total count for all transects. The maximum of the four summed transect counts on each day was used to calculate the mean daily maxima across the five count days.

[2] Mean of all five counts, except for Little Egret, Ringed Plover, Sanderling, Dunlin, Black-headed Gull, Herring Gull and Great Black-backed Gull. For these species, the October count was not used to calculate the mean because it was much higher (Little Egret and the gull species) or lower (the other species) than the other counts.

[3] The raw values of the transect counts as percentages of the Castlemaine count were corrected by a factor of 1.31, which is the ratio of the total extent of the mussel nursery area to the area covered by the transect counts.

Additional species recorded on the transect counts with mean daily maxima of < 0.5 were Wigeon, Mallard, Pintail, Red-breasted Merganser, Great Northern Diver, Ringed Plover, Grey Plover, Black-tailed Godwit and Lesser Black-backed Gull.

3.37 We have also examined the flock distribution maps from the NPWS Baseline Waterbird Survey counts to check if the spatial distribution of waterbirds was different earlier in the winter. On the first count (5th October 2009), 46 foraging Wigeon were recorded on intertidal habitat in sector OK445 and 580 roosting Wigeon were recorded on intertidal habitat in sector OK447. According to the flock distribution maps, most of the Wigeon in sector OK447 were within the mussel nursery area, while a small part of the Wigeon flock in sector OK445 were also within the mussel nursery area (Figure 3.6). On the other counts, the species with mapped flock locations within the mussel nursery area did not include significant numbers of any species that were not recorded in significant numbers in the transect counts.

3.38 While the October count shows an indication that Wigeon may make more use of the mussel nursery area than suggested by the transect counts, it is notable that the main flock recorded in the nursery area was roosting, not feeding. It is also difficult to precisely record the position relative to the tideline of birds feeding on intertidal habitat from vantage points over 1 km away. Therefore, it is quite possible that the Wigeon flock in sector OK445 was actually feeding on *Zostera* habitat, as the recorded flock location is only just outside the mapped area of *Zostera* habitat (Figure 3.6).

3.39 Taking account of the above considerations, overall the flock distribution maps do not provide strong evidence that waterbird usage of the mussel nursery area differed significantly between the transect counts and earlier in the winter.

Waterbird usage of the nursery area in a local context

3.40 We have also compared waterbird numbers in the nursery area, as recorded by the transect counts, with waterbird numbers in the three count sectors overlapping the nursery area, as recorded by the low tide counts (Table 3.13). This comparison indicates whether birds that occur in this part of Castlemaine Harbour show a positive, negative or neutral association with the nursery area.

3.41 The nursery area occupies 94 ha of intertidal habitat, while the total area of intertidal habitat in the three count sectors is 515 ha. Therefore, if waterbirds are randomly distributed throughout the intertidal habitat within these count sectors, around 20% would be expected to occur within the nursery area. However, many species of waterbirds follow the tideline so the actual area of available habitat is much less. The tideline, during the period when it is within the nursery area, has a total length of around 4.6 km within these sectors, of which around 2.6 km is within the nursery area. Therefore, if waterbirds are randomly distributed along the tideline within these count sectors, around 55% would be expected to occur within the nursery area.

Table 3.13 – Transect counts of waterbirds in the mussel nursery area compared to 2009/10 counts for sectors OK444, OK445 and OK447.

Species	Daily maxima of transect counts[1]		Mean sectors count[2]	Nursery area count as % of sectors count[3]
	Mean	s.d.		
Special Conservation Interests				
Light-bellied Brent Goose	73	71	566	17%
Wigeon	0.2		318	0%
Mallard	0.4		410	0%
Pintail	0.2		52	1%
Cormorant	1	0.4	20	6%
Oystercatcher	126	36	605	27%
Ringed Plover	0.4		94	1%
Sanderling	16	18	103	20%
Bar-tailed Godwit	20	10	45	58%
Redshank	96	16	209	60%
Greenshank	2	0.9	14	19%
Turnstone	18	10	19	126%
Other species				
Shelduck	0	0	143	0%
Teal	0	0	173	0%
Little Egret	4	2.4	16	33%
Grey Heron	0	0	8	0%
Grey Plover	0	0	45	0%
Knot	1	1.3	5	28%
Dunlin	133	107	449	39%
Curlew	129	21	466	36%
Black-headed Gull	3	1.9	157	3%
Common Gull	7	3.5	220	4%
Lesser Black-backed Gull	0.4		2	23%
Herring Gull	22	14	134	22%
Great Black-backed Gull	1	1.1	34	4%

[1] The transect counts for all 20 transects on each complete series of counts (n = 4 per day) were summed to provide a total count for all transects. The maximum of the four summed transect counts on each day was used to calculate the mean daily maxima across the five count days.

[2] Sectors included: OK444, OK445 and OK447. Mean of all five counts, except for Shelduck, Wigeon, Teal, Mallard, Pintail, Little Egret, Ringed Plover, Grey Plover, Sanderling, Dunlin, Black-headed Gull, Herring Gull and Great Black-backed Gull. For these species, the October count (or November for Wigeon and Mallard; or October and November for Teal, Pintail and Shelduck) was not used to calculate the mean because it was much higher (Little Egret and the gull species) or lower (the other species) than the other counts.

[3] The raw values of the transect counts as percentages of the Castlemaine count were corrected by a factor of 1.31, which is the ratio of the total extent of the mussel nursery area to the area covered by the transect counts.

3.42 Light-bellied Brent and most wader species occurred in numbers equal to or greater than predicted by the availability of intertidal habitat, while Bar-tailed Godwit, Redshank and Turnstone occur in numbers equal to or greater than predicted by the availability of tideline habitat.

3.43 Ringed Plover and Grey Plover were very rare, or absent, during the transect counts despite occurring in significant numbers in the count sectors. Both species feed on open sandflats. This species mainly feeds on open sandflats and so would be expected to avoid the mussel biotope, even in the absence of any intertidal relay.

3.44 Most ducks were very rare, or absent, during the transect counts despite occurring in significant numbers in these count sectors. This probably reflects their association with freshwater inflows and proximity to saltmarsh (National Parks and Wildlife Service, 2011). Apart from the Wigeon flocks in the October count (paragraphs 3.37-3.38), all dabbling duck flocks in these count sectors recorded on the flock maps were close in to the shore and/or along the tidal creek in the western part of sector 0K447.

Distribution of waterbirds that feed in subtidal habitat

Seed mussel fishery

3.45 The main area identified as suitable for seed mussel extraction area overlaps three of the NPWS Baseline Waterbird Survey count sectors (OK443, 917 and 918) but part of the area falls outside any of the count sectors (Figure 3.1). It only forms a small (OK443) or very small (OK917 and 918) component of the sectors that it overlaps so the overall numbers of waterbirds counted within these sectors (Table 3.14) are of little value in assessing its usage. The seed mussel fishery occurs within subtidal activity and will not affect birds using intertidal habitat. Therefore, it is only those species in Table 3.14 that use subtidal habitat that are relevant to this issue.

Table 3.14 – Waterbird counts in sectors OK443, 917 and 918.

	05/10/2009	21/11/2009	04/01/2010	25/01/2010	01/02/2010
Light-bellied Brent Goose	2	2	2	6	163
Mallard	4				
Common Scoter	1892	912	560	979	1001
Red-breasted Merganser	2	1		5	10
Red-throated Diver		3	2	2	33
Great Northern Diver		9	7	16	24
Cormorant	25	5	1	12	17
Shag	4	7		9	9
Little Egret	10				
Grey Heron	3				2
Oystercatcher	94	60	11	198	59
Ringed Plover	2		8	25	2
Golden Plover			6		
Grey Plover			8	5	20
Sanderling				133	
Dunlin			219	103	
Bar-tailed Godwit			1		11
Curlew	24	5	12	36	24
Greenshank	5		2	2	3

	05/10/2009	21/11/2009	04/01/2010	25/01/2010	01/02/2010
Redshank	31		21	2	6
Turnstone	19	2	1	2	1
Black-headed Gull	31	34	10	42	9
Common Gull	7		1	48	7
Lesser Black-backed Gull	2				
Herring Gull	25	29	9		20
Great Black-backed Gull	5	5			7

Also one unidentified diver on 05/10/2009, one unidentified Cormorant/Shag on 01/02/2010 and one unidentified gull on 01/02/2010

3.46 Flock locations were mapped in sector OK918 on 25th January, 1st February and 8th March 2010 (the latter being the dedicated seaduck/diver survey). These were all in the northern two-thirds of the sector, with none of the mapped concentrations within 1 km of the seed mussel fishery (Figure 3.7 - Figure 3.9).

3.47 The main flock locations in sectors OK916 and 917 across the duration of the survey are shown in Figure 2.6. Between 224 and 1248 Common Scoters were recorded in these sectors during the counts. The scoter were largely recorded either in one larger group in location A in Sector OK917 and/or in two main groups, one in location A in Sector OK917 and one in location B in sector OK916. These locations are over 4 km from the 2009 seed mussel extraction area. A flock of 300+ scoter was also seen in the area marked C on a reconnaissance visit on 24 September 2009, but scoters were not recorded in this location (according to the information provided) on the other visits. This flock location is partially within the seed mussel fishery (Figure 3.11). The largest count of Red-throated Divers (total of 23) in these sectors, on 1 February 2010, was located in the area marked D on Figure 2.6.

3.48 All the available data on scoter flock locations is summarised in Table 3.15. Assuming that each count in each sector represents a single flock only, one in twelve of the recorded scoter flocks occurred in location C. In fact, as most scoter flocks at Castlemaine Harbour are of 100 birds or less, most sector counts represent several flocks and the frequency of flocks at location C would have been a lot less than one in twelve.

Table 3.15 – Common Scoter counts by sector and flock location at Castlemaine Harbour in the winter of 2009/10.

Sector	0K475	0K916	0K917		0K918	Total
Flock ref.		B	A	C		
24/09/2009	nc	nc	nc	300+	nc	-
05/10/2009		1248			**644**	1892
21/11/2009	537	375				912
04/01/2010			560			560
25/01/2010			480		499	979
01/02/2010		120	224		**777**	1121
08/03/2010			94		169	263

nc = no count available; blank cells indicate zero counts. Counts in bold were of roosting/other birds. All other counts were of feeding birds, except for the 24/09/2009 count for which activity data was not supplied.

3.49 The distribution of the areas favoured by Common Scoter, based on the experience of a local naturalist over many years, is shown in Figure 3.12. The scoters mainly occur in areas with depths of 10 m or less (Figure 3.12). They largely avoid the central channel (where the seed mussel fishery is located), but occur regularly just to the sides of this channel (see O'Clery, 2011).

Subtidal ongrowing areas

3.50 Seven of the NPWS Baseline Waterbird Survey count sectors overlap areas that may be affected by boat activity during mussel ongrowing and harvesting operations (excluding seed mussel extraction) (Figure 3.1). These sectors contain 1904 ha of subtidal habitat, which amount to 26% of the total extent of subtidal habitat within the area covered by the NPWS Baseline Waterbird Survey at Castlemaine Harbour.

3.51 Common Scoter was not recorded within these sectors during the NPWS Baseline Waterbird Survey counts (Table 3.16). In fact Common Scoter was not recorded at all within the inner part of Castlemaine Harbour (i.e., east of Inch) during these counts. I-WeBS data show that in the past, Common Scoter did occur in the inner part of Castlemaine Harbour but have not been recorded there since the 2002/03 season.

3.52 The percentage occurrence of other subtidal-feeding waterbird species was broadly in line with the percentage expected if the birds were randomly distributed across the subtidal habitat covered by the survey.

3.53 The percentage occurrence of the two diver species in these sectors is probably overestimated in Table 3.16. The dedicated seaduck/diver survey on 8th March 2010 recorded 262 Red-throated Divers and 36 Great Northern Divers in the outer part of Castlemaine Harbour (west of Inch), compared to mean counts in these areas during the standard counts of 8 Red-throated Divers and 11 Great Northern Divers.

Table 3.16 – Percentage of the total Castlemaine Harbour population of subtidal feeding waterbirds recorded in sectors OK444, OK445, OK447, OK448, OK469, OK473 and OK474 during the NPWS Baseline Waterbird Survey counts.

Species	Mean	s.d.
Common Scoter	0%	0%
Red-breasted Merganser	39%	25%
Great Northern Diver	25%	20%
Red-throated Diver	12%	27%
Cormorant	23%	15%

High tide roosts

3.54 The distribution of high tide roosts recorded on 26th February 2010, in relation to activities associated with the mussel order area, is shown in Figure 3.13.

3.55 No high tide roosts were recorded in the vicinity of the main seed mussel fishery. Two small Oystercatcher roosts were recorded near the minor seed mussel fishery on the western side of Cromane.

3.56 The mussel nursery area is in intertidal habitat, distant from any shoreline areas. Therefore, nigh tide roosts would not be expected to occur in the vicinity of the nursery area, and none were recorded during the high tide roost survey.

3.57 Two small Oystercatcher and Black-headed Gull roosts occur in the vicinity of the main subtidal relay area at the Lack Point. No high tide roosts were recorded in the vicinity of the minor subtidal relay area on the eastern side of Cromane.

3.58 Therefore, no major high tide roosts were recorded in the vicinity of any areas affected by activity associated with the mussel seed fishery and mussel ongrowing in the mussel order area. However, the above data is from a survey carried out on a single day. Waterbirds may vary in their use of particular high tide roost sites depending upon the state if the tide (neap or spring), weather conditions and random factors such as disturbance.

Conclusions

3.59 The 2009/10 waterbird counts from the NPWS Baseline Waterbird Survey programme show apparent increases in many species compared to the recent I-WeBS counts. It is highly unlikely that so many waterbird species would show increased numbers in a single winter, and no species would show a significant decrease. Therefore, it seems likely that, given the acknowledged problems with coverage in the I-WeBS counts, I-WeBS counts in recent years have significantly underestimated the population of many species.

3.60 The fact that I-WeBS counts in the 1990s are generally closer to the 2009/10 count levels, suggest that either there has been a long-term decline (i.e., counts in the 1990s had a similar level of underestimation as those of more recent years) or counts in the 1990s were of higher quality.

3.61 For three of the waterbird species of Special Conservation Interest (Wigeon, Scaup and Common Scoter), the 2008/09 and 2009/10 data still show substantially lower numbers compared to those recorded in the mid-1990s. Scaup has declined nationally and the decline at Castlemaine Harbour appears to reflect a regional decline in this species. Wigeon has also experienced a national decline but regional trends are less clear. National and regional trends in Common Scoter numbers are not clear. However, the apparent decline since the 1990s at Castlemaine Harbour may reflect poor coverage and numbers may in fact be relatively stable.

3.62 Comparison of the mean daily maxima of the transect counts with the mean 2009/10 Castlemaine count indicates that the mussel nursery area was used by significant components of the Castlemaine populations of Light-bellied Brent, Little Egret, Sanderling, Dunlin, Bar-tailed Godwit, Curlew, Redshank, Turnstone and Herring Gull.

3.63 Comparison of the mean daily maxima of the transect counts the mean counts of the sectors overlapping the nursery area indicates that the mussel nursery area was used by representative proportions of the total Light-bellied Brent and most wader species in the local area. Ringed Plover and Grey Plover were very rare, or absent, during the transect counts despite occurring in significant numbers in the count sectors. Most ducks were very rare, or absent, during the transect counts despite occurring in significant numbers in these count sectors. This probably reflects their association with freshwater inflows and proximity to saltmarsh.

3.64 The main Common Scoter flock locations recorded during the 2009/10 waterbird count data were at least 1 km from the main seed mussel fishery, although a flock was recorded on one date close to this area. The distribution of the areas favoured by Common Scoter, based on the experience of a local naturalist over many years, also indicates that they mainly avoid the main seed mussel fishery.

3.65 The subtidal habitat that may be affected by boat activity during mussel ongrowing and harvesting operations (excluding seed mussel extraction) was not used by Common Scoter during the 2009/10 waterbird counts and was used by Cormorant, Red-throated Diver, Great Northern Diver and Red-breasted Merganser in numbers broadly corresponding to the those expected if the birds were randomly distributed across the subtidal habitat covered by the survey.

3.66 No major high tide roosts were recorded in the vicinity of any areas affected by activity associated with the mussel seed fishery and mussel ongrowing in the mussel order area.

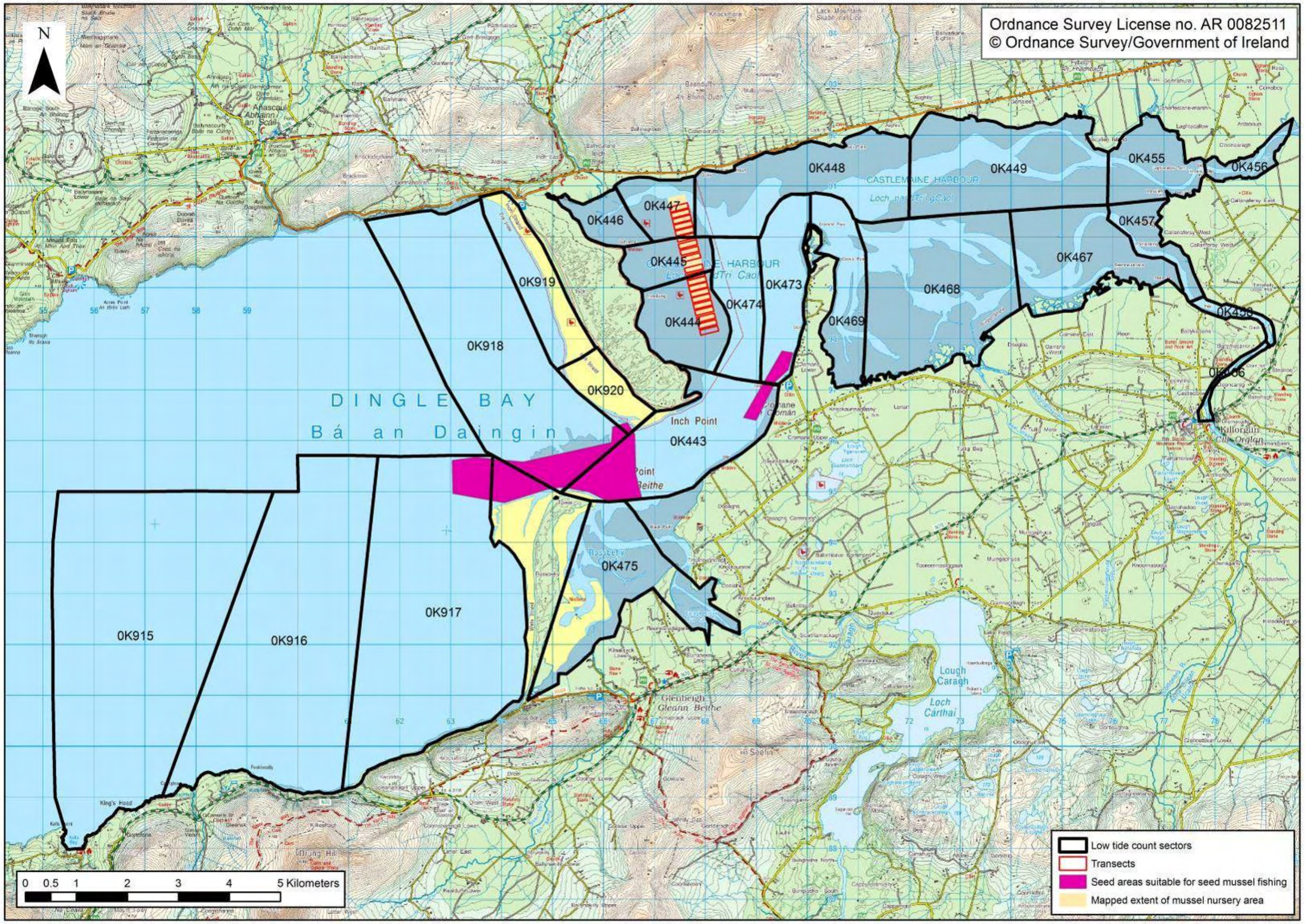


Figure 3.1 – Count sectors used in the NPWS Baseline Waterbird Survey Programme 2009/10 at Castlemaine Harbour.

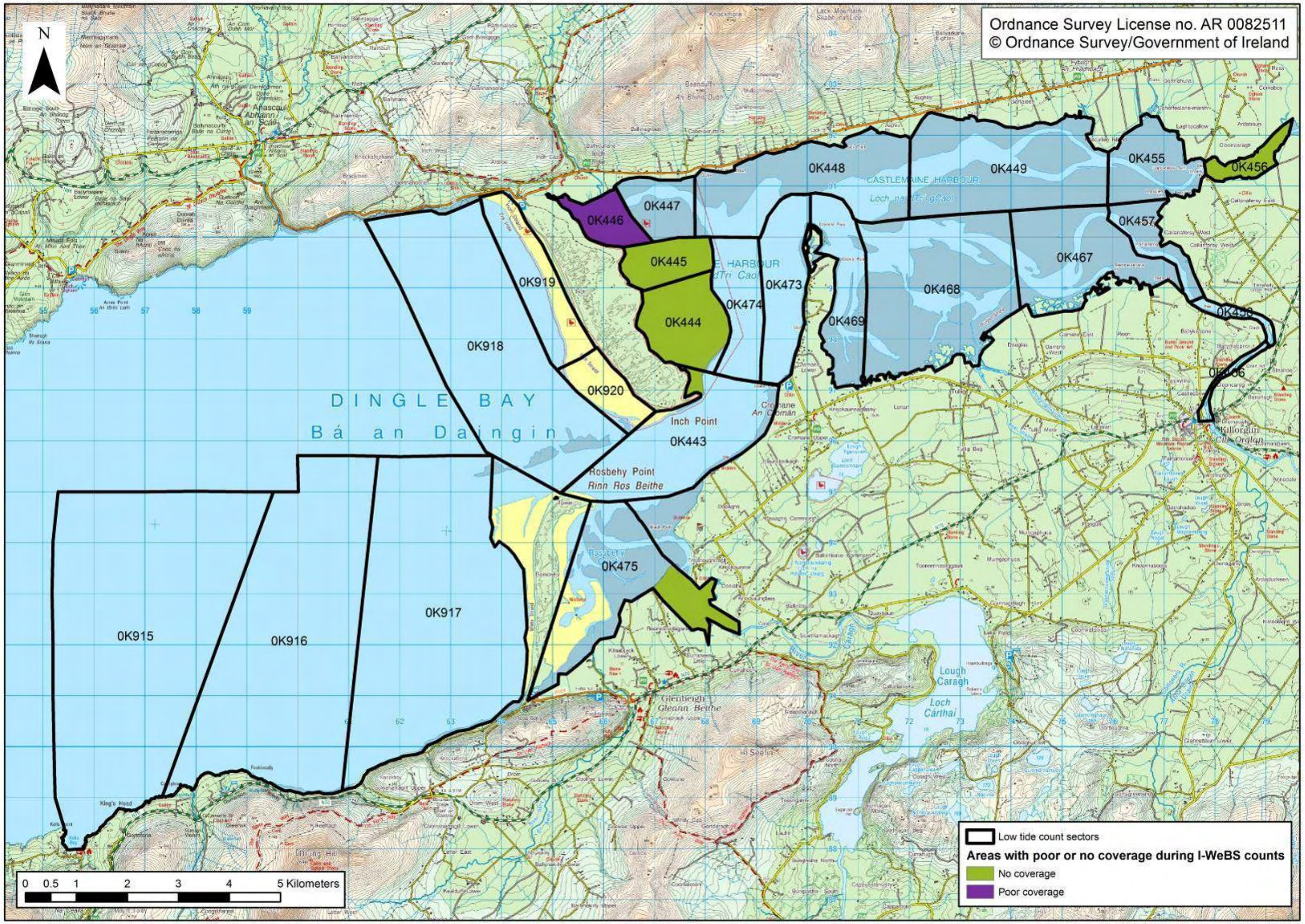


Figure 3.2 – Areas that had poor or no coverage during I-WeBS counts.

