Testing the efficacy of Spiral Vibration Dampers™ to reduce bird collisions with overhead transmission wires at the Roberts Bank Superport in 1997

by

Alice L.E.V. Cassidy[1], Alan E. Burger[2] and Moira J.F. Lemon[3]

[1]Alice Cassidy's Birds in View Research and Education
301-2446 Point Grey Road
Vancouver B.C., V6K 1A2

[2]Alan Burger Environmental Science and Ornithology
5012 Old West Saanich Road
Victoria, B.C. V8X 3X1

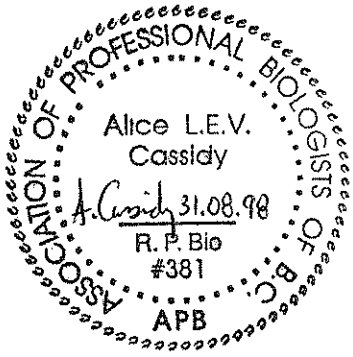
[3]Environment Canada, Canadian Wildlife Service
5421 Robertson Road,
Delta, B.C V4K 3N2

Report to:

Vancouver Port Corporation

British Columbia Hydro

August 1998



ABSTRACT

1. We studied bird activity at the Roberts Bank Superport from January through December 1997. In late 1996, Spiral Vibration Dampers™ were installed on selected sectors of the overhead wires. Our focus was to test the efficacy of these dampers to reduce mortality of birds colliding with the wires. Eight test sectors, arranged in pairs, each pair with one Flanking and one Control sector on either side of the Damper sector, were arranged in the experimental area (Sectors 3-26), where the highest crossing rates were observed in the 1994/95 study. Each test sector included ten yellow PVC dampers placed on the upper conductor wire, with approximately 3.3 m spacing between the 2 m-long dampers.

2. Weekly censuses were made from Brunswick Point to the start of the causeway and on both sides of the causeway out to 500 m from shore. A weekly average of 12,259 birds was counted, with the higher densities occurring from October through April. Dabbling ducks, Dunlin and Western Sandpiper made up the majority of birds counted. There were generally fewer birds present in 1997 than in 1994/95.

3. Observations of flight behaviour of birds while crossing the causeway were made year-round, and we recorded 5643 crossing events, totaling 46,875 birds. Our observation efforts focused primarily on the 24 sectors within the experimental area (Sectors 3-26), with 40-41 hours of observation per sector.

4. The dampers significantly reduced the number of abrupt or severe reactions, especially for shorebirds (marginal significance; $P=0.05$), raptors ($P<0.05$) and 'all birds combined' ($P<0.01$). These findings suggest that some birds were able to see the dampers and react earlier (eliciting mild reactions to the power line rather than abrupt or severe), possibly avoiding risk of collision.

5. In poor visibility conditions such as precipitation or foggy patches (that were not so severe that they obscured the observation area), shorebirds elicited significantly fewer abrupt or severe reactions when crossing Dampers than when crossing Controls

(marginal significance; P= 0.05), however there were no significant differences for other groupings of birds, or for 'all birds combined'.

6. In high wind conditions (Beaufort scale of 4 or more; >20 km/h), there were generally lower frequencies of abrupt or severe reactions at Damper sectors than at Controls; these differences were statistically significant for gulls ($P< 0.05$) and for 'all birds combined' ($P<0.01$).

7. For all weather and wind conditions combined, the dampers caused birds to cross the power lines higher in height above the upper wire and therefore at less risk of collision. These differences were statistically significant for shorebirds ($P<0.01$), gulls ($P<0.05$) and 'all birds combined' ($P<0.001$). However in poor visibility conditions, there were no significant differences in the proportions of any groupings of birds crossing within 2 m of the upper wire and those crossing more than 2 m above the wire between Damper sectors and Control sectors.

8. Most groupings of birds, including herons, waterfowl, gulls, Caspian Tern and raptors, crossed 3-9% higher in height, and hence at less risk of collision, at Damper sectors than at Control sectors. Shorebirds crossed 13% higher in height at Dampers than at Controls, indicating that the dampers may be especially helpful to Dunlin, Western Sandpipers and other shorebird species.

9. In high wind conditions, 'all birds combined' crossed the wires at a greater height at Damper sectors than at Controls (significant; $P<0.001$); this difference was not statistically significant for any specific grouping of birds.

10. We conducted systematic searches along the causeway at 7-day intervals year-round. These yielded 238 bird carcasses, of which 200 were considered to have been deposited during the study. As in 1994/95, the majority of fresh carcasses were waterfowl (55%), shorebirds (21%) and gulls (9%). Birds which had obvious injuries resulting from collisions included five grebes, two cormorants, one Great Blue Heron, one American Coot, 37 waterfowl, 36 shorebirds (including ten Western Sandpiper and 20 Dunlin), five gulls, one Belted Kingfisher, one Northern Flicker and 12 passerines.

11. The species distribution of carcasses reflected their flight paths. Carcasses of waterfowl were distributed along the causeway, often near poles, and, as in 1994/95, the majority of these birds were killed elsewhere and brought to the causeway by predators and scavengers. Raptors, especially Bald Eagles, Northern Harriers and Red-tailed Hawks, and other scavengers were present year-round and in all parts of the causeway.

12. Although differences are statistically non-significant and sample sizes are small, there is a weak trend of dampers reducing the risk of collision for all birds, and especially for shorebirds, based on findings of wire killed birds. Fewer Damper sectors (25%) had shorebird carcasses than Flanking (50%) and Controls (75%). Most shorebird carcasses found (88%) were a result of collisions with wires.

13. The study area has undergone major structural change (especially to the substrate in the carcass search area) and increased disturbance, since the 1994/95 study. To test our search efficiency and to estimate rates of disappearance of carcasses between searches under these new conditions, we conducted three replicate tests in one series in May for search efficiency and three series of tests (May, August and December) using approximately 20 carcasses placed randomly in the regular search area.

14. Search efficiency indices were 0.18 for Dunlin and other small birds, 0.56 for gulls, waterfowl and other large birds, and 1.00 for very large birds such as cormorants and swans. In general, search efficiency for all birds was lower in 1997 (0.37) than in 1994/95 (0.58). This may be a result of the new, predominantly gravel substrate making detection of birds more difficult than on the previous substrate of dirt with some or much vegetation.

15. As in 1994/95, carcass persistence was modeled with polynomial regressions. Mean persistence indices were calculated for each size class of bird, in both May through October and November through April. The persistence values were higher in 1997 than in 1994/95, especially from November through April. We also found fewer raptors in 1997, which contributed to the higher persistence values. This may be a

result of increased disturbance and activity at the site, or decreased search efficiency of scavengers due to the changed substrate. The 1997 values were applied to models estimating total carcass deposition.

16. Monthly estimates of carcass deposition for each species were derived from carcass counts, search efficiency and persistence. This model gave an estimate of 635 carcasses deposited through the year. The estimates of total carcass deposition are very sensitive to changes in the search efficiency and persistence indices. We present an alternate estimate of 429 carcasses deposited through the year by applying the 1994/95 ratio of actual to estimated to the 1997 actual count. This range (429 - 635), with estimates for groupings of birds, can be considered only a minimum estimate, since many birds that collide with the wires undoubtedly fly elsewhere to die and/or are carried away by trains. Estimates of these two sources of error cannot be tested in the field.

17. Overall, shorebirds showed the most consistent behavioural change in response to the dampers, both in approach reaction and in crossing height, in a variety of weather and wind conditions. These findings, coupled with the carcass data, indicate that the dampers are most beneficial for these species. Overall for other groupings of birds, there is some weak evidence (from flight data) that the dampers may help to reduce the risk of collision.

18. All birds still showed abrupt and severe reactions at Damper sectors, and herons, shorebirds, gulls, Caspian Terns and raptors still often crossed close to the wires even with dampers, indicating that dampers will not eliminate the risk of collision.

19. We conclude that the Spiral Vibration Dampers have shown promising results. We suggest several options, ranging from an inexpensive literature review of studies that test the efficacy of markers of various designs and layouts to reduce bird collisions with wires; to an expensive option of considering burying the cables along sections of the causeway, especially where shorebirds and Caspian Terns cross most frequently. Whatever option is considered, the situation at Roberts Bank should continue to be monitored, since the problem of bird mortality has not been entirely resolved.

TABLE OF CONTENTS

	Page
1. Introduction	1
2. General methods: description of study area, power lines and damper set-up	3
2.1. Study area	3
2.2. Description of the power lines and sectors	3
2.3. Activity along the causeway	6
2.4. Layout of dampers	6
3. Birds at risk: census for species diversity and seasonal abundance	7
3.1. Background	7
3.2. Methods	7
3.3. Results	9
3.3.1. Bird counts per species, with comparisons to 1994/95 study	9
3.3.2. Species of special concern	10
4. Flight behaviour of birds crossing power lines	20
4.1. Background	20
4.2. Methods	21
4.2.1. Field techniques	21
4.2.2. Analysis techniques, definitions and treatment of data	22
4.3. Results	24
4.3.1. Total number of crossings	24
4.3.2. Effect of dampers on approach behaviour	26
4.3.2.1. Approach behaviour for all weather and wind conditions pooled	26
4.3.2.2. Approach behaviour in poor visibility	26
4.3.2.3. Approach behaviour in high winds	31
4.3.3. Effect of dampers on crossing height	31
4.3.3.1. Crossing height for all weather and wind conditions pooled	31
4.3.3.2. Crossing height in poor visibility	39
4.3.3.3. Crossing height in high wind	41
4.4. Collisions	41

5. Densities of carcasses 42
5.1. Background 42
5.2. Methods 42
5.3. Results of carcass searches 43
5.3.1. Carcasses found 43
5.3.2. General distribution of carcasses 46
5.3.3. Carcass distribution within the experimental sectors 48
5.3.4. Conclusions from the carcass data 48

6. Carcass search efficiency, carcass persistence and estimating total mortality 51
6.1. Background: changes and disturbances to the search area 51
6.2. Carcass search efficiency 52
6.2.1. Background 52
6.2.2. Methods 52
6.2.3. Results of carcass search efficiency tests 53
6.3. Carcass persistence 55
6.3.1. Background 55
6.3.2. Methods 55
6.3.3. Results of carcass persistence tests 56
6.4. Estimating total mortality 58
6.4.1. Background 58
6.4.2. Methods 58
6.4.3. Results: estimated total carcass deposition 59

7. Conclusions: did the dampers make a difference? 63

8. Acknowledgments 66

9. Literature Cited 67

Appendices 1-4

1. INTRODUCTION

Roberts Bank is the tidal flat which reaches south from the main arm of the Fraser River, and is a major component of the ecologically important Fraser River estuary (Environment Canada 1996). The causeway and loading facilities of the Roberts Bank Superport were built on this area of extensive mudflats and shallow water in 1969. This area is one of the most important feeding and staging areas for migratory birds in British Columbia and supports tens of thousands of birds, principally shorebirds and waterfowl. Two studies have documented mortality of these birds through collisions with human-built structures here, mainly the 4 km overhead power lines (Roe and Williams 1984, Burger and Cassidy 1995). The latter study, which was conducted year-round, estimated that 710 birds were killed each year, with Dunlin (30%), Western Sandpiper (10%), American Wigeon (9%), Least Sandpiper (7%) and Mallard (5%) the most common species. Caspian Tern was identified as an important species, showing a high proportion of collisions in relation to crossing events. It is federally listed as Vulnerable (<www.ec.gc.ca/cws-scf/hww-fap/endanger/table.html> 1997). The effects on Double-crested Cormorant, Great Blue Heron and Black-bellied Plover were also considered to be significant (Burger and Cassidy 1995). Burger and Cassidy (1995) reviewed mitigation methods applicable to the Roberts Bank Superport, and suggested one or more of the following options to reduce mortality: i) burying the power cables; ii) marking the existing power lines to make them more conspicuous; iii) attaching markers to a new non-conducting upper line; iv) re-arranging the conducting wires to be more conspicuous; v) planting trees.

Mortality of birds from collisions with human-built structures (e.g. power lines, broadcasting and telecommunications towers, lighthouses, office buildings) has been documented in hundreds of studies (e.g. bibliography by Avery et al. 1980). Bradley (B. Bradley, personal communication) points out that differences in design of transmission lines affect risk of collision. For example, overhead ground wires (which are smaller in

diameter than conducting wires) pose a particular threat to birds when they exist as the upper wire, making the marking of these ground wires extremely important. Recently there has been an increase in the number of tests of various methods to prevent or reduce collisions of birds with various designs of wires (Beaulaurier 1981, Alonso et al. 1994, Bevanger 1994, Frederick and Jie 1997). To our knowledge, a published review of all such studies has never been done.

Following the Roberts Bank baseline study in 1994/95 (Burger and Cassidy 1995) meetings were held with representatives of the Roberts Bank Environmental Review Committee (established in 1980; see Environment Canada 1996), B.C. Hydro, the Vancouver Port Corporation, and Environment Canada, Canadian Wildlife Service. This group endorsed the experimental installation of some form of marker on test sections of the power line. In late 1996, B.C. Hydro installed 80 Spiral Vibration Dampers™ (Dulmison) on eight of 69 sectors. The present study tested the efficacy of these dampers to reduce bird collisions with overhead transmission wires. Our main objectives were:

i) To determine the number and species of birds at risk

We conducted weekly censuses year-round of all birds using the mudflats and nearshore shallow water adjacent to the causeway.

ii) To assess whether the behaviour of birds crossing the power lines is different in damper sectors and other sectors

We conducted systematic observations (3-4 hours each week) of birds crossing the power lines, in the experimental areas where behaviour of birds crossing the sectors with and without dampers could be made simultaneously. Additional observations were made in the non-experimental (Outside) areas of sectors, in order to monitor the crossing behaviour of all birds crossing the transmission wires.

iii) To estimate the number, species, chronology and spatial distribution of birds killed by collisions with the power line

We conducted weekly searches under the power lines for bird carcasses. For each carcass, we aimed to identify species, time since death and cause of death. We conducted tests to measure our search efficiency and to determine the rates of disappearance of carcasses, and applied results of these tests to simple models to estimate overall carcass deposition rates.

iv) Though the overall goal of the present study was to test the efficacy of the dampers to reduce collisions by birds, we compared results for censuses, flight activity, carcass searches and related data collection between the present study and the 1994/95 study, where relevant.

2. GENERAL METHODS: DESCRIPTION OF STUDY AREA, POWER LINES AND DAMPER SET-UP

2.1. Study area

The Roberts Bank superport is situated off Tsawwassen, south of Vancouver. The coal loading terminal and container port development are at the end of a 4 km long causeway crossing the intertidal mudflats (Figure 1). The shallow, placid sea is a favoured foraging area for a diverse and very large assemblage of waterbirds, while the exposed mudflats are equally important for migrant shorebirds (Butler and Campbell 1987, Butler and Cannings 1989, Butler 1992, Summers et al. 1994). At high tide, the water reaches close to the proximate (shoreward) end of the causeway, while at the lowest tides most of the causeway is flanked by extensive mudflats.

2.2. Description of the power lines and sectors

At the start of the current study, the power lines consisted of three live 60 kV wires with no overhead ground wire, supported on wooden poles about 18 m tall. The wires were mounted in a 'Vertical configuration triangular' (B. Bradley, personal communication;

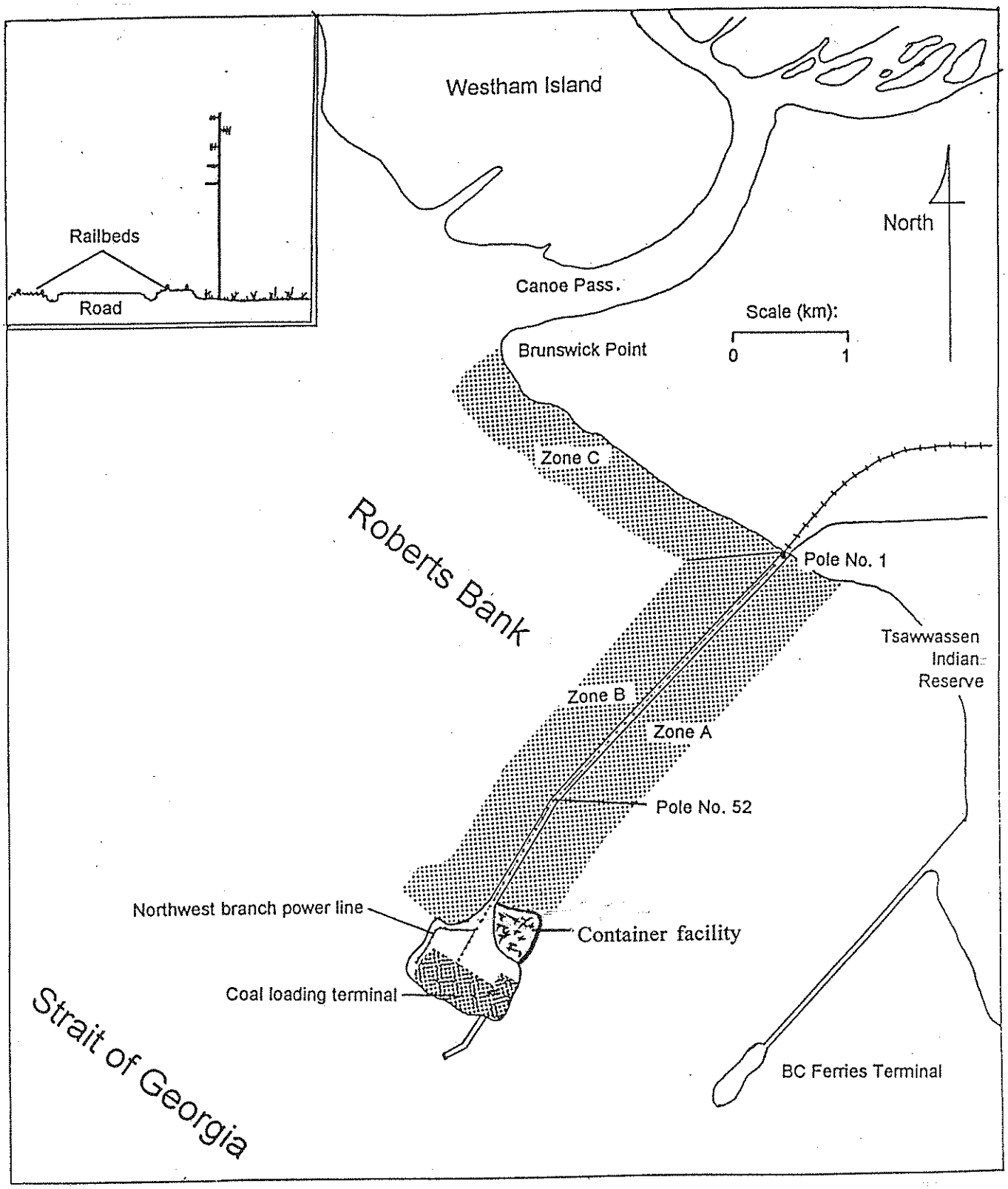


Figure 1. Schematic map of the Roberts Bank Superport, showing the three zones (A,B and C) used for censusing birds (light stippling). The inset shows the arrangement of the transmission wires on the pole, including the position of the two newly installed wires from Pole 1-50, and the location of the road and rail bed.

inset in Figure 1). The main line along the length of the causeway consisted of 70 poles, evenly spaced 60 m apart. The poles were labelled (Pole 1 is at the proximate end of the causeway); the distances between each pair of poles, called sectors, were used for flight observations and carcass searches.

There were several changes to the power lines since the 1994/95 study. Power lines and Poles 71-75 that existed during the 1994/95 study were removed before we began the current study. The power lines and Poles 51-70 were moved approximately 75 m to the north since the 1994/95 study, and the paved road at that end of the causeway was relocated. During the last months of the study, two additional distribution wires were installed from Pole 1-48. According to installation personnel, these wires were approximately 2 m and 4 m below the previously lower (third) wire.

During the current study, the power lines from Pole 1-50 were flanked on the causeway by a paved road, up to nine rail beds, and open ground largely covered by sand, gravel and crushed rock, with some areas covered by herbs, low shrubs or grass with no trees. In many places, especially north of the power lines, one or two new rail beds were located in the carcass search area. The search area covered by substrate other than vegetation was much greater in this study than during the 1994/95 study. The power lines from Pole 51-70 were flanked by a paved road, up to four rail beds, open ground, and a large paved area (for holding and moving stacked containers) with chain link fencing, tall light standards and moving cranes.

A branch transmission line, leading off from Pole 68, curves around a large area called Pod 3 towards the northwest to enter the coal terminal. While this area of the causeway was not investigated in the current study, it was the focus of a concurrent study completed for the Saskatchewan Wheat Pool (Cassidy 1998).

2.3. Activity along the causeway

During the study, there was much construction activity along parts of the causeway. This included the above-mentioned installation of wires, as well as installation of light poles, traffic signals and signs. There was concentrated activity during the study at the proximate end of the causeway; an overpass was being built, along with re-paving activity and installation of a few new poles and power lines north of Pole 1. The study area has much increased train, semi-truck and trailer, road-washing and other vehicular activity since the 1994/95 study.

2.4. Layout of dampers

The focus of the study was to test the efficacy of the presence of Spiral Vibration Dampers on selected sectors of the overhead wires to reduce mortality of birds crossing those wires. The 69 sectors along the causeway were divided into four treatment types: Damper (we use the word Diverter synonymously in tables and figures), Flanking, Control (these three treatments make up the experimental area) and Outside (non-experimental area). Sectors 3 through 26 were chosen as the experimental area because they had high frequencies of crossings, as well as the highest number of carcasses, in the 1994/95 study. These 24 sectors were divided into three treatment types with eight sectors in each:

- Dampers - sectors arranged in pairs (Sectors 5,6,11,12,17,18,23,24)

Each Damper sector had ten Spiral Vibration Dampers installed (in late 1996) on the upper wire, spaced equally with approximately 3.3 m between dampers. The dampers, designed and manufactured by Dulmison, were yellow in colour and made of non-corrosive PVC; each damper was made in a single piece approximately 2.4 m (8') in length. Damper sectors were arranged in pairs in order to reduce errors in assigning whether a bird or flock was crossing in a Damper or a Flanking sector. This was especially important for crossings viewed furthest from the observer, where the depth of field distortion is greatest. To further reduce this error, we reduced the observation distance from ten sector lengths (used in 1994/95) to six sector lengths.

- Flanking - sectors adjacent to the Damper sector pairs (Sectors 4,7,10,13,16,19,22,25) in which flight behaviour might be affected as a result of the adjacent sectors with dampers

- Controls - sectors separating the Flanking sectors (Sectors 3,8,9,14,15,20,21,26), in which it is assumed that flight behaviour would not be affected as a result of the dampers

The remaining 45 sectors (1,2, 27 through 69) were not part of the experimental area and were classified as the Outside treatment type, in which it is assumed that flight behaviour would not be affected as a result of the dampers. In the 1994/95 study, crossings by Caspian Terns were tightly concentrated in Sectors 60-70. Other bird groupings that crossed mainly in this Outside area included loons, cormorants, diving ducks. Great Blue Herons crossed along the entire length of the causeway.

3. BIRDS AT RISK: CENSUS FOR SPECIES DIVERSITY AND SEASONAL ABUNDANCE

3.1. Background

The study area is located within one of the most important bird habitats in the lower mainland. Hundreds of thousands of birds pass through the area, sometimes staying for a few days only (B. Elner, personal communication). Most of the birds that might be affected by the superport are migrants; species composition and population densities change dramatically through the year. It is important to know whether changes in flight behaviour or carcasses deposition are due to the experimental treatment of the dampers, or to changes in species density or seasonal distribution.

3.2. Methods

We conducted 52 censuses of birds between 7 January and 30 December, 1997, at weekly intervals. The census area was divided into the same three zones as in the 1994/95 study (Figure 1). Zone A covered the south side of the causeway, however the small bay at the

distal end of the causeway that was present in the 1994/95 study has been reduced drastically in size by infilling for the new container port. Zone B covered the north side of the causeway, including a shallow bay with a sandy reef at low tide. The census data collected from this bay (called B Pod) were also used in a concurrent study for the Saskatchewan Wheat Pool (Cassidy 1998). Zone C extended from the proximate end of Zone B along the dike to the small bay just south of Brunswick Point.