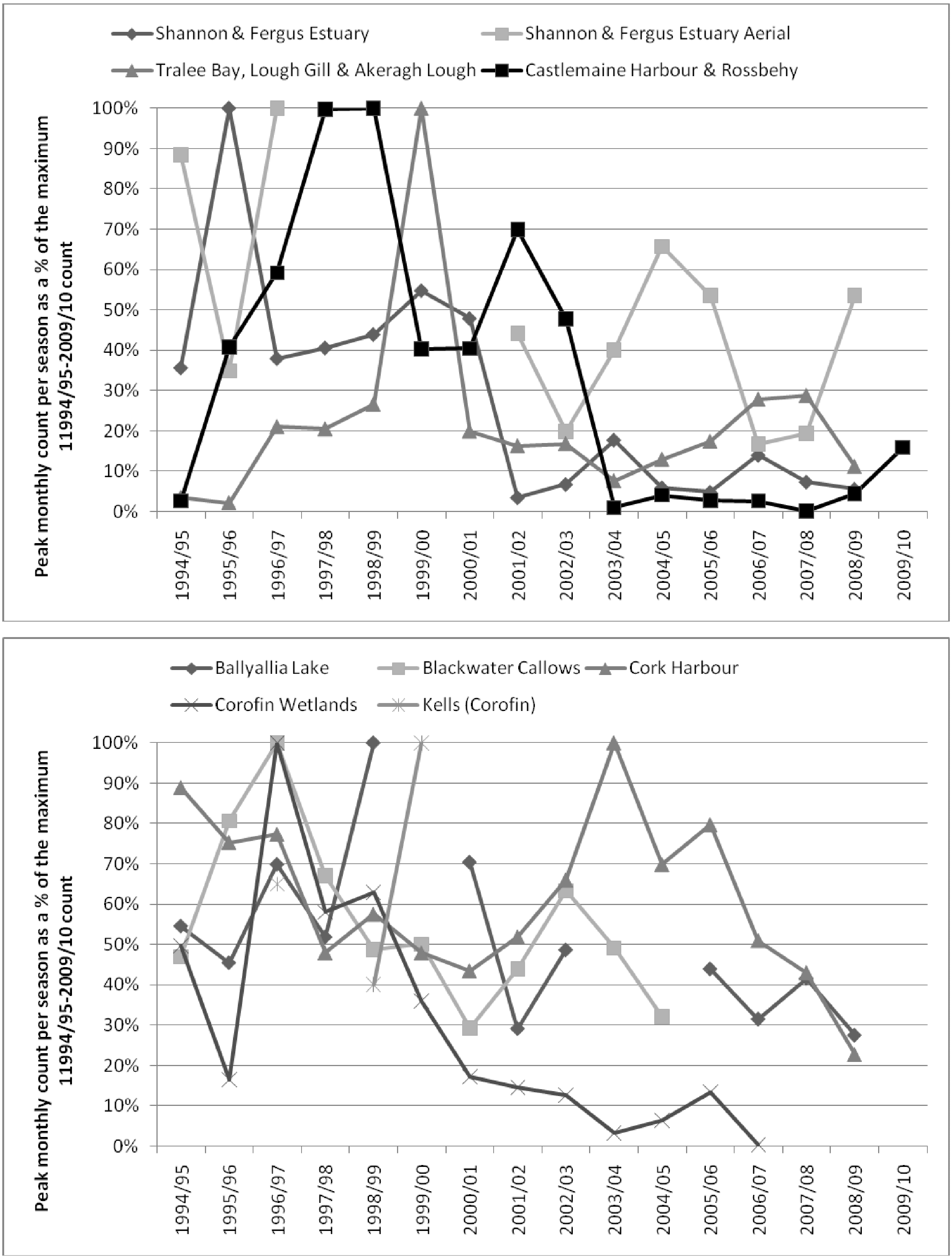


Figure 3.3 – Comparison of trends in Wigeon numbers at Castlemaine Harbour with trends at other sites with nationally important populations in the Munster region.

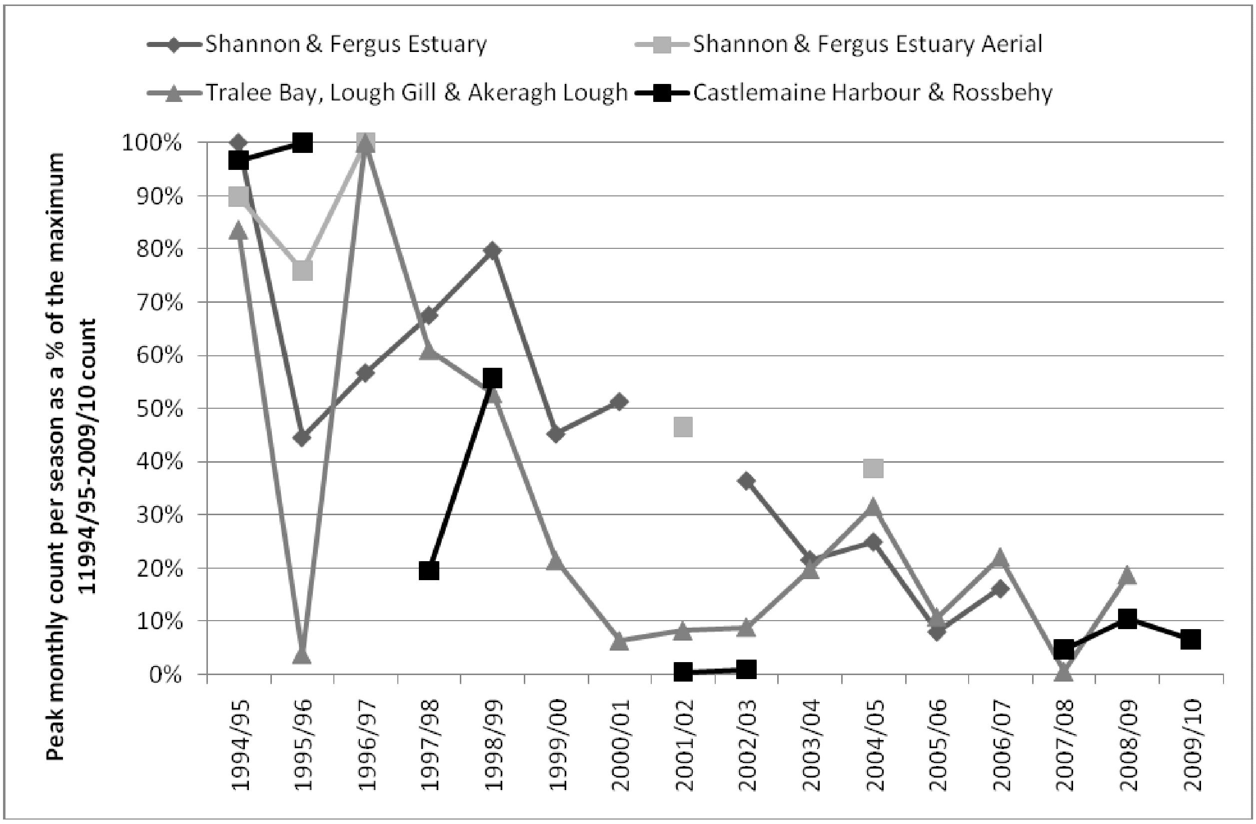


Figure 3.4 – Comparison of trends in Scaup numbers at Castlemaine Harbour with trends at other sites with nationally important populations in the Munster region.

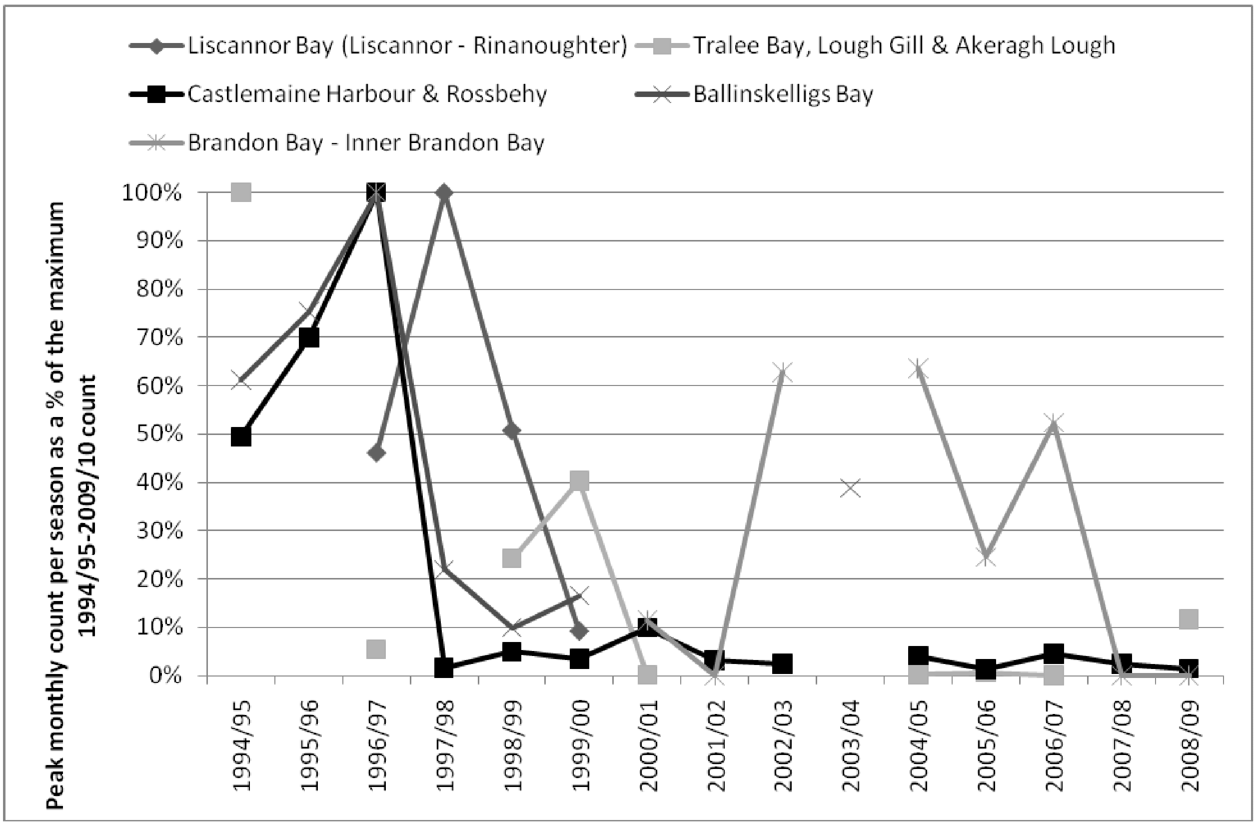


Figure 3.5 - Comparison of trends in Common Scoter numbers at Castlemaine Harbour with trends at other sites with nationally important populations in the Munster region.

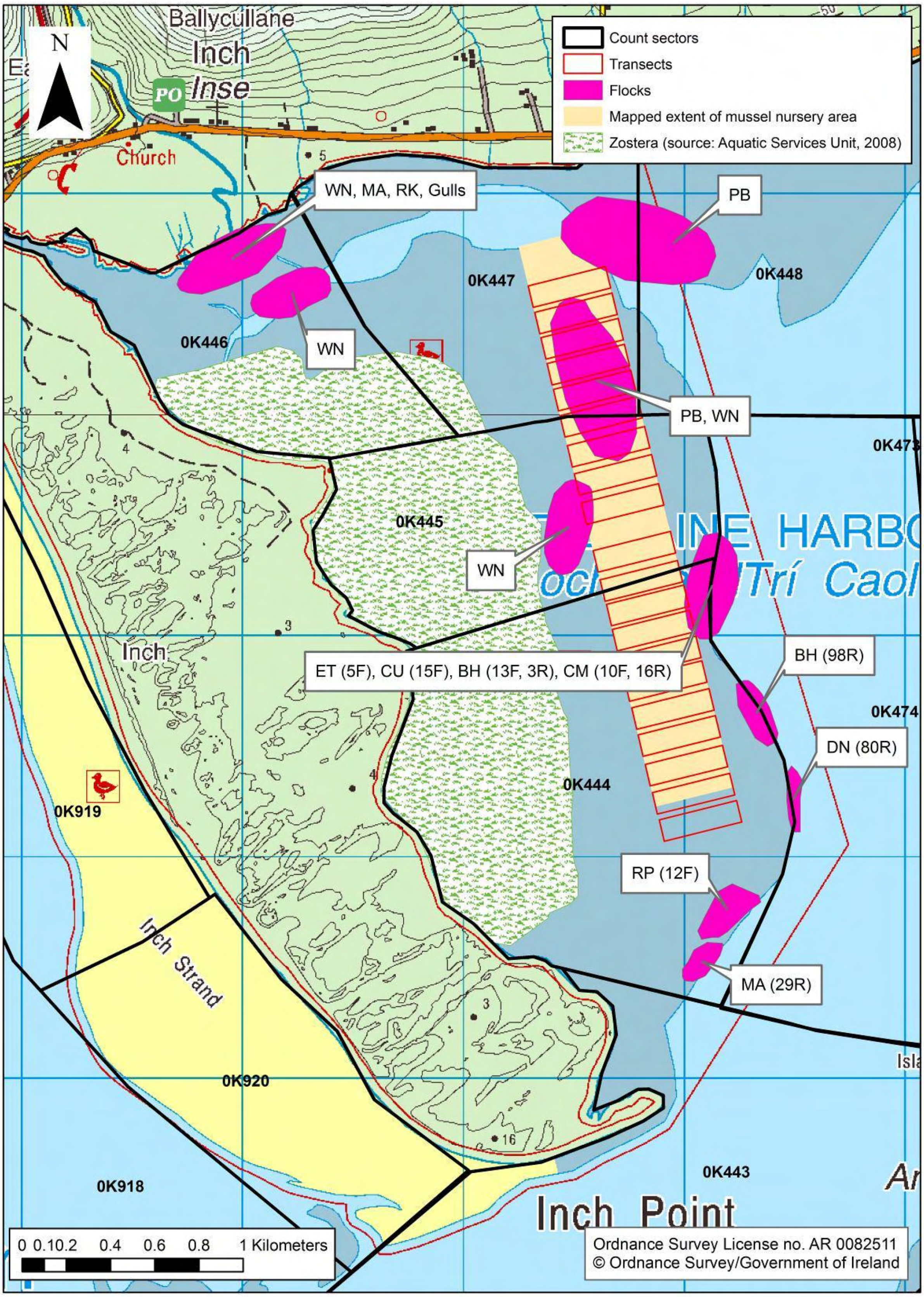


Figure 3.6 – Distribution of waterbird flocks recorded in sectors OK444-447 on the NPWS Baseline Waterbird count on October 5 2009.

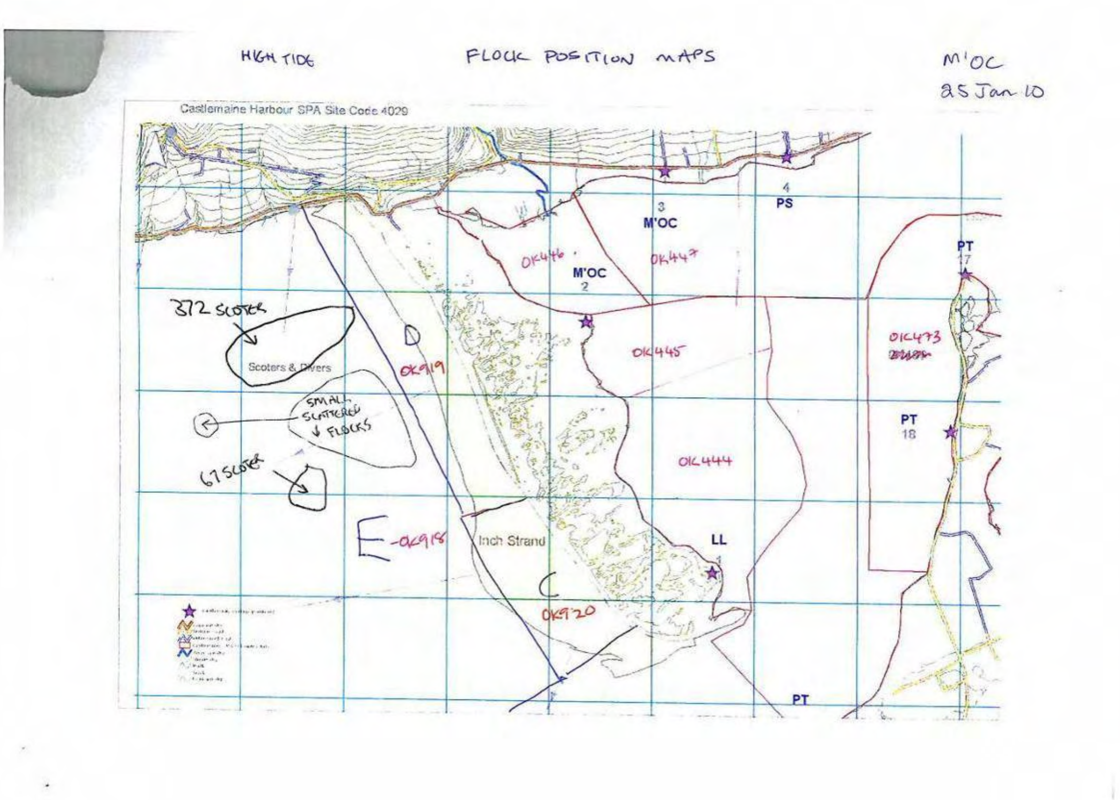


Figure 3.7 - Locations of scoter concentrations recorded in sector OK918 during the high tide count carried out on 25 January 2010.

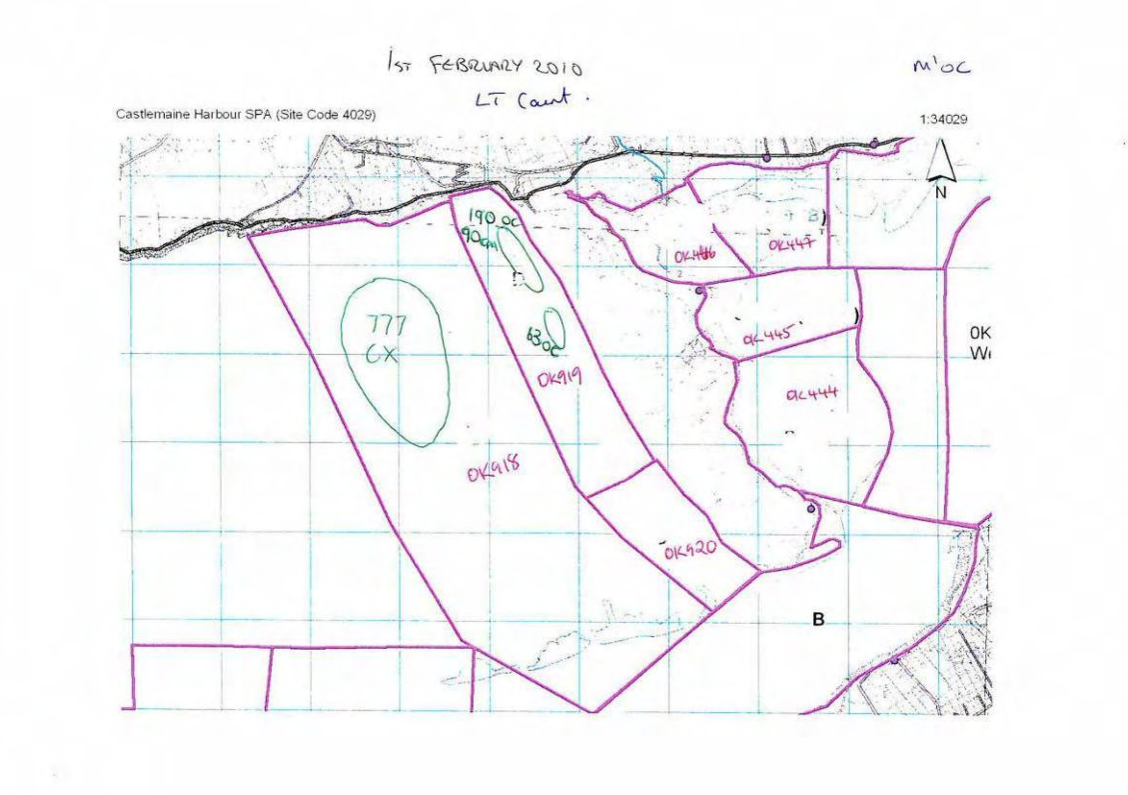


Figure 3.8 - Locations of scoter concentrations recorded in sector OK918 during the low tide count carried out on 4 February 2010.