In all zones, all water birds and raptors within 500 m of the shoreline were counted and identified, with the aid of 7x35 binoculars, and a 15-45x spotting scope mounted on a tripod or vehicle window. Occasionally, with poor light or glare, some birds could not be identified to species level.

All counts were initiated approximately one hour before high tide (for relative consistency between counts and the best opportunity for high species abundance and diversity), with similar techniques to the 1994/95 study. On each census, we recorded the starting time, duration, time and heights of low and high tides, percent cloud cover, wind speed (Beaufort scale) and wind direction.

Numbers in very large flocks of waterfowl and shorebirds were estimated in one of three ways, with the first method being the most common:

i) Counting birds individually up to 10 and then counting the number of such groups; with larger flocks, once 100 or 1000 was reached, this became the new unit of estimation;

ii) Using the above technique to estimate the number of birds in the field of view of the spotting scope and then scanning the flock to count the number of 'scope-views';

iii) Choosing two or more spots along extremely large and continuous solid bands of birds, estimating the number of birds at that spot using one of the above techniques, then extrapolating to the whole band based on the distance between counting spots.

We estimated the proportion of individual duck species in large mixed-species flocks (generally greater than 1000 birds in a flock) by first scanning the whole flock to confirm that the species make-up was uniform, then choosing random scope-views, counting the number of each species in the view, then extrapolating those same proportions to the whole flock. Nomenclature used in this report (including four-letter codes for common names in tables and graphs) follows Campbell (1998).

3.3. Results

3.3.1. Bird counts per species, with comparisons to 1994/95 study

Table 1 indicates the mean number of each species from year round counts (N = 52), as well as during the main occupancy period of each species. The monthly mean count for the major taxonomic groupings of birds during their main occupancy period (4-5 counts per month, mode 4) is shown in Figure 2. The monthly mean count (year round) of each species is summarized in Appendix 1, along with the equivalent data from 1994/95.

Overall, the species composition and seasonal distributions were similar to the results from 1994/95. The highest densities were represented by waterfowl (October through May), Dunlin (October through May), Western Sandpiper (April through September), gulls (May through October) and Caspian Terns (April through September). Some species' peaks differ slightly between years because of annual differences in densities and timing of migration. Because most species varied in number from week to week due to factors such as varying tide heights, weather and feeding aggregations, quantitative comparisons are difficult. The data do not meet requirements for parametric tests and non-parametric tests (ranking) are not very informative for these data. Because of this weekly variability, we made yearly comparisons by major bird groupings using the monthly mean for the period of main occupancy, and using paired t-tests for matching months from each year (significance level = .05; Table 2).

Table 1. Mean numbers of birds per census through the year, and during the main period of occupancy of each species in 1997.
Data from Brunswick Point through Roberts Bank.

	Species	Year-round (N = 52 counts)			During main occupancy period			
Species	code	Mean	SD	Maximum	Period	Mean	SD	No. counts
Red-throated Loon	RTLO	0	0	0	Dec	-	-	-
Pacific Loon	PALO	0.5	0.9	4	Oct-Feb	0.8	1.0	20
Common Loon	COLO	6.7	7.4	32	Aug-Apr	8.4	7.8	39
Unidentified loon	Loon sp	0.1	0.3	2	Aug-Apr	0.03	0.2	39
Pied-billed Grebe	PBGR	0.1	0.4	3	Jan-Feb	0.5	1.1	8
Horned Grebe	HOGR	8.3	17.7	116	Aug - Jan	13.6	23.7	25
Red-necked Grebe	RNGR	0.3	0.7	3	Oct-Dec	0.5	0.9	13
Western Grebe	WEGR	2.4	6.7	33	Oct-Dec	7.4	11.0	13
Unidentified grebe	Grebe sp	0.3	1.4	10	Oct-Dec	0.7	2.6	13
Double-crested Cormorant	DCCO	42.6	25.3	100	All year	42.6	25.3	52
Brandt's Cormorant	BRCO	0.1	0.7	5	Oct	0.8	2.0	6
Pelagic Cormorant	PECO	0.1	0.2	1	Mar	0.3	0.5	4
Great Blue Heron	GBHE	15.8	29.1	116	Apr-Nov	23.1	33.2	35
Swan spp.	Swan sp	10.6	60.3	428	Nov-Jan	42.2	118.3	13
Snow Goose	SNGO	63.5	417.3	3000	Oct-Nov	366.7	992.5	9
Brant	BRAN	143.9	385.9	2090	Mar-May	548.7	627.6	13
Canada Goose	CAGO	6.2	26.7	188	May-Aug	16.6	44.9	17
Green-winged Teal	GWTE	1337.2	2748.6	12583	Aug-Apr	1781.7	3054.2	39
Mallard	MALL	968.0	1611.1	6008	Aug-Apr	1280.0	1755.9	39
Northern Pintail	NOPI	1163.1	2413.0	13066	Aug-Apr	1549.1	2683.8	39
Northern Shoveler	NOSL	1.0	4.2	28	Aug-Sep	5.0	10.0	8
Gadwall	GADW	20.1	51.4	280	Apr-Jun	71.7	84.8	13
American Wigeon	AMWI	1510.7	2396.6	8901	Aug-Apr	2009.6	2585.7	39
Canvasback	CANV	3.4	10.0	46	Feb-Mar	17.3	20.2	8
Unidentified Scaup	Scaup sp	135.5	173.7	602	Oct-May	200.3	178.9	35
Oldsquaw	OLDS	0.1	0.5	3	Oct-Nov	0.4	1.0	9
Black Scoter	BLSC	24.2	72.0	480	Sep-Apr	39.3	89.0	32
Surf Scoter	SUSC	37.3	47.1	193	Sep-Apr	59.5	48.0	32
White-winged Scoter	WWSC	18.0	25.4	113	Sep-Apr	28.8	27.3	32
Unidentified Scoter	Scoter sp	23.4	56.4	327	Sep-Apr	36.9	68.8	32
Common Goldeneye	COGO	1.9	3.0	11	Nov-Apr	3.7	3.3	26
Barrow's Goldeneye	BAGO	0.1	0.4	3	Nov-Apr	0.1	0.6	26
Bufflehead	BUFF	30.1	41.7	200	Nov-Apr	54.1	42.5	26
Hooded Merganser	HOME	0.2	1.2	9	May	2.3	4.5	4
Common Merganser	COME	0.0	0.1	1	Jan	0.3	0.5	4
Red-breasted Merganser	RBME	2.2	5.4	28	Oct-May	3.3	6.3	35
Unidentified Duck	Duck sp	1459.8	3650.2	23546	Nov-Apr	1248.0	2037.3	26
Bald Eagle	BAEA	1.3	1.8	8	Nov-Jul	1.6	1.9	39
Northern Harrier	NOHA	1.8	2.0	9	Oct-Jul	2.0	2.0	44
Red-tailed Hawk	RTHA	0.0	0.1	1	Nov-Jul	0.03	0.2	39
Merlin	MERL	0.0	0.1	1	Nov-Jul	0.03	0.2	39
Peregrine Falcon	PEFA	0.1	0.3	1	Nov-Jul	0.1	0.2	39

Continued on next page

Table 1 continued

Species	Species code	Year-round (N = 52 counts) Mean	SD	Maximum	During main occupancy period Period	Mean	SD	No. counts
Black-bellied Plover	BBPL	52.8	106.2	565	All year	52.8	106.2	52
Semi-palmated Plover	SEPL	0.1	0.7	5	Aug & May	1.3	2.5	4
Killdeer	KILL	0.7	2.2	14	All year	0.7	2.2	52
Unidentified yellowlegs	Yellowleg sp.	0.2	1.4	10	Jul	2.0	4.5	5
Black Turnstone	BLTU	0.2	0.9	6	Aug	1.5	3.0	4
Sanderling	SAND	0.3	2.1	15	Aug	3.8	7.5	4
Western Sandpiper	WESA	506.9	1566.0	6901	May, Jul-Aug	1647.6	2516.6	16
Least Sandpiper	LESA	0.4	1.8	10	Aug	4.8	5.5	4
Pectoral Sandpiper	PESA	0.5	3.6	26	Aug	6.5	13.0	4
Dunlin	DUNL	2929.5	4552.7	16630	Oct-April	5438.1	5001.1	28
Unidentifed Peep	Unid Peep	1187.4	7403.6	53150	Apr	20500.0	28355.1	3
Unidentified Dowitcher	DOWIT sp.	0.1	0.4	3	May	1.0	0.0	0
Whimbrel	WHIM	0.0	0.3	2	June	0.7	0.0	0
Black Oystercatcher	BLOY	0.2	0.6	3	All year	0.2	0.6	52
Unidentified shorebird	Unid. Shorebi	2.2	14.0	100	Jul	23.0	43.5	5
Bonaparte's Gull	BOGU	8.7	42.6	295	Jun-Jul	49.9	96.2	9
Mew Gull	MEGU	38.4	104.5	472	Nov-May	66.9	133.9	29
Ring-billed Gull	RBGU	124.5	222.1	777	Nov-May	6.4	20.8	29
California Gull	CAGU	11.4	59.5	425	Jul-Sep	51.2	125.7	11
Herring Gull	HEGU	0.4	1.9	13	Feb	1.3	1.5	4
Glaucous-winged Gull	GWGU	93.3	123.4	599	All year	93.3	123.4	52
Unidentified Gull	Gull sp.	214.0	600.9	3703	All year	214.0	600.9	52
Caspian Tern	CATE	45.3	84.8	334	Apr-Sep	90.4	102.1	26
Snowy Owl	SNOW	1.5	3.7	18	Jan-Mar	6.2	5.7	12
Short-eared Owl	SEOW	0.1	0.2	1	All year	0.1	0.2	52
Common Raven	CORA	0.0	0.3	2	All year	0.04	0.3	52
Total all birds	TOTAL	12259.5	11571.0	55588	Sept-May	16619.4	11700.0	34

Rare birds not included in the table: Eared Grebe (1 on 18 Sep); Osprey (1 on 4 Jun, 1 on 2 Oct); unidentified phalarope (1 on 24 Sep); Surfbird (2 on 19 Aug); Ruddy Turnstone (1 on 23 Jul); Western Gull (3 on 19 Aug); Sharp-shinned Hawk (1 on 19 Nov).

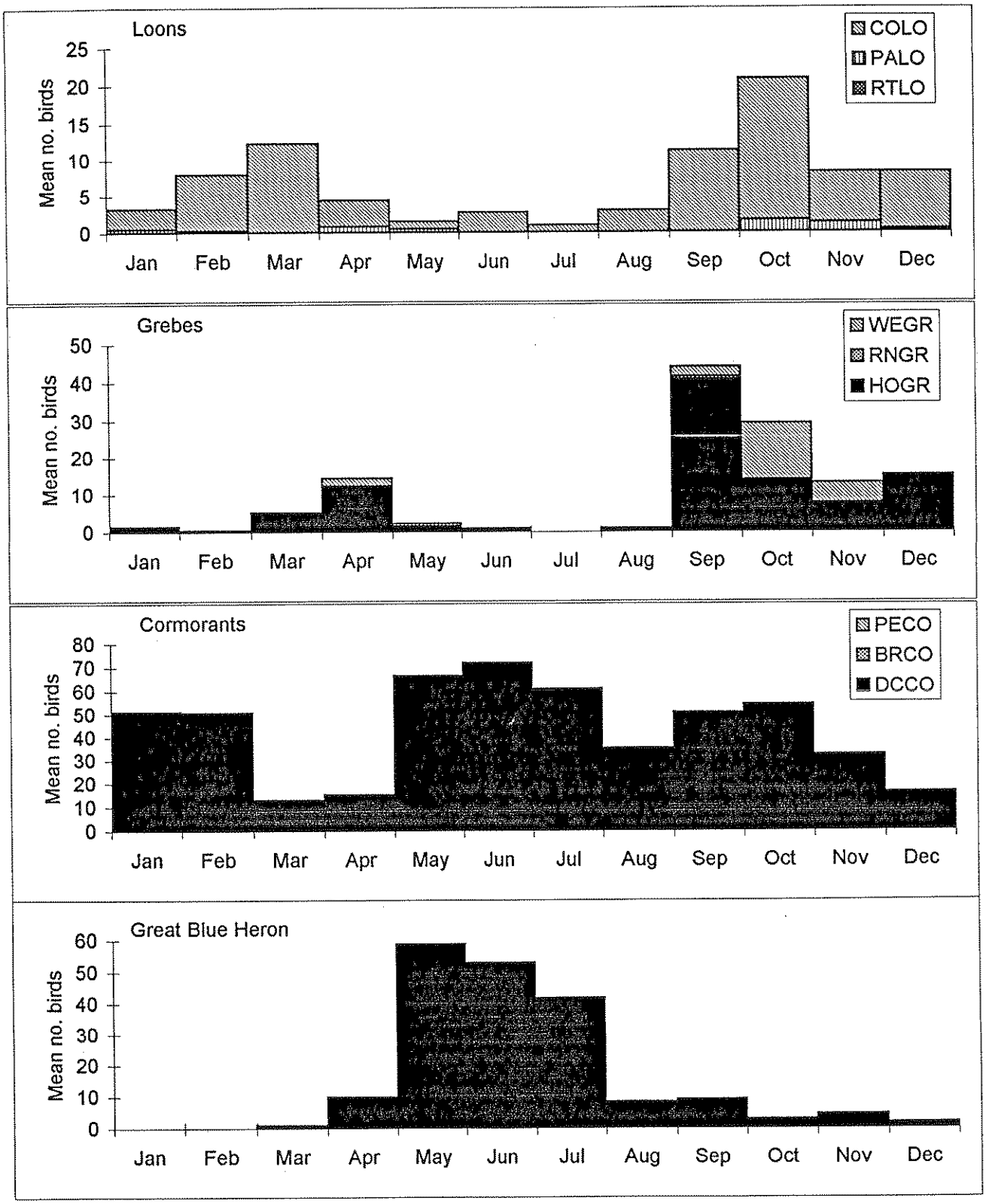


Figure 2. Monthly mean counts of birds off Brunswick Point and the Roberts Bank Causeway in 1997. See Table 1 for species codes. Continued on following pages.

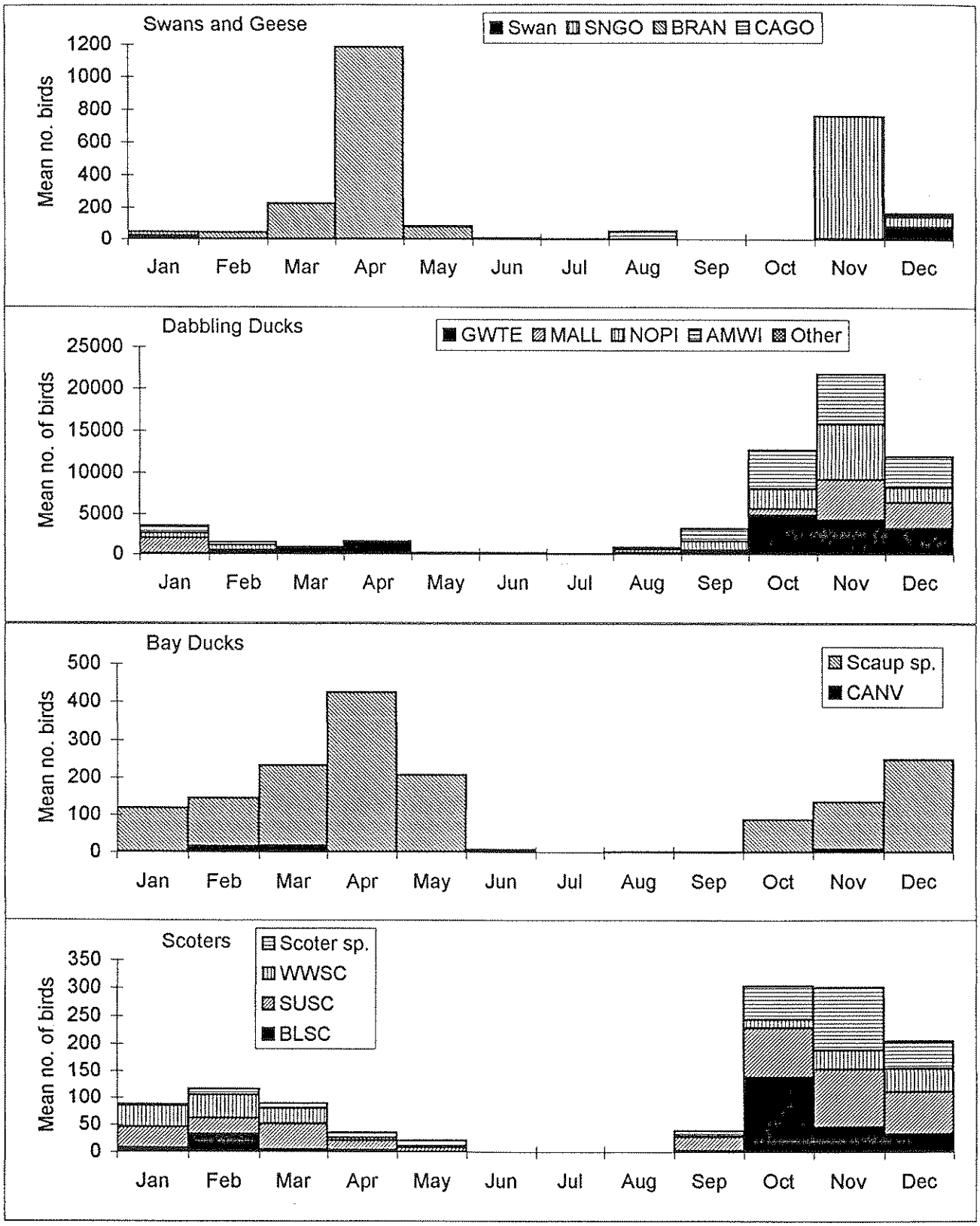


Figure 2, continued. Monthly mean counts of birds off Brunswick Point and the Roberts Bank Causeway in 1997. See Table 1 for species codes. Continued on following pages.

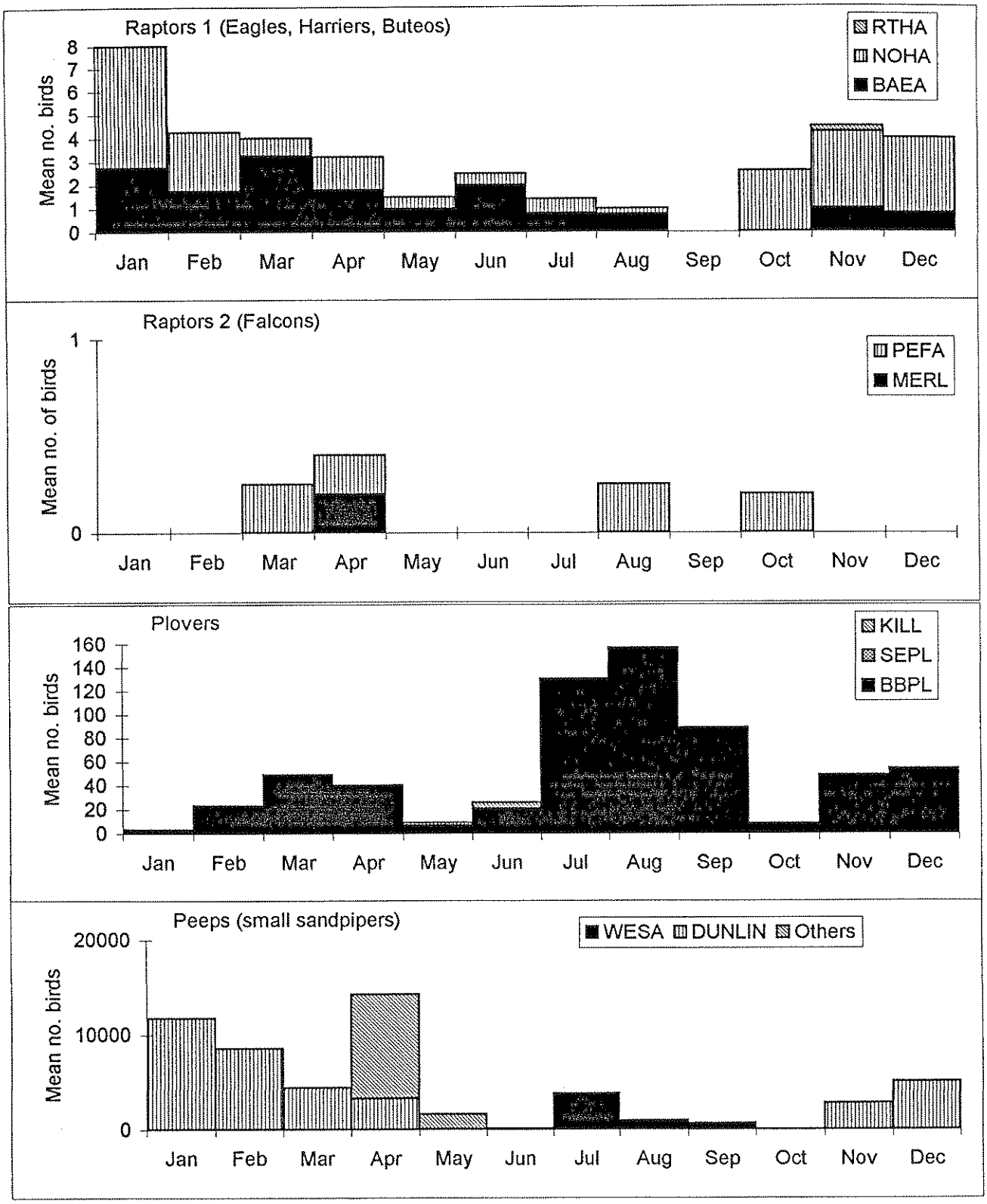
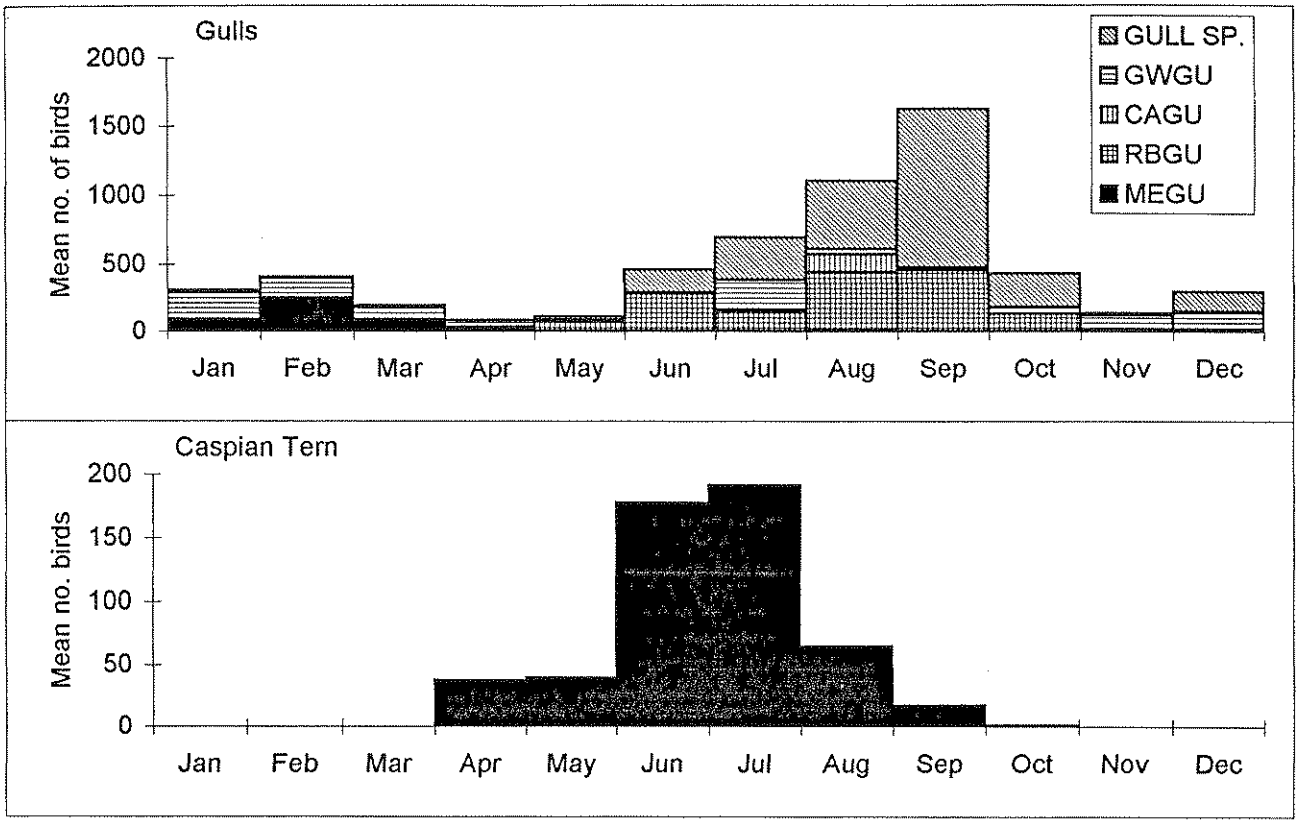


Figure 2, continued. Monthly mean counts of birds off Brunswick Point and the Roberts Bank Causeway in 1997. See Table 1 for species codes. Continued on following page.