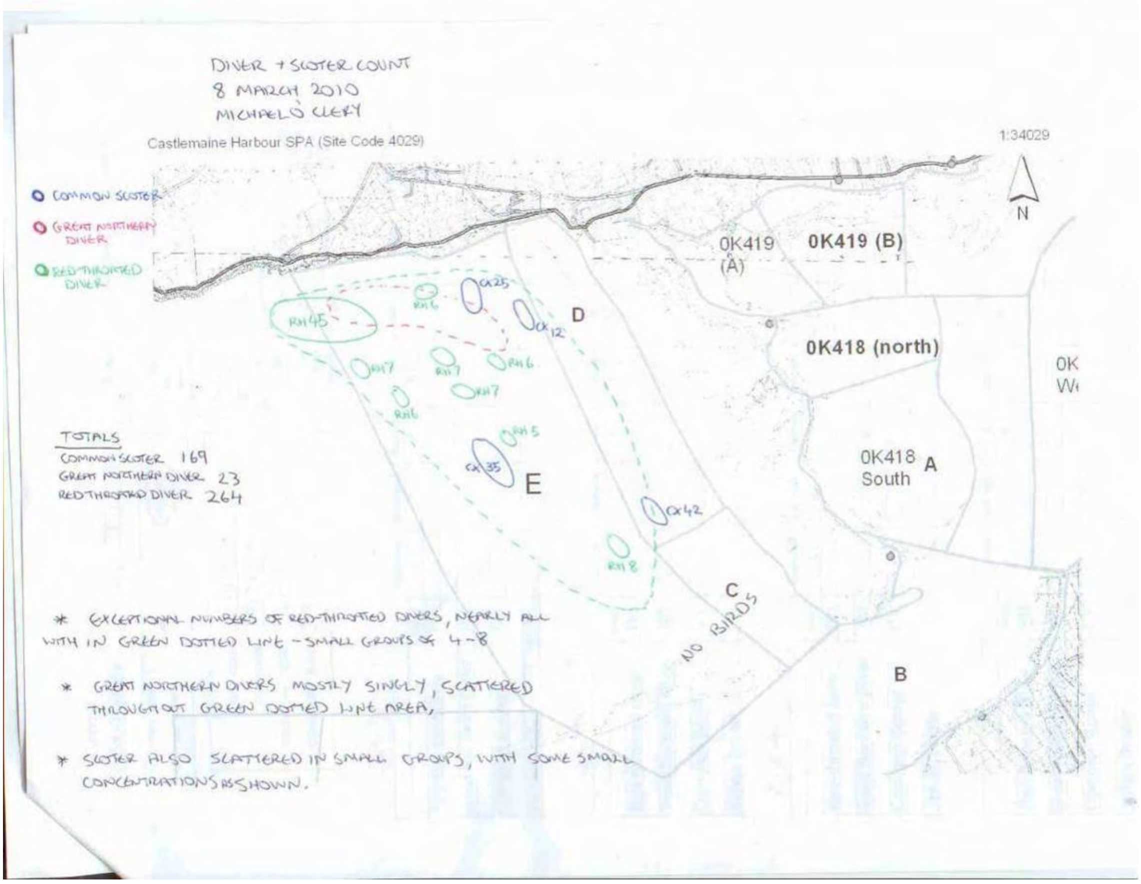


Figure 3.9 – Locations of scoter and diver concentrations recorded in sector OK918 during the dedicated seaduck/diver survey carried out on 8 March 2010,

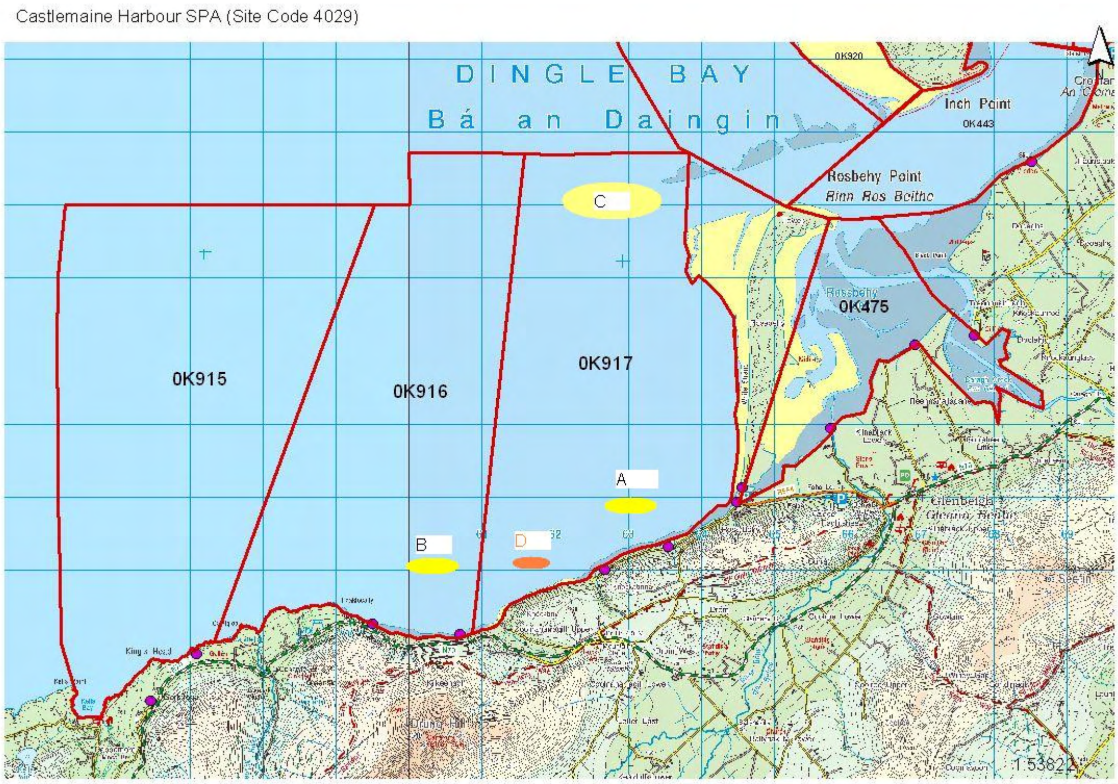


Figure 3.10 –Main locations of scoter and diver concentrations recorded in sectors OK915-917 across the duration of the NPWS Baseline Waterbird Survey Programme 2009/10 at Castlemaine Harbour,

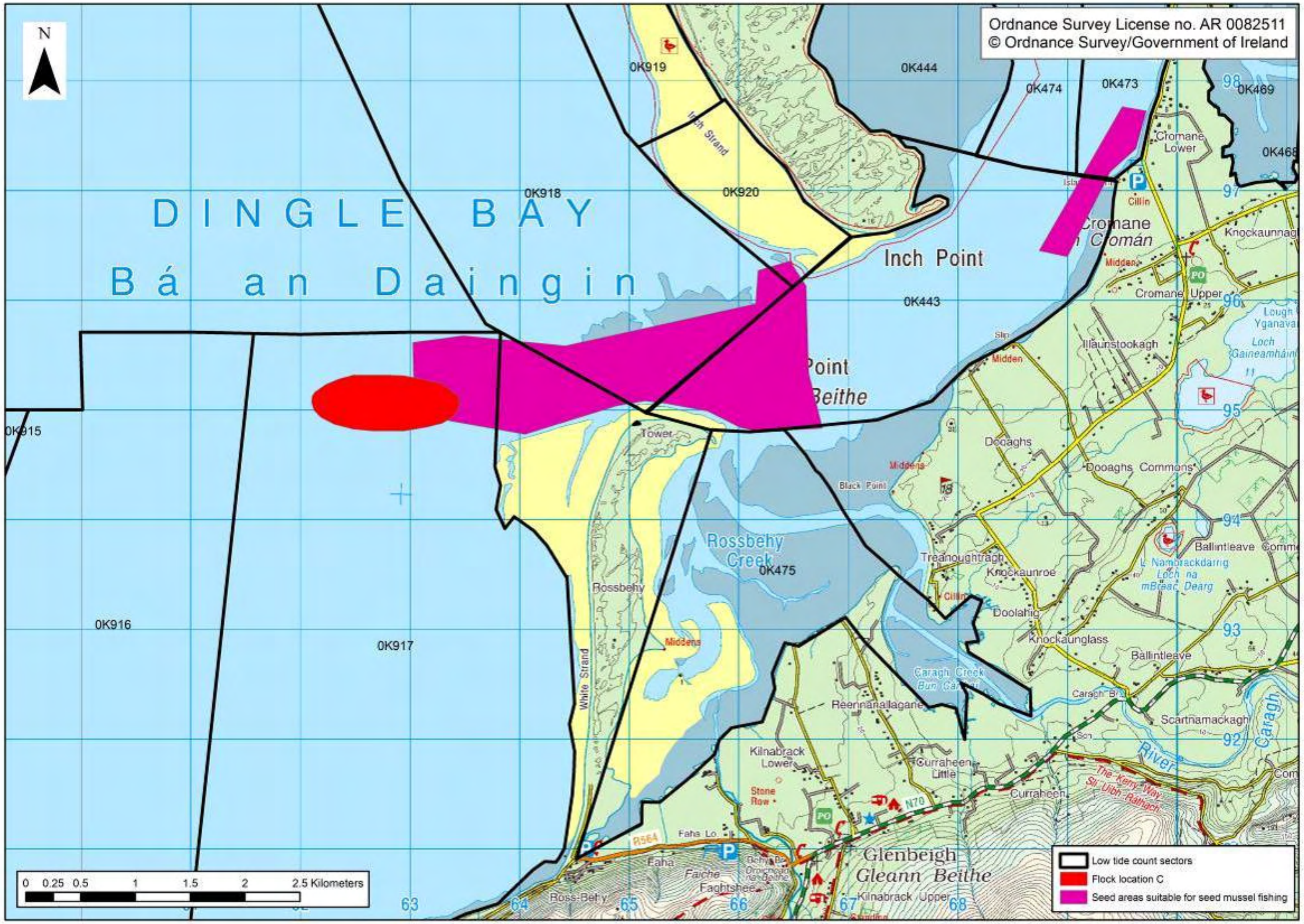


Figure 3.11 – Position of flock location C in relation to the 2009 seed mussel extraction area.

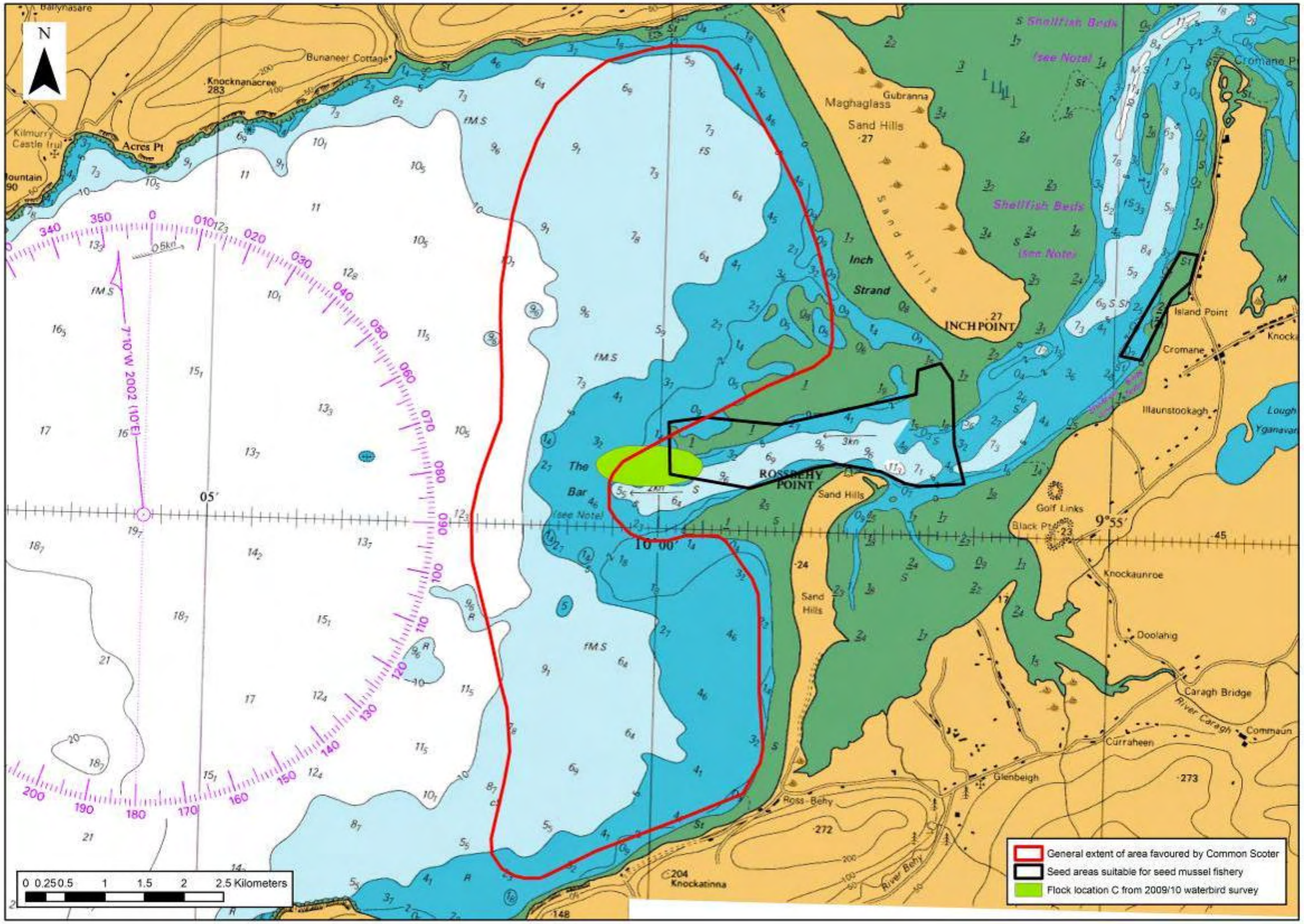


Figure 3.12 – Common Scoter distribution in relation to the seed mussel fishery areas.

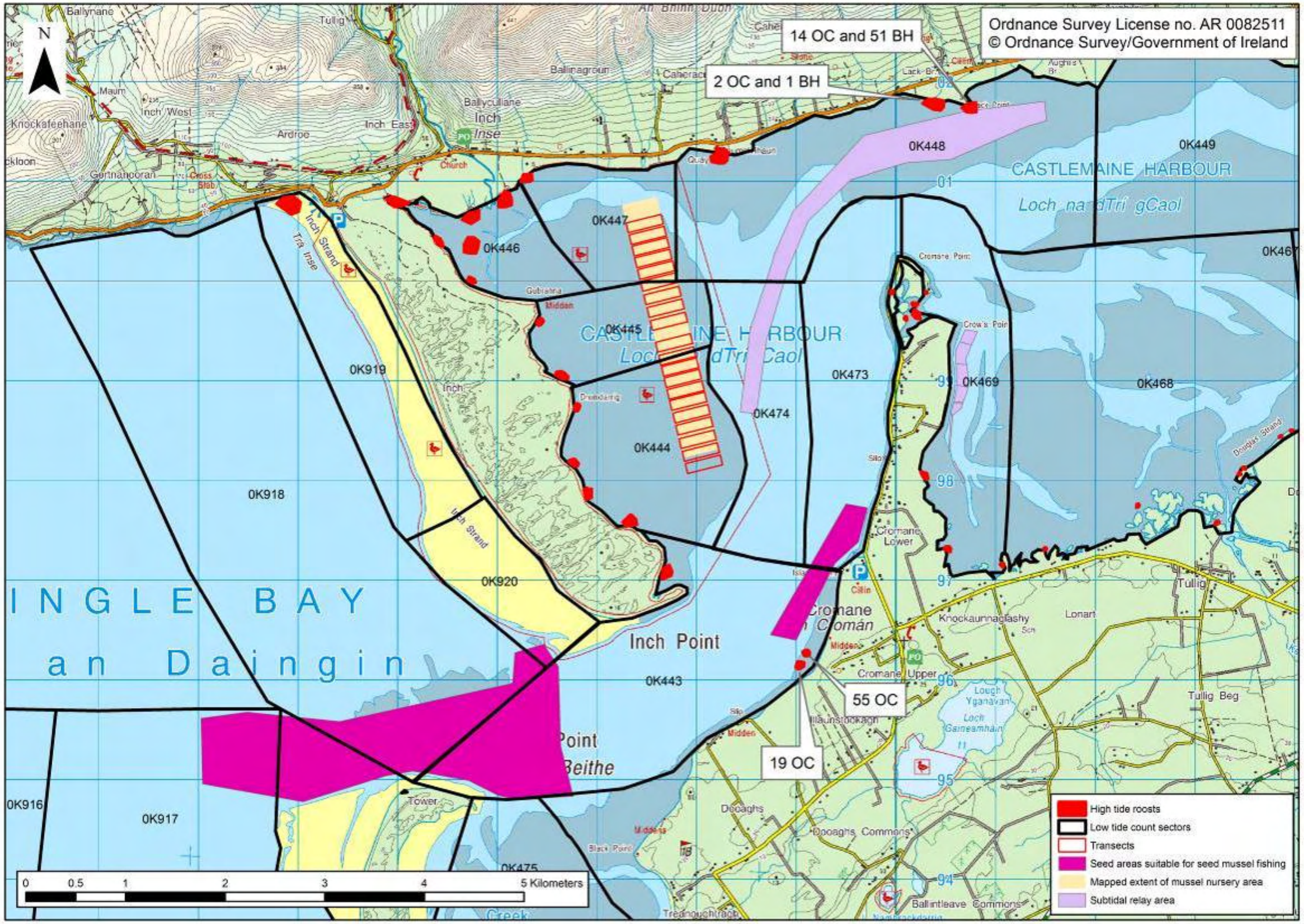


Figure 3.13 – High tide roosts recorded on 26 February 2010 in relation to activities associated with the mussel order area.

4. Mussel cover and the distribution of waterbirds

Methods

Study design

4.1 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.

4.2 In order to select appropriate transect locations we carried out an initial qualitative survey of mussel cover on 15th 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.

4.3 The transects covered most of the extent of the mussel nursery area as indicated in mapping data supplied by the Marine Institute (Figure 4.1). 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.

4.4 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.

4.5 Each transect was 100 m wide and 360 m long and was divided into three 120 m long sectors (Figure 4.2).

Mussel survey

4.6 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.

4.7 We reviewed the relevant literature in an attempt to find an appropriate method of surveying mussel cover. The published methods of mussel surveys (Herlyn & Millat, 2000; e.g., McGrorty *et al.*, 1990) 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.

4.8 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 4.3) 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.

4.9 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.

4.10 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.

4.11 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

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

4.13 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 (Table 3.1). 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.

4.14 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 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 4.2).

Table 4.1 – 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 4.2 – Transects counted by each counter on each count day.

	Transect groups				
Date	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

4.15 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 (see Section 5).

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

Data processing

4.17 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

4.18 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

4.19 The results of increasing sampling intensity are summarised in Figure 4.5. 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.

4.20 The mean mussel cover estimates for each sector surveyed are presented in Plate 4.1. The spatial pattern of variation in mussel cover across the mussel nursery area is shown in Figure 2.1.

4.21 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 4.11); see Plate 4.1 – 4.4 for illustration of differing percentages of mussel cover.

4.22 Seaweed cover was closely correlated with mussel cover, except in sectors with high amounts of seed mussel cover (Figure 3.6). This reflects the fact that seaweed cover occurred almost exclusively on older mussels and presumably represents natural colonisation over a period of years. Seed mussels have a very clean appearance and usually lack any seaweed cover.

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

Plate 4.1 - 3% Mussel Cover (January 2010).

Table 4.3 – 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]	% seaweed cover
1	A	5.42	5.99	0	0.00	4.33
1	B	5.92	5.53	0	0.00	5.58
1	C	7.92	6.72	0	0.00	7.50
2	A	1.33	1.10	0	0.00	1.25
2	B	5.25	4.57	0	0.00	3.33
2	C	4.00	2.35	0	0.00	1.75
3	A	1.67	1.38	0	0.00	1.67
3	B	17.25	16.85	2	1.44	11.00
3	C	25.08	14.53	0	0.00	19.00
4	A	7.67	6.64	0	0.00	7.25
4	B	19.42	28.65	0	0.00	13.50
4	C	2.42	1.22	0	0.00	2.25
5	A	5.92	6.08	0	0.00	5.67
5	B	5.92	4.29	7	1.73	4.67
5	C	8.00	16.05	0	0.00	3.00
6	A	6.00	5.67	6	1.50	5.25
6	B	8.67	7.27	12	4.33	1.33
6	C	8.08	5.76	4	1.35	6.58
7	A	4.64	2.39	0	0.00	4.38
7	B	3.36	1.38	0	0.00	3.12
7	C	8.00	4.92	0	0.00	7.08
8	A	2.92	1.67	0	0.00	2.75
8	B	3.90	3.38	0	0.00	3.70
8	C	3.92	4.21	0	0.00	3.75
10	A	21.58	20.78	0	0.00	20.33
10	B	13.75	16.63	0	0.00	13.67
10	C	2.75	2.90	0	0.00	2.75
11	A	21.17	9.29	2	1.76	19.08
11	B	21.08	17.88	0	0.00	19.00
11	C	42.58	30.47	0	0.00	25.17
13	A	30.08	18.23	22	27.58	0.25
13	B	23.75	13.99	18	17.81	3.42
13	C	12.92	11.70	19	10.23	3.33
14	A	19.08	13.84	24	19.08	1.08
14	B	28.00	17.67	24	28.00	1.08
14	C	7.75	3.71	14	4.52	0.67

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

Plate 4.2 - 8% Mussel Cover (January 2010).

Plate 4.3 - 13% Mussel Cover at rear of photo (January 2010).

Plate 4.4 - 43% Mussel Cover (January 2010).

Waterbird counts

4.24 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.

4.25 A total of 22 species were recorded across all the counts. The most abundant species were Oystercatcher, Curlew, and Redshank (Table 4.4). These were also the most frequent and were recorded on 15-20% of the sector counts (Table 4.5). 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 4.4 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 4.4 – 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 4.5 – 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
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

4.26 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 4.7-Figure 4.9). 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 4.6).

Table 4.6 – 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%

4.27 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 4.10). 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).

4.28 The analysis presented in Figure 4.10 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.

4.29 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 4.11-Figure 4.13). The within-sector distribution of Light-bellied Brent also indicates a preference of mussel beds (Figure 4.14) although the number of qualifying sectors is low. Other species with more than five qualifying sectors are shown in Table 4.7. 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 4.7 – 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

4.30 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.

4.31 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.

4.32 Because of the speed with which the tideline moves through 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.

4.33 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 over dispersion, and to species for which the above criteria produce a dataset that did not contain excessive numbers of zeros.

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

4.35 We did not use counts where the observer had recorded that the count had been affected by disturbance. However, 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.

4.36 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.

4.37 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.

4.38 The parameters that we used in our model building are defined in Table 4.8. 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 4.8 – 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

4.39 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.

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

4.41 Before beginning the analyses we used Cleveland dot plots 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.

4.42 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.

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

4.44 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.

4.45 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

4.46 The results of the GLMM analyses are summarised in Table 4.9. 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 4.9 – 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.

4.47 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

4.48 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.

4.49 The distribution of residuals in relation to TRANS and TSEC do show heterogeneity (Figure 4.15 and Figure 4.16). This is particularly strong in the latter case, where it may reflect the small sample sizes of some of the sectors.

4.50 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 4.17). 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

4.51 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.

4.52 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.

4.53 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.

4.54 We used the same environmental parameters as included in the GLMM analyses (Table 4.8), with the addition of the x and y co-ordinates of the transect sectors.

Analysis results

4.55 The final CCA model included mussel cover, day and the x and y co-ordinates as explanatory variables (Table 4.10). 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.

4.56 The eigenvalues of the ordination axes are low and the species-environment correlations are low (Table 4.10) indicating that there is alot of assemblage variation which is not explained by the CCA model.

4.57 The CCA triplot (Figure 4.18) 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.

4.58 The vectors for sqrtMUSS and DAY represent very similar gradient of assemblage variation. Therefore, the position of species along this gradient (Figure 4.19) represents an interaction between these two parameters and cannot be simply used to indicate associations with high or low levels of mussel cover.

Table 4.10 – 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

4.59 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%.

4.60 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.

4.61 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.

4.62 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

4.63 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.

4.64 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.

4.65 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

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

4.67 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

4.68 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

4.69 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.

4.70 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.

4.71 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

4.72 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%.

4.73 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.

4.74 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.

Figure 4.1 – Location of bird survey transects in Castlemaine Harbour.

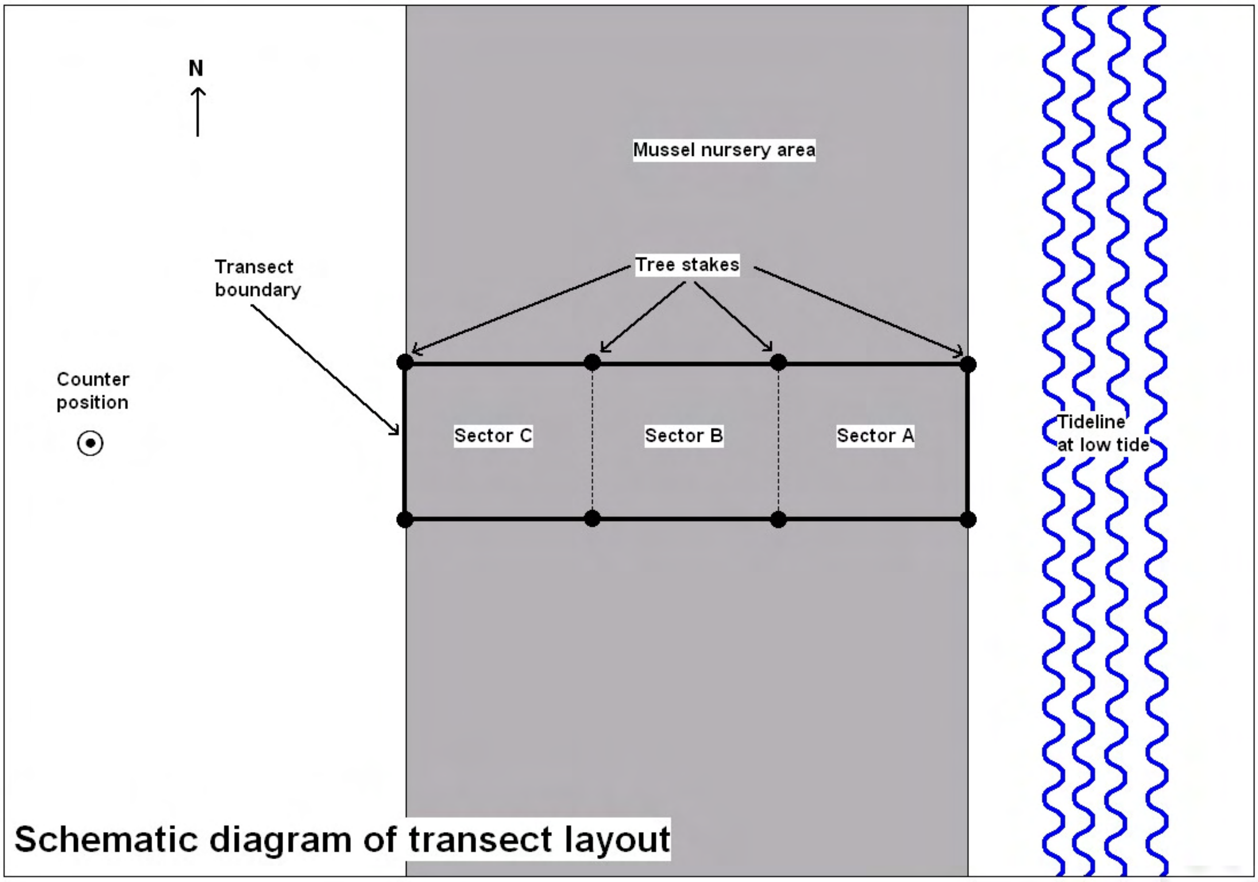


Figure 4.2 – Schematic diagram of the layout of the transects used for the waterbird counts.

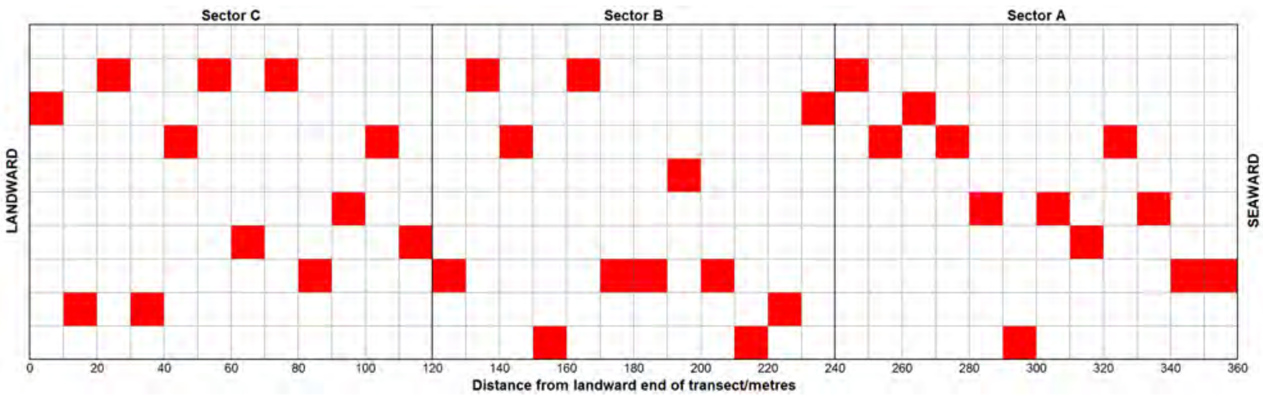


Figure 4.3 – Arrangement of quadrat grid used for the mussel surveys, with an example of randomly selected quadrats.

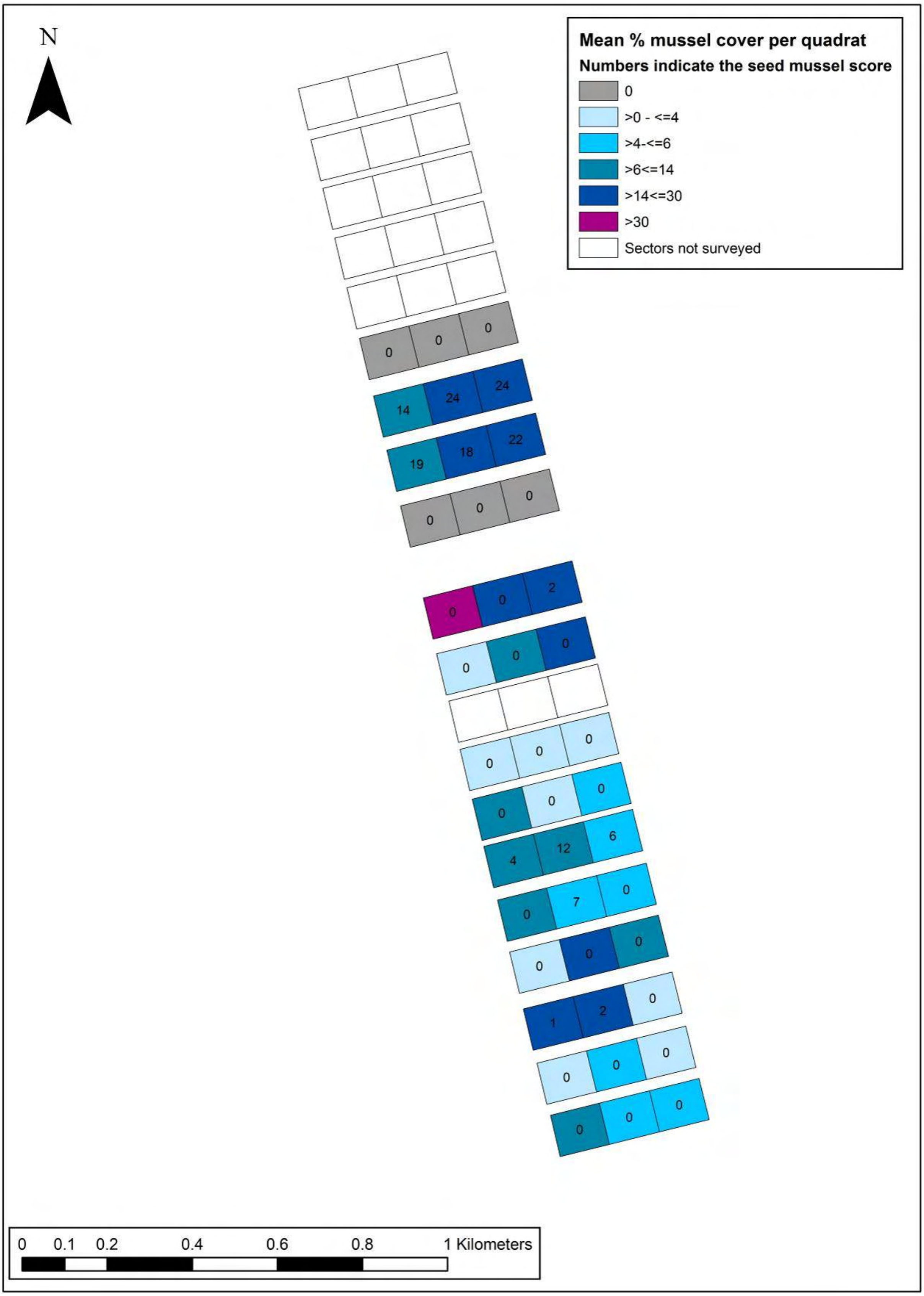


Figure 4.4 – Mussel cover in the transect sectors.

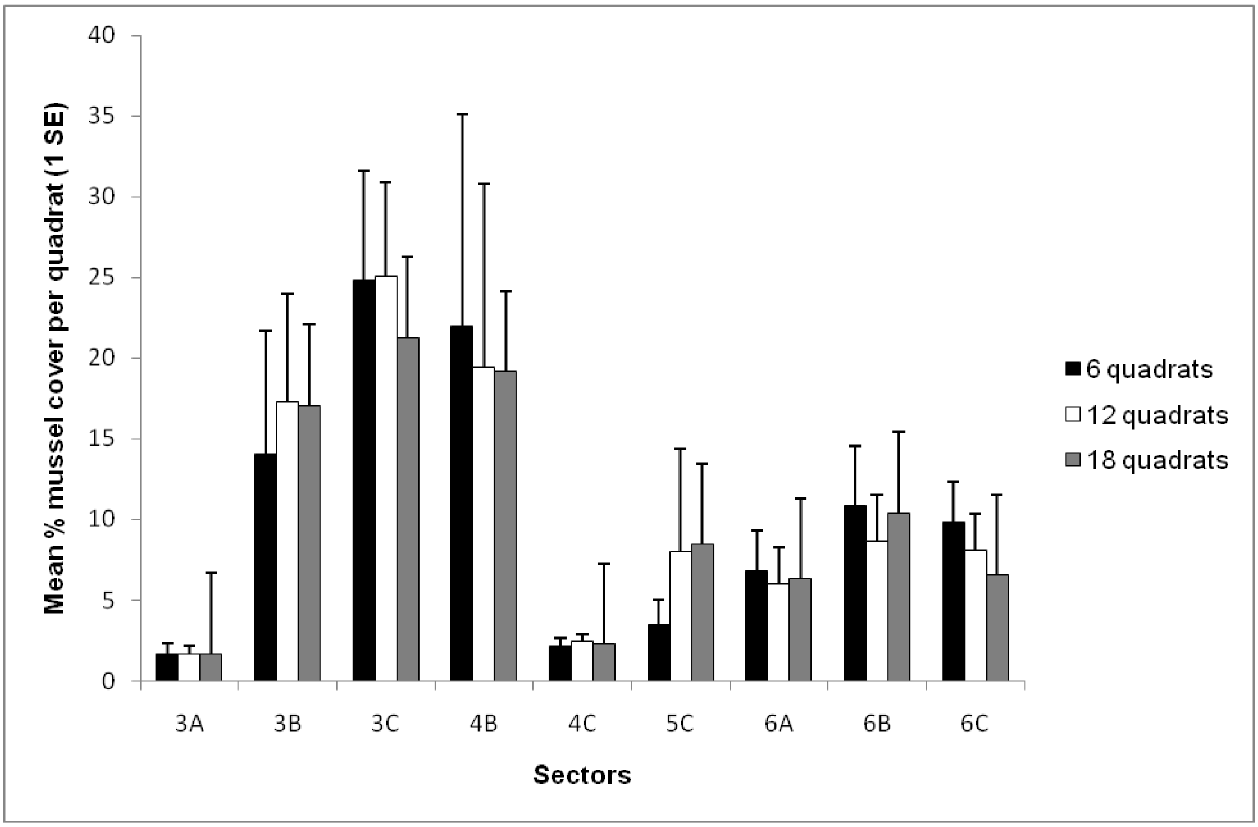


Figure 4.5 – Relationship between mussel cover and increasing sampling intensity.

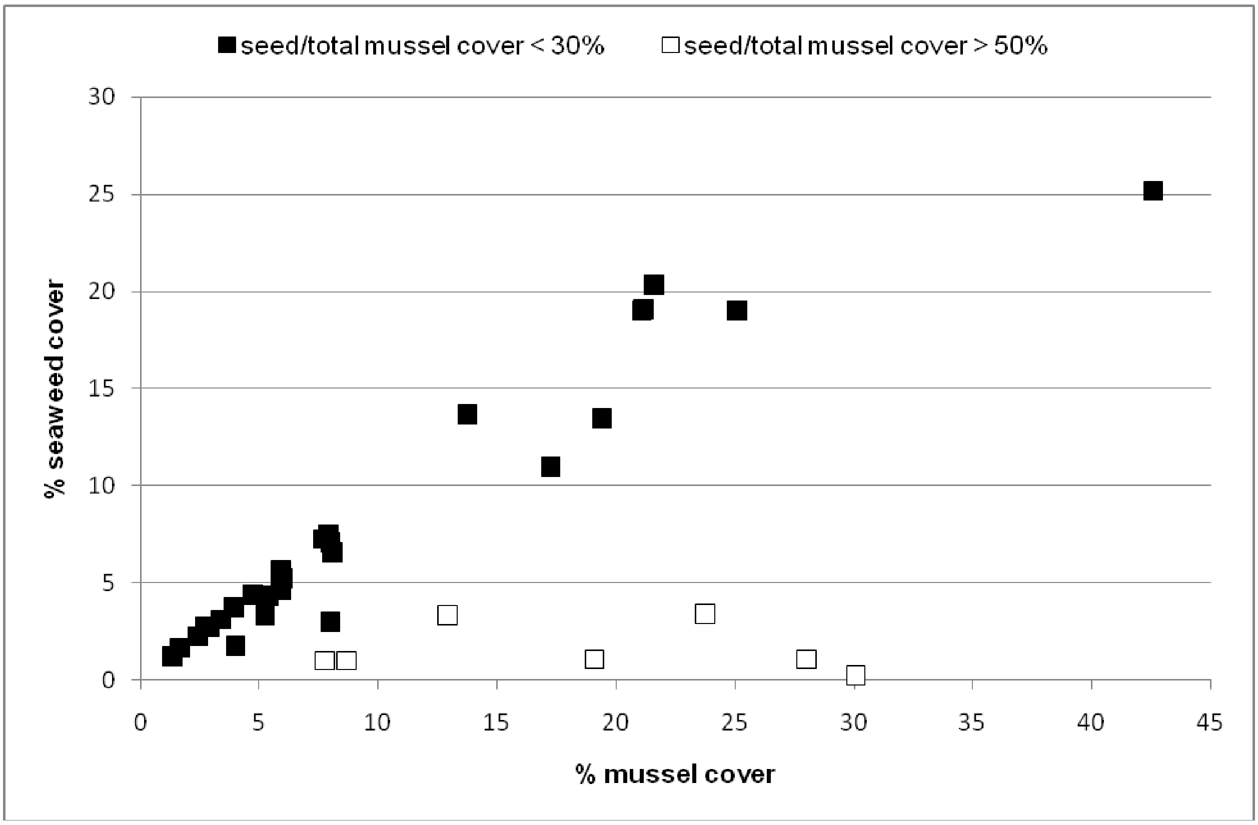


Figure 4.6 – Relationship between mussel cover and seaweed cover.

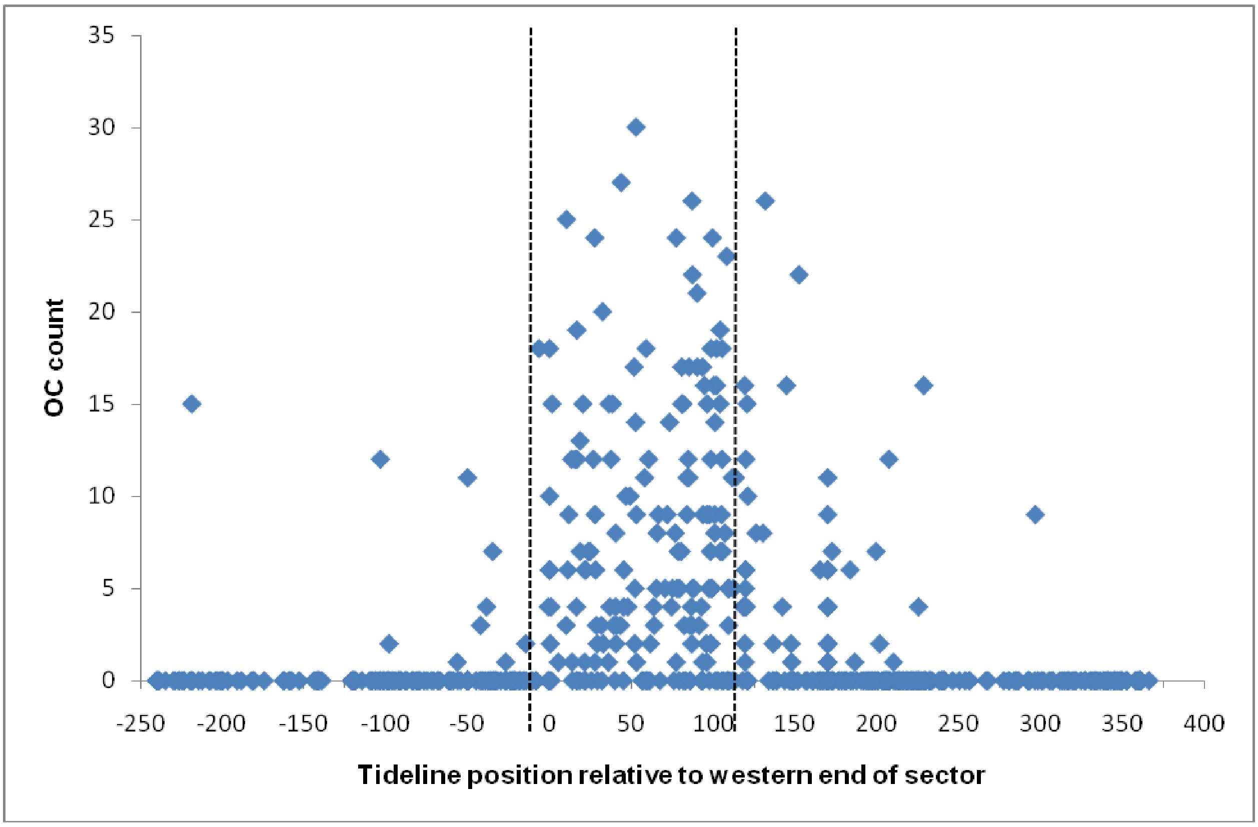


Figure 4.7 – Oystercatcher sector counts in relation to tideline position.

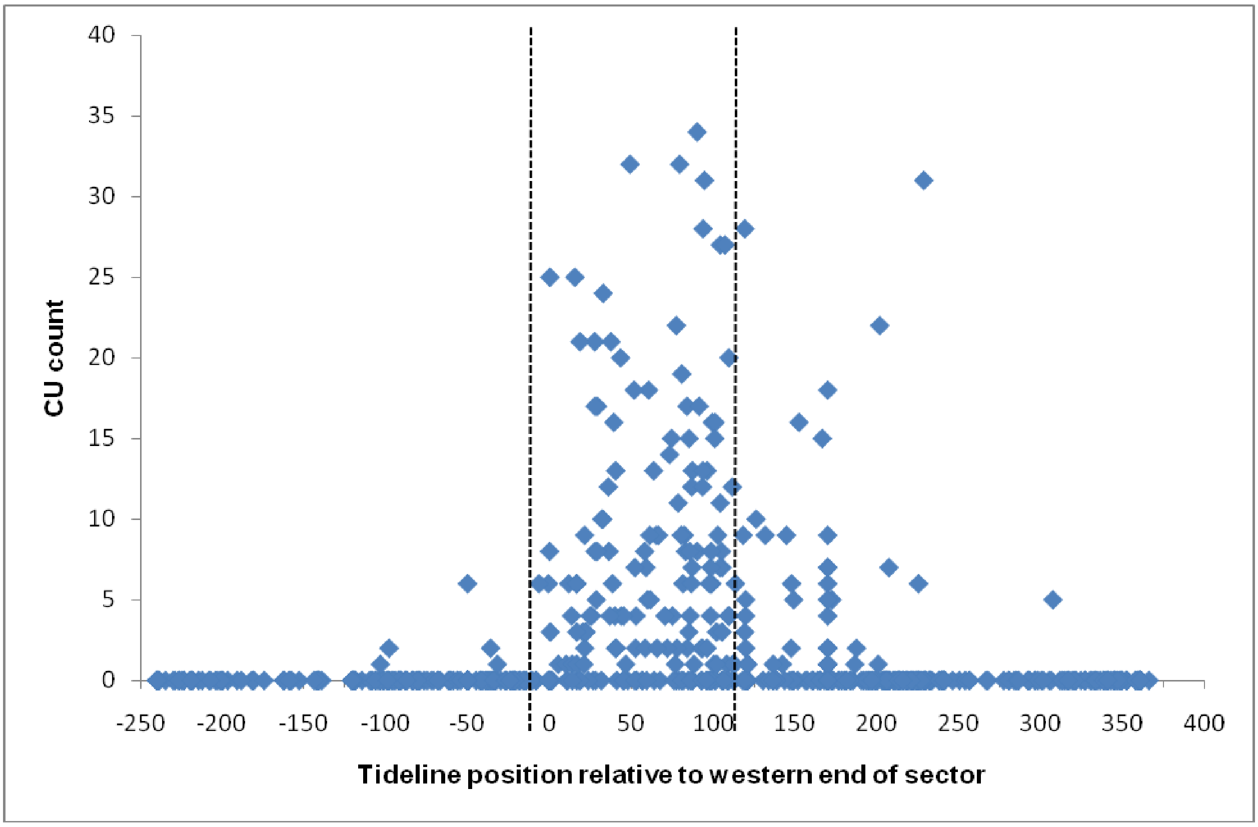


Figure 4.8 – Curlew sector counts in relation to tideline position.

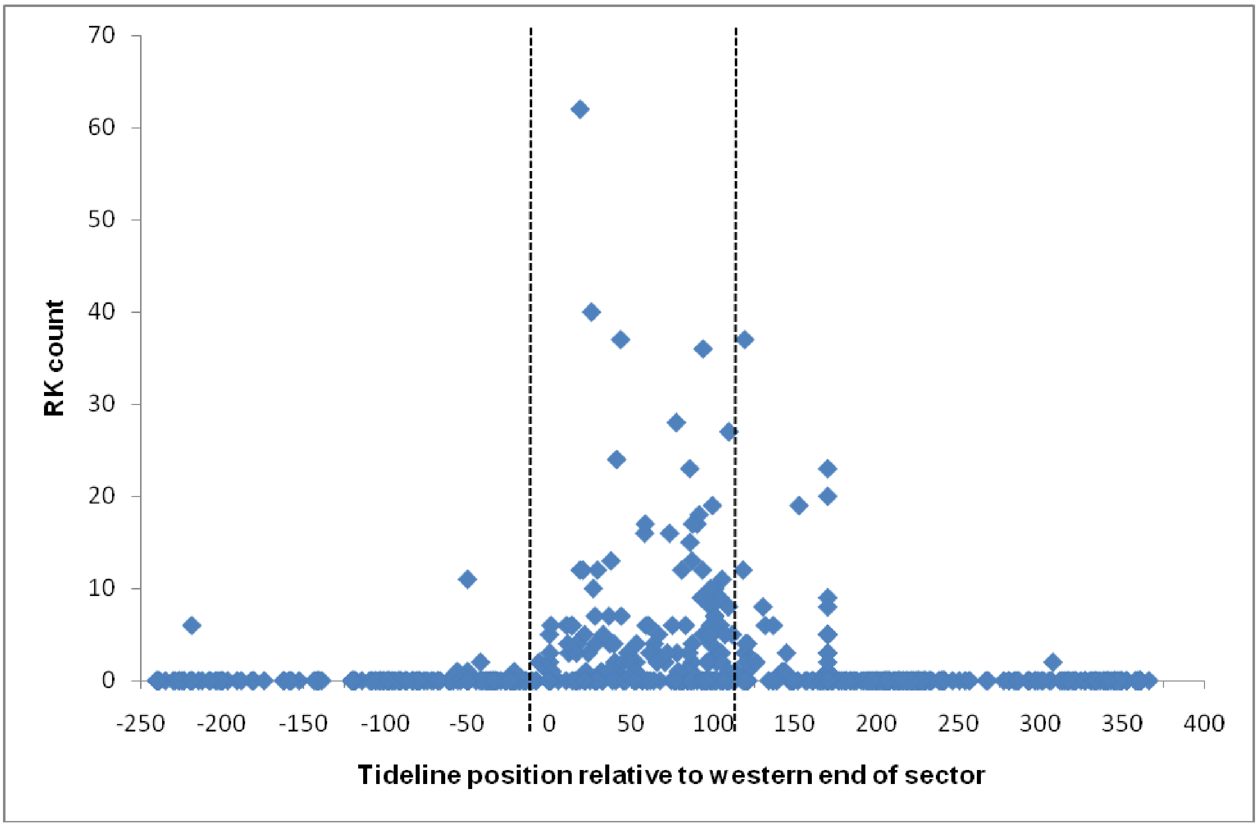


Figure 4.9 – Redshank sector counts in relation to tideline position.