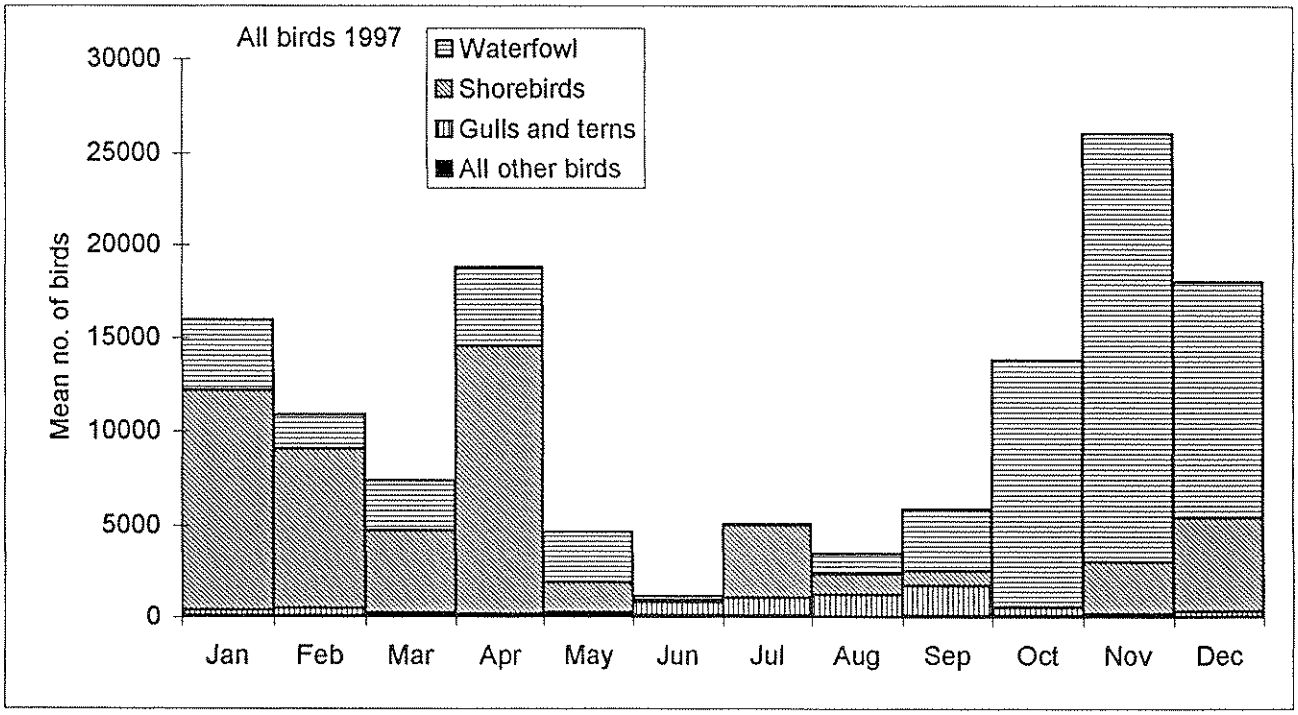


Figure 2, continued. Monthly mean counts of birds off Brunswick Point and the Roberts Bank Causeway in 1997. See Table 1 for species codes.

Table 2. Comparison of monthly mean counts of birds at Roberts Bank and Brunswick Point in 1994/1995 compared with 1997.

	Months	N	1994-1995		1997		Paired-t-test		% change
Bird group	compared	(months)	Mean	SD	Mean	SD	t	P	1994/95 - 1997
Loons	Sep-Apr	8	6.6	2.3	5.4	1.9	0.855	0.421, N.S.	-18
Dabbling ducks	Oct-Feb	5	11394	3157	10295	8109	0.247	0.817, N.S.	-10
Bay ducks	Oct-Apr	7	133	118	200	116	1.009	0.352, N.S.	50
Scoters	Oct-Apr	7	129	61	163	108	0.951	0.378, N.S.	26
Raptors	Oct-Jul	10	6.7	3.9	3.8	1.9	3.243	0.010	-43
Sandpipers	Nov-Apr	6	18950	11178	7832	4533	2.876	0.035	-59
Gulls	May-Oct	6	1070	900	756	539	1.451	0.207, N.S.	-29
Caspian Terns	May-Sep	5	79	90	98	81	0.329	0.758, N.S.	25
All waterfowl	Oct-Apr	7	9758	5125	10524	10092	0.205	0.844, N.S.	8
All shorebirds	Nov-Apr	6	19005	11175	7868	4522	2.883	0.034	-59
All gulls & terns	May-Oct	6	1136	967	838	533	1.215	0.279, N.S.	-26
All birds (peak months)	Oct-May	8	24129	11256	15716	8728	2.323	0.053, N.S.	-35
All birds (year-round)	Jan-Dec	12	17257	13590	11937	9021	1.959	0.076, N.S.	-31

There were generally fewer birds present in 1997 than in 1994/95. Most groupings showed a decline (Table 2), which was statistically significant for raptors (43% decline; p= 0.010) and sandpipers (59% decline; p=0.035). 'All birds combined' in peak months showed a 35% decline, and 'all birds combined' year-round showed a 31% decline (though neither difference was statistically significant; p= 0.053 and p = 0.076 respectively).

A few bird groupings increased in number from 1994/95 to 1997, though none of the differences was statistically significant, possibly because of small sample sizes: bay ducks (50% increase; p = 0.352), scoters (26% increase; p = 0.378) and Caspian Tern (25% increase; p = 0.758).

There were many possible causes of the overall reduction in numbers of birds. Our survey zone was within 500 m of the shoreline; slight shifts in distributions of birds between years could give quite large numerical differences. Likewise, if there were more 'rough water' days, with reduced visibility, in 1997, counts would go down. Other possible causes of reduction in numbers of birds include: i) increased disturbance to the study area from the construction activity, infilling of the bay in Zone A or increased traffic; ii) large-scale weather patterns, such as El Nino, increasing temperatures which may result in more birds wintering farther north or in other ice-free sites normally not available; iii) population dispersal over larger area as a result of other factors; iv) population decline. Evidence suggests that some water and landbird species are declining in abundance (e.g. Ralph et al. 1993).

Species detected on counts in 1994/95 that were not present in 1997 are: Tundra Swan, Emperor Goose, Greater Scaup (all scaup detected in 1997 were classified as Scaup spp., possibly since they were found further from shore and therefore not identifiable to species), Prairie Falcon, American Kestrel, American Avocet, Lesser Yellowlegs, Semi-palmated Sandpiper, Whimbrel and Long-billed Dowitcher.

Species detected on counts in 1997 that were not present in 1994/95 are: Pied-billed Grebe, Eared Grebe, Oldsquaw, Hooded Merganser, Osprey, Sharp-shinned Hawk, Surfbird, Sanderling, Black Oystercatcher, Phalarope sp., Herring Gull, Western Gull and Snowy Owl.

These species were uncommon to the area, their inclusion in the census often based on single sightings. These differences in occurrence of uncommon species are important to note as baseline information, as abundance and distribution of species change over time; however these differences are negligible in comparing the two studies,.

3.3.2. Species of special concern

As in the 1994/95 study, we paid special attention in our analyses to species for which Roberts Bank was of national or global significance, and to species which are rare, threatened or endangered.

The area is extremely important for Dunlin and Western Sandpiper. The Fraser Delta, including Roberts Bank, is one of the primary wintering grounds of Dunlin, and therefore of global significance (Butler and Campbell 1987, Butler 1992). The intertidal mudflats are its principal foraging and roosting sites. Large numbers of Dunlin regularly cross the causeway during the winter, including at night and in foggy conditions, and there is concern that the power lines pose a significant source of mortality to the wintering population (Burger and Cassidy 1995).

The mudflats are also of global significance as a migratory staging ground for Western Sandpiper. Nearly the entire world population of this species passes through British Columbia, with most birds congregating on the tidal flats of the Fraser River estuary, the last known major stop before south-central Alaska (Butler and Campbell 1987, Butler and Cannings 1989, Campbell et al. 1990a). Individuals remain in the area for an average of three days, with single flocks of up to 100,000 birds reported to concentrate for a day at Roberts Bank or Iona Island during the peak of migration (Campbell et al. 1990a). The

total numbers of Western Sandpipers passing through the Fraser Delta reach 500,000 in April and May and 1.2 million in July and August (Butler and Campbell 1987).

In 1994/95, the year-round annual mean number of Dunlin was 7632 (maximum count 37,000) with a mean of 11,652 birds counted during the main occupancy period of October through April (present on 28 of 42 counts). In 1997, the year-round annual mean was 2929 (maximum count 16,630) with a mean of 5438 birds during the same occupancy period (present on 28 of 52 counts).

In 1994/95, the year-round annual mean number of Western Sandpiper was 2925 (maximum count 110,705) with a mean of 13,816 birds during the main occupancy periods of April, May, July and August (present on 8 of 42 counts). In 1997, the year-round annual mean as 507 (maximum count 6901) with a mean of 1648 birds during the main occupancy period of May, July and August (present on 16 of 52 counts). However, in 1994/95, there were relatively few 'unidentified peeps', whereas in 1997, large numbers of unidentified peeps (mixed Dunlin and Western Sandpiper, with a large percentage of the latter) which were seen mainly in April, may account for some of the difference in numbers of Western Sandpipers between years.

Several other species of birds identified in 1997 in the study area (highlighted in **bold**; subspecies were not identifiable in the field), or with the potential to visit the study area, are on the national and provincial lists of endangered, threatened and vulnerable species. Birds listed nationally by the Council on the Status of Endangered Wildlife in Canada (COSEWIC; <www.ec.gc.ca/press/cosewic_b.htm> 1998) as endangered include the Continental race of Peregrine Falcon (*Falco peregrinus anatum*), while those listed as vulnerable include **Trumpeter Swan**, **Caspian Tern**, Cooper's Hawk, Tundra race of Peregrine Falcon (*F. p. tundrias*), **Barn Owl** and **Short-eared Owl**. Species listed on British Columbia's Red List (endangered or threatened or considered for such status) include **Western Grebe**, Pelagicus race of Pelagic Cormorant [*Phalacrocorax pelagicus pelagicus*; visits this area in winter (Campbell et al. 1990b], Brandt's Cormorant,

Continental race of Peregrine Falcon and Prairie Falcon. Species on the Blue List (considered to be vulnerable and at risk) **include Double-crested Cormorant, Great Blue Heron, Trumpeter Swan, Surf Scoter**, Peale's race of Peregrine Falcon (*P.f. pealei*), Gyrfalcon, **California Gull, Caspian Tern, Barn Owl** and **Short-eared Owl** (<www.elp.gov.bc.ca:80/ wld/cdc/atrkprov.htm> 1997). Of the three subspecies of Peregrine Falcon, Peale's is most common in this area, Continental is migratory, and there is evidence that Tundra passes through the province (Campbell et al. 1990a).

Caspian Terns seem to be increasing both in numbers and in duration of occurrence at Roberts Bank. In 1994/95, Caspian Terns were found from May through September (detected on 15 of 42 counts), with a mean year-round count of 28 birds (maximum 419 birds). In 1997, Caspian Terns were found from April through September (detected on 26 of 52 counts), with a mean year-round count of 45 birds (maximum 334 birds). Since the 1980's, there has been an increasing trend in the numbers of Caspian Terns in British Columbia, including an extension of their range to the north coast and the Queen Charlotte Islands (Campbell et al. 1990b). There is recent evidence that Caspian Terns bred in the Roberts Bank area in 1997 (I. Robertson, personal communication).

4. FLIGHT BEHAVIOUR OF BIRDS CROSSING POWER LINES

4.1. Background

In the 1994/95 base-line study at Roberts Bank, Burger and Cassidy (1995) offered a range of viable options for reducing mortality by birds crossing the power lines. It was thought that marking the existing conductors (a cheaper option than the preferred but most expensive option of burial) was unlikely be completely effective, even if deployed along the entire line. Burger and Cassidy (1995) suggested that the most effective and economical procedure might require combining two or more methods.

The most appropriate markers to test included Spiral Vibration Dampers (Dulmison), Bird Diverters (Preformed Line Products Ltd.) or Swan Diverters. Line markers (Ray Chem),

which have been used at Boundary Bay, are more visible than diverters, but fastening is a problem (B. Bradley, personal communication). Other markers of varying design exist. Alonso et al. (1994) reported that red PVC spirals on two overhead ground wires reduced collisions of birds at a power transmission line in southwestern Spain. A recent study completed in west-central Spain (Janss and Ferrer 1998) compared the ability of three types of marking systems to diminish mortality of birds in cultivated areas. Janss and Ferrer (1998) found that while there were no significant differences in avian mortality amongst treatments, white spirals on ground wires reduced collisions somewhat; black crossed bands on conductors were effective for some species, though not for the most vulnerable Great Bustard (*Otis tarda*); and black stripes on conductors did not reduce mortality.

B.C. Hydro installed Spiral Vibration Dampers on test sectors at Roberts Bank in late 1996. The only other known test of this specific design of marker was a brief and anecdotal study of bird flight behaviour in relation to overhead wires on the access road to Westham Island, very close to Roberts Bank (Manning, 1995). The current study aims to determine if the dampers at Roberts Bank caused changes in the flight behaviour of birds crossing the power lines and in mortality of birds from collisions with the wires.

4.2. Methods

4.2.1. Field techniques

We used the same protocol for observations as in the 1994/95 study, with one exception. In 1994/95, each observation block covered one hour and 10 sectors at a time (600 m). For the current study, each observation block covered one hour and six sectors at a time (360 m), in order to reduce errors in recording the correct sector crossed by each bird, and to allow the experimental design of observing two Damper sectors, two Flanking and two Control sectors at the same time. The observer sat at one end of the six sectors in order to have a clear view of the entire area without having to turn back and forth. Binoculars were used for species identification.

Data were recorded on standardized sheets (Appendix 2), with weather and tide conditions recorded every 15 minutes. Each bird or flock that approached within 20 m of the power lines was treated as a separate 'crossing event record', with the following data recorded: time, sector number, species, age and sex, flock size, approach (before crossing) and departure (after crossing wires), behaviour within 10-20 m of the wires: N (no reaction to the wire as approach); C (climb or gain altitude); D (descend or lose altitude); M (maintain height after crossing); T (turn back before crossing); S (spiral climb); and X (collide with wire). We further described these behaviours with qualifiers: G (gradual - occurs 10-20 m from wire); A (abrupt - occurs 5-10 m from wire); and F (flare, swerve, hover, flap wildly) to indicate increasing severity of the approach and departure responses. The crossing height was estimated in meters above the upper wire (+), between the wires (B) or below the lower wire (-), and the flight direction was noted. We estimated all heights and approach/departure distances using the pole length (18 m) and the spacing between wires (2.5 m) as reference.

4.2.2. Analysis techniques, definitions and treatment of data

Our analyses used crossing events (not numbers of birds) as a measure, because each flock can be treated as an independent event, but each bird cannot. We used frequency analysis (Chi-squared), rather than comparing means, since our focus was to determine how many, and what proportion of the birds crossing the wires were at risk (crossing close to the wire or showing abrupt or severe reactions to the wire).

In particular, we focused analyses on crossing events under conditions when collisions seem more likely, for example, when precipitation might decrease visibility or when high winds might affect flight stability. Statistical tests using flight behaviour compared Damper and Control sectors since there was a chance that some of the birds recorded as crossing Flanking sectors might have actually been crossing either Damper or Control sectors due to depth of field errors during observations.

We ranked approach reactions following our 1994/95 protocol [see Table 3, p. 29 of Burger and Cassidy (1995)]. In summary, they are:

- No reaction - no obvious reaction
- Mild reaction - any behaviour occurring within 10-20 m of wire
- Abrupt reaction - any behaviour occurring with 5-10 m of wire
- Severe reaction - any behaviour involving flare activity

Where sample sizes were limited, some pooling of data was done (No reaction + Mild reaction) or (Abrupt reaction + Severe reaction) to meet the minimum requirements of Chi-squared tests (Zar 1996).

The 1994/95 study showed that most of the birds crossing the causeway were at risk of collision with the upper wire [95% of crossing events (N = 40,504) were above the wires, with most of these (69% of all events) close to the power lines, within 10 m or less of the upper wire (Burger and Cassidy 1995)]. Since the current study seeks to determine the efficacy of the dampers, we wanted to focus on the birds at greatest risk of collision (within 2 m of the wires or flying between the wires). We therefore pooled crossing heights into the following categories:

- >2 m above upper wire
- <=2 m above upper wire (also referred to as 'close to the wire')
- Between wires
- Below lower (third) wire

We selected 2 m as the division point since many large birds have wingspans of about 1 m but it is difficult to differentiate between 1 m and 2 m in the field. Few birds crossed between the wires or below the lower wire so most statistical analyses focused on those birds crossing <=2 m above and those crossing >2 m above the upper wire.

Analyses focused on the bird groupings making up the bulk of the crossing events. Some groupings, such as cormorants, tended to cross mainly in the non-experimental, Outside treatment type (seaward end of the causeway) and so had too few samples for statistical testing. They were all included in the 'all birds combined' category.

In mid-October, 1997, two additional wires were installed on all of the experimental sectors and many of the Outside sectors (see Section 6.1.). Because we were not aware of the plans for this installation, and because the bulk of our flight observation data had already been collected, we could not conduct a separate analysis of the possible effects of these wires on behaviour of birds crossing the power lines. It is probable that these new wires would affect the behaviour of the small proportion (6.5% or 357 crossing events) of birds that crossed below the previously lower wire (= third wire; see Section 4.3.3.1.). It is also possible that the new wires could affect the overall visibility of the power lines, though the details such as approach distance efficacy and relationship to the dampers is unknown.

4.3. Results

4.3.1. Total number of crossings

Overall, we obtained 5643 records of crossing events, totalling 46,875 birds (mean flock size 8.3 birds per crossing event). Our observation effort focused primarily on the 24 experimental sectors, with 40-41 hours of observation per sector (Figure 3). Some additional observations made in the Outside treatment type were also included in the general analysis of flight patterns. Observations were made in all months, generally 10-17 hours per month, with slightly more effort in August (Figure 3) to track flight activity during the peak time for Western Sandpiper. Most observations were made between 0800 and 1600 hours, which covered most of the daylight hours (Figure 3). As in the 1994/95 study, observations covered all phases of the tide cycle and, while they included a range of weather conditions, sampling during some fog conditions was problematic. Although it occurred rarely, heavy fog reduced visibility such that birds that might be crossing the

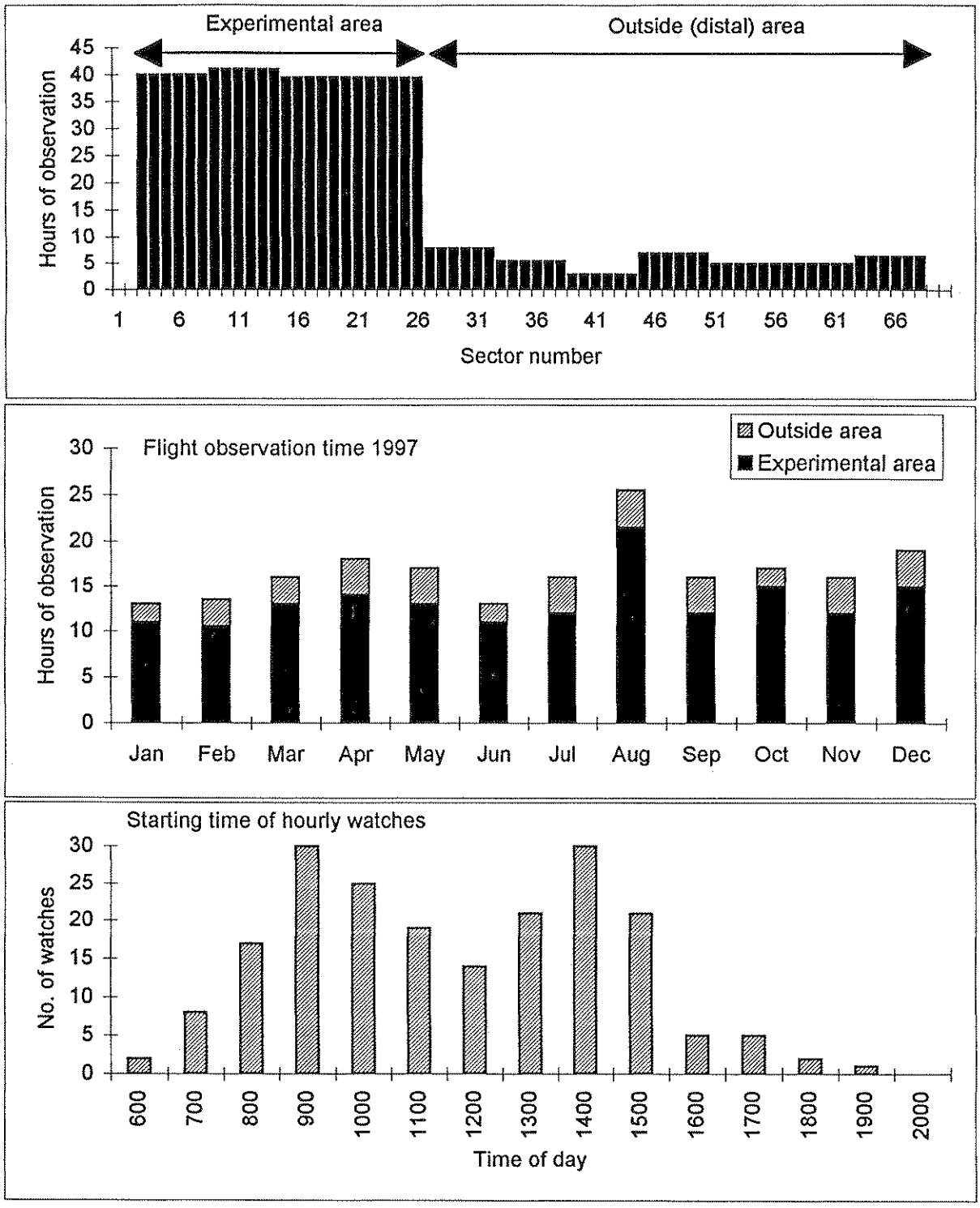


Figure 3. Distribution of observational effort to observe crossing flights at Roberts Bank in 1997. A: hours of observation per sector; B: hours of observation per month; and C: starting times of hourly observation watches.

power lines could not be seen (nor could the poles or the power lines), and the observation block had to be ended.

4.3.2. Effect of dampers on approach behaviour

4.3.2.1. Approach behaviour for all weather and wind conditions pooled

Approach behaviour is defined as the flight reaction of birds in the 20 m before the wires as they approach. For each bird grouping (or species, such as Great Blue Heron or Caspian Tern) for which there was sufficient sample size, and for 'all birds combined', we broke down flight reactions into severe, abrupt, mild and no reaction, for each of the four treatment types: Dampers, Flanking, Controls and Outside (Figure 4). While there were generally lower frequencies of abrupt or severe reactions in the Damper sectors than in other treatment types, for most birds the differences were relatively minor, and not statistically significantly (Chi-squared tests; Table 3). The frequency of approach behaviour categories between Damper and Control sectors were significantly different in shorebirds (marginal significance $P=0.05$), raptors ($P<0.05$) and 'all birds combined' ($P<0.01$; Table 3), with fewer severe and abrupt reactions in Damper sectors than in Controls.