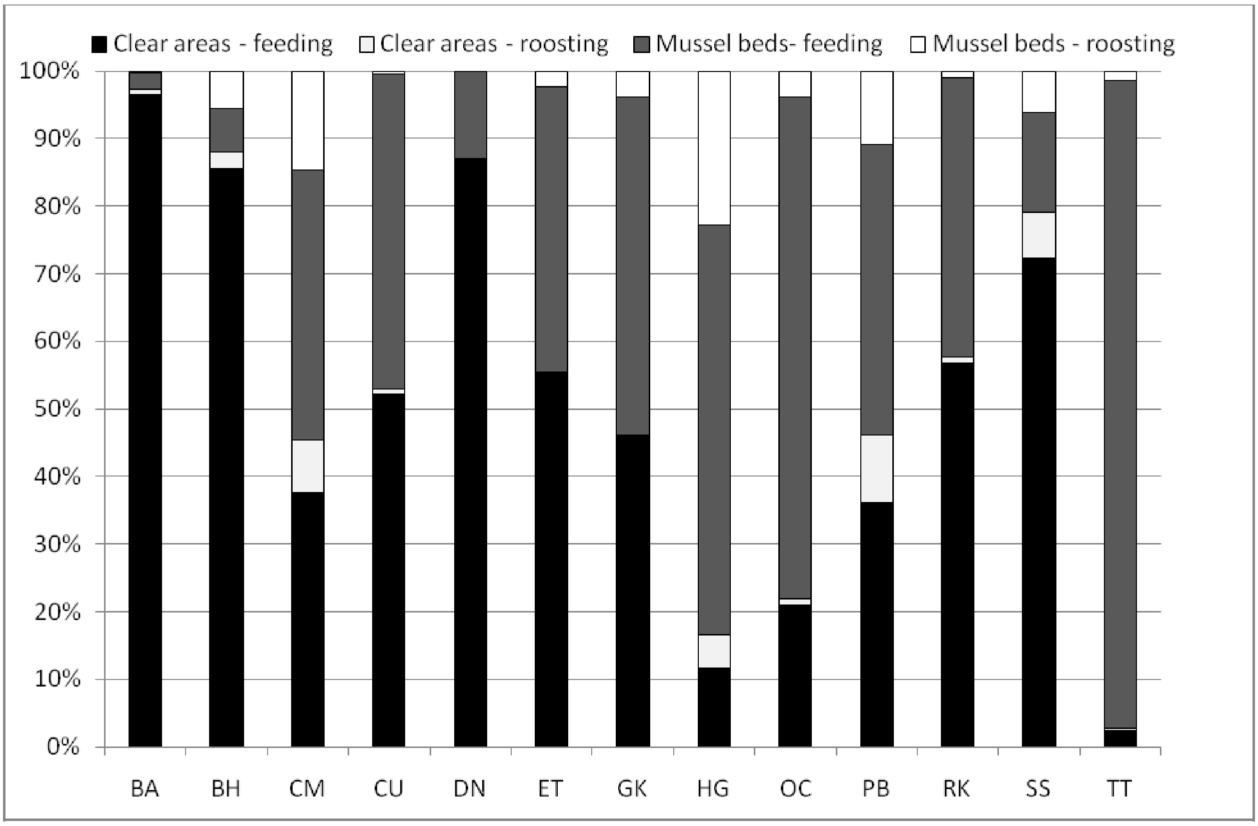


Figure 4.10 – Percentage composition of total count by location and activity of waterbird species recorded in the transect counts.

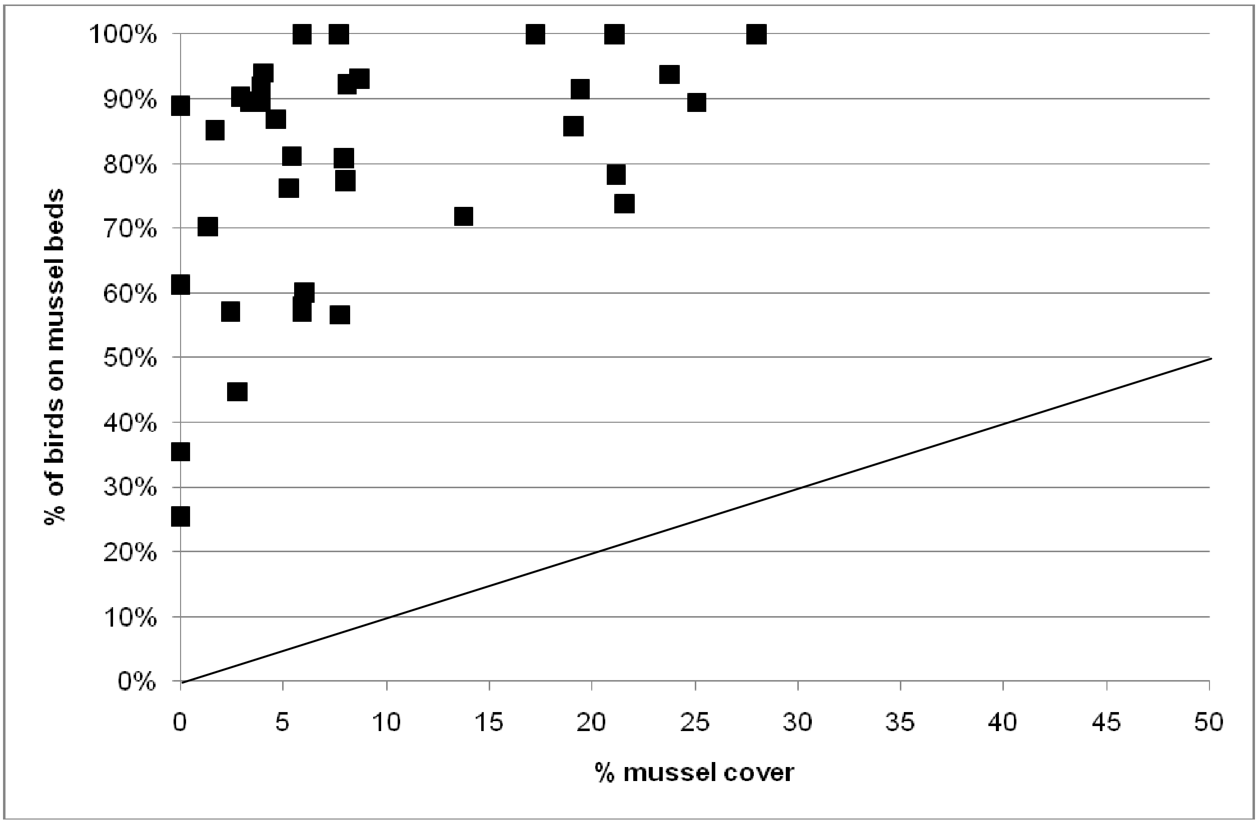


Figure 4.11 – Mussel cover and percentage occurrence of Oystercatcher on mussel beds for sectors with a total count of ten or more.

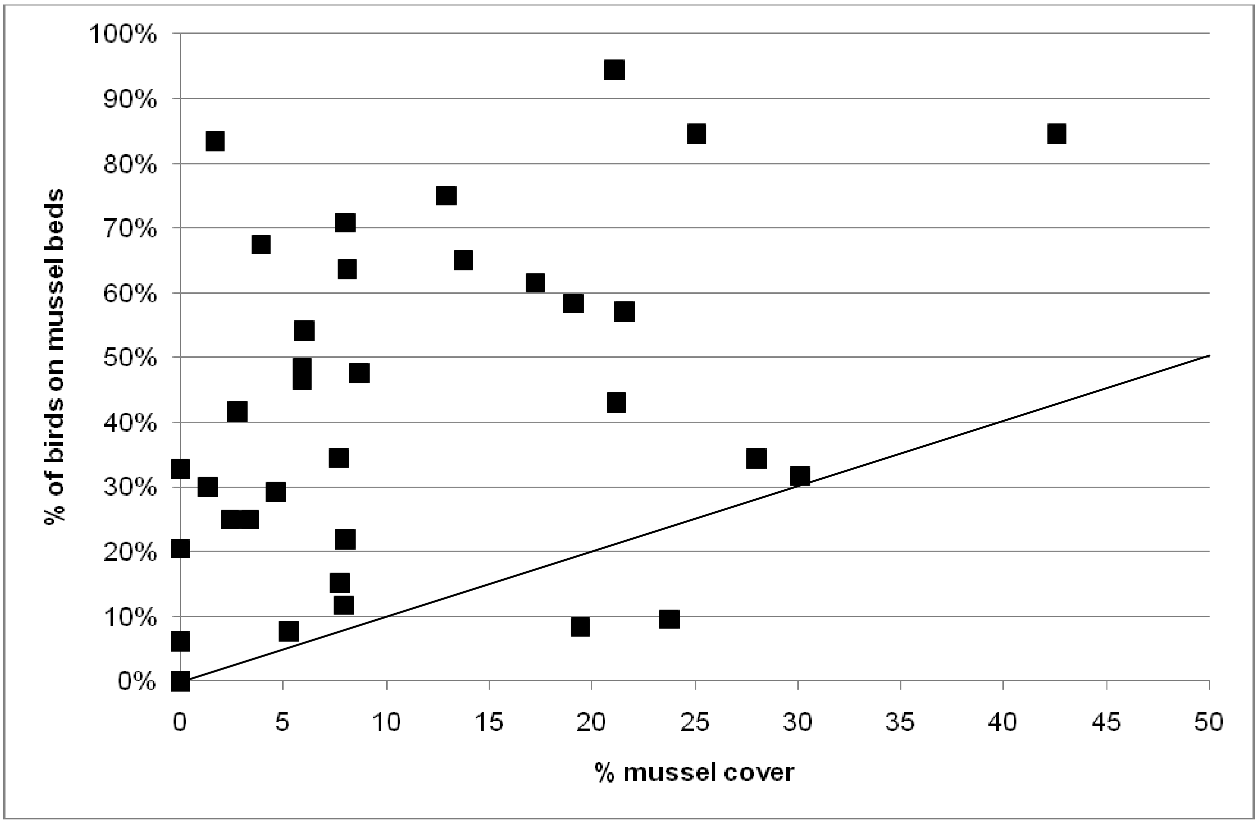


Figure 4.12 – Mussel cover and percentage occurrence of Curlew on mussel beds for sectors with a total count of ten or more.

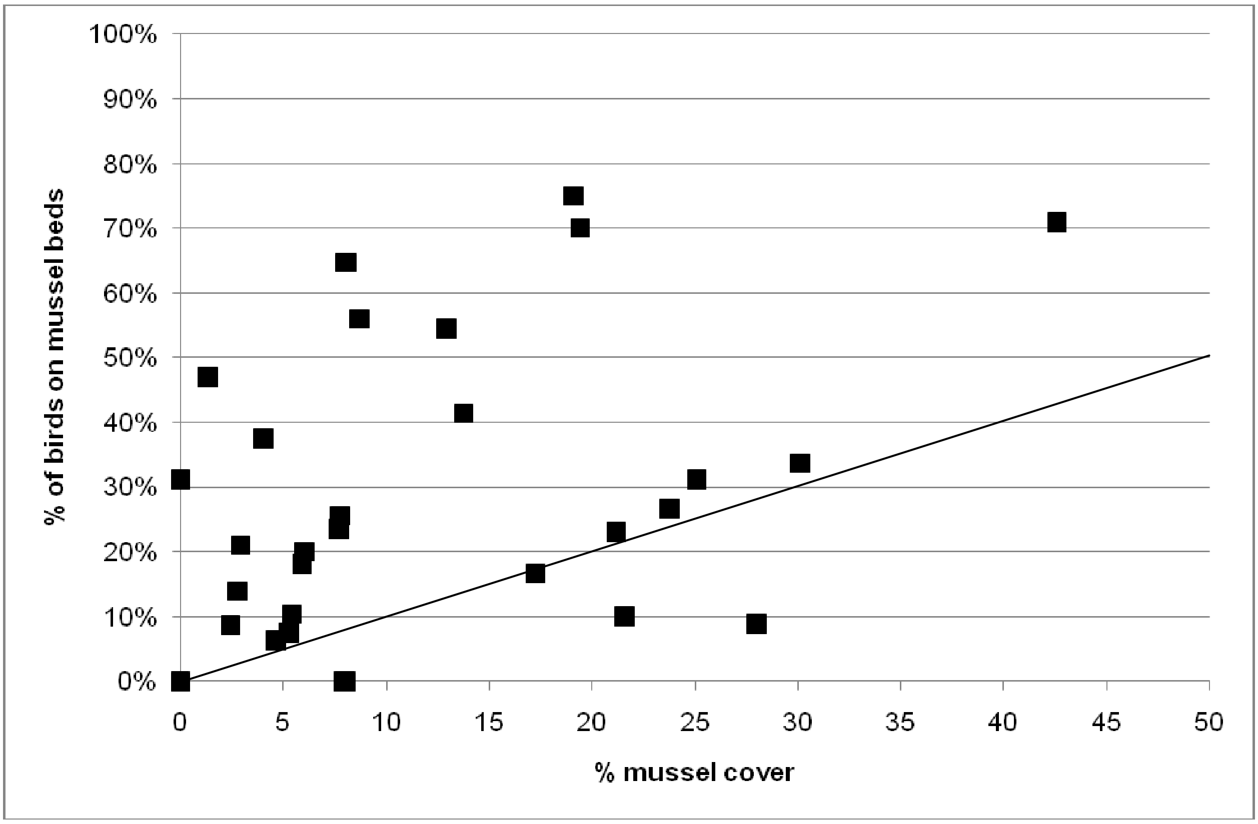


Figure 4.13 – Mussel cover and percentage occurrence of Redshank on mussel beds for sectors with a total count of ten or more.

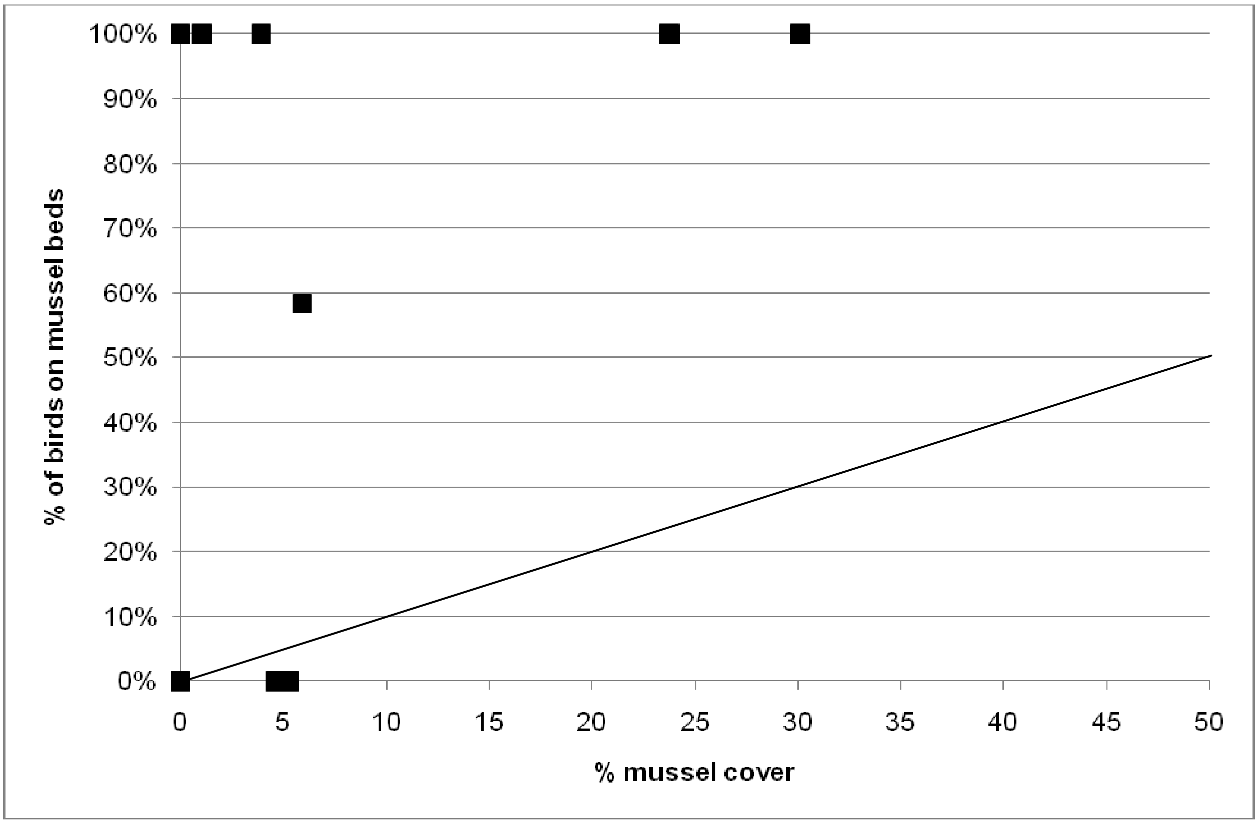


Figure 4.14 – Mussel cover and percentage occurrence of Light-bellied Brent on mussel beds for sectors with a total count of ten or more.

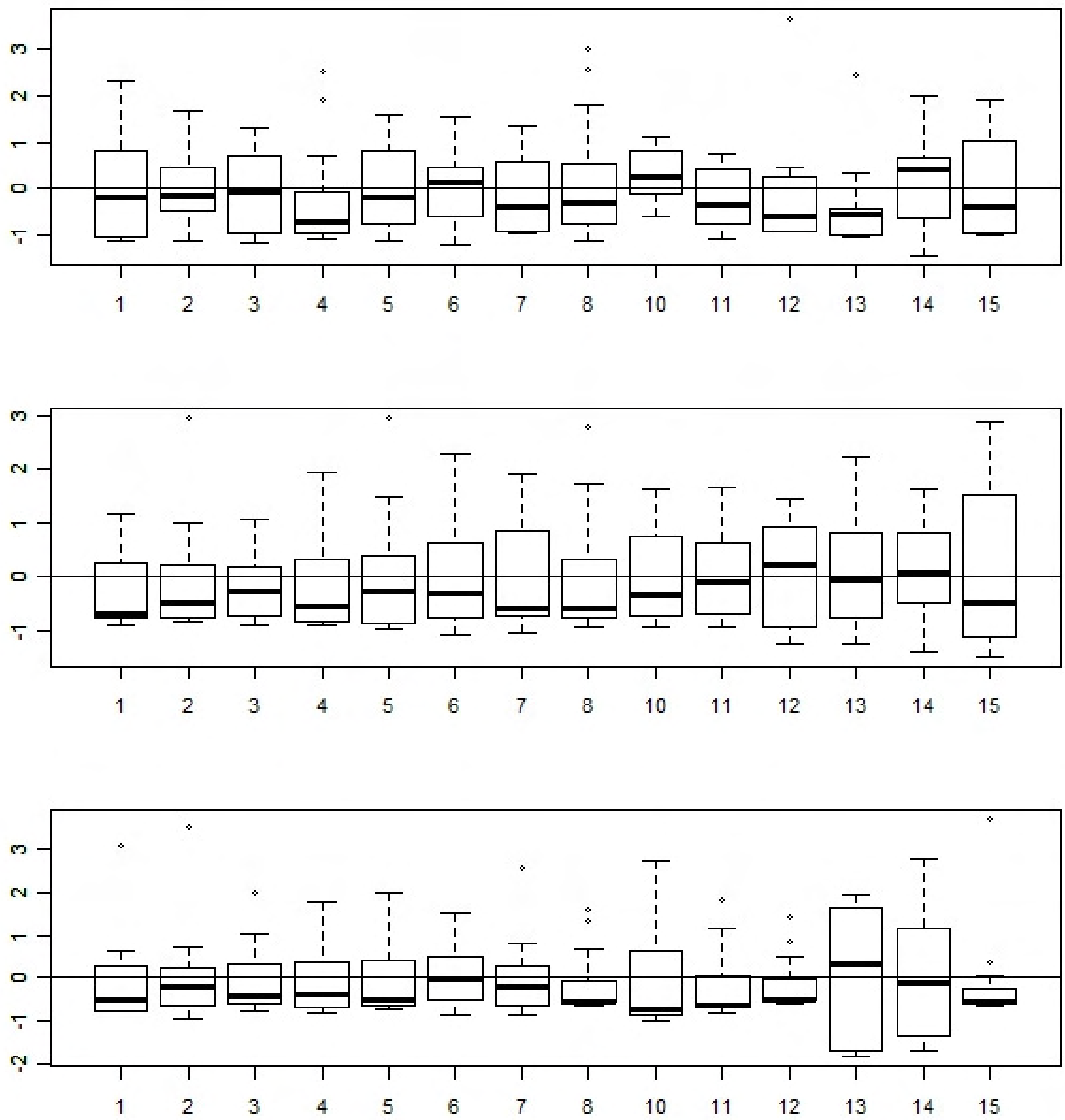


Figure 4.15 – Boxplot of Pearsons residuals from GLMM Oystercatcher (upper), Curlew (middle) and Redshank (lower) models against TRANS.