4.3.2.2. Approach behaviour in poor visibility

Poor visibility was a result of precipitation in some form (mist, drizzle, rain or light snow), or foggy patches that were not so severe that they obscured the observation area. Small sample sizes resulted in separate analyses for four groupings - waterfowl, shorebirds, gulls and terns, and 'all birds combined' (Figure 5). In poor visibility, shorebirds elicited significantly fewer abrupt or severe reactions when crossing Dampers than when crossing Controls (marginal significance $P=0.05$). There were no significant differences for other groupings, or for 'all birds combined'.

We also considered the high risk situation of birds crossing within 2 m above the upper wire or below the lower wire in poor visibility. We had small samples and could do separate treatment type breakdown for three groupings - shorebirds, gulls and terns, and

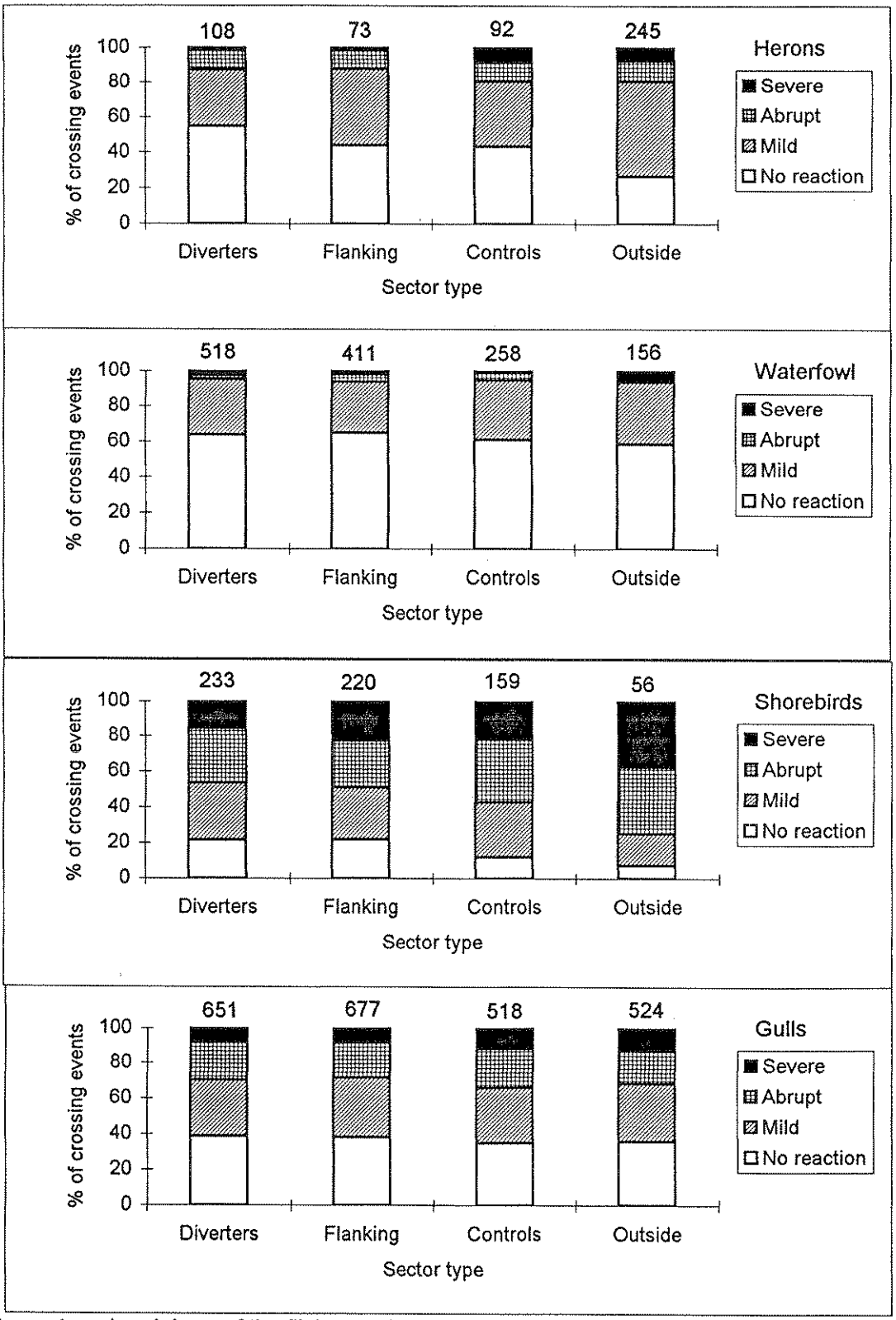


Figure 4. Percentage breakdown of the flight reactions by birds approaching the power lines, Jan-Dec 1997. Observations were made within the experminetal sectors (those with Diverters, Flanking the diverters, or Controls), and outside the experimental area. Sample numbers are crossing events. (continued)

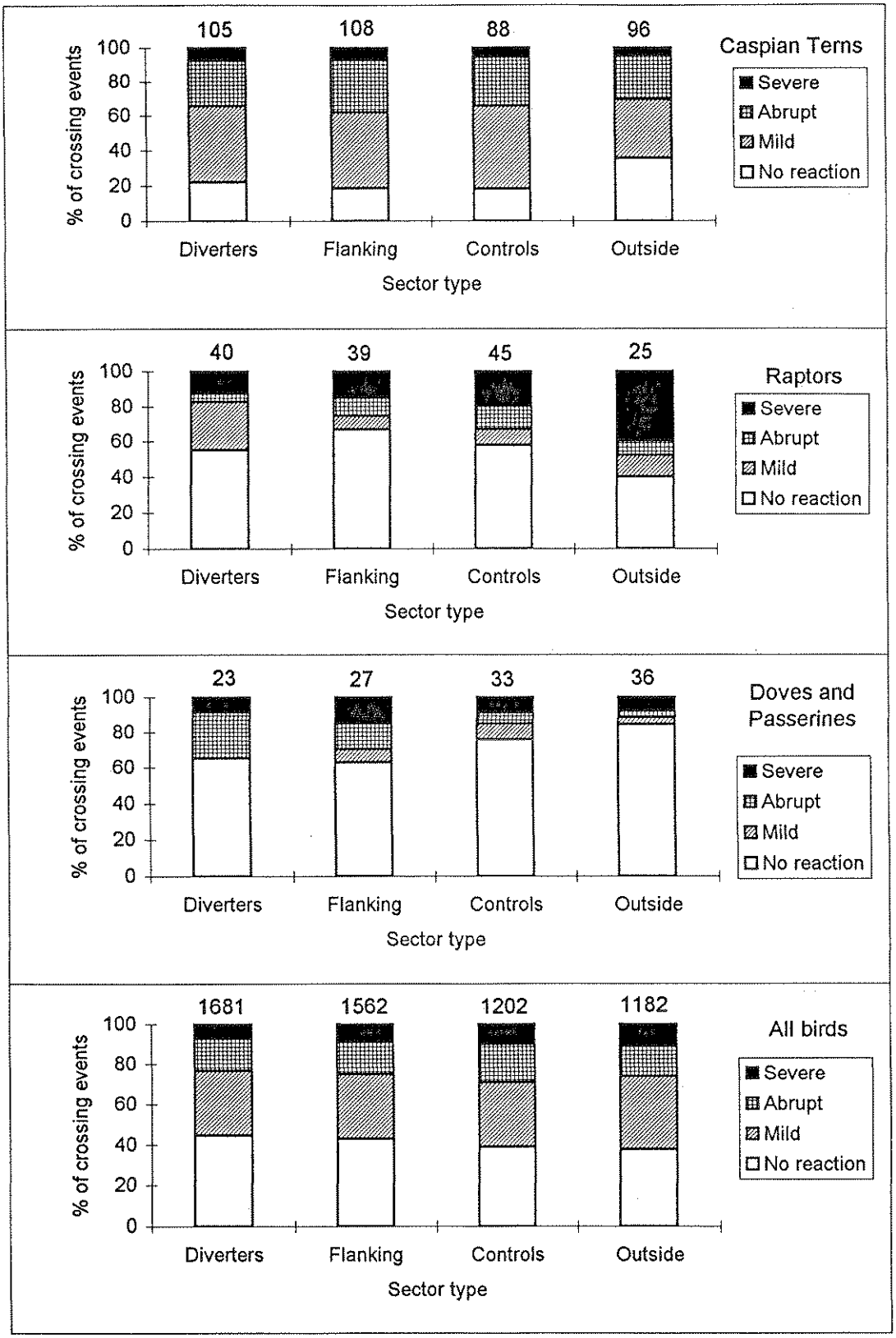


Figure 4 (continued)

Table 3. Tests of the effects of diverters on approach flight behaviour and crossing height.

Behaviour and heights of birds crossing Diverter sectors were compared with Control sectors.

Bird type	Chi-square	df	P
A. Tests for differences in approach behaviour (all weather and wind conditions)			
Herons*	2.900	2	>0.05, N.S.
Waterfowl	3.622	3	>0.05, N.S.
Shorebirds	7.504	3	ca. 0.05
Gulls	3.858	3	>0.05, N.S.
Caspian Terns	0.809	3	>0.05, N.S.
Raptors*	6.237	2	<0.05
Passerines*	4.552	2	>0.05, N.S.
All birds	15.967	3	<0.01
B. Tests for differences in approach behaviour in poor visibility (some precipitation)			
Waterfowl*	0.536	2	>0.05, N.S.
Shorebirds*	2.907	2	ca. 0.05
Gulls and terns*	1.529	2	>0.05, N.S.
All birds	2.393	3	>0.05, N.S.
C. Tests for differences in approach behaviour in high winds (>20 km/h)			
Herons*	2.071	2	>0.05, N.S.
Waterfowl*	0.647	2	>0.05, N.S.
Shorebirds**	2.022	2	>0.05, N.S.
Gulls	8.568	3	<0.05
Caspian Terns**	3.126	2	>0.05, N.S.
All birds	13.49	3	<0.01
D. Tests for differences in crossing height above the wires (all weather and wind conditions)			
Herons	1.219	1	>0.05, N.S.
Waterfowl	6.136	1	<0.05
Shorebirds	7.409	1	<0.01
Gulls	4.587	1	<0.05
Caspian Terns	0.471	1	>0.05, N.S.
Raptors	3.021	1	>0.05, N.S.
All birds	33.507	1	<0.001
E. Tests for differences in crossing height above the wires in poor visibility (some precipitation)			
Waterfowl	0.859	1	>0.05, N.S.
Shorebirds	0.139	1	>0.05, N.S.
Gulls and terns	0.019	1	>0.05, N.S.
All birds	1.857	1	>0.05, N.S.
F. Tests for differences in crossing height above the wires in high winds (>20 km/h)			
Waterfowl	2.224	1	>0.05, N.S.
Shorebirds	0.379	1	>0.05, N.S.
Gulls and terns	1.001	1	>0.05, N.S.
All birds	14.437	1	<0.001

* The "abrupt" and "severe" reactions were pooled to meet minimum sample requirements for the Chi-squared test

** The "no reaction" and "mild reaction" categories were combined to meet Chi-squared requirements.

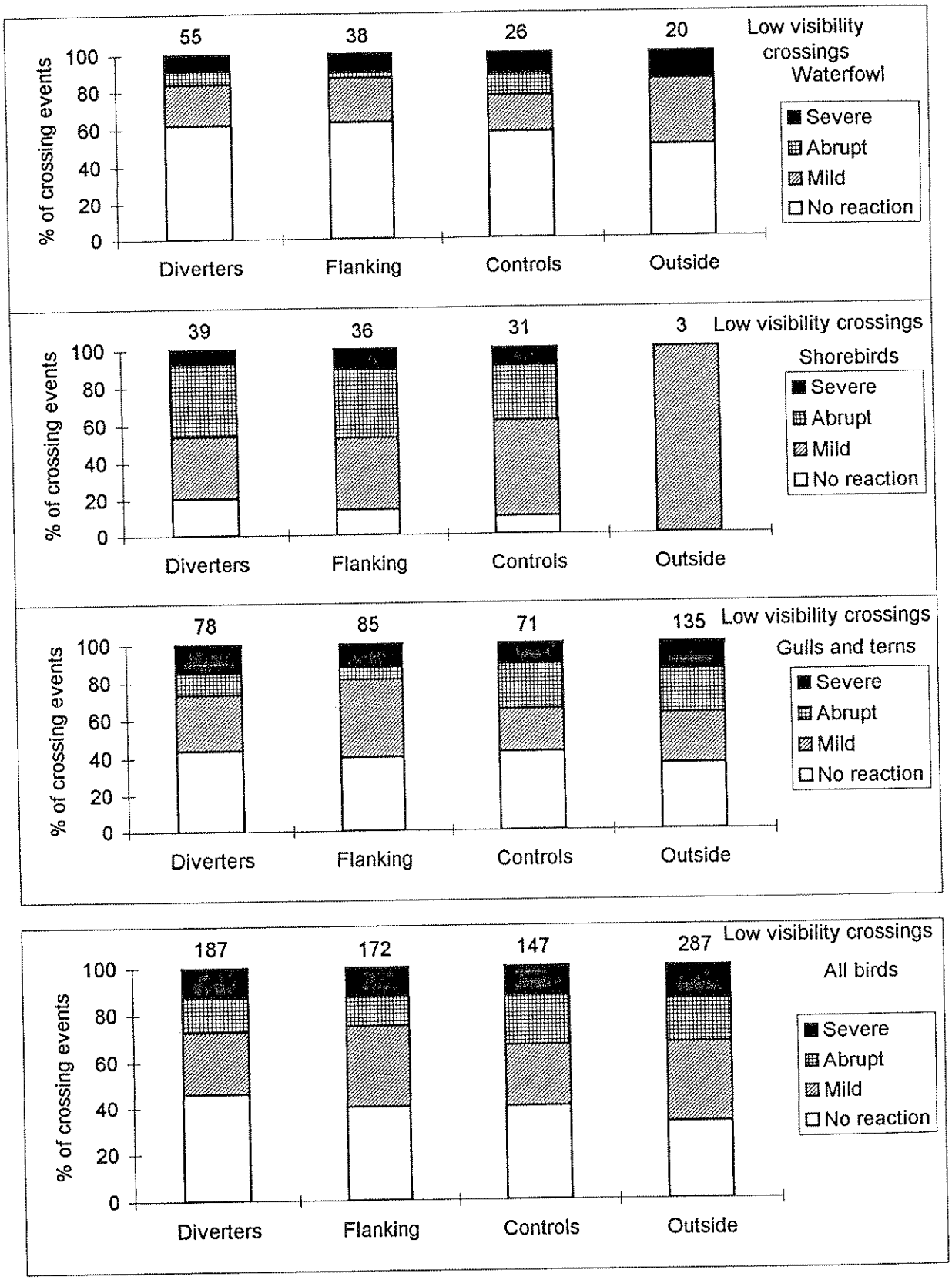


Figure 5. Flight reactions of birds approaching the power line during periods of poor visibility (in falling snow, drizzle, mist or rain), Jan-Dec 1997.

'all birds combined' (Figure 6). As in the 1994/95 study, we found that 'all birds combined' showed a high proportion of abrupt or severe reactions, indicating that crossing close to the wire in poor visibility is risky and provokes alarm reactions (Figure 6). Only gulls and terns (Chi-squared test = 1.179, 1 df, P>0.05 with 'No + Mild reactions' pooled and 'Abrupt + Severe reactions' pooled) and 'all birds combined'(Chi-squared test = 1.069, 2 df, P>0.05, with No + Mild reactions pooled) had sufficient sample sizes for frequency analyses; in both cases, there were no significant differences in approach reaction between Dampers and Controls. There is no indication that the dampers made much difference in the approach behaviour of birds under the high risk conditions of crossing close to the wire in poor visibility.

4.3.2.3. Approach behaviour in high winds

High winds, defined as equal to or exceeding Beaufort scale 4 (> 20 km/h), are likely to affect the flying ability of birds. Although we noted wind speed, direction and flight direction of birds, we did not separate flight direction in relation to wind direction in our analyses. We noted increasingly greater proportions of abrupt and severe reactions as wind speed rose from Beaufort 0-1 (0-3 km/h) to Beaufort 6+ (> 45 km/h) for shorebirds (Figure 7) and for 'all birds combined'(Figure 8); these trends held for all treatment types. The reactions of birds during all crossing events in high winds are shown in Figure 9. While there were generally lower frequencies of abrupt or severe reactions in high winds at Damper sectors than at Controls, for most birds the differences were minor and not statistically significant (Table 3). The frequency of abrupt or severe reactions when crossing Dampers in high winds was significantly lower than when crossing Controls for gulls (P<0.05) and 'all birds combined' (P<0.01; Table 3).

4.3.3. Effect of dampers on crossing height

4.3.3.1. Crossing height for all weather and wind conditions pooled

Overall, we recorded height for 5485 of 5643 crossing events. Height was not recorded for birds who approached within 20 m but turned back, or, in some instances, when there

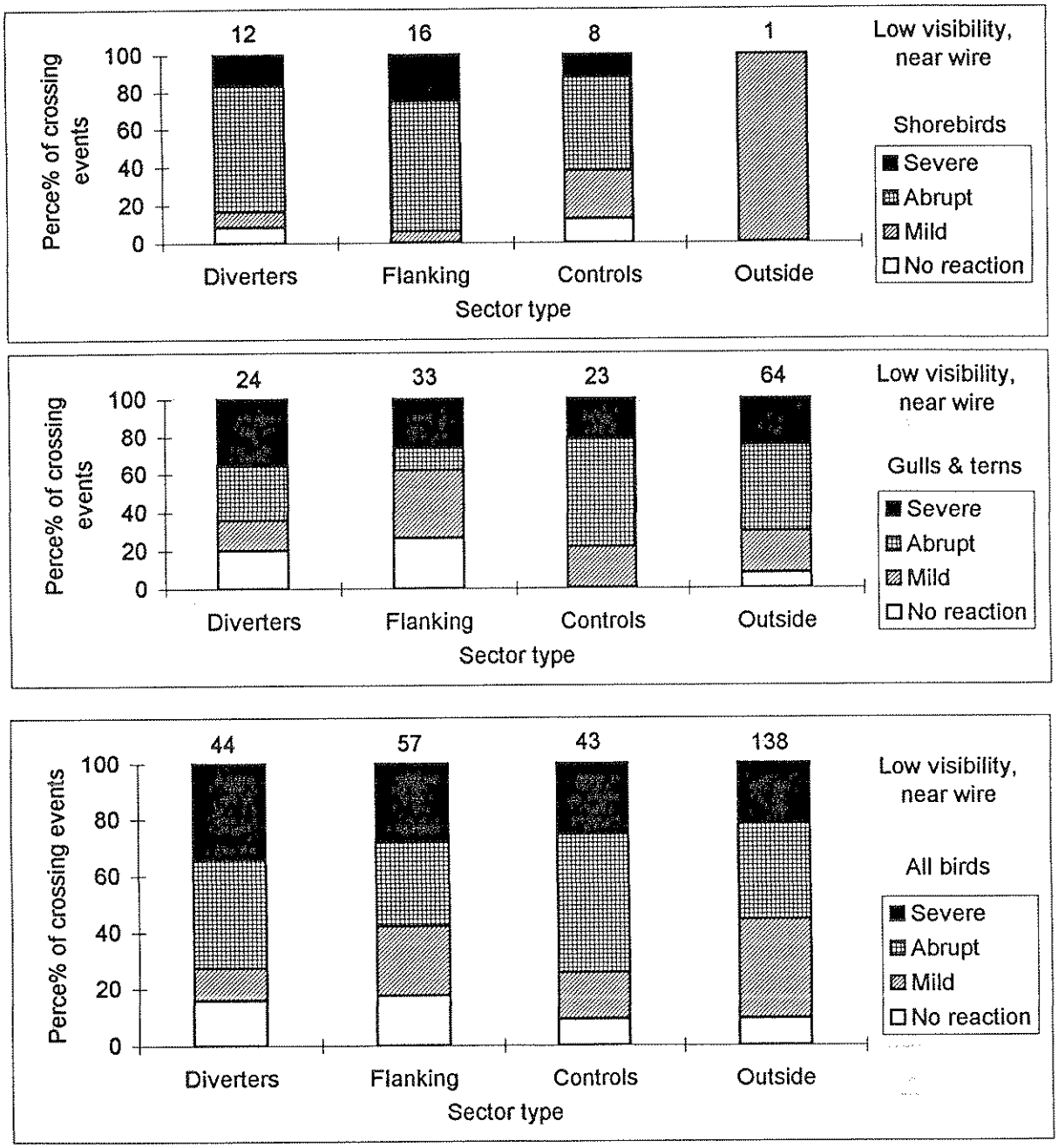


Figure 6. Flight reactions of birds approaching the power line in poor visibility (some precipitation) and crossing within 2 m of the wires. These might be considered high risk situations.

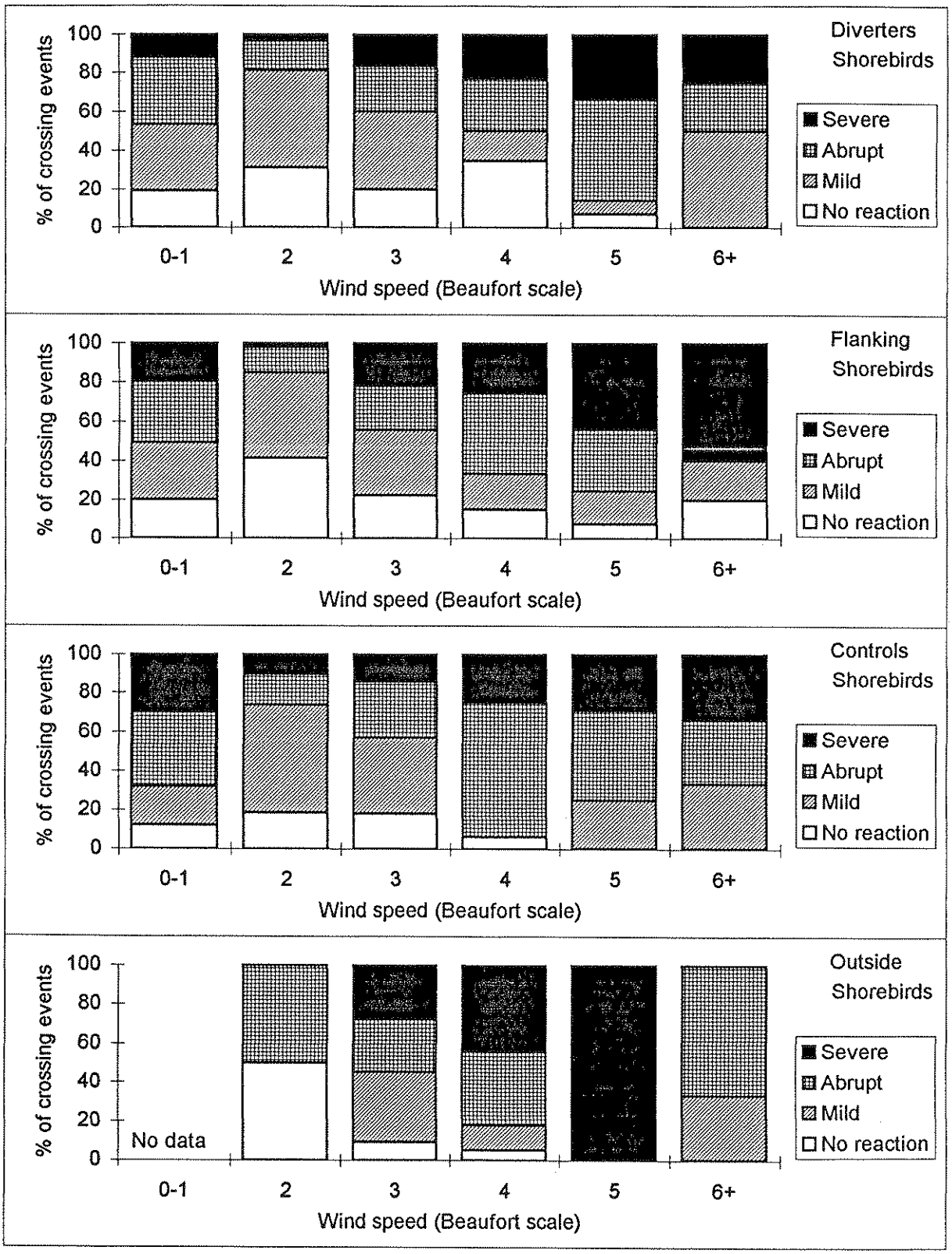


Figure 7. Effect of increasing windspeed on flight reactions of shorebirds approaching the power line in the diverter, flanking and control sectors, and those outside the experimental sectors in 1997.