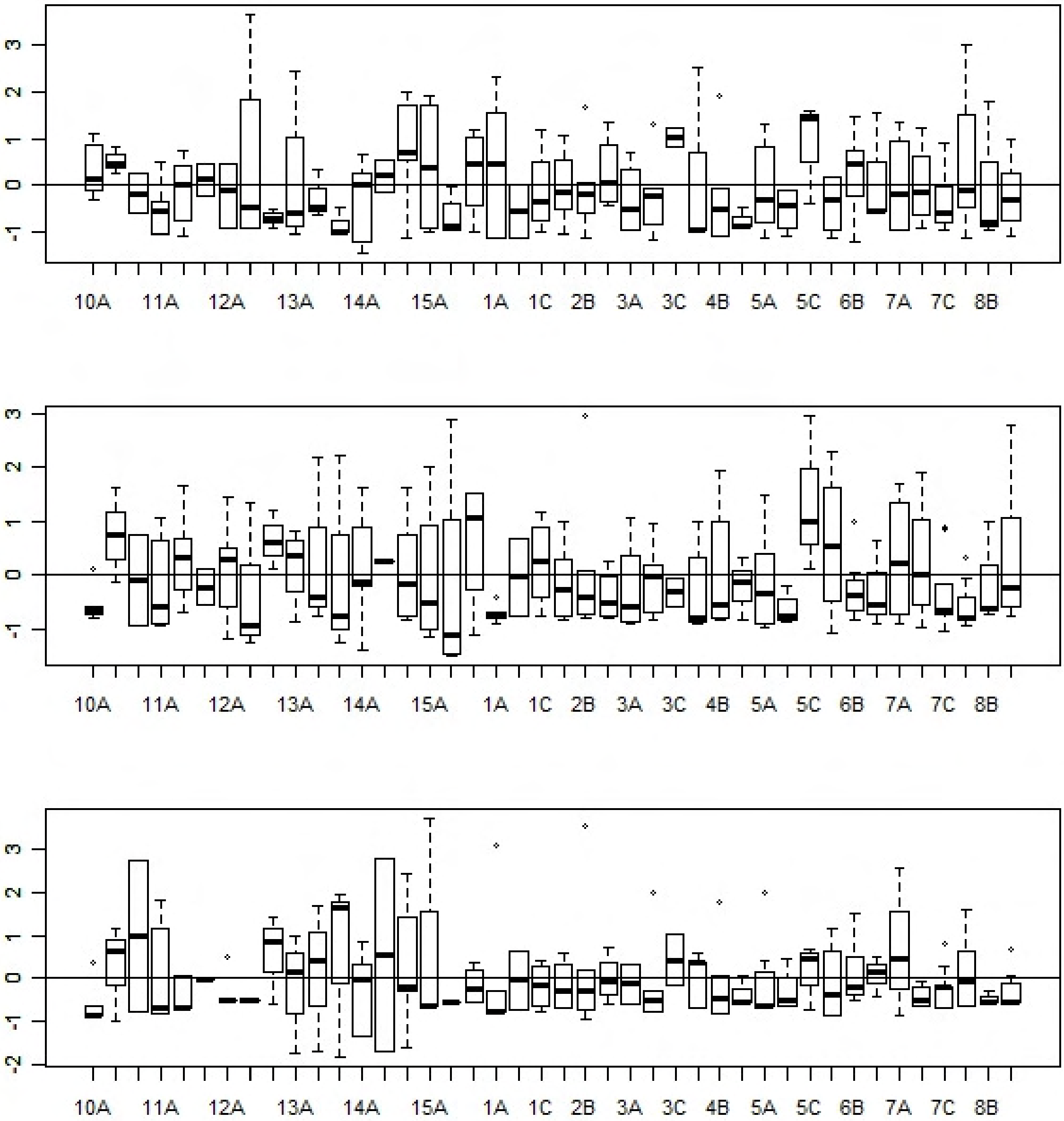


Figure 4.16 – Boxplot of Pearsons residuals from GLMM Oystercatcher (upper), Curlew (middle) and Redshank (lower) models against TSEC.

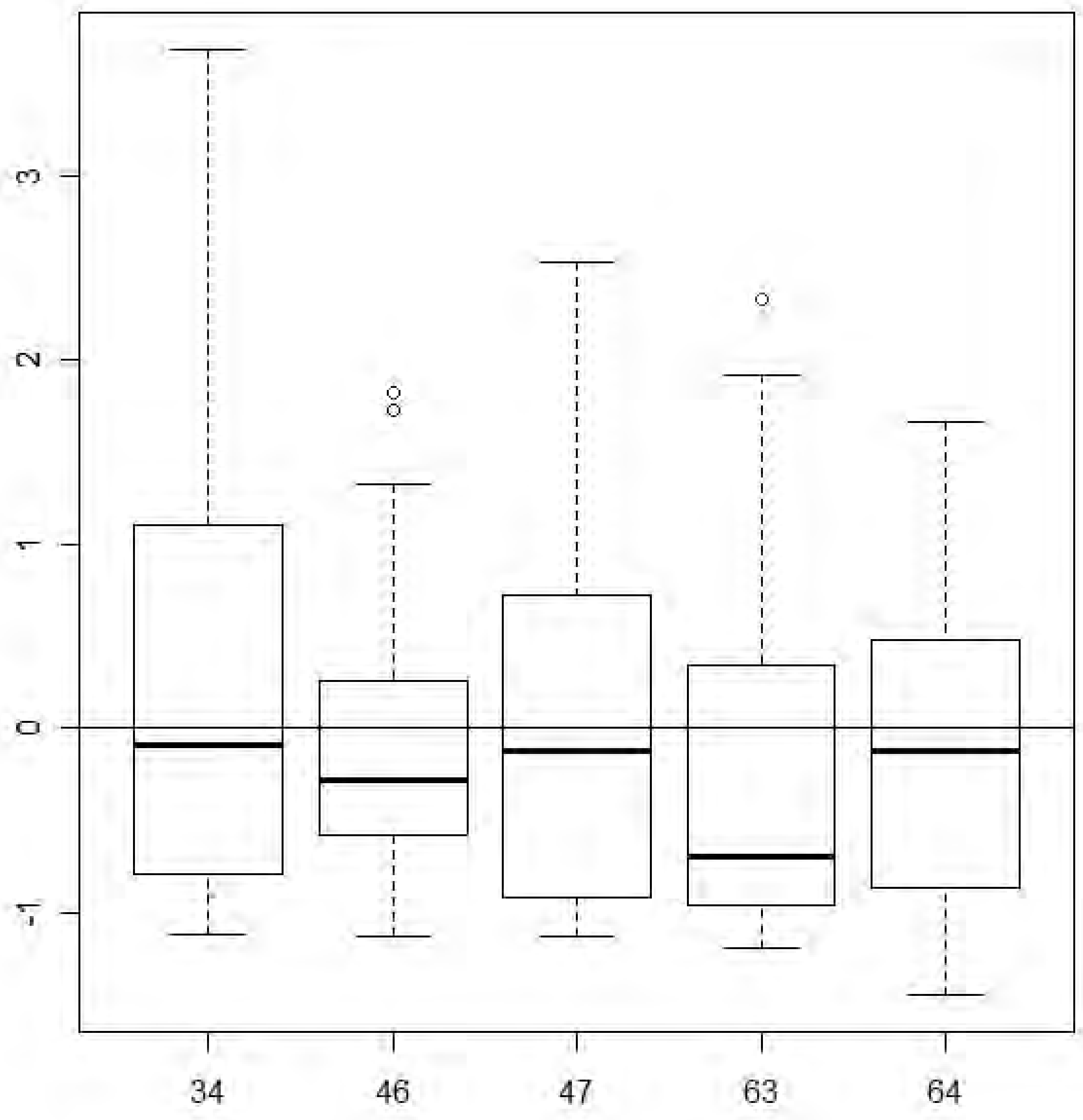


Figure 4.17 – Boxplot of Pearsons residuals from the GLMM Oystercatcher model against DAY.

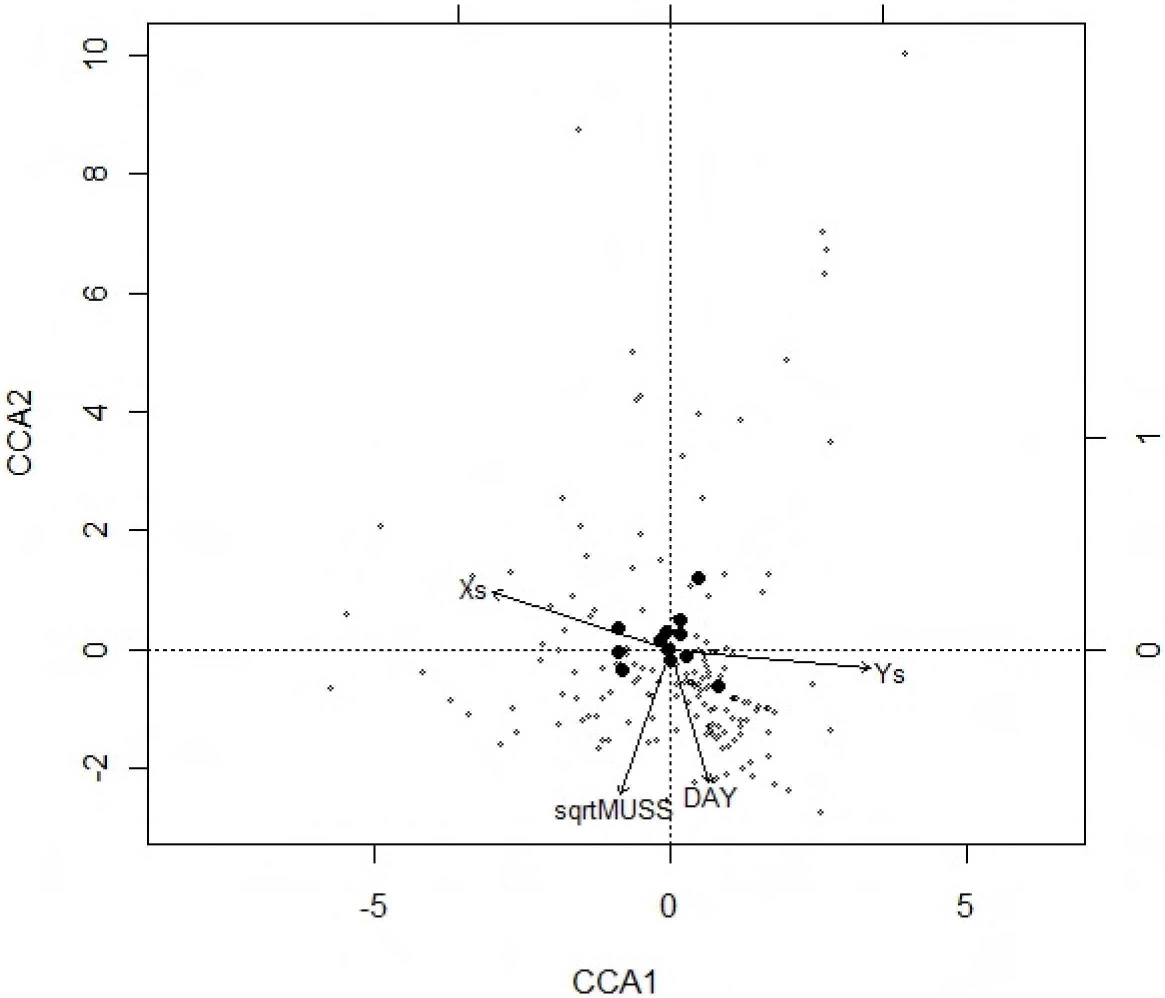


Figure 4.18 – CCA triplot of waterbird species assemblages recorded on the transect counts with counts shown as small open circles and species shown as large solid circles.

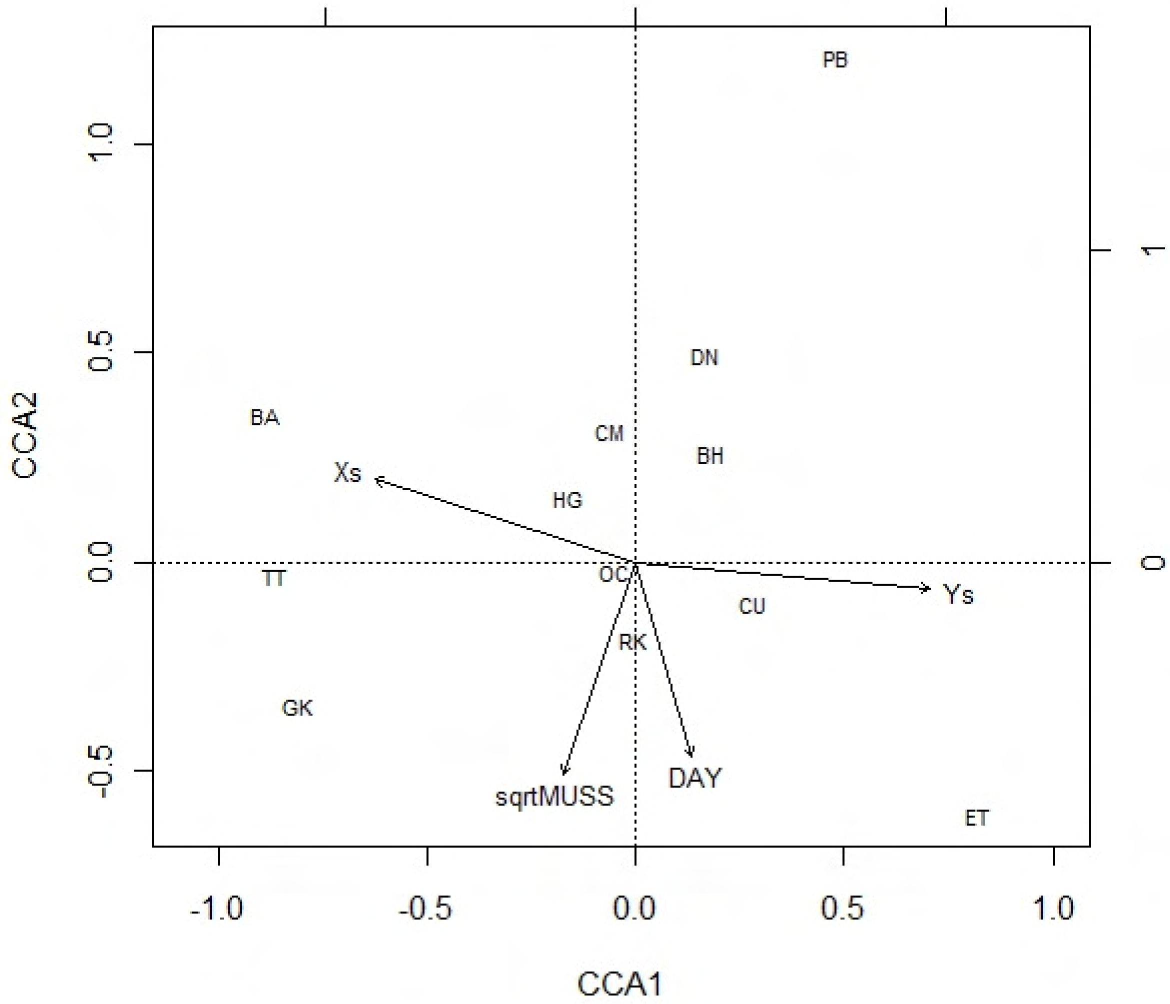


Figure 4.19 – CCA biplot showing the ordination of waterbird species recorded on the transect counts in relation to the environmental variables.

5. Disturbance

Methods

5.1 Disturbance recording was carried out during the transect counts on 3th February, 14th February, 15th February, 4th March and 5th March 2010. The disturbance recording took place throughout the count period, including any gaps between counts, and was not limited to events that took place during individual counts.

5.2 Each counter was instructed to record all human activity within 200 m of the transects that they were counting and any other factors (birds of prey, or human activity more than 200 m from the transects) that caused disturbance to the birds in the transects being counted. However, one counter did not submit any disturbance information

5.3 Counters recorded disturbance activities and impacts directly onto standardised disturbance maps and forms (see Appendix D) in the field. The recording of disturbance activities and impacts followed a logical sequence:

- The spatial extent of the relevant activities was recorded onto the disturbance map and each activity assigned a unique event reference.
- Details of the timing and nature of the activity was recorded on the disturbance activity form and cross-referenced to the disturbance map by the event reference.
- If the activity caused impacts to birds, then details of the impact was recorded on the disturbance impact form and cross-referenced to the disturbance map and disturbance activity form by the event reference. In addition, the time of the impact was recorded, allowing cross-reference to the relevant count, if applicable.

5.4 Because the recording of disturbance activities and impacts extended for up to 200 m outside the transects being counted, there was some duplication in the recording of disturbance activities and impacts. During data processing, we screened the data to identify duplication. Where duplication occurred, the data from the counter that was closer to the event being recorded was used. We did not identify any major discrepancies in the recording of disturbance activities and impacts where duplication occurred.

5.5 During data processing, we classified activities as mussel-related if either the observer had indicated this in the information that they had recorded, or if the description of the activity indicated that it was mussel-related. The latter involved cases where people were recorded arriving by boat and walking around a section of the mussel nursery area without engaging in any distinct activity such as winkle picking. We considered this behaviour to be seed mussel inspections.

5.6 As discussed above, one counter did not record any disturbance information. The disturbance information recorded by the counters covering the adjacent transect groups on each survey day indicates that disturbance activities occurred in the transect groups covered by this counter on at least some of the count days. However, because of the overlap in areas covered by the various counters, the actual area not covered by any of the other four counters on any of the days was small. In some cases we have interpolated disturbance information from the counters covering the adjacent transect groups to fill in gaps due to the counter who did not record disturbance information.

5.7 In some cases counters recorded alert or flight response distances as a range (e.g., 50-100 m) or as a minimum (e.g., 100+ m). In such cases, for calculation of means we used the midpoint of the range or the minimum value.

5.8 Data analysis methods are described in the relevant sections of the results.

Results

Disturbance activities and impacts

5.9 Between one and four disturbance events were recorded on the five transect count days (Table 5.1). The spatial distribution and extent of the disturbance activities on each count day are shown in Figure 5.1-Figure 5.5.

Table 5.1 – Potential disturbance events recorded during transect counts.

Date	Event	Activity	Humans	Dogs	Duration	Impact
03-Feb	1	Winkle picking	3		02:59	No
03-Feb	2	Working on lower shore cages (mussel-related)	3		03:30	No
15-Feb	1	Winkle picking	1	1	03:29	Yes
16-Feb	1	Winkle picking	4	1	03:20	Yes
16-Feb	2	Seaweed collection (mussel-related)	1	1	02:35	Yes
16-Feb	3	Forking mussels into boat	1		> 00:15	Yes
16-Feb	4	Working on lower shore cages (mussel-related)	4		04:00	?
04-Mar	1	Winkle picking	1		03:00	Yes
04-Mar	2	Working on lower shore cages (mussel-related)	2		02:39	Yes
04-Mar	3	Mussel inspection	1		00:15	Yes
05-Mar	1	Winkle picking	1	1	02:43	Yes
05-Mar	2	Hanging nets (mussel-related)	2		02:36	No
05-Mar	3	Walking along lower shore	1	1	?	Yes
05-Mar	4	Mussel inspection	1		00:39	Yes

5.10 A total of 14 incidences of disturbance causing detectable impacts to birds were recorded, out of which a flight response was recorded on 13 occasions (Table 5.2). Of the 14 disturbance incidences, 13 involved Oystercatchers, nine involved Curlew and seven involved Redshank, with single incidences affecting Light-bellied Brent, Dunlin, Bar-tailed Godwit, Herring Gull, Great Black-backed Gull and unidentified gulls.

Table 5.2 – Disturbance incidences recorded.

Date	Alert response		Flight response	
	Recorded	Not recorded	Flew	Did not fly
03-Feb	0	0	0	0
15-Feb	1	0	1	0
16-Feb	4	3	6	1
04-Mar	2	0	2	0
05-Mar	3	1	4	0

5.11 The frequency distribution of distances at which birds showed alert and flight responses are shown in Figure 5.6 and Figure 5.7.

5.12 The mean recorded distance at which birds showed an alert response was 125 m (s.d. = 48.6, n = 10). There were four incidents when the alert response was not recorded. On these four occasions, birds flew at a distance of 200-300 m in response to a dog that was running up and down the intertidal area and it is unlikely that the birds would have had time to show an alert response before they flew due to the rapid movement of the disturbance source. Therefore, we have calculated an adjusted mean alert response distance by using a value of 250 m as the alert response for these incidents. This gives a mean alert distance of 161 m (s.d. 71, n = 14).

5.13 The mean recorded distance at which birds showed a flight response was 79 m (s.d. = 68, n = 14). There was one incident when birds did not fly. On this occasion, the birds showed an alert response at a distance of 50-60 m. Therefore, we have calculated an adjusted mean flight response distance by using a value of 55 m as the flight response distance for this incident. This gives a mean flight distance of 78 m (s.d. 66, n = 15)[4].

5.14 38 of the 469 transect counts were considered by the counters to have been affected by disturbance (Table 5.3). On 18 of the 31 of these counts where it was recorded the distance from the last disturbance event was 100 m or less while on three of these counts the distance was 200 m or more.

5.15 On 27 of the 33 counts affected by disturbance where it was recorded, the time since the last disturbance event was 1 minute or less, while the maximum time since the last disturbance event after which a count was still considered to be affected by disturbance was 45 minutes.

[4] There was one incident when the species affected by the disturbance impact showed flight responses at different distances (CU at 100 m and GB at 50 m). This accounts for the difference in sample sizes between the adjusted alert response and flight response data.

Table 5.3 – Transect counts affected by disturbance

Distance from transect of last disturbance event	Number of incidences	Time since last disturbance event[1]
0 m	15	0 min (13), 15 min, NR
40 m	1	0 min
50 m	3	0 min (3)
50-150 m	2	0 min, 10 min
100 m	2	0 min, 20 min
150 m	4	0 min (3), 25 min
170 m	1	43 min
200 m	2	0 min (2)
250 m	1	0 min
NR	7	1 min (2), 45 min, NR (4)

NR = not recorded
[1] where multiple incidences of the same time value were recorded the number of incidents is given in parentheses

5.16 The recovery period recorded by counters following a disturbance event within 100 m of a transect varied from 7-45 minutes (Table 5.4). The recovery period recorded by the counters was constrained by the timing of the transect counts. Therefore, the actual recovery period will usually have been less than the recorded value.

Table 5.4 – Transect counts not affected by disturbance and with non-zero waterbird counts where the distance from the transect of the last disturbance event was 100 m or less and the time since the last disturbance event was 45 minutes or less.

Distance from transect of last disturbance event	Number of incidences	Time since last disturbance event
0 m	3	15 min, 20 min, 30 min
50 m	1	35 min
75 m	1	45 min
100 m	4	7 min, 15 min, 35 min, 45 min

5.17 On 4 and 5 March, a dredger was working in the channel close to the tideline below the nursery area. This dredger did not cause any detectable impacts to birds within the nursery area.

Potential disturbance impact from mussel-related activities

5.18 We have attempted to quantify the potential disturbance impact from mussel-related activities by applying buffers to the mapped activities representing the mean alert and flight response distances (161 and 78 m, respectively) and multiplying the area affected by the duration of the activity plus a recovery time. Therefore, we have quantified the potential disturbance impact as a value in hectare minutes (ha min) representing the habitat resource that was potentially affected.

5.19 The total number of disturbance incidences recorded during the transect counts was low and most affected more than one species at the same time. In these cases, the counters generally did not record disturbance responses separately for different species. Therefore, we did not consider that we had sufficient data to attempt to analyse individual species separately.

5.20 To quantify the relative disturbance effect, we divided the potential disturbance impact value by the total habitat resource available. We defined the latter as the total area surveyed (the area enclosed by a 200 m buffer of all the transects minus the area not covered by disturbance recording) multiplied by the total duration of the period during which the mussel nursery area is exposed. On each low tide, the mussel nursery area is fully exposed for around two hours. There are periods of approximately one hour either side of this when the tideline is moving through the mussel nursery area. Therefore, we used a value of 180 minutes for the total duration of the period during which the mussel nursery area is exposed.

5.21 Using the mean of the times in Table 5.3 or Table 5.4 for the recovery time would not necessarily be appropriate as these values are constrained by the timing of the transect counts and do not necessarily reflect the actual distribution of recovery times. However, Table 5.3 shows that in 25 of the 27 counts affected by disturbance where it was recorded the time since the last disturbance event was 25 minutes or less, while the mean of the recorded recovery periods in Table 5.4 is 27 minutes (s.d. 14, n = 9). Therefore, a value of 30 minutes seems to be reasonable as a typical recovery period duration.

5.22 Because the humans and dogs that were responsible for disturbance activities moved around during the duration of the activity, we applied buffers to each location that they visited in sequence. We calculated the duration of potential impact in areas of overlap between buffers by taking the earliest start time and the latest end time. If the start time of the later buffer was more than 30 minutes after the end time of the earlier buffer, we retained separate buffers in the area of overlap.