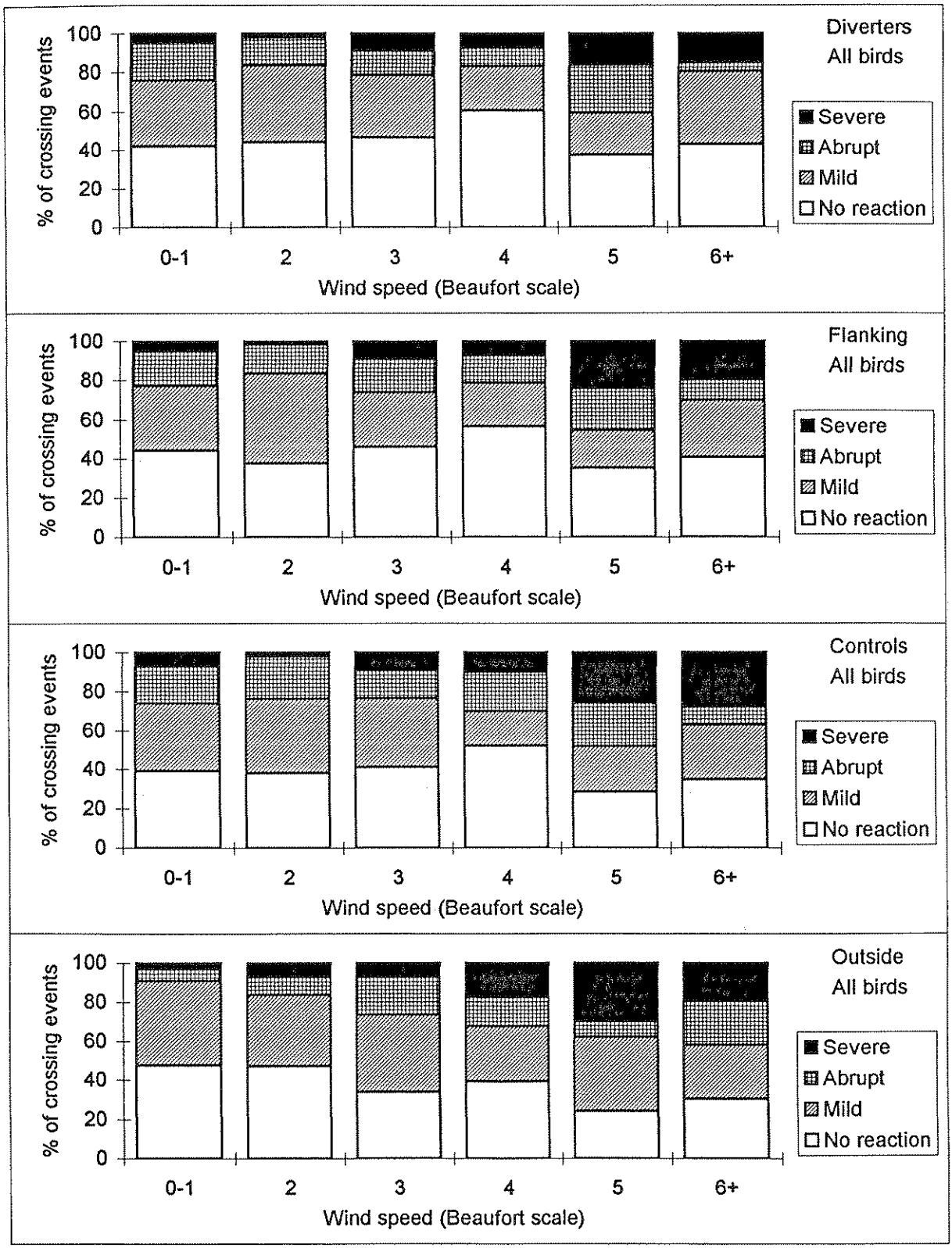


Figure 8. Effect of increasing windspeed on the flight reactions of birds approaching the power line in the diverter, flanking and control sectors, and those outside the experimental sectors in 1997.

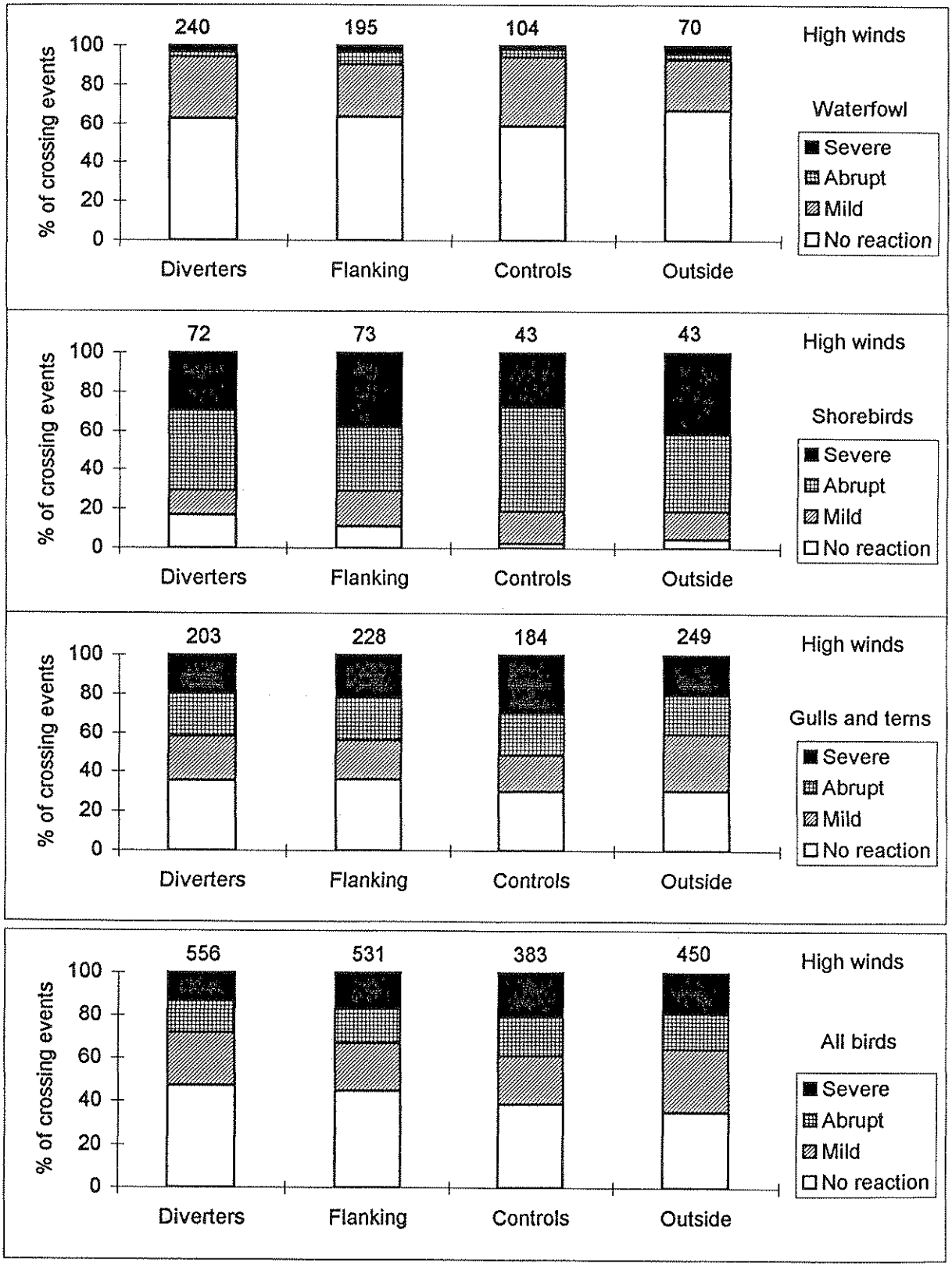


Figure 9. Flight reactions of birds approaching the power line during high winds (>20 km/h), 1997.

was so much crossing activity that height could not be noted for all events. Of the 5485 crossing events with height data:

- 59.6% (3269 events) were more than 2 m above the upper wire (Figure 10)
- 33.2% (1821 events) were within (<=2 m) above the upper wire
- 6.5% (357 events) were below the lower wire (mostly passerines, raptors and heron)
- 0.7% (38 events) were between wires

The percentage of birds that crossed above the upper wire (92.8%) is almost identical to that found in 1994/95 (95%). Since only 0.4% (22 birds) crossed within 2 m below the lower wire (and hence at risk of collision when flying under the wire), our analyses to test the effects of the dampers focused on comparing the proportions of crossing events that were within 2 m of the upper wire and those that were more than 2 m of the upper wire.

The crossing heights of the major groupings and species of birds are summarized in Figure 10. Herons, shorebirds, gulls and Caspian Terns were found to be most at risk since high proportions of each of these groupings cross the wires within 2 m of the upper wire. Waterfowl cross the power lines almost exclusively more than 2 m above the upper wire, while the highest proportion of doves and passerines cross below the lower wire. Although raptors as a grouping showed no preference for crossing height, there were distinct species differences. Northern Harriers crossed the power lines almost exclusively well below, and probably oblivious to, the lower wire, while hunting. Bald Eagles often crossed within 2 m above the upper wire, as they landed on a pole, and other raptors tended to cross the wire at greater heights. These trends are generally similar to those found in 1994/95.

For several groupings of birds, fewer birds crossed Damper sectors close to the wire (within 2 m above the upper wire) than the number of birds crossing Control sectors at that height; these differences were statistically significant for shorebirds ($P<0.01$), gulls ($P<0.05$), and 'all birds combined' ($P<0.001$; Figure 10, Table 3). The Interim Report for

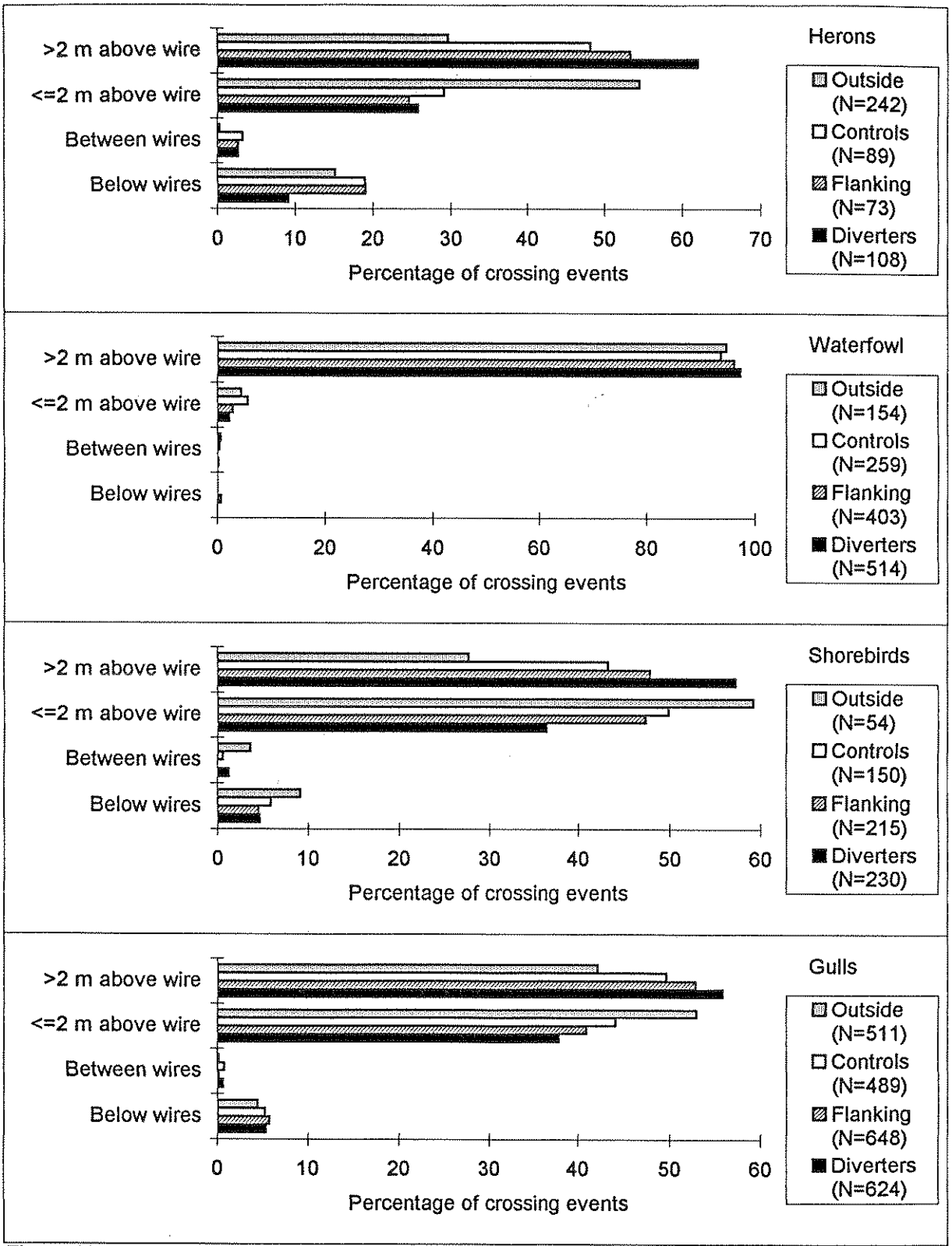


Figure 10. Percentage distribution of the crossing heights of birds crossing the sections with Diverters, Flanking the diverters, and Controls within the experimental area, and those crossing outside the experimental area. Sample sizes show numbers of crossing events.
(Continued on next page)

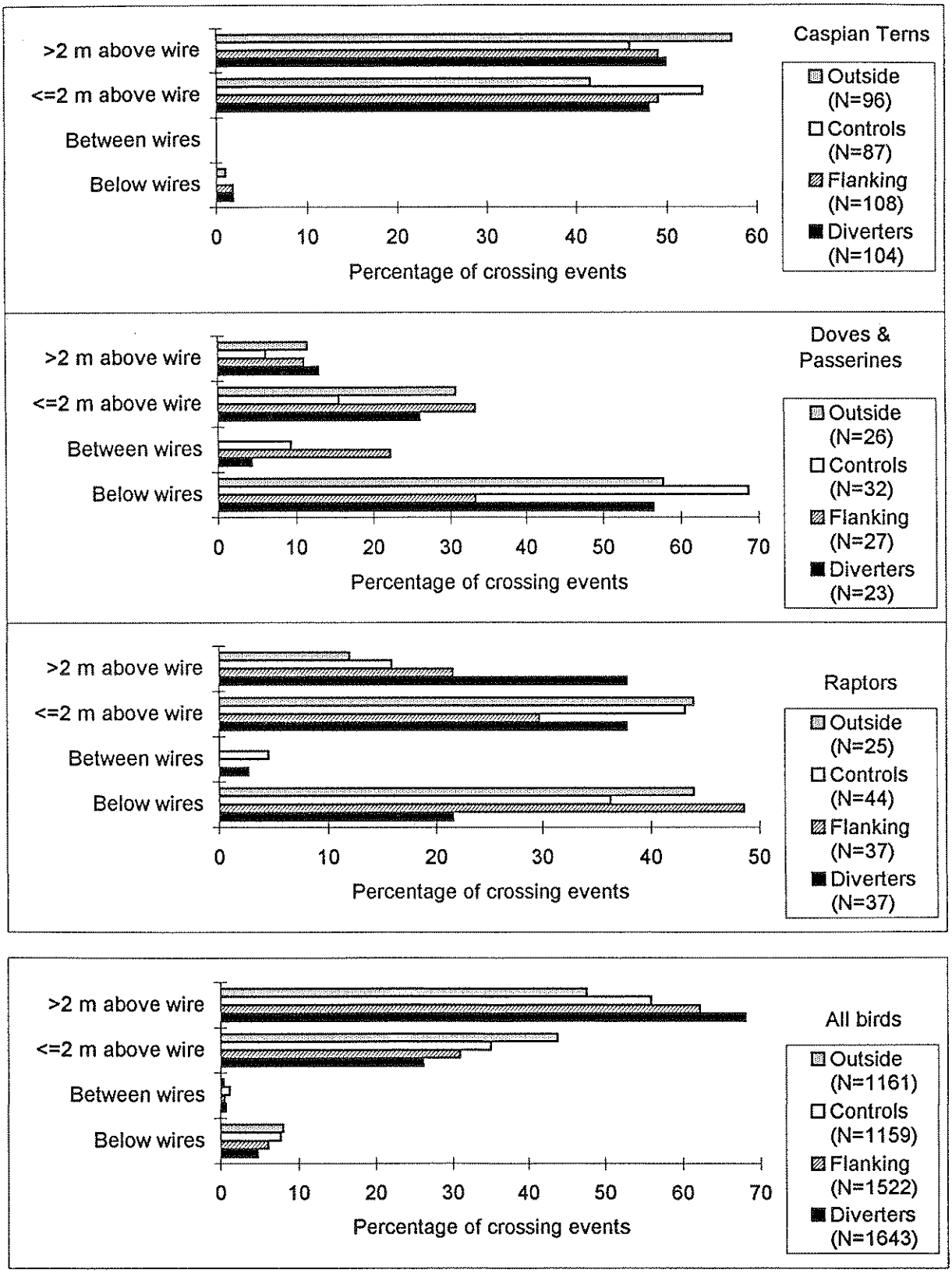


Figure 10 (continued). Heights of birds crossing the Roberts Bank power line in 1997.

this study (Cassidy and Burger 1997) reported that more shorebirds (sample made up of Dunlin only) crossed Damper sectors within 2 m above the upper wire than the number of Dunlin that crossed Controls in that height range; this finding was likely a result of low sample size.

While the close-crossing comparison between Dampers and Controls for waterfowl showed statistical significance ($P<0.05$), this is likely not biologically significant, since so few waterfowl crossed the power lines within 2 m above the upper wire. Caspian Tern showed a trend of fewer birds crossing Dampers within 2 m above the upper wire than the number of birds crossing Controls at that height, however, the differences were not statistically significant. The other groupings of birds for which there were no significant differences in the same comparisons were herons and raptors.

For all weather and wind conditions combined, the dampers caused birds to cross the power lines higher in height above the upper wire and therefore less at risk of collision. Generally the differences between Dampers and Controls are less than 10% for the high risk heights of within 2 m of the upper wire (herons 3%, waterfowl 3%, raptors 5%, gulls 6%, Caspian Tern 6% and 'all birds combined' 9%). However shorebirds showed a 13% difference between Dampers and Controls, indicating that the dampers may be especially helpful to Dunlin, Western Sandpiper and other shorebird species. The only anomaly in the reactions of birds to the dampers was for passerines and doves, which were more likely to cross close to the wire in Damper sectors than in Control sectors (-10% difference). This could be a result of small sample size (N=55 for Dampers + Controls, doves and passerines; N=2802 for Dampers + Controls, 'all birds combined') or the fact that European Starlings, which made up most of the sample, might be more inclined to land on readily visible structures such as the yellow dampers.

4.3.3.2. Crossing height in poor visibility

Small sample sizes resulted in separate analyses for four groupings - waterfowl, shorebirds, gulls and terns, and 'all birds combined' (Figure 11). In poor visibility, there

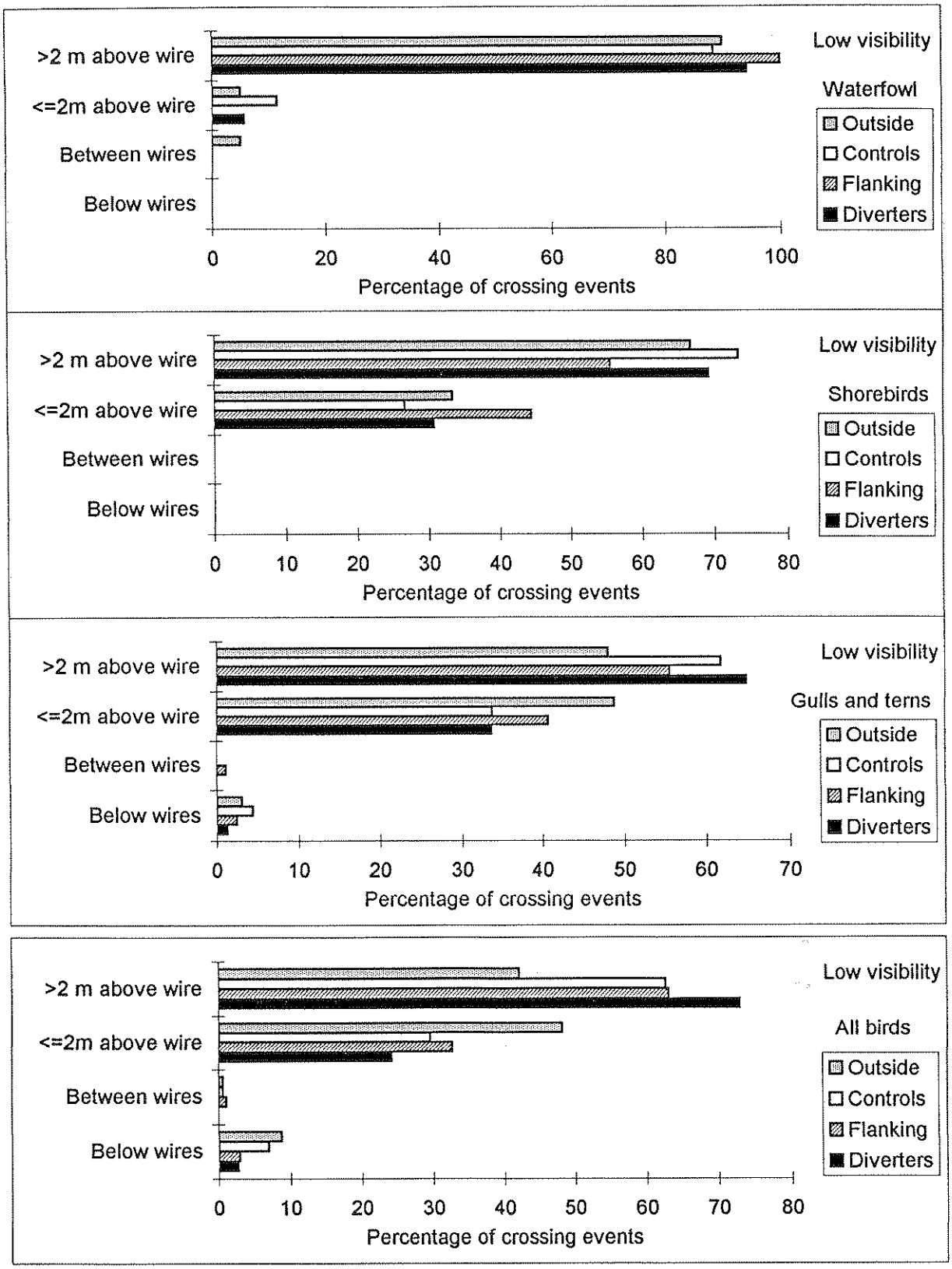


Figure 11. Crossing heights of birds crossing the power line during periods of poor visibility (in falling snow, rain, drizzle or mist), Jan-Dec 1997.

PoorVis97.xls HeightPlot

was no significant difference in the proportion of any groupings of birds crossing close to the wire (within 2 m above the upper wire) and those crossing more than 2 m above the upper wire between Damper sectors and Control sectors (Table 3).

These results indicate that the dampers do not seem to make any difference, in poor visibility, in helping birds to cross the power lines at greater, safer, heights. Of course extremely poor visibility, such as at night, in heavy wind, rain or fog, represents both the highest risk of collision and the poorest opportunity for observing flight behaviour. A more visible marker might be more successful during these high risk conditions (B. Bradley, personal communication).

4.3.3.3. Crossing height in high wind

Small sample sizes resulted in separate analyses for four groupings - waterfowl, shorebirds, gulls and terns, and 'all birds combined'. Only for 'all birds combined' was there a significant difference, where fewer birds crossed close to the wire at Dampers than at Controls ($P<0.001$; Table 3).

4.4. Collisions

In 1997 we witnessed no collisions, although two birds (a female White-winged Scoter and an American Coot) were found alive, under the power line, each with a critical injury that was a result of colliding with the wire (the scoter died hours after detection, and the coot, which crawled under some construction debris, was found dead and scavenged a few days later). Similarly in 1994/95, we witnessed remarkably few collisions; only five such occurrences in 192 hours, watching 5664 crossing events involving 52,990 birds (Burger and Cassidy 1995). While this number seems low, it should be noted that at the 1994/95 rate of collisions witnessed, this would amount to almost 1600 collisions per year. Frederick and Jie (1997) also report low rates of collisions based on observation alone, witnessing two collisions in 1831 span-hours, watching 7900 crossing events involving 41,717 birds. They (Frederick and Jie 1997) were testing Swan Flight Diverters at a newly-constructed power transmission line in the Florida Everglades.

The 1994/95 study used radar to determine that high levels of flight activity among birds crossing the power lines took place at night. We noted earlier in this report that extremely poor visibility from high winds, rain and/or fog, precludes observations of crossing behaviour. It is possible that collisions occurred during the night and/or in poor visibility when we could not observe them.

5. DENSITIES OF CARCASSES

5.1. Background

We report results from systematic searches made for dead or injured birds along the entire length of the causeway. These data provide the basis for estimating the species, numbers, time and place of birds killed at the causeway.

5.2. Methods

We conducted systematic searches for bird carcasses at weekly intervals, covering the 'Inner' search area, within 20 m on either side of the power lines from Sector 1 through 69. We used the same methodology as in 1994/95, walking slowly in a zig-zag path, scanning the ground. We recorded data on standardized data sheets (Appendix 3) including the duration of search and factors affecting the search such as disturbances that might cover or remove carcasses (see Section 6.1.).

For each dead bird we found, we also recorded: species, age, sex, Sector number, distance to nearest mainland Pole, perpendicular distance to wire, location north or south of wire, condition of carcass, estimated number of days since death, degree of scavenging, details of injuries or broken bones, and, on the basis of parts found and injuries, and the likelihood that the bird was killed by colliding with the power lines. This latter measure was coded as very likely, possibly, probably not, or unknown. Carcasses were identified with the aid of field guides, including one specifically for beached birds (Ainley et al. 1980), and by comparing partial bird remains to reference skins and skeletons in the

Cowan Vertebrate Museum in the Zoology Department of the University of British Columbia.

While there was a slight difference in search effort between the two studies, we do not feel that it is a source of error in comparing years . In both studies, we conducted a weekly search of the Inner search area, within 20 m on either side of the power line. However in 1994/95, we also conducted some non-systematic searches of the 'Outer' search area, from 20-40 m on either side of the power line. Each sector was searched in this way between 5 and 15 times in the 1994/95 study. Relatively few carcasses were found more than 20 m from the power lines (see Figure 16 in Burger and Cassidy, 1995), with 74% of the 590 carcasses (304 Fresh and 286 Old) found with 10 m of the wires, and more than 90% found within the Inner search area.

As in the 1994/95 study, carcasses were separated into two classes based on the estimated time since death. Fresh carcasses were those in which the state of decomposition suggested they were deposited during the period of the study (January - December, 1997). Old carcasses were those deposited prior to January 1997. While we conducted statistical analyses of flight behaviour for Damper vs. Control sectors only (to reduce the chance of observation error assigning the wrong sector as a result of depth of field distortion), for carcass analyses we kept all experimental (Damper, Control and Flanking) treatment types separate, since no such error was possible.

5.3. Results of carcass searches

5.3.1. Carcasses found

The experimental sectors (Damper, Flanking, Control; 3-26) were each searched 52 times while the non-experimental, Outside sectors (1,2, 27-69) were searched an average of 44 times per sector, for an overall average of 49 searches per sector from January through December, 1997. Table 4 summarizes the species and numbers of carcasses found in 1997. Generally, we found fewer Fresh carcasses in 1997 (200) than in 1994/95 (304). We also found fewer carcasses that were suspected wire kills (combining the categories of

Table 4. Identity of carcasses found on the Roberts Bank causeway, Jan-Dec 1997.
Carcasses likely to have been deposited during the study (Fresh) are separated from those long dead (Old). The number and % of "Fresh" carcasses considered definite or probable wire kills is also shown.

			Fresh		Old		Total		Wire kills*		
Family	Species	Code	No.	%	No.	%	No.	%	No.	% of all wirekills	% by species
Loons	Common Loon	COLO	1	*0.5*	0	*0.0*	1	*0.5*	0	*0.0*	*0*
Grebes	Western Grebe	WEGR	4	*2.1*	0	*0.0*	4	*1.8*	3	*3.0*	*75*
	Horned Grebe	HOGR	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Pied-billed Grebe	PBGR	0	*0.0*	1	*4.5*	1	*0.5*	-	-	-
	Grebe sp.	Grebe	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Total grebes		6	*3.1*	1	*4.5*	7	*3.2*	5	*5.0*	*83*
Cormorants	Pelagic Cormorant	PECO	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Cormorant sp.	Corm	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Total cormorants		2	*1.0*	0	*0.0*	2	*0.9*	2	*2.0*	*100*
Herons	Great-blue Heron	GBHE	1	*0.5*	2	*9.1*	3	*1.4*	1	*1.0*	*100*
Rails	American Coot	AMCO	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
Waterfowl	Trumpeter Swan	TRUS	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Brant	BRAN	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Canada Goose	CAGO	1	*0.5*	0	*0.0*	1	*0.5*	0	*0.0*	*0*
	Green-winged Teal	GWTE	4	*2.1*	0	*0.0*	4	*1.8*	3	*3.0*	*75*
	Mallard	MALL	22	*11.3*	0	*0.0*	22	*10.1*	5	*5.0*	*23*
	Northern Pintail	NOPI	10	*5.1*	1	*4.5*	11	*5.1*	3	*3.0*	*30*
	Northern Shoveler	NOSL	1	*0.5*	0	*0.0*	1	*0.5*	0	*0.0*	*0*
	American Wigeon	AMWI	10	*5.1*	0	*0.0*	10	*4.6*	2	*2.0*	*20*
	Greater Scaup	GRSC	3	*1.5*	0	*0.0*	3	*1.4*	3	*3.0*	*100*
	Scaup sp.	Scaup	5	*2.6*	1	*4.5*	6	*2.8*	2	*2.0*	*40*
	Oldsquaw	OLDS	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Surf Scoter	SUSC	2	*1.0*	0	*0.0*	2	*0.9*	1	*1.0*	*50*
	White-winged Scoter	WWSC	6	*3.1*	0	*0.0*	6	*2.8*	6	*5.9*	*100*
	Bufflehead	BUFF	2	*1.0*	0	*0.0*	2	*0.9*	2	*2.0*	*100*
	Unidentified duck	DUCK	39	*20.0*	9	*40.9*	48	*22.1*	7	*6.9*	*18*
	Total waterfowl		108	*55.4*	11	*50.0*	119	*54.8*	37	*36.6*	*34*
Shorebirds	Killdeer	KILL	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Black Turnstone	BLTU	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Western Sandpiper	WESA	10	*5.1*	1	*4.5*	11	*5.1*	10	*9.9*	*100*
	Dunlin	DUNL	24	*12.3*	0	*0.0*	24	*11.1*	20	*19.8*	*83*
	Small sandpiper (peep)	PEEP	5	*2.6*	0	*0.0*	5	*2.3*	4	*4.0*	*80*
	Total shorebirds		41	*21.0*	1	*4.5*	42	*19.4*	36	*35.6*	*88*

Continued on next page.

Table 4 continued

Family	Species	Code	Fresh No.	Fresh %	Old No.	Old %	Total No.	Total %	Wire kills* No.	Wire kills* % of all wirekills	Wire kills* % by species
Gulls	Bonaparte's Gull	BOGU	0	*0.0*	1	*4.5*	1	*0.5*	-	-	-
	Mew Gull	MEGU	1	*0.5*	0	*0.0*	1	*0.5*	0	*0.0*	*0*
	Ring-billed Gull	RBGU	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	California Gull	CAGU	1	*0.5*	0	*0.0*	1	*0.5*	0	*0.0*	*0*
	Glaucous-winged Gull	GWGU	5	*2.6*	0	*0.0*	5	*2.3*	3	*3.0*	*60*
	Gull sp.	GULL	10	*5.1*	4	*18.2*	14	*6.5*	1	*1.0*	*10*
	Total gulls		18	*9.2*	5	*22.7*	23	*10.6*	5	*5.0*	*28*
Raptors	Sharp-shinned Hawk	SSHA	0	*0.0*	1	*4.5*	1	*0.5*	-	-	-
Kingfishers	Belted Kingfisher	BEKI	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
Woodpeckers	Northern Flicker	NOFL	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
Passerines	North-western Crow	NWCR	1	*0.5*	0	*0.0*	1	*0.5*	-	-	-
	American Robin	AMRO	2	*1.0*	0	*0.0*	2	*0.9*	2	*2.0*	*100*
	European Starling	EUST	4	*2.1*	0	*0.0*	4	*1.8*	3	*3.0*	*75*
	Warbler sp.	WARB	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Spotted Towhee	SPTO	2	*1.0*	0	*0.0*	2	*0.9*	1	*1.0*	*50*
	Savannah Sparrow	SASP	3	*1.5*	0	*0.0*	3	*1.4*	3	*3.0*	*100*
	Song Sparrow	SOSP	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Sparrow sp.	Sparro	0	*0.0*	1	*4.5*	1	*0.5*	-	-	-
	Unidentified passerine	passeri	1	*0.5*	0	*0.0*	1	*0.5*	1	*1.0*	*100*
	Total passerines		15	*7.7*	1	*4.5*	16	*7.4*	12	*11.9*	*80*
Total identified carcasses			195	*100*	22	*100*	217	*100*	101	*100*	*52*
Unidentified			5		16		21		0		*0*
Total all carcasses			200		38		238		101		*51*

*Probable wire kills were assessed among the "fresh" carcasses only. The % shown are the % of the total identified wirekill sample, and the % of each species suspected of being wire-killed.

'very likely' and 'possibly' killed by wire) in 1997 (101) than we found in 1994/95 (120). These results might be explained by the difference in search efficiency between years which may have resulted from the difference in substrate under the power lines (see Section 6.4.3.).

As in 1994/95, the majority of the Fresh carcasses were waterfowl (55% or 108 birds), shorebirds (21% of 41 birds) and gulls (9% or 18 birds; Table 4). The total number of suspected wire kills was made up mostly of waterfowl (37% or 37 birds), shorebirds (36% or 36 birds), gulls (5% or 5 birds) and passerines (12% or 12 birds). Within most groupings, all (100%) or nearly all (80-88%) of the grebes, cormorants, heron, rail, swan, shorebirds, kingfisher, woodpecker and passerines were probable wire kills (Table 4). As we found before, some wire kills were known positively, from such injuries as smashed skulls and bills, broken wing bones, furcula, sternums or pectoral girdles or traumatized flesh injuries. Likewise, we found that most waterfowl (66%; N = 108) were likely not wire kills, but killed by raptors, or killed or wounded by hunters and then brought to the causeway to be eaten by Bald Eagles, falcons or hawks. This could have been the case for gulls as well (72% were likely not wire kills; N = 18).

5.3.2. General distribution of carcasses

The distribution of carcasses along the causeway was generally similar to that in 1994/95, with most carcasses found in the first 40 sectors overlapping the experimental area (Figure 12). Likewise, carcasses of waterfowl and gulls were distributed along the causeway and were not tied to crossing events, but, more likely to the fact that many of these carcasses were brought to the area by predators and scavengers. Of the 41 shorebird carcasses found along the causeway, 17 of these were found within the experimental area (Sectors 3-26) while 24 were found Outside (1,2, 27-69).

In 1994/95, Caspian Tern carcasses were strongly clumped in Sectors 60-70, where they most frequently crossed the power lines. In the current study, with Caspian Terns

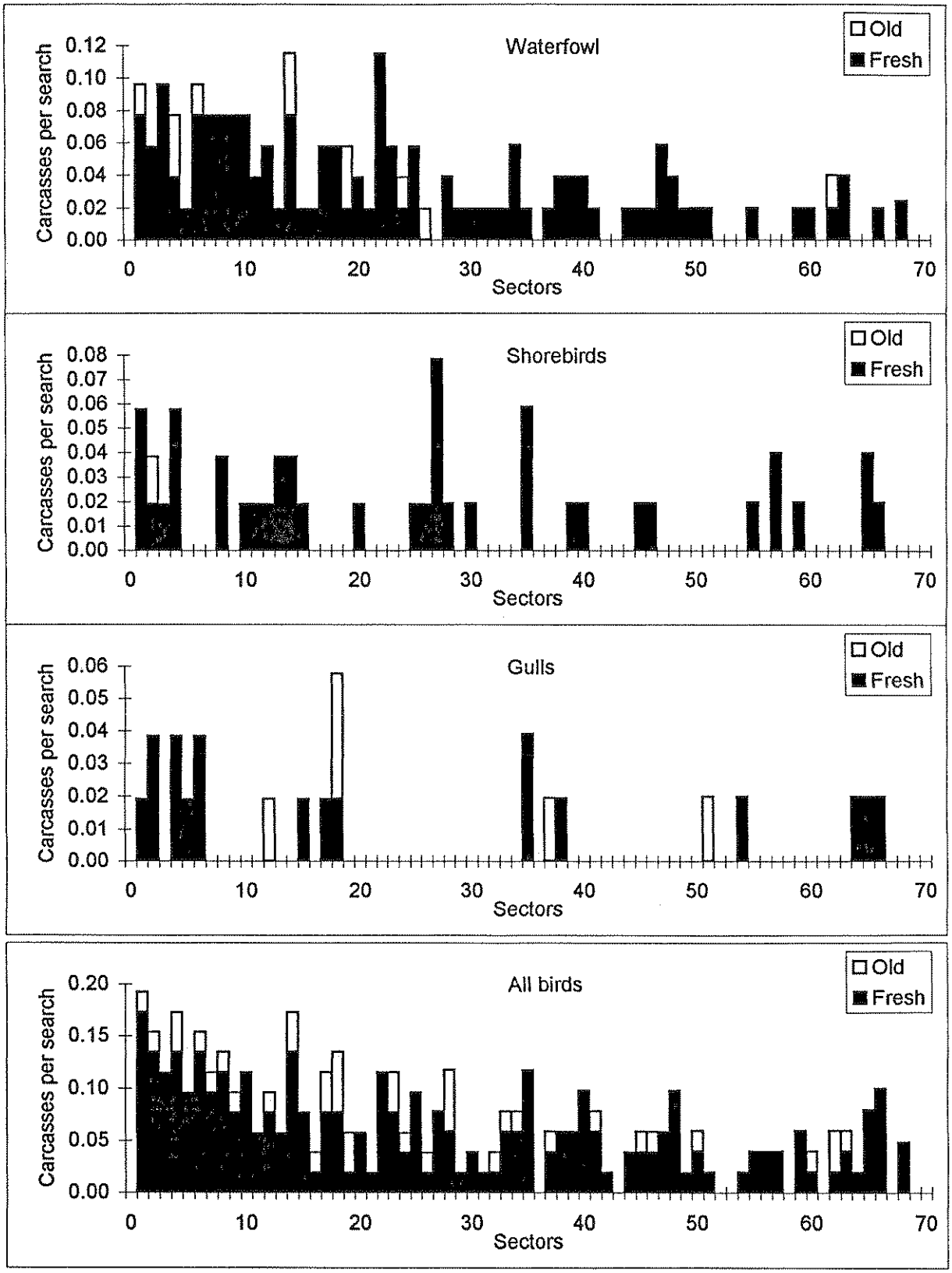


Figure 12. Distribution of carcasses per 60 m sector along the Roberts Bank Superport causeway in 1997, shown as carcasses per search for each sector. "Fresh" and "Old" carcasses were probably deposited during and before the 1997 study period, respectively.

observed using the mudflats and crossing the power lines along a much greater length of the causeway than in 1994/95, not a single Caspian Tern carcass was found.

5.3.3. Carcass distribution within the experimental sectors

We searched for carcasses in Damper, Flanking and Control sectors with equal effort (Table 5). There was generally no difference in the numbers of Fresh carcasses found in each of these three treatment types, except for Dunlin (none was found in Damper sectors, five in Flanking, and six in Controls), all shorebirds combined (two were found in Damper sectors, seven in Flanking and eight in Controls), and gulls, where the opposite trend was found (five were found in Dampers, two in Flanking and one in Controls). Of all Fresh shorebird carcasses found, 88% were wire kills, whereas for all Fresh gull carcasses found, 28% were wire kills. Overall, there were slightly fewer wire-killed birds in Damper sectors (11) than in Flanking (12) or Controls (17); these differences were not statistically significant.

Finally, we calculated the mean carcasses per search through the year for each sector independently, then calculated the mean and standard deviation for the Damper, Flanking and Control sectors (Figure 13). Analysis of variance tests on these data (data were transformed by log transformation (Zar 1996: 279) show no significant differences between treatment types or among any of the groupings (waterfowl, shorebirds, gulls, all birds, wire kills; $P>0.05$ for each test).

5.3.4. Conclusions from the carcass data

Although differences are statistically insignificant and sample sizes are small, there is a weak trend of dampers reducing risk of collision for all birds (this is consistent with the flight observation data) and especially for shorebirds.

Table 5. Summary of the distribution of Fresh bird carcasses within and outside the experimental area in 1997.

	Experimental sectors			Outside experimental	
	Diverters	Flanking	Control	area	Total
Number of sectors	8	8	8	45	69
Mean no. of searches	52	52	52	49	50
Number of carcasses found					
Waterfowl	20	22	21	45	108
Dunlin	0	5	6	13	24
Western Sandpiper & Peeps	2	2	2	9	15
All shorebirds	2	7	8	24	41
Gulls	5	2	1	10	18
All birds	33	34	32	101	200
All suspected wirekills	11	12	17	61	101
Percentage of sectors with carcasses					
Waterfowl	100	100	87.5	68.2	77.9
Shorebirds	25	50	75	34.1	39.7
Gulls	50	12.5	12.5	18.2	20.6
All birds	100	100	100	84.1	89.7
Wirekill	75	75	87.5	70.5	73.5

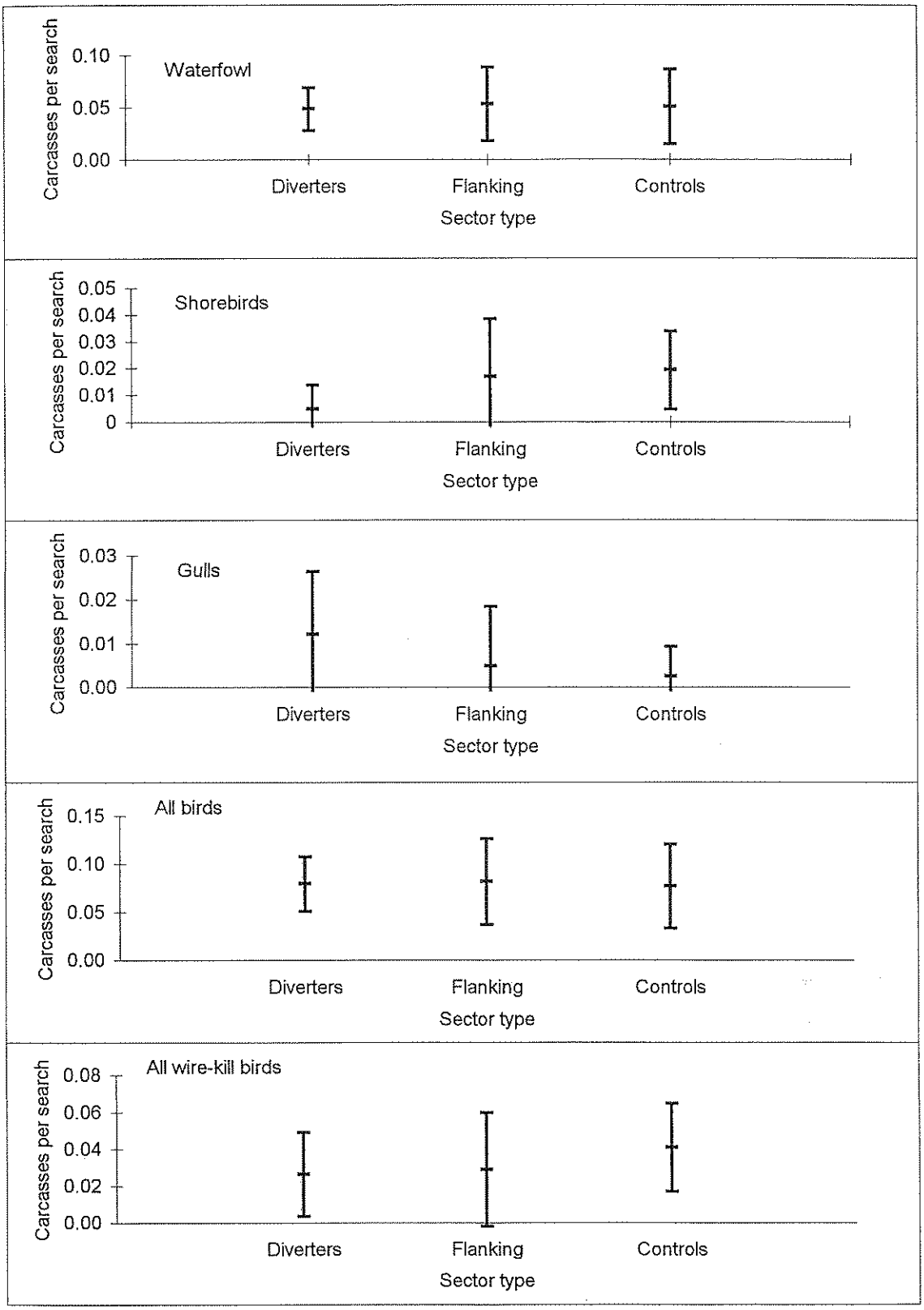


Figure 13. Annual means (+/- SD) carcass density per sector within Diverter, Control and Flanking sectors in 1997. Each treatment had 8 sectors searched 52 times.

6. CARCASS SEARCH EFFICIENCY, CARCASS PERSISTENCE AND ESTIMATING TOTAL MORTALITY

6.1. Background: changes and disturbances to the search area

In 1994/95, we conducted field tests to calculate indices of search efficiency and carcass persistence, which we applied to our carcass search data to derive an estimate of the total number of carcasses deposited along the causeway. The intent was to use these indices for 1997 as well. However, there have many changes to the carcass search area, both prior to the start of fieldwork in January, 1997, and during the study. These changes (new rail beds and cryptic substrate) likely affected the efficiency of finding carcasses, as well as the rate at which scavengers might eat or remove carcasses. Therefore, we conducted new tests in 1997.

New rail beds: There are many new rail beds in the carcass search area, especially north of the wires, with the elevated section of the bed hiding the view of carcasses deposited in the depression north of the bed. Increased train activity has undoubtedly increased the likelihood of carcasses being deposited in rail cars where they would never be detected.

Cryptic substrate: Small and large gravel, sand and crushed rock has been placed over the majority of the search area, eliminating the dirt and vegetation that existed in the 1994-95 study. Of the 69 sectors, 25 sectors now have 0-25% of the search area covered by vegetation, 30 sectors have 75% of the area covered, and only nine sectors have 100% of the area covered by vegetation. Overall, approximately 42% of the carcass search area is covered by vegetation, while approximately 58% is covered with substrate that is white, grey, black, white or brown in colour, very similar in colour to most shorebirds, and many gulls and ducks.

During the study, there was much disturbance to the study area, which may have affected the ability to detect freshly deposited carcasses, as a result of the search area being covered, removed, trampled or otherwise altered (see Appendix 4). These activities, as well as increased train activity may have affected the densities, behaviour or distribution of

avian scavengers (and possibly mammals such as Coyote) and so are likely to affect the rates of removal of carcasses.

6.2. Carcass search efficiency

6.2.1. Background

We conducted a series of tests to derive a search efficiency index (e), a measure of the proportion of the carcasses detected during a search. The index was then applied to the carcass counts to estimate the total numbers of carcasses present at the time of each search, including those not found.