5.23 Where the end time plus 30 minutes exceeded the end time of the observation period, we used the end time of the observation period to calculate the duration of potential impact. On each day, the observation period ended when the tide had covered the mussel nursery area, so disturbance activities could not have had any impact on waterbirds using intertidal habitat after this time.

5.24 Mussel-related disturbance activities occurred on four out of the five survey days. The potential disturbance effect from these activities affected between 7-11% of the habitat resource (mean 6.8%, s.d. 4.1), using the alert response distance, and 2-4% (mean 2.4, s.d. 1.5) using the flight response distance (Table 5.5).

Table 5.5 – Potential disturbance impact of mussel-related activities on the available habitat resource, where the habitat resource is measured as the product of the area of intertidal habitat available and the duration of its exposure.

Date	Area covered by disturbance recording	Habitat resource potentially affected:	
		Alert response	Flight response
03-Feb	212 ha	2533 ha min (7%)	779 ha min (2%)
15-Feb	184 ha	0	0
16-Feb	187 ha	3566 ha min (11%)	1098 ha min (3%)
04-Mar	209 ha	2487 ha min (7%)	992 ha min (3%)
05-Mar	203 ha	3272 ha min (9%)	1384 ha min (4%)

5.25 The potential disturbance effects in Table 5.5 will be overestimates of the actual disturbance impacts for a number of reasons:

1. The buffer areas used to calculate these effects will include some areas that are covered by the tide for at least part of the duration of the potential disturbance effect. This would mainly involve the periods at the start/finish of the disturbance activity when the tideline is within the alert/flight response distance of the activity. This would typically amount to around 25% of the duration of activities that lasted the duration of the low tide period. However, this factor would not be so relevant to seed mussel inspections, as these are of short duration and typically occur during the middle of the low tide period.

2. Waterbirds mainly use the mussel nursery area while the tideline is moving through it. Very few waterbirds use the mussel nursery area when the tideline is below it. Therefore, much of the duration of the potential disturbance effects (probably at least 50%) will have covered periods during which waterbirds are unlikely to have used the areas affected even if there had not been any disturbance activities.

3. Disturbance activities were recorded on days with spring low tides and with good weather conditions. Inspections of the seed mussel typically take place during spring low tides (Marine Institute Fisheries Science Services, 2009) so less activity is likely to take place during neap low tides. It is also likely that less activity will take place on days with poor weather conditions, particularly when strong northerly winds prevent boat access from Cromane.

4. During low tide periods that occur at night there will presumably not be any disturbance impacts. Nocturnal feeding is known to be important for both Curlew and Redshank (Cramp & Simmons, 2004) and Curlew habitually feed at night on intertidal habitat in Cork Harbour (T. Gittings, pers. obs.).

5.26 For the above reasons, we consider it likely that the actual mean disturbance impact per low tide period would be much lower than the potential disturbance effect values in Table 5.5. The factors listed in 1 and 2 above, would probably reduce the disturbance impact by around 50-75% and the factors listed in 3 and 4 above would further reduce the disturbance impact, depending on weather conditions and species behaviour.

5.27 There is possibility that, by chance, our count days coincided with days of unusually low activity. However, Atkins personnel were on site on the mussel nursery area for the full duration of low tide periods on another 11 days during January-April 2010 installing stakes to mark transect boundaries and carrying out mussel surveys and we consider that the overall level of activity during the count days was not atypical.

Comparisons with scientific literature

5.28 There is a large scientific literature on the effects of disturbance on waterbirds. However, a general theme in this literature is that responses to disturbance are site-specific and results from one site usually cannot be used to predict the effects at another site. Therefore, data on response to disturbance from other sites has to be interpreted with caution.

5.29 The method that we used to quantify the potential impact of disturbance by mapping buffers based on alert and flight distances around disturbance sources is similar to that used by Dias *et al.* (2008) to quantify the effect of disturbance by traditional clam fishers in the Tagus Estuary, Portugal. However, they used flight distances derived from the literature, rather than empirically-derived site-specific alert and flight distances as in our study. The flight distances that they used ranged from 26 m for Sanderling to 107 m for Bar-tailed Godwit (compared to 78 m in our study). The percentage of habitat potentially affected by disturbance in their study ranged from 0.6% (Kentish Plover) to 4.2% (Black-tailed Godwit).

5.30 Navedo and Masero (2007) studied the effects of hand-harvesting of shellfish on Curlew foraging behaviour in the Santona Marshes Nature Reserve, Spain. They found that a density of 0.56 person per 10 ha significantly reduced foraging activity, but concluded that because there were no significant differences in other foraging variables between days with and without harvesting, Curlews were able to compensate for this impact. The area covered by the disturbance recording in our study varied from 184-212 ha and the number of mussel workers recorded each day varied from 0-6 (mean 3.0, s.d. 3.1, n = 5). Therefore, the level of mussel-related activity that we recorded (maximum of 0.32 person per 10 ha) was below the 0.56 person per 10 ha activity level in Navedo and Masero (2007)'s study

5.31 An issue with the literature on disturbance is that many of the studies simply report the behavioural response of birds to disturbance (e.g., the flight distance) without assessing the overall impact of the disturbance factor on the capacity of the site to maintain the species population. Some of the few studies that do the latter include:

- Gill *et al*. (2001a) related prey depletion to human disturbance across a range of spatial scales and found no evidence that disturbance was limiting the number of Black-tailed Godwits supported by the food supply in coastal areas in eastern England.

- West *et al*. (2002) used an individual-based behavioural model to determine the effect of disturbance on the mortality rates and equilibrium population size of Oystercatchers in the Exe Estuary, England. They looked at a range of scenarios, but found that the simulation best approximating the existing disturbance level (10% of the feeding area disturbed by major disturbers on spring tides in daylight) showed no increase in mortality rate.

- Goss-Custard *et al*. (2006) used an individual-based behavioural model to determine that Oystercatchers in the Baie de Somme, France could be put to flight by disturbance up to 1.0-1.5 times/daylight hour before their fitness was reduced, although this threshold was reduced to 0.2-0.5 times/daylight hour when feeding conditions were poor.

- In separate individual-based behavioural model analyses at the same site, Durell *et al*. (2008) found threshold disturbance levels of one disturbance event per hour (Oystercatcher) and six per hour (Curlew). Dunlin survival was not affected by disturbance.

5.32 In the Gill *et al*. (2001a) study, a wide range of disturbance levels were included. Among the highest were footpaths along estuaries with usage rates of > 20 people h^{-1} and with the response measured adjacent to the footpath (closest sample < 20 m). This would represent a much higher level of potential disturbance than that we recorded at Castlemaine.

5.33 To compare our results with the West *et al*. (2002) study, we need to convert our estimates of areas affected by disturbances to percentages of the available habitat in the entire site. Oystercatchers fed in 19 count sectors during the NPWS Baseline Waterbird Survey low tide counts. However, the five sectors with the highest mean percentages of feeding Oystercatchers supported a mean of 66% of the total number of feeding Oystercatchers. Therefore, we used the intertidal habitat (from the NPWS habitat map) in these five sectors (but excluding the seagrass habitat, which Oystercatchers rarely used) to calculate the available habitat. This gives a total of 1001 ha. The area covered by the disturbance recording in our study varied from 184-212 ha, which is, therefore, around one-fifth of the total amount of available habitat in Castlemaine Harbour. Therefore, our estimates of the percentage of the habitat resource affected by mussel-related disturbance should be divided by five to give an estimate of the percentage of the available habitat in Castlemaine Harbour affected, giving 1.4%, using the alert response distance, and 0.5% using the flight response distance. The mussel-related disturbance would be classified as major disturbance by the criteria of West *et al*. (2002) and is largely restricted to spring tides. Therefore, the disturbance levels in our study were smaller by a factor of 10 than the disturbance levels that West *et al*. (2002) found not to affect Oystercatcher mortality rates.

5.34 The disturbance rates in the Baie de Somme studies can be compared with the disturbance rates that we recorded. To make this comparison, we have used the non-zero sector counts as the sample. Each sector count lasted a nominal duration of five minutes (i.e., the count could be continued longer than five minutes if required to complete the count). Therefore, the survey duration in minutes can be calculated as the number of non-zero sector counts multiplied by five.

To calculate the flight response events/hour, we only included events resulting from mussel-related activities that occurred during transect counts (surveyors also recorded events that occurred outside transect counts). We have only included Oystercatcher, Curlew and Redshank in this analysis because the sample sizes (non-zero sector counts) for the other species are much smaller. The results (Table 5.6) show that the flight response event rates were well below the threshold levels determined in the Baie de Somme studies, apart from the threshold level for Oystercatchers when feeding conditions are poor.

Table 5.6 – Flight response events/hour for disturbances caused by mussel-related activities at Castlemaine Harbour.

	Non-zero sector counts	Total survey duration	Number of flight response events	Flight response events/hour
Oystercatcher	166	13.83 hours	4	0.29
Curlew	147	12.25 hours	3	0.20
Redshank	119	9.92 hours	4	0.34

Discussion

5.35 The potential impact of disturbance on waterbird populations includes two components: the effective loss of habitat due to displacement of birds from the disturbed area; and/or the energetic costs incurred by birds either through moving from the disturbed area or, for birds that remain, from increased stress or reduced food intake.

5.36 The above assessment of potential disturbance impacts is based mainly on the potential for disturbance to cause behavioural responses. The flight response distance indicates the effective habitat loss due to displacement of birds from the disturbed area. The alert response distance indicates the minimum area within which birds that remain in the affected area may suffer energetic costs. However, where there is limited availability of alternative habitat, or where the energetic costs of moving to alternative habitat is high, disturbance may not cause a behavioural response (such as an alert response), but may still have population-level consequences (e.g., through increased stress, or reduced food intake, leading to reduced fitness) (Gill *et al*., 2001b). However, assessing these types of potential impacts would require detailed population modelling, which would require a major research effort that is beyond the scope of the present study.

5.37 Species may vary in their response to disturbance. However, the total number of disturbance incidences recorded during the transect counts was low and most affected more than one species at the same time. In these cases, the counters generally did not record disturbance responses separately for different species. Therefore, we did not consider that we had sufficient data to attempt to analyse individual species separately.

5.38 In general, the magnitude of the behavioural response to disturbance is positively correlated with body size (Laursen *et al*., 2005). In a study in the Wadden Sea, Curlew was the wader species with the largest flight distances (Laursen *et al*., 2005), and had a flight distance 2-4 times greater than the other species included in that study (including Oystercatcher, Dunlin, Bar-tailed Godwit and Redshank). In our study, the mean alert distance for disturbance impacts including Curlew was 122 m (S.D. = 48, n = 7) and the mean flight distance was 91 m (S.D. = 70, n = 8), compared to the overall values of 161 m (alert distance) and 78 m (flight distance) used in the above assessment. Therefore, the limited data that we have does not indicate that that our assessment underestimated the potential disturbance impact on particularly sensitive (in terms of behavioural response) species.

5.39 Species may be particularly sensitive to disturbance during periods of cold weather, or in late winter when food resources are low, because they will have limited capacity to absorb any energetic costs due to disturbance. However, the argument in Gill *et al.* (2001b) suggests that, in these circumstances, the magnitude of the behavioural response may be lower. Therefore, observational data on species behavioural response would be unlikely to demonstrate the consequences of any such increased sensitivity to disturbance. Instead detailed population modelling would be required to investigate this issue.

Conclusions

5.40 Mussel-related disturbance activities occurred on four out of the five survey days and affected a mean of 6.8% of the habitat resource, using the alert response distance, and 2.4% using the flight response distance.

5.41 These potential disturbance effects are overestimates of the actual disturbance impacts for a number of reasons. We consider that the actual mean disturbance impact per low tide period would be reduced by at least 50-75%, and probably lower than even the lower end of that range.

5.42 Comparisons with relevant studies in the scientific literature show that these levels of disturbance intensity and impact are generally much lower than levels reported to affect survivorship.

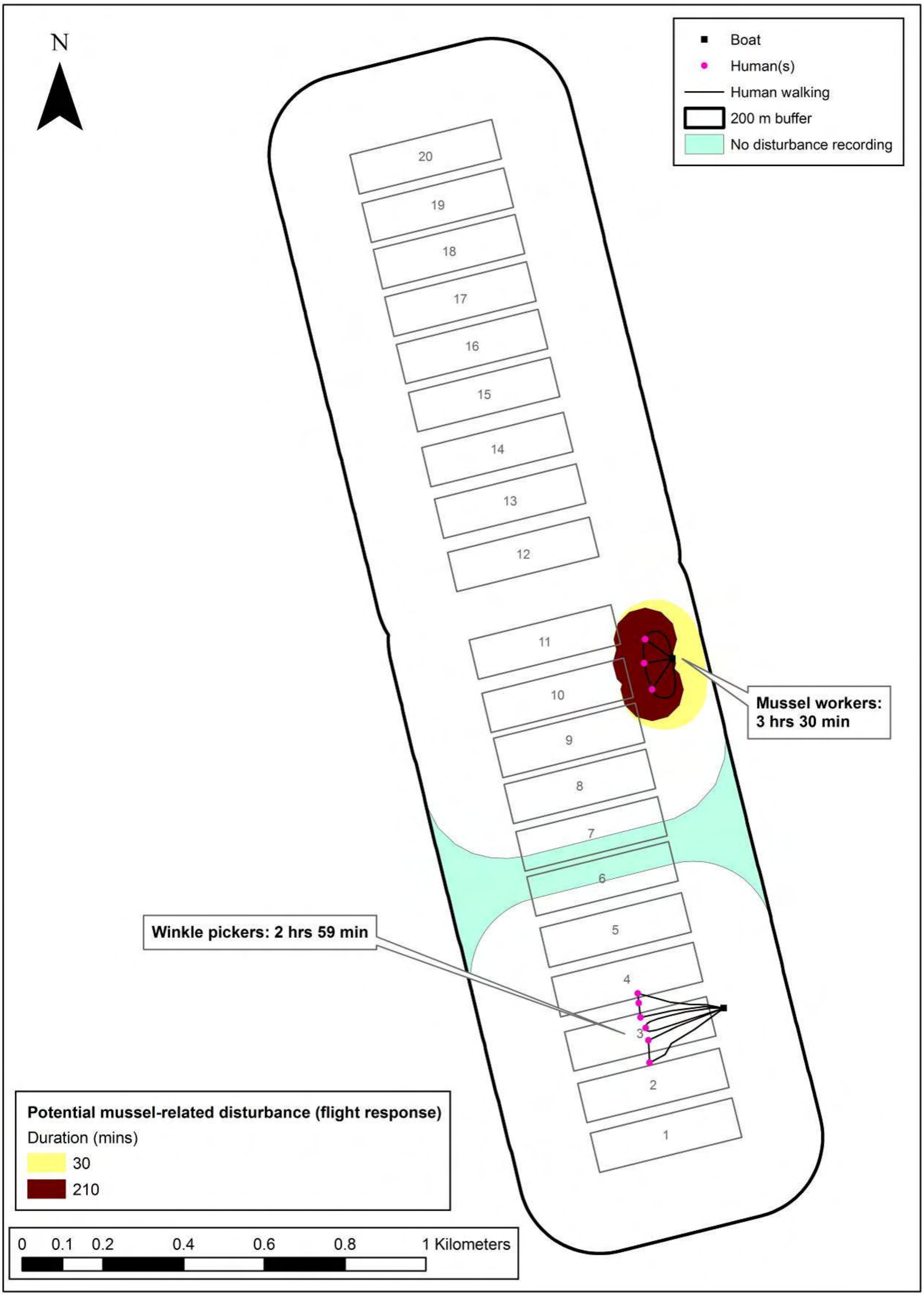


Figure 5.1 – Disturbance activities recorded on 3rd February 2010.

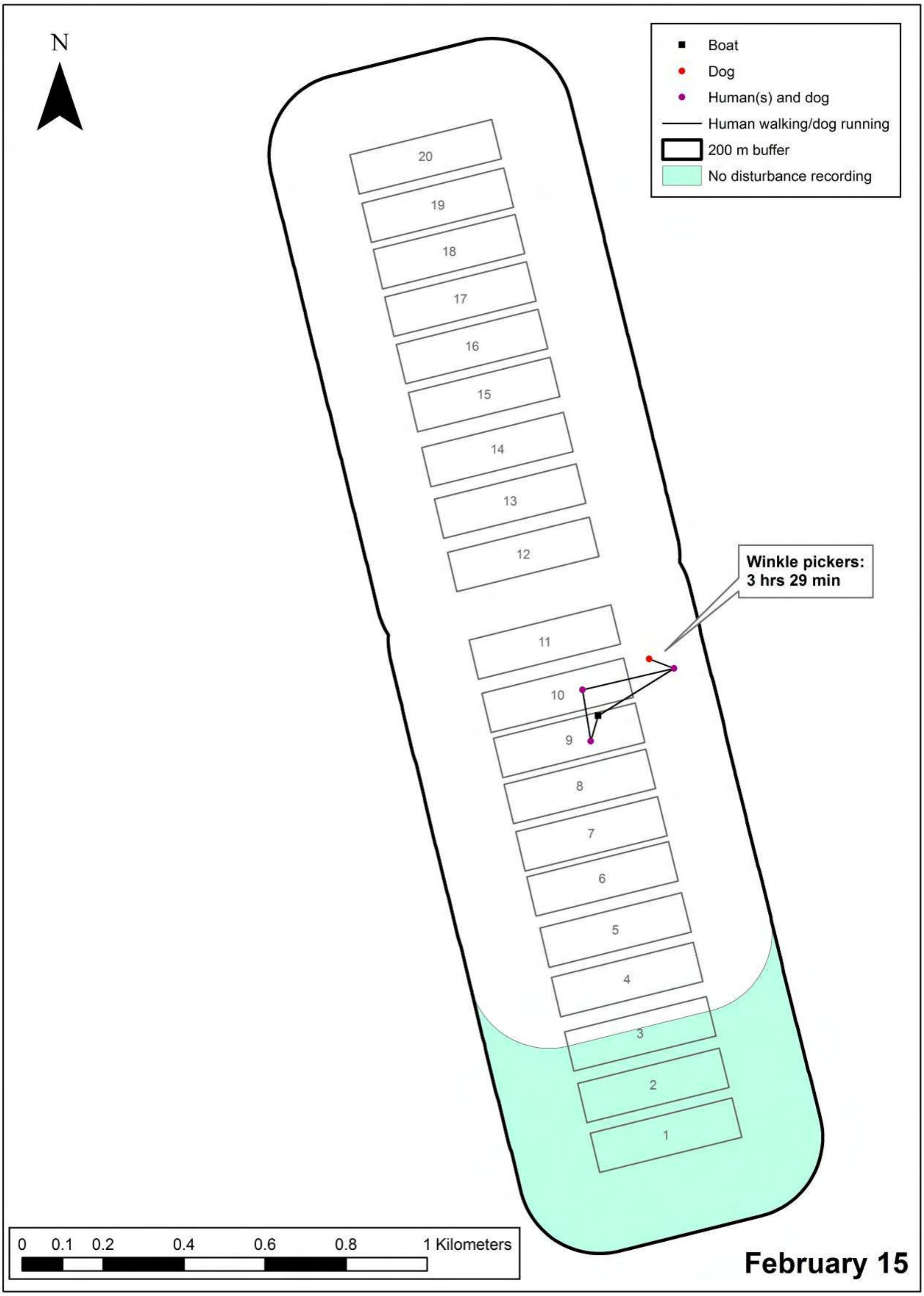


Figure 5.2 – Disturbance activities recorded on 15th February 2010.

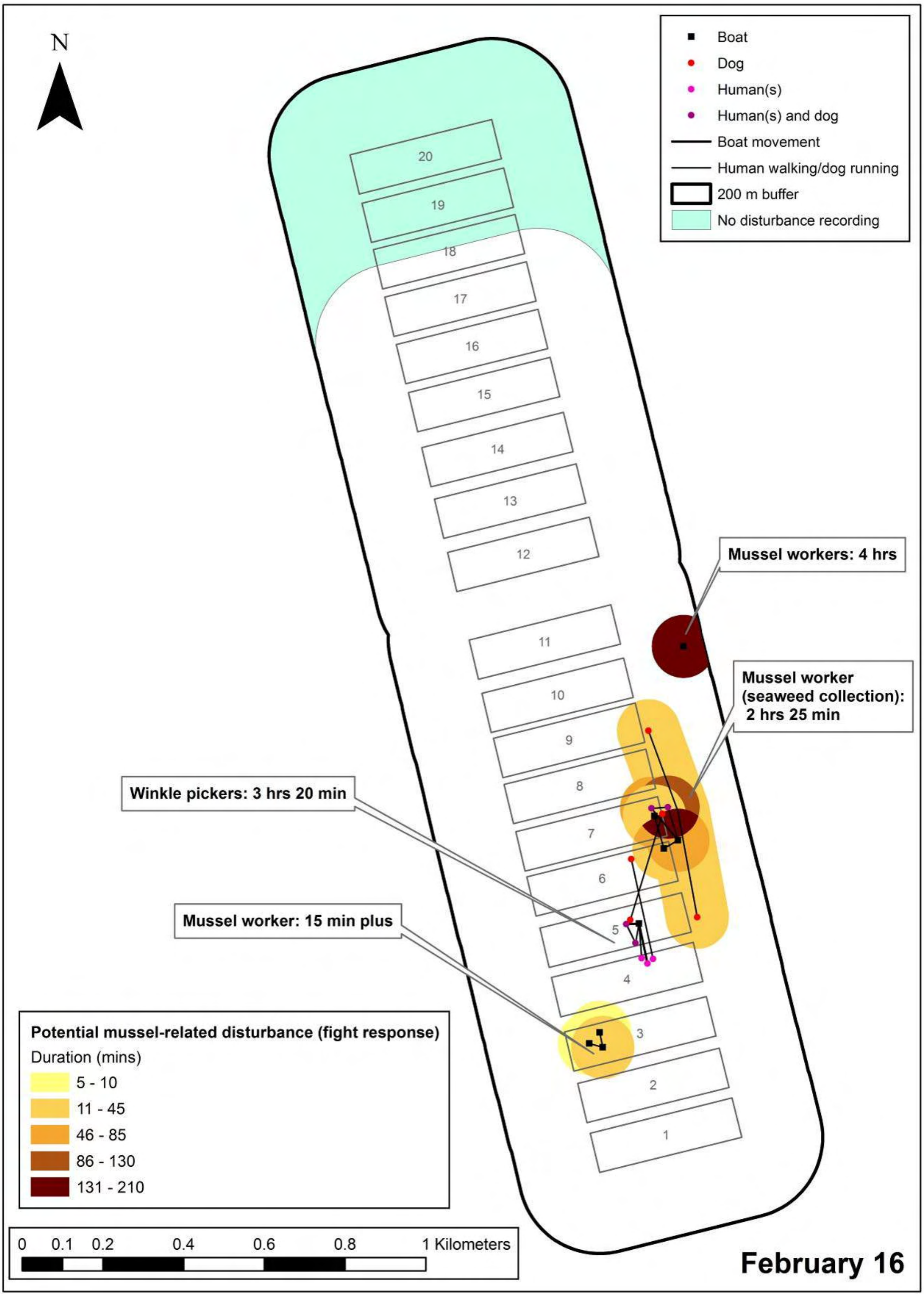


Figure 5.3 – Disturbance activities recorded on 16th February 2010.