6.2.2. Methods

One set of tests was done on 1 May, 1997. In 1994/95, four sets of tests were done, one in each season, to cover the varying conditions of vegetation height and background colouration. It was felt that testing in a single season would suffice in the current study, since there were no significant differences between tests done in the four different seasons for mid-sized water birds, gulls or for all birds pooled (Burger and Cassidy, 1995). Three replicate tests were conducted using carcasses laid out in different parts of the causeway. The sample for the first replicate test consisted of 20 intact carcasses, including 11 shorebirds or shorebird-sized birds (including dull-coloured passerines, and two small owls) and nine larger birds (ducks, gulls, alcids, a raptor and a grebe). The sample for the second and third replicate tests consisted of all the same birds, except for the grebe which was removed by a scavenger during the first test. The carcasses had been gathered as wire kills on the causeway or elsewhere, or as beached birds, window kills or road kills. No birds were killed for these tests.

For each replicate, an assistant (KB) distributed the carcasses randomly along 20 sectors (1.2 km), within 10 m on either side of the power line, and the researcher (ALEVC) who conducted virtually all of the carcass searches conducted a carcass search. We used a single searcher during this current study, since there were no significant differences in the efficiencies of the three searchers during search efficiency tests conducted in 1994/95

(Burger and Cassidy, 1995). Test carcasses were marked and individually identified with numbered, inconspicuous cable-ties around the wing at the humerus. After the last test, the carcasses were left in place for carcass persistence tests (see Section 6.3.).

6.2.3. Results of carcass search efficiency tests

Efficiency at finding smaller, shorebird-sized birds was much lower (mean = 0.18) than that for larger birds (mean = 0.56; Table 6), following the same trend as in1994/95. However, in that study, two of the four seasonal sets of tests used Dunlin exclusively as the 'smaller bird sub-sample'; a difference in search efficiency was noted between the two tests in February and April using Dunlin (0.44) and the two tests in August and October using other small birds (0.19; Burger and Cassidy, 1995). The current study's single set of tests (conducted in May) used a mixture of species for the 'smaller bird sub-sample'. Search efficiency for Dunlin carcasses was therefore assumed to be 0.18, the same as for other small birds.

Gulls, waterfowl and other larger birds were found less frequently (0.56) in 1997 than in 1994/95 (0.77; the mean of 0.71 for waterfowl and alcids and 0.83 for gulls). Even if we look at the test results from the most comparable time of year (12 April, 1995), search efficiency in 1997 is still much lower for larger birds than in 1994/95 (0.75).

As in the 1994/95 study, we assumed a search efficiency of 1.0 for very large birds (loons, herons, swans and geese; all would be found if present during a search). We have applied the 1997 results to our analysis. In general, search efficiency for all birds was lower in 1997 (0.37) than in 1994/95 (0.58). This may be a result of the new, predominantly gravel substrate (similar in colour to many of the birds found) making detection more difficult than on the previous substrate of dirt with some or much vegetation.

Table 6. The proportion of carcasses found in three replicate search efficiency tests at Roberts Bank Causeway on 1 May 1997. Results of similar tests in 1994-1995 are included for comparison.

	Shorebirds and other small birds		Gulls, waterfowl and other large birds	
	Proportion found	No. carcasses	Proportion found	No. carcasses
Test 1	0.27	11	0.56	9
Test 2	0.18	11	0.38	8
Test 3	0.09	11	0.75	8
Mean	0.18		0.56	
SD	0.09		0.19	
Results from 1994/95				
Mean	0.19*		0.77	
SD	0.19		0.25	
No. tests	10		22	

* This excludes tests for Dunlin, which were tested separately in 1994/95 and the mean proportion found was 0.44 (SD = 0.18, N = 12 tests).

6.3. Carcass persistence

6.3.1. Background

Carcasses that are not found on one search may be detected on a subsequent search, if they are still there; or they may never be detected, if they were eaten or removed between deposition and time of the next search. We needed to know the rate at which carcasses were scavenged or had disappeared (removed by scavengers or people). We therefore conducted tests to determine the rate and timing of carcass persistence.

6.3.2. Methods

We conducted three separate carcass persistence tests. On 1 May, we left the 19 carcasses used in the search efficiency tests in place at the end of the last test; we also added two more birds to the sample, for a total of 21 carcasses (12 small, 9 large). On 7 August, 26 carcasses (17 small, 9 large) were randomly laid out, and on 2 December, 23 carcasses were laid out (11 small, 12 large). All birds were obtained and identified as described in Section 6.2.2. above.

Birds were checked after 2 days, 8-10 days, and additionally, in August and December, 14-15 days. We felt that this reduced sampling schedule was adequate (compared to sampling up to Day 30 in 1994/95), since that study showed relatively little change after 10 days (Burger and Cassidy, 1995). We made detailed notes of the location and body condition (proportion scavenged or decomposing) on each check. When a carcass was not found, we searched thoroughly to a 30 m radius of its original site.

Almost all carcasses were attacked by insects within 1-2 days, with flesh and muscle often completely eaten by insects within 7-10 days, but skeletons remained in place. We did not include them in the scavenged category. Those carcasses attacked by avian and mammalian scavengers, however, were usually torn apart and scattered about and hence less likely to be detected. We did include these carcasses in the scavenged category.

6.3.3 Results of carcass persistence tests

Rates of carcass persistence and scavenging differed between shorebird-like birds and larger birds, and there were also differences among the three tests (Figure 14). As in 1994/95, within each bird size group, relatively few birds disappeared in summer (August), but rates of disappearance were highest in winter (December), when high numbers of scavenging birds were visiting the causeway. In general, the persistence of shorebird types was similar in both years. However, larger birds seemed to persist more in 1997 than in 1994/95, especially during winter and spring.

As in the 1994/95 study, based on the seasonal densities of the most common scavengers (raptors; Figure 2), we applied the pooled data from May and August to the seasonal period May through October and the data from December to the seasonal period November through April.

As in the 1994/95 study, we tried several survival equations to model carcass persistence during the first ten days, and again found that the persistence of carcasses (including scavenged carcasses still present) was best fit by second-order polynomials plotted for the two groups of birds separately in the two seasonal periods. We extrapolated the persistence between days of measurement. These equations predicted the proportion of carcasses present (N_t) as a function of time (t) in days since deposition. The relevant equations were:

i) for shorebird types from May through October (data from May and August 1997)

$N_t = 1.0046 - 0.0267t + 0.0027t^2$ ($r^2 = 0.966$, $P<0.001$, $df = 12$)

ii) for shorebird types from November through April (data from December 1997)

$N_t = 1.0535 - 0.0499t + 0.0051t^2$ ($r^2 = 0.968$, $P<0.001$, $df = 12$)

iii) for larger birds from May through October (data from May and August 1997)

$N_t = 0.9929 - 0.0213t + 0.0015t^2$ ($r^2 = 0.981$, $P<0.001$, $df = 12$)

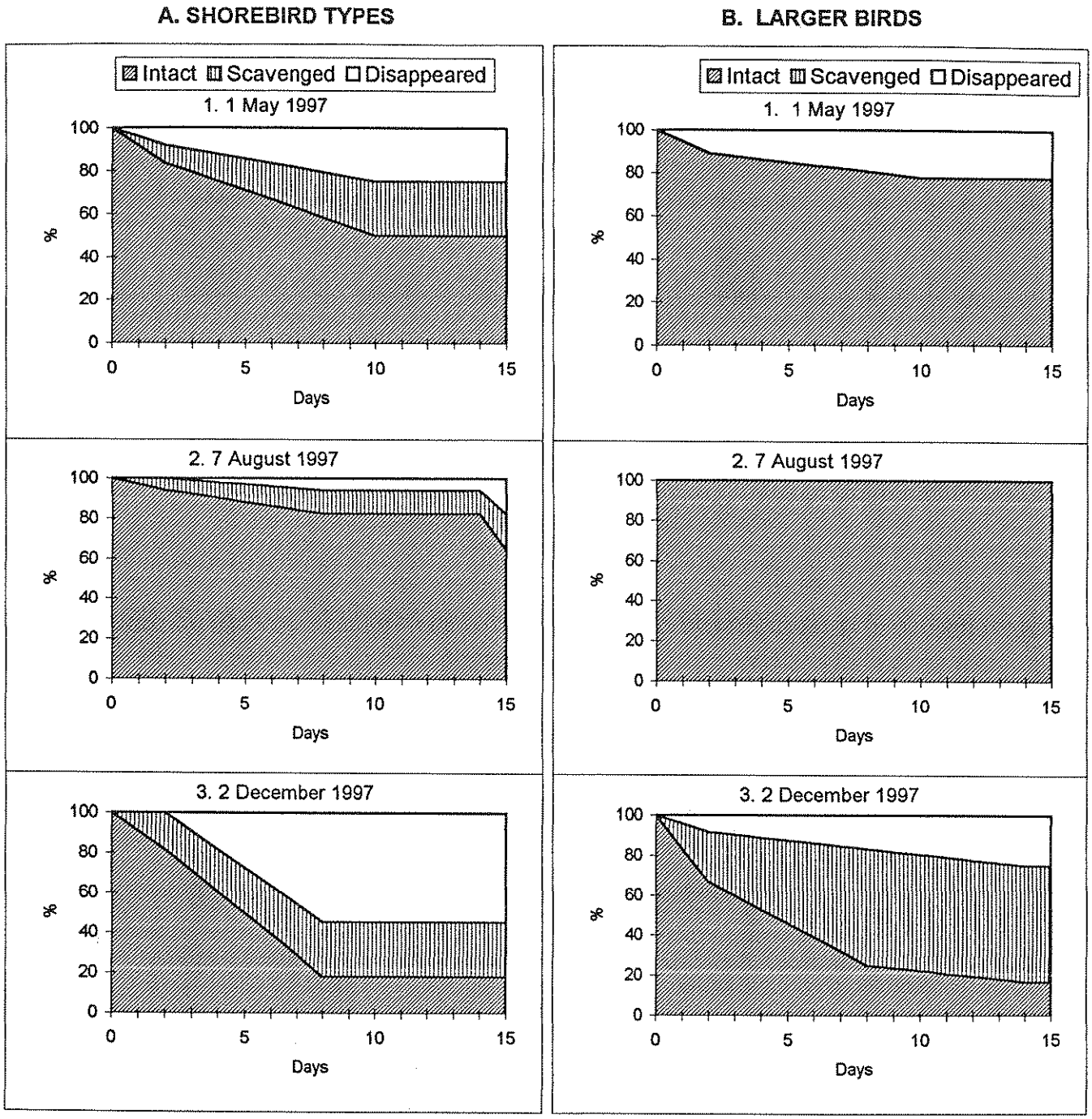


Figure 14. Results of three carcass persistence experiments made in spring (1 May 1997), summer (7 August 1997) and winter (2 December 1997). Results from shorebirds and other small birds are plotted on the left, and waterfowl and other larger birds on the right. See text for sample sizes.
All carcasses were attacked by insects, but considered intact until they disintegrated.
Scavenged carcasses were those dismembered or partly eaten by birds and mammals.

iv) for larger birds from November through April (data from December 1997)

$N_t = 0.9896 - 0.0325t + 0.0021t^2$ ($r^2 = 0.992$, $P<0.001$, $df = 12$)

Carcass searches were made at 7-day intervals. We therefore applied the equations for Days 0, 1, 2, 3, 4, 5 and 6 (days between searches) and derived the following mean persistence index (**p**) between searches:

Shorebird types:	0.9459 for May through October (0.87 in 1994/95);
	0.8298 for November through April (0.65 in 1994/95);
All larger birds:	0.9434 for May through October (1.00 in 1994/95);
	0.9150 for November through April (0.74 in 1994/95).

The persistence values were higher in 1997 than in 1994/95, especially from November through April for all birds. We found fewer raptors in 1997 (Tables 2 and 3) which should contribute to higher persistence values since Northern Harrier and Red-tailed Hawk were major scavengers in 1994/95. Increased disturbance from construction and increased traffic may account for lower abundance or activity of bird and mammal scavengers. It is also possible that the substrate made detection of carcasses more difficult, decreasing search efficiency of bird scavengers, which locate food by sight predominantly.

6.4. Estimating total mortality

6.4.1. Background

Data from the weekly carcass search, the search efficiency tests and the carcass persistence tests must be considered together to derive an estimate of the total number of carcasses deposited along the causeway during the one-year study.

6.4.2. Methods

We considered carcass deposition for the 12 months, January - December, 1997. For each species, we calculated the monthly total carcass deposition (C_{tot}) as:

$$C_{tot} = C_f/(e.p)$$

where C_f is the number of Fresh carcasses (deposited during the study) found in that month, e is the search efficiency index (see Section 6.2.) and p is the carcass persistence index for that size type of bird in that month (see Section 6.3.).

6.4.3. Results: estimated total carcass deposition

A total of 200 Fresh carcasses was found along the causeway in the one-year study (Tables 4, 7). Variability among and between species and months (Table 7) track the abundance and distribution of species throughout the year, shown by the census data (see Section 3.3.).

The search efficiency and seasonal carcass persistence indices for each species found during carcass searches are summarized in Table 8, along with the estimated number of carcasses deposited each month, and totals for the year. As in 1994/95, for large species with high e and p indices (easily found, tend to persist a long time), the estimated total carcass deposition differs little from the number actually found (e.g. Common Loon, Great Blue Heron, Trumpeter Swan, Brant, Canada Goose; Table 8).

Overall, using these indices for search efficiency and persistence, we estimate that a total of 635 carcasses was deposited in 1997, compared with the estimate of 710 carcasses in 1994/1995. Table 9 summarizes comparisons between 1997 and 1994/95 for the major groupings of birds. In 1997, there was generally a decrease in the number of carcasses found (200 vs. 304 in 1994/95) and in the estimated number of carcasses deposited (635 vs. 708 in 1994/95). Actual counts and estimated totals for grebes, gulls and passerines increased in 1997. Single carcasses of kingfisher and woodpecker were found in 1997, while no carcasses of Caspian Terns, raptors or owls (which were found in 1994/95) were found in 1997.

The estimates of total carcass deposition are sensitive to changes in the search efficiency and persistence indices. Minor changes in either result in substantial changes in estimated

Table 7. Monthly counts of "fresh" carcasses found in 1997. See Table 4 for species codes.

Family	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Loons	COLO	0	0	0	0	0	0	0	0	0	0	0	1	1
Grebes	HOGR	0	0	0	0	0	0	0	0	0	0	0	1	1
	WEGR	1	3	0	0	0	0	0	0	0	0	0	0	4
	Grebe sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Cormorants	PECO	0	1	0	0	0	0	0	0	0	0	0	0	1
	Cormorant sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Herons	GBHE	0	0	0	0	0	0	0	1	0	0	0	0	1
Rails	AMCO	0	0	0	0	0	0	0	0	0	0	1	0	1
Waterfowl	TRUS	0	1	0	0	0	0	0	0	0	0	0	0	1
	BRAN	0	0	0	0	0	0	0	0	0	0	0	1	1
	CAGO	0	0	1	0	0	0	0	0	0	0	0	0	1
	GWTE	0	0	0	2	0	0	0	0	0	0	0	2	4
	MALL	13	2	4	0	0	0	0	0	0	0	2	1	22
	NOPI	4	1	1	0	0	0	0	0	0	0	2	2	10
	NOSL	1	0	0	0	0	0	0	0	0	0	0	0	1
	AMWI	4	3	0	1	1	1	0	0	0	0	0	0	10
	GRSC	0	1	0	0	0	0	0	0	0	2	0	0	3
	SCAUP	1	0	2	1	0	0	0	0	0	0	1	0	5
	OLDS	0	0	0	0	0	0	0	0	0	0	1	0	1
	SUSC	0	1	0	1	0	0	0	0	0	0	0	0	2
	WWSC	0	0	0	0	0	0	0	0	0	2	2	2	6
	BUFF	0	2	0	0	0	0	0	0	0	0	0	0	2
	Duck sp.	20	4	6	2	2	0	1	0	0	0	1	3	39
Shorebirds	KILL	0	0	0	0	0	0	0	0	0	0	0	1	1
	BLTU	0	0	0	0	0	0	0	0	0	1	0	0	1
	WESA	0	0	1	0	4	0	1	4	0	0	0	0	10
	DUNL	4	4	6	0	3	0	0	0	0	1	3	3	24
	PEEP	1	0	0	0	2	0	0	0	0	0	1	1	5
Gulls	MEGU	0	0	0	0	0	0	0	0	0	0	0	1	1
	RBGU	0	0	0	0	0	0	0	1	0	0	0	0	1
	CAGU	0	0	1	0	0	0	0	0	0	0	0	0	1
	GWGU	0	4	0	0	0	0	0	0	0	1	0	0	5
	Gull sp.	2	1	5	1	0	0	0	0	0	1	0	0	10
Kingfisher	BEKI	0	1	0	0	0	0	0	0	0	0	0	0	1
Woodpecker	NOFL	0	0	0	0	0	0	0	0	0	1	0	0	1
Passerines	NWCR	0	0	1	0	0	0	0	0	0	0	0	0	1
	AMRO	0	0	0	0	0	0	0	1	0	1	0	0	2
	EUST	1	0	0	1	0	0	0	0	0	1	1	0	4
	Warbler sp.	0	0	0	0	0	0	0	0	1	0	0	0	1
	SPTO	0	0	0	0	0	0	0	0	0	2	0	0	2
	SASP	0	0	0	1	0	1	0	0	1	0	0	0	3
	SOSP	0	0	0	0	0	0	0	0	0	0	1	0	1
	Passerine sp.	0	0	0	0	0	0	0	0	0	0	0	1	1
Unidentified	UN	2	1	1	1	0	0	0	0	0	0	0	0	5
Total		54	32	29	11	12	2	2	7	2	13	16	20	200

Table 8. Calculation of monthly and total number of carcasses deposited on the Roberts Bank Causeway in 1997.

The numbers of carcasses found (Table 7) were converted to numbers deposited by applying search efficiency and persistence coefficients (see text).

		Search	Persistence		Estimated number of carcasses deposited per month												
Family	Species	efficiency	May-Oct	Nov-Apr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Loons	COLO	1	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1
Grebes	HOGR	0.56	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
	WeGr	0.56	0.9459	0.915	2.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8
	Grebe sp.	0.56	0.9459	0.915	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Cormorants	PECO	0.56	0.9459	0.915	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
	Cormorant sp.	0.56	0.9459	0.915	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Herons	GBHE	1	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	1.1
Rails	AMCO	0.56	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0
Waterfowl	TRUS	1	0.9459	0.915	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
	BRAN	1	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.1
	CAGO	1	0.9459	0.915	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1
	GWTE	0.56	0.9459	0.915	0.0	0.0	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	7.8
	MALL	0.56	0.9459	0.915	25.4	3.9	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	2.0	42.9
	NOPI	0.56	0.9459	0.915	7.8	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	3.9	19.5
	NOSL	0.56	0.9459	0.915	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
	AMWI	0.56	0.9459	0.915	7.8	5.9	0.0	2.0	1.9	1.9	0.0	0.0	0.0	0.0	0.0	0.0	19.4
	GRSC	0.56	0.9459	0.915	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	5.7
	SCAUP	0.56	0.9459	0.915	2.0	0.0	3.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	9.8
	OLDS	0.56	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	2.0
	SUSC	0.56	0.9459	0.915	0.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
	WWSC	0.56	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.9	3.9	11.6
	BUFF	0.56	0.9459	0.915	0.0	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9
	Duck sp.	0.56	0.9459	0.915	39.0	7.8	11.7	3.9	3.8	0.0	1.9	0.0	0.0	0.0	2.0	5.9	75.9
Shorebirds	KILL	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	6.7
	BLTU	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	5.9
	WESA	0.18	0.9434	0.8298	0.0	0.0	6.7	0.0	23.6	0.0	5.9	23.6	0.0	0.0	0.0	0.0	59.7
	DUNL	0.18	0.9434	0.8298	26.8	26.8	40.2	0.0	17.7	0.0	0.0	0.0	0.0	5.9	20.1	20.1	157.5
	PEEP	0.18	0.9434	0.8298	6.7	0.0	0.0	0.0	11.8	0.0	0.0	0.0	0.0	0.0	6.7	6.7	31.9
Gulls	MEGU	0.56	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
	RBGU	0.56	0.9459	0.915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	1.9
	CAGU	0.56	0.9459	0.915	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
	GWGU	0.56	0.9459	0.915	0.0	7.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	9.7
	Gull sp.	0.56	0.9459	0.915	3.9	2.0	9.8	2.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	19.5
Kingfisher	BEKI	0.18	0.9434	0.8298	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7
Woodpecker	NOFL	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	5.9
Passerines	NWCR	0.56	0.9459	0.915	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
	AMRO	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	5.9	0.0	0.0	11.8
	EUST	0.18	0.9434	0.8298	6.7	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	5.9	6.7	0.0	26.0
	Warbler sp.	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.0	5.9
	SPTO	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.8	0.0	0.0	11.8
	SASP	0.18	0.9434	0.8298	0.0	0.0	0.0	6.7	0.0	5.9	0.0	0.0	5.9	0.0	0.0	0.0	18.5
	SOSP	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	6.7
	Passerine sp.	0.18	0.9434	0.8298	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	6.7
Unidentified	UN	0.56	0.9459	0.915	3.9	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8
Total					134	85	89	31	59	8	8	32	12	53	60	66	635

Table 9. Comparison between years of the number of Fresh carcasses found and estimated deposited on the Roberts Bank causeway. Both sample periods covered 12 months.

	1994/95	1994/95	1997	1997a	1997b
Taxonomic group	Actual count	Estimated deposited	Actual count	Estimated deposited	Estimated deposited applying 1994/95 ratio of actual: estimated to 1997 actual count
Loons	0	0	1	1	1
Grebes	3	5	6	12	10
Cormorants	4	4	2	4	2
Herons	1	1	1	1	1
Rails (Coot)	2	3	1	2	2
Waterfowl	149	253	108	208	184
Dunlin	60	206	24	157	64
Peeps	25	126	15	92	76
Other shorebirds	5	22	2	13	9
Gulls	12	15	18	35	24
Caspian Tern	10	12	0	0	-
Raptors	1	1	0	0	-
Owls	2	3	0	0	-
Kingfisher	0	0	1	7	-
Woodpeckers	0	0	1	6	-
Passerines	11	25	15	89	35
Unidentified	19	32	5	10	8
Total	304	708	200	635	429

total carcass deposition. This estimate may be best represented by the range for each bird grouping (Table 9), which should be treated as a minimum. In addition, birds were most probably killed by colliding with the wires, but never found (injured but flew away to die elsewhere, injured but managed to hide in a place where we could not find them, died and fell into the train). Our carcass persistence tests were unable to estimate these aforementioned possibilities, nor is there any field test that could.

Our general feeling is that, while not conclusive from the small number of search efficiency tests conducted in 1997, the new substrate did reduce both the ability of the researcher to detect carcasses (lowering the efficiency) and the ability of visual scavengers to detect and hence eat or remove carcasses (increasing the persistence). The lower overall search efficiency explains both: i) the fact that there were fewer Fresh carcasses found in 1997 (200) than in 1994/95 (304); and ii) that the estimated number of carcasses deposited has increased in 1997 to 3.2x the actual count (estimated = 635) from the 1994/95 ratio of 2.3 x the actual count (estimated = 708).

7. CONCLUSIONS: DID THE SPIRAL VIBRATION DAMPERS MAKE A DIFFERENCE?

The presence of the dampers resulted in fewer abrupt or severe reactions, especially for shorebirds, raptors, and 'all birds combined'. These findings suggest that some birds were able to see the dampers and react earlier (eliciting mild reactions to the power line rather than abrupt or severe), avoiding the risk of collision. In poor visibility conditions, shorebirds likely see the dampers and react earlier, however this does not seem to be the case for other birds. In high wind conditions, there are indications that dampers resulted in fewer abrupt or severe reactions, especially for gulls and 'all birds combined'.

The dampers result in fewer birds crossing within 2 m of the wires, especially shorebirds, gulls, waterfowl (which already fly high above the wires) and 'all birds combined'. For all weather conditions combined, most groupings of birds, including herons, waterfowl, gulls, Caspian Tern, raptors and 'all birds combined', crossed wires 3-9% higher, and

hence at less risk of collision, at Damper sectors than at Controls. Shorebirds showed the largest difference (13%) in crossing height at Damper sectors as compared with Controls. However in poor visibility conditions, the dampers seem to have no effect on crossing height of any bird groupings. In high wind conditions, dampers have resulted in greater crossing height for 'all birds combined', but not for specific groupings.