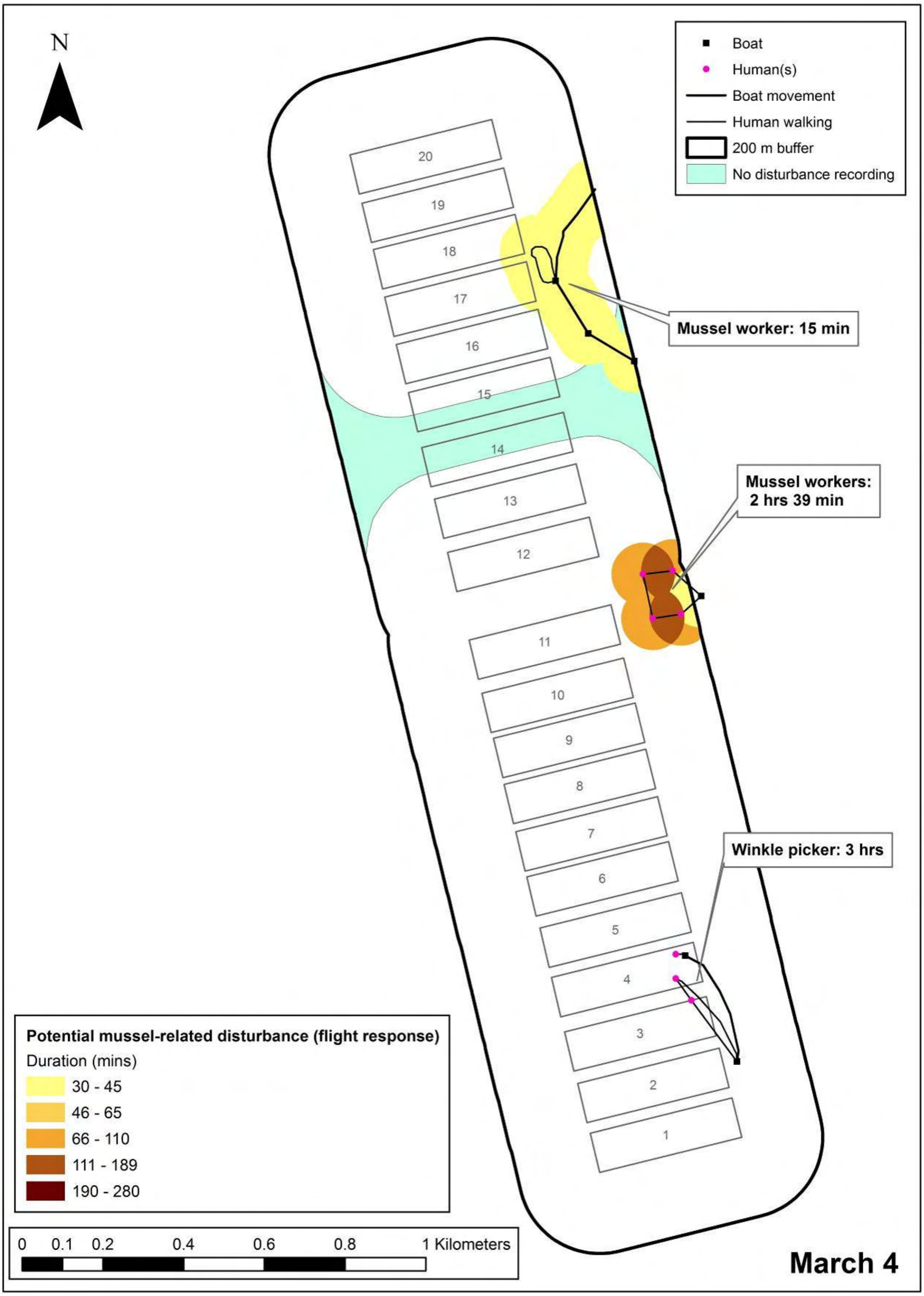


Figure 5.4 – Disturbance activities recorded on 4th March 2010.

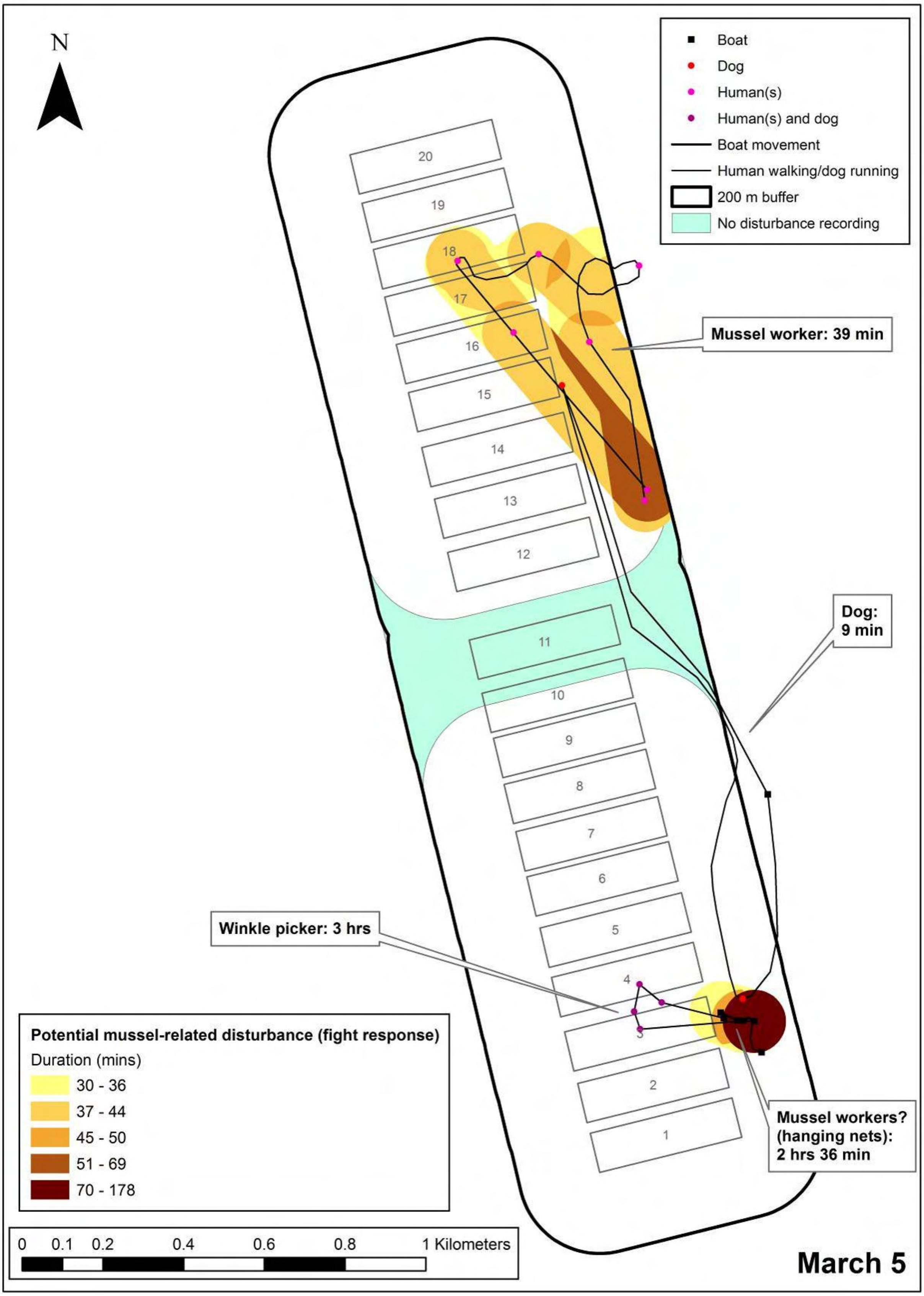


Figure 5.5 – Disturbance activities recorded on 5th March 2010.

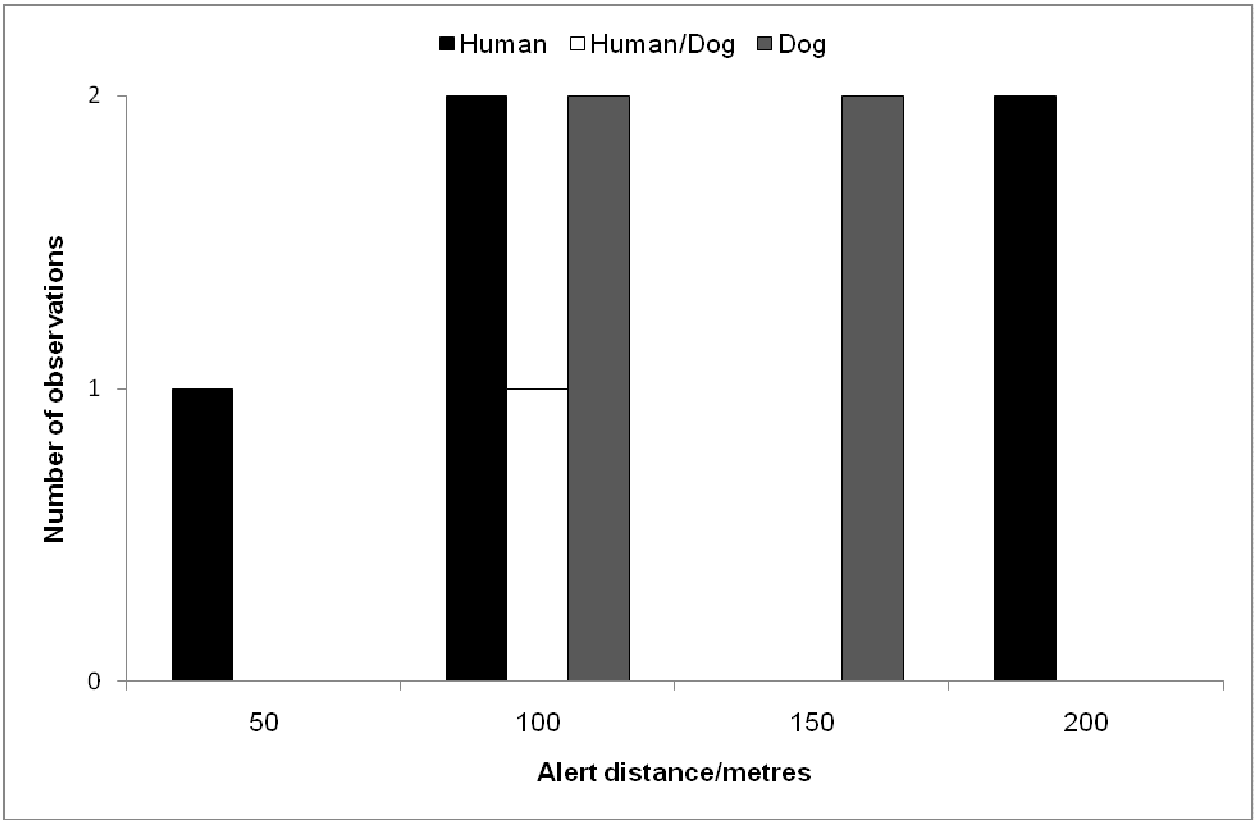


Figure 5.6 – Alert distances recorded during observed disturbance incidents.

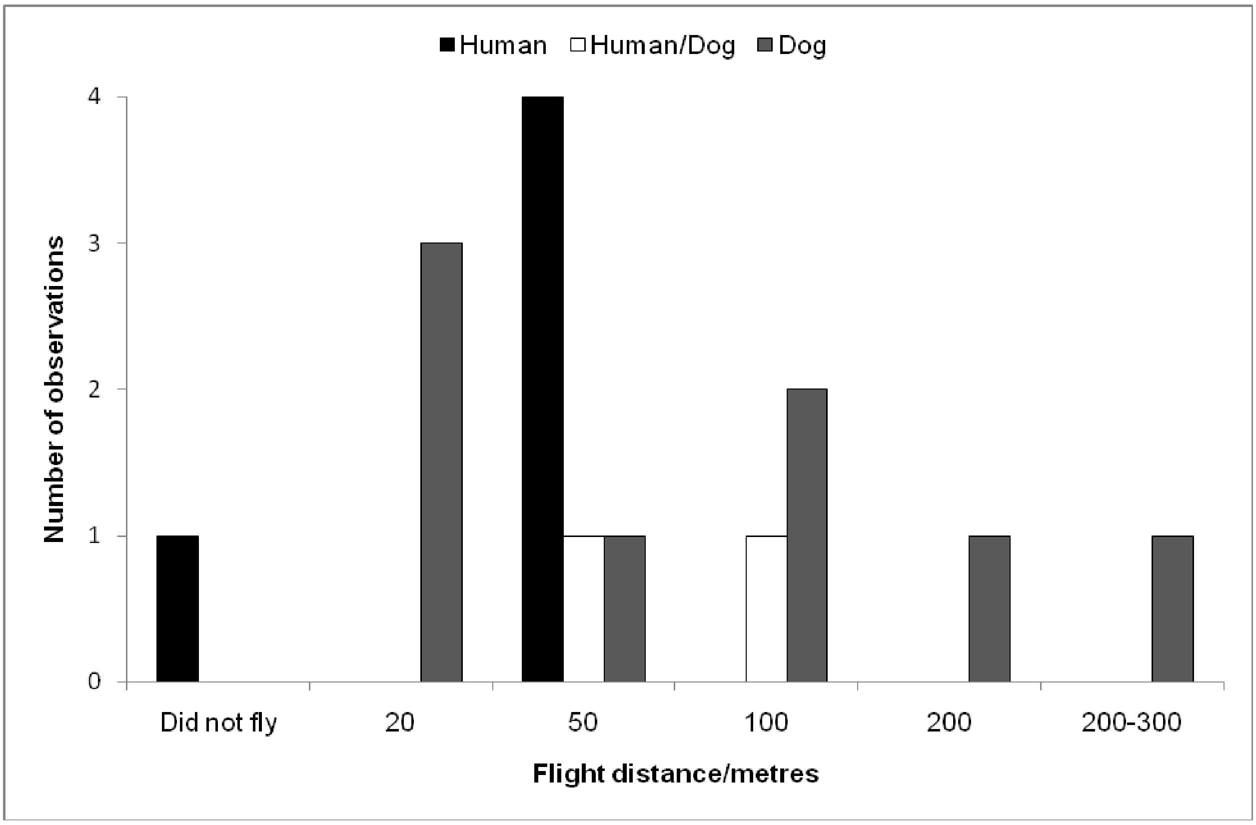


Figure 5.7 – Flight distances recorded during observed disturbance incidents.

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 2010					15-Feb 2010					
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											
13A	1							1			
13B											
13C				1					1		

Sector	03-Feb 2010					15-Feb 2010					
	1	2	3	4	5	1	2	3	4	5	6
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 2010						04-Mar 2010			
	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			
10B				1						
10C										1
11A		1								
11B				1	1		1			1
11C										
12A				1				1		1

Sector	16-Feb 2010						04-Mar 2010			
	1	2	3	4	5	6	1	2	4	5
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 2010					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
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

Sector	05-Mar 2010					Overall total
	1	2	4	5	6	
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	120 m – 240 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:

Appendix D - Instructions given to counters for disturbance recording.

D.1 Disturbance map

Instructions for completing the disturbance map

D.1.1 Use a single disturbance map for each count day, unless the map becomes too cluttered.

D.1.2 The disturbance map shows the location of the transects and of the tall wooden posts that mark the boundaries and subdivisions of the mussel beds.

D.1.3 Record all human activities within 200 m of the transects that you are surveying on this map.

D.1.4 Record other factors (birds of prey, or human activity more than 200 m from the transects) that cause disturbance to the birds in the transects being counted.

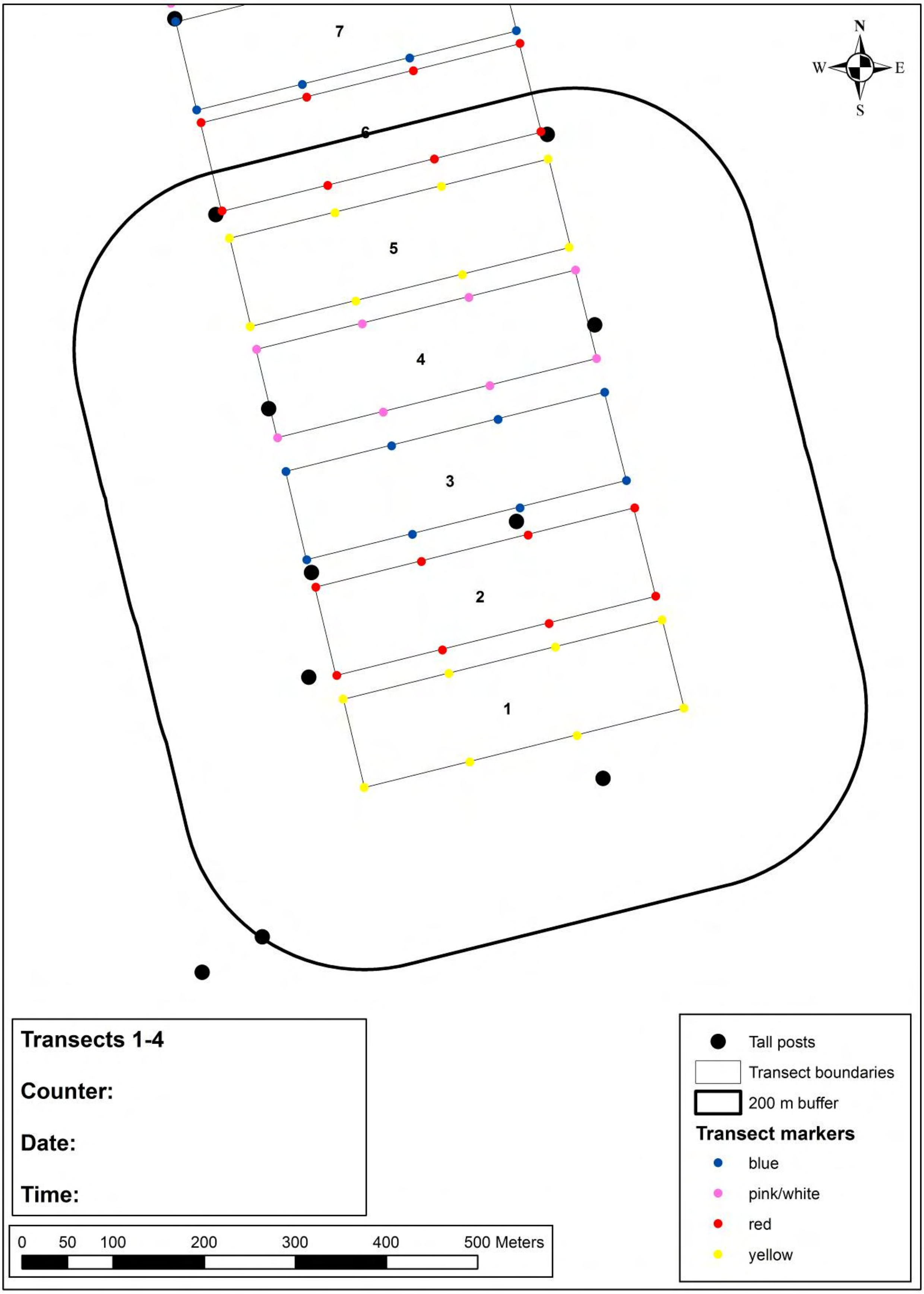
D.1.5 Use the following symbols to record the activities:

Symbol	Activity
10 □	Location of boat moored on, or close to, shoreline, with number of minutes spent at this location by people.
----------	Path of human walking across intertidal area
5 ----X----	Location where human stopped, with number of minutes spent at this location.
*	Other activity

D.1.6 Each activity should be assigned a unique sequential event reference (alphabetical letter), which cross-references to the disturbance activity form.

Disturbance map

D.1.7 An example of the disturbance map used for transects 1-4 is shown on the next page. Similar maps were used for the other transect groups.


7
6
5
4
3
2
1
N
W
E
S
Transects 1-4
Counter:
Date:
Time:
0 50 100 200 300 400 500 Meters
Tall posts
Transect boundaries
200 m buffer
Transect markers
blue
pink/white
red
yellow

D.2 Instructions for completing the disturbance activity form

D.2.1 Use a single disturbance impact form for each count day, unless additional forms are required because of the number of disturbance events.

D.2.2 **Counter:** enter counter name in this space.

D.2.3 **Date:** enter the date in the format dd/mm/yy.

D.2.4 **Transects:** enter the transect numbers in this space. Transect numbers are shown on the map of the plot locations.

D.2.5 **Time:** enter the start and finish time of the entire observation period (i.e., from the first count to the last count) in the format hh:mm-hh:mm.

D.2.6 **Disturbance events:** record details of all disturbance events marked on the disturbance map.

- **Event reference:** enter the unique sequential event reference that corresponds to the recording of the event on the disturbance map.
- **Start time** and **End time:** record the times in the format hh:mm. The times refer to the period when the activity occurred within 200 m of the transect.
- **Number of people:** record the number of people involved in the activity. If a group of people split up while they are in your recording area, record the activity of individuals following the splitting of the group as separate events.
- **Impact:** record whether the activity had any impact on birds (yes/no). If yes, then record details of the impact on the disturbance impact form.
- **Description of activity:** describe the nature of the activity and its pattern (see examples in sample completed form).

D.3 Instructions for completing the disturbance impact form

D.3.1 Use a single disturbance impact form for each count day, unless additional forms are required because of the number of disturbance impacts.

D.3.2 **Counter:** enter counter name in this space.

D.3.3 **Date:** enter the date in the format dd/mm/yy.

D.3.4 **Transect numbers:** enter the transect numbers in this space. Transect numbers are shown on the map of the plot locations.

D.3.5 **Time:** enter the start and finish time of the entire observation period (i.e., from the first count to the last count) in the format hh:mm-hh:mm.

D.3.6 **Disturbance impacts:** enter details of all the disturbance impacts recorded on the disturbance activity form. A single disturbance event may have multiple impacts and would then require multiple entries on this form.

- **Time:** record the time of the impact in the format hh:mm. The time refers to when the impact on birds occurred, not when the activity started.

- **Transect/sector:** record the transect number and sector where the birds were when impacted: e.g., 3C would indicate that the birds were in transect 3, sector C.

- **Count?:** record whether the disturbance impact occurred during a count (yes/no).

- **Species:** record the bird species involved using the standard waterbird species codes. More than one species can be entered here if they all responded the same way. If two or more species are affected by the same disturbance event, but responded differently, details should be entered separately on this form.

- **Event reference:** enter the unique sequential event reference that corresponds to the recording of the event on the disturbance activity form.

- **Alert distance:** estimate the distance of the activity from the affected birds in metres at the point where the activity caused an alert response. If you did not observe this stage of the impact (e.g., you only noticed the impact when the birds flew) enter NR. If birds were under observation and flew without showing any alert response first, draw a diagonal line through the box.

- **Flight distance:** estimate the distance of the activity from the affected birds in metres at the point where the activity caused birds to fly. If you did not observe this stage of the impact enter NR. If birds were under observation and only showed an alert response, draw a diagonal line through the box.

- **Response of birds:** record the response of the birds as Alert (A) or Flew Off (F) and the numbers showing each response: e.g. 10A50F would indicate that ten birds showed an alert response and 50 birds flew off.

- **Notes:** record any other relevant details here, such as any unusual behaviour or any difficulties in categorising the impact.

Castlemaine aquaculture impact study: Disturbance activity form

Counter:	
Date:	
Transects:	
Time:	

Event reference	Start time	End time	Number of people	Impact	Description of activity

Castlemaine aquaculture impact study: Disturbance impact form

Counter:	
Date:	
Transects:	
Time:	

Time	Transect/ Sector	Count?	Species	Event reference	Alert distance	Flight distance	Response of birds	Notes

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