Overall, shorebirds seem to have shown the most consistent behavioural changes in Damper sectors, both in approach reaction and in crossing height, in a variety of weather and wind conditions. These findings, coupled with the carcass data, suggest that the dampers are most beneficial to these species. Overall, for other groupings of birds, there is some evidence (from flight data) that the dampers may help to reduce risk of collision. But, all birds still showed abrupt and severe reactions at damper sectors, and herons, shorebirds, gulls, Caspian Terns and raptors still often crossed within 2 m of the wires in these sectors, indicating that dampers do not eliminate the risk of collision.

There are a few suggested explanations for the absence of Caspian Tern carcasses this year. Where terns still frequently crossed the power lines in Sectors 50-69, the structural changes to the Superport may provide an earlier signal to terns and other birds that they must rise in height to cross the causeway. The in-filling of the bay at the southwest end of the causeway (one of the two locations where terns were found most of the time in 1994/95) has undoubtedly forced the terns to forage and roost at other locations along the causeway. This dispersal effect, which resulted in a high number of Caspian Terns crossing the wires in Damper sectors, may have contributed to the apparent lack of collisions with wires (though tern response to dampers was not significantly different to response to Controls). Finally, in the 1994/95 study, 90% (9 out of 10) of the terns killed were juveniles which flew close behind adults begging for food. We had few juvenile sightings in 1997, and it is possible that post-fledging family groups were not at Roberts Bank that year. However, they might show up in future years and it would be worthwhile to monitor these occurrences.

We conclude that the presence of the Spiral Vibration Dampers along test sectors of the power lines at Roberts Bank have shown promising results. However, the installation of these dampers was a test; it is now worthwhile to consider options available as follow-up. Our recommendations based on the findings of this study include the following:

i) Conduct a comprehensive review of studies that test the efficacy of markers of various designs and layouts to reduce bird collisions with overhead wires. Such a review would provide the information required to determine suggested alternatives and their anticipated success relative to the Spiral Vibration Dampers.

ii) Conduct a systematic study of the efficacy of the Spiral Vibration Dampers on Westham Island, relative to unmarked sectors along that length of power line and compare results between the Westham Island Damper layout with that of Roberts Bank.

iii) Install more Spiral Vibration Dampers on wires at Roberts Bank, either in a different layout, or regularly spaced along its length and monitor such effects.

iv) Install another type of marker as described above and monitor such effects.

Burying the cables in some areas (where shorebird and Caspian Tern crossings are most frequent) should still be considered. Whatever option(s) are considered, the situation at Roberts Bank should continue to be monitored since the problem of bird mortality has not been entirely resolved.

Species of birds that should be monitored exclusively or most closely in future studies at Roberts Bank are Dunlin and Western Sandpiper, Caspian Tern, Great Blue Heron and gulls, which are most at risk of collision (high proportions of birds cross the wires within 2 m of the upper wire). Field effort should focus on increasing the frequency of flight observations, especially in poor visibility conditions; increasing the frequency of carcass searches; and reducing or eliminating time spent on censuses of the area.

8. ACKNOWLEDGEMENTS

The study was funded by the Vancouver Port Corporation and B.C. Hydro, along with donation of field time by Environment Canada, Canadian Wildlife Service (CWS). We thank John Jordan of the Vancouver Port Corporation, Bob Bradley of B.C. Hydro and Bob Elner of CWS for their input into all phases of this study. Thanks to Andrea Lawrence, Kathrin Beckmann, Pippa Shepherd, Bob Elner and Saul Schneider for their valuable field assistance. David Crook of Westshore Terminals allowed us access onto their property when required. The Zoology Department at the University of British Columbia is thanked for allowing access to the Cowan Vertebrate Museum, and we thank Christina Adkins of the Zoology Department, UBC, and John Ireland, Reifel Bird Sanctuary for their assistance. Thanks to Dave Dhensaw and Harpal Singh Gill of B.C. Rail for keeping an eye out for carcasses (and finding the Belted Kingfisher); also to Ken Emerson of CP Rail, and all personnel of B.C. Rail, CP Rail, Westshore Terminals and Switching Services for their friendly waves and greetings during fieldwork. John Jordan, Bob Elner, Bob Bradley and Brendan Killackey of B.C. Hydro reviewed the manuscript and offered many valuable suggestions which led to an improved final report. Their input is greatly appreciated by the authors.

9. LITERATURE CITED

Ainley, D.G., G.W. Page, L.T. Jones, L.E. Stenzel and R.L. LeValley. 1980. Beached marine birds and mammals of the North American west coast: a manual for their census and identification. US Fish and Wildlife Service Publication No. FWS/OBS - 80/03, Department of Interior. Washington, D.C.

Alonso, J.C., J.A. Alonso and R. Munoz-Pulido. 1994. Mitigation of bird collisions with transmission lines through groundwire marking. Biol. Conserv. 67: 129-134.

Avery, M.L., P.F. Springer and N.S. Dailey. 1980. Avian mortality at man-made structures: an annotated bibliography (revised). Biological Services Program, National Power Plant Team, FWS/OBS - 80/54: 1-152. US Fish and Wildlife Service. Ann Arbor, Mich.

Bevanger, K. 1994. Bird interactions with utility structures: collisions and electrocution, causes and mitigating measures. Ibis 136: 412-425.

Beaulaurier, D.L. 1981. Mitigation of bird collisions with transmission lines. Bonneville Power Administration. US Department of Energy. Portland, Ore.

Burger, A.E. and A.L.E.V. Cassidy. 1995. Impacts of overhead transmission wires on birds at the Roberts Bank Superport in 1994-1995. Report to Roberts Bank Environmental Review Committee, B.C. Hydro and the Vancouver Port Corporation.

Butler, R.W. (ed.). 1992. Abundance, distribution and conservation of birds in the vicinity of Boundary Bay, British Columbia. Tech. Rep. Series No. 155. Canadian Wildlife Service, Pacific and Yukon Region. Delta, B.C.

Butler, R.W. and R.W. Campbell. 1987. The birds of the Fraser River delta: populations, ecology and international significance. Canadian Wildlife Service Occ. Paper, No. 65. Ottawa.

Butler, R.W., and R.J. Cannings. 1989. Distribution of birds in the intertidal portion of the Fraser River delta, British Columbia. Tech. Rep. Series No. 93. Canadian Wildlife Service, Pacific and Yukon Region, Delta, B.C.

Campbell, R.W. 1998. British Columbia Birds: a species list - 1997. Wild Bird Trust of B.C. Wildlife Report No. 2, West Vancouver.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990a. The Birds of British Columbia. Volume II. Non-passerines. Diurnal Birds of Prey through Woodpeckers. Royal B.C. Museum. Victoria.

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990b. The Birds of British Columbia. Volume I. Non-passerines. Introduction, Loons through Waterfowl. Royal B.C. Museum. Victoria.

Cassidy, A.L.E.V. 1998. Brief summary of tasks, field methods and results - proposed Saskatchewan Wheat Pool/Cargill Agricultural Products Handling Facility, Roberts Bank, B.C. Report to Saskatchewan Wheat Pool.

Cassidy, A.L.E.V. and A.E. Burger. 1997. Impacts of the overhead transmission wires on birds at Roberts Bank and the effects of bird-diverters. Interim Report. 18 June, 1997. Report to the Vancouver Port Corporation and B.C. Hydro.

Environment Canada. 1996. Final report of the Roberts Bank Environmental Review Committee, 1996.

Frederick, P. and D. Jie. 1997. Bird-Strike mortality on the Everglades section of the Levee-Midway Powerline. Report for Florida Power and Light Co., North Palm Beach, Florida.

Janss, G.F.E. and M. Ferrer. 1998. Rate of bird collision with power lines: effects of conductor-marking and static wire-marking. J. Field Ornithol. 69(1): 8-17.

Manning, J. 1995. Observations - Synopsis. Unpublished report.

Ralph, C.J., G.R. Geupel, P. Pyle, T.E. Martin and D.F. DeSante. 1993. Handbook of field methods for monitoring landbirds. Gen. Tech. Rep. PSW-GTR-144. US Department of Agriculture. Albany, California.

Roe, N.A. and M.T. Williams. 1984. A field study to determine hazards to birds at Roberts Bank coalport, including a review of potential mitigation measures.

Report to the Roberts Bank Environmental Review Committee and the Vancouver Port Corporation. B.C. Environmental Management Associates, Vancouver.

Summers, K., P. Hayes and R. McKelvey. 1994. Aerial surveys of waterfowl and gulls on the Fraser River delta, 1992-93. Tech. Rep. Series No. 203. Canadian Wildlife Service, Pacific and Yukon Region. Delta, B.C.

<www.ec.gc.ca/cws-scf/hww-fap/endanger/table.html> 1997. Environment Canada.

<www.ec.gc.ca/press/cosewic_b.htm> 1998. Council on the Status of Endangered Wildlife in Canada.

<www.elp.gov.bc.ca:80/wld/cdc/atrkprov.htm> 1997. Ministry of Environment, British Columbia. Red List and Blue List.

Zar, J.H. 1996. Biostatistical analysis (Third edition). Prentice Hall, Upper Saddle River, New Jersey.

Monthly means: Brunswick Point and Roberts Bank Bird Census

	1997 Jan	1997 Feb	1997 Mar	1997 Apr	1997 May	1997 Jun	1997 Jul	1997 Aug	1997 Sep	1997 Oct	1997 Nov	1997 Dec
No counts	4	4	4	5	4	4	5	4	4	5	4	5
RTLO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PALO	0.5	0.3	0.0	0.8	0.5	0.0	0.0	0.0	0.0	1.6	1.3	0.4
COLO	2.8	7.8	12.3	3.6	1.0	2.8	1.0	3.0	11.3	19.2	7.0	7.8
loon sp	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PBGR	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HOGR	1.0	0.5	4.8	11.8	1.5	1.0	0.0	1.0	40.8	13.6	7.0	14.4
EAGR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
RNGR	0.0	0.0	0.5	0.4	0.8	0.0	0.0	0.0	0.8	0.2	0.5	0.2
WEGR	0.5	0.0	0.0	2.2	0.0	0.0	0.0	0.0	2.5	15.4	5.5	0.6
grebe sp	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	2.5	0.0	0.0	0.2
DCCO	50.8	50.8	13.0	15.6	66.5	71.8	61.0	35.3	50.8	53.2	32.5	16.4
BRCO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
PECO	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GBHE	0.0	0.0	1.0	10.0	58.8	53.0	41.8	8.5	9.3	3.0	4.5	1.8
TUSW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Swan spp.	22.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	85.6
SNGO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	750.0	60.0
BRAN	24.5	41.8	226.8	1181.4	79.8	1.0	0.0	0.0	0.0	0.0	0.0	16.2
CAGO	0.0	0.0	0.0	0.0	5.8	7.3	3.2	53.5	0.0	0.0	0.0	7.6
GWTE	72	466	537	964	0	0	9	202	472	4890	4292	3213
MALL	1925	75	45	180	16	70	15	378	44	710	4895	3205
NOPI	584	586	245	318	12	2	2	205	1102	2471	6635	1808
NOSL	0.0	0.0	0.0	1.8	0.0	0.0	0.0	7.3	2.8	0.4	0.0	0.0
GADW	0.0	0.0	5.3	10.4	77.0	120.3	18.8	11.0	0.5	0.0	1.0	7.4
EUWI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMWI	952	362	84	127	46	0	0	54	1555	4685	5916	3725
CANV	0.0	17.0	17.5	0.0	0.0	0.0	0.0	0.8	0.0	0.0	8.5	0.0
GRSC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LESC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scaup sp.	119	128	217	425	208	7	0	0	1	88	128	250
OLDS	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.6	0.3	0.0
BLSC	8.3	32.8	4.3	3.6	0.0	0.0	0.0	0.0	2.8	139.2	46.0	33.6
SUSC	36.8	29.0	47.5	17.0	8.3	0.0	0.0	0.0	25.3	89.8	107.5	78.2
WWSC	40.8	44.3	28.3	6.0	3.5	0.0	0.0	0.0	2.0	14.8	35.3	43.0
Scoter sp.	2.8	11.0	9.5	9.6	9.3	0.0	0.0	0.0	9.5	60.2	112.3	50.4
COGO	6.5	5.3	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	3.0
BAGO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
BUFF	35.3	58.0	86.8	43.2	1.5	0.0	0.0	0.0	0.0	30.8	63.8	43.0
HOME	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COME	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RBME	1.3	0.3	4.0	9.2	8.3	0.0	0.0	0.0	0.0	1.4	1.0	0.4
DUCK sp.	499	174	214	196	33	21	2	672	1501	6909	3659	2657
OSPREY	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.2	0.0	0.0
BAEA	2.8	1.8	3.3	1.8	1.0	2.0	0.8	0.8	0.0	0.0	1.0	0.8
NOHA	5.3	2.5	0.8	1.4	0.5	0.5	0.6	0.3	0.0	2.6	3.3	3.2
SSHA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
RTHA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
AMKE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MERL	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PEFA	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0
GYRF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BBPL	3.3	23.5	49.0	40.6	7.0	20.8	130.2	154.8	88.0	8.2	48.5	54.0
SEPL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.3	0.0	0.0	0.0
KILL	0.3	0.0	0.3	0.2	2.3	5.3	0.0	0.5	0.3	0.2	0.0	0.0
AMAV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEYE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Years reversed to show data in monthly sequence for 1994-1995

	1995 Jan	1995 Feb	1995 Mar	1995 Apr	1995 May	1994 Jun	1994 Jul	1994 Aug	1994 Sep	1994 Oct	1994 Nov	1994 Dec
No. censuses	2	4	6	4	2	3	3	3	4	4	3	4
RTLO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.8
PALO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
COLO	1.5	3.5	6.2	3.8	0.5	1.0	0.3	2.7	17.5	19.5	8.0	6.3
loon sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PBGR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HOGR	5.0	0.3	2.5	2.5	0.0	0.0	0.0	6.3	35.3	18.3	4.3	6.3
EAGR	0	0	0	0	0	0	0	0	0	0	0	0
RNGR	0.0	0.0	0.3	0.3	0.0	0.0	0.0	1.0	0.0	4.3	0.3	0.0
WEGR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	176.3	2.0	0.8
grebe sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DCCO	19.5	22.3	15.5	24.5	73.5	67.3	155.3	73.7	101.8	172.3	29.7	17.5
BRCO	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PECO	0.0	0.0	0.0	0.5	0.0	0.3	0.3	0.0	0.3	0.3	0.0	0.3
GBHE	0.3	1.2	2.8	10.3	14.0	35.7	51.7	10.7	8.0	13.0	4.0	1.0
TUSW	40.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
TRUS	68.0	12.3	0.2	0.8	0.0	0.0	0.0	0.0	0.0	7.5	0.0	48.0
SNGO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.3	26.7	0.0
BRAN	0.0	0.0	85.2	804.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
CAGO	0.0	0.0	0.5	2.3	110.0	0.0	260.3	29.3	4.0	13.0	0.0	0.0
GWTE	932	1260	839	1187	4	1	2	137	240	928	208	1189
MALL	4400	1152	447	62	69	67	20	103	74	2420	1812	2868
NOPI	7618	2458	1243	250	2	18	0	0	487	1770	4304	3615
NOSL	1.0	0.0	0.0	5.0	0.0	1.3	0.0	0.0	12.8	1.3	0.0	0.0
GADW	0.0	0.0	0.0	28.8	0.0	25.7	0.0	0.0	0.0	0.0	0.0	0.0
EUWI	0.5	4.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.0	1.8
AMWI	3859	4429	846	591	5	6	0	0	883	6014	2702	3030
CANV	7.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5.5
GRSC	48.5	32.5	84.2	173.3	27.0	0.0	2.0	2.0	1.5	19.8	0.3	92.0
LESC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scaup sp.	65	26	1	0	0	0	0	0	0	358	18	1
OLDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLSC	55.5	13.3	23.5	16.5	0.0	0.0	0.0	0.0	0.0	37.5	166.3	42.3
SUSC	107.0	46.8	40.3	15.5	0.0	0.0	0.0	0.0	0.3	32.3	50.0	51.8
WWSC	18.0	19.3	44.7	28.3	0.0	2.0	0.0	0.0	5.8	26.0	5.3	8.5
Scoter sp.	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0	0.0	0.0
COGO	9.5	7.0	4.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	12.8
BAGO	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0
BUFF	9.5	7.8	58.7	72.3	0.0	0.0	0.0	0.0	0.0	0.5	16.3	14.3
HOME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COME	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0
RBME	0.0	0.0	8.7	14.5	0.5	0.0	0.0	0.0	0.0	0.3	0.0	0.3
DUCK sp.	205	108	0	0	0	4	17	1186	1054	2280	4	4
OSPREY	0	0	0	0	0	0	0	0	0	0	0	0
BAEA	7.5	8.0	3.0	1.3	1.5	2.3	2.3	0.3	0.0	1.5	0.7	3.0
NOHA	3.0	4.5	2.0	1.3	1.5	1.3	0.7	0.7	0.5	2.3	4.0	5.5
SSHA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RTHA	1.0	0.8	0.8	0.3	0.0	0.7	1.0	0.0	0.0	0.8	0.3	0.5
AMKE	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0
MERL	1.5	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
PEFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.7	0.3
GYRF	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BBPL	11.0	88.2	7.3	31.0	35.5	28.3	146.7	12.0	114.0	108.5	51.0	136.0
SEPL	0.0	0.0	0.0	0.0	4.0	0.0	0.0	3.3	0.5	0.0	0.5	0.7
KILL	0.0	1.0	1.7	2.3	4.5	5.3	2.0	0.7	36.3	2.0	0.0	0.0
AMAV	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LEYE	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	1.0	0.0	0.0

	1997 Jan	1997 Feb	1997 Mar	1997 Apr	1997 May	1997 Jun	1997 Jul	1997 Aug	1997 Sep	1997 Oct	1997 Nov	1997 Dec
Yellowleg sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.5	0.0	0.0	0.0
SPSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RUTU	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
BLTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.6	0.0	0.2
SURF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
SAND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0
SESA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WESA	0	0	0	0	39	131	3812	948	707	0	0	0
LESA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0
PESA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0	0.0
DUNL	11790	8596	4457	3266	17	0	0	0	0	28	2781	5060
Unid Peep	0	0	0	11041	1574	1	16	40	0	0	0	0
LBDO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DOWIT sp.	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WHIM	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLOY	0.0	0.0	1.3	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phalarope sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Unid. Shorebird	0.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	0.0	0.0	0.0	0.0
BOGU	0.0	0.0	0.0	0.0	0.5	38.5	59.0	0.3	0.3	0.0	0.0	0.0
MEGU	94.3	253.8	81.8	33.2	1.0	0.0	0.0	12.3	1.3	0.0	0.8	9.8
RBGU	0.0	0.0	0.0	0.2	76.0	284.3	155.6	430.0	455.0	132.0	10.3	2.2
CAGU	0.0	0.0	0.0	4.0	0.3	1.5	2.0	131.0	7.5	0.0	0.0	0.4
HEGU	0.0	1.3	0.0	0.0	0.0	0.0	0.0	3.3	0.3	0.0	0.3	0.0
WEGU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
GWGU	209.5	142.3	100.0	45.4	8.5	7.8	224.8	36.8	13.3	52.2	113.8	142.4
Gull sp.	6.5	12.5	15.3	4.8	29.0	168.5	313.0	492.5	1146	252.0	18.5	145.0
CATE	0.0	0.0	0.0	38.0	40.3	177.8	191.4	65.5	17.5	1.0	0.0	0.0
SNOW	12.8	2.5	3.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEOW	0.3	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CORA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
TOTAL	16510	11128	6519.3	18016	2437	1195	5085	3965	7271	20674	29697	20747
Loons	3	8	12	5	2	3	1	3	11	21	8	8
Grebes	2	1	5	15	3	1	0	1	49	29	13	15
Cormorants	51	51	13	16	67	72	61	35	51	54	33	16
GreatBlue Heron	0	0	1	10	59	53	42	9	9	3	5	2
Swans & Geese	47	43	227	1181	86	8	3	54	0	0	757	169
Dabbling Ducks	3532	1490	916	1601	150	192	45	856	3175	12757	21739	11958
Bay Ducks	119	145	234	425	208	7	0	1	1	88	137	250
Scoters	89	117	90	36	21	0	0	0	40	304	301	205
Raptors	8	4	4	4	2	3	1	1	0	3	5	4
Plovers	4	24	49	41	9	26	130	157	89	8	49	54
Sandpipers	11790	8596	4458	14308	1631	132	3851	1005	707	28	2781	5061
Gulls	310	410	197	88	115	501	754	1107	1623	436	144	300
Caspian Tern	0	0	0	38	40	178	191	66	18	1	0	0
Owls	13	3	4	1	0	0	0	0	0	0	0	0
Waterfowl	4329	2032	1776	3493	510	228	51	1583	4716	20091	26660	15286
Shorebirds	11794	8620	4507	14348	1640	158	3984	1162	796	37	2830	5115
Gulls and terns	310	410	197	126	156	678	946	1172	1641	437	144	300
All other birds	77	67	40	49	132	131	105	50	120	110	63	46
Total	16510	11128	6519	18016	2437	1196	5085	3966	7273	20675	29697	20747

	1995 Jan	1995 Feb	1995 Mar	1995 Apr	1995 May	1994 Jun	1994 Jul	1994 Aug	1994 Sep	1994 Oct	1994 Nov	1994 Dec
Yellowleg sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SPSA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RUTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
BLTU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.5	0.3
SURF	0	0	0	0	0	0	0	0	0	0	0	0
SAND	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SESA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0	0.0
WESA	0	0	121	36917	4362	87	747	877	95	3	0	9
LESA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	0.0	0.0
PESA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	4.5	0.0	0.0
DUNL	11641	11365	15780	3923	941	0	1	13	0	3069	13997	19936
Unid Peep	0	0	0	0	0	0	95	51	1	15	0	0
LBDO	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.3	0.0	0.0	0.0
DOWIT sp.	0.0	0.0	0.0	0.0	2.5	18.3	0.0	2.0	0.0	0.0	0.0	0.0
WHIM	0.0	0.0	0.0	0.0	0.0	3.7	4.0	0.0	0.0	0.0	0.0	0.0
BLOY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phalarope sp.	0	0	0	0	0	0	0	0	0	0	0	0
Unid. Shorebird	8.3	0.0	0.0	0.0	0.5	0.0	0.0	3.3	4.0	0.0	0.0	0.0
BOGU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.5	0.0	0.0
MEGU	312.5	122.8	45.8	45.8	56.5	0.0	0.0	4.3	7.8	25.3	15.0	63.3
RBGU	0.0	0.0	0.3	0.0	20.0	400.3	873.7	338.3	357.8	20.3	0.3	0.5
CAGU	0.0	0.0	5.7	1.5	0.0	15.7	46.7	271.0	97.0	169.5	0.0	0.0
HEGU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WEGU	0	0	0	0	0	0	0	0	0	0	0	0
GWGU	16.5	34.0	13.2	25.8	40.5	19.3	52.7	166.3	54.8	18.3	29.7	27.5
Gull sp.	5.5	0.0	0.0	0.0	0.0	216.7	255.3	1629.0	1242.8	18.0	0.0	1.3
CATE	0.0	0.0	0.0	0.0	32.0	59.7	26.3	238.0	39.3	0.0	0.0	0.0
SNOW	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEOW	2.5	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CORA	0.0	0.0	0.3	0.5	0.0	0.0	1.0	0.0	0.5	0.3	0.0	0.8
Total	29500	21227	19737	44243	5807	1089	2766	5184	5017	17841	23470	31207
Loons	2	4	6	4	1	1	0	3	18	20	8	8
Grebes	5	0	3	3	0	0	0	7	66	199	7	7
Cormorants	20	22	16	25	74	68	156	74	102	173	30	18
GreatBlue Hero	0	1	3	10	14	36	52	11	8	13	4	1
Swans & Geese	108	13	86	807	110	2	260	29	4	51	27	54
Dabbling Ducks	16810	9302	3376	2123	80	118	22	240	1696	11133	9026	10703
Bay Ducks	121	59	85	173	27	0	2	2	2	377	19	99
Scoters	201	79	109	60	0	2	0	0	6	131	222	103
Raptors	13	14	6	3	3	5	4	1	1	5	6	9
Plovers	11	89	9	33	44	34	149	16	151	111	52	137
Sandpipers	11649	11365	15901	40839	5306	109	849	967	108	3092	13998	19945
Gulls	335	157	65	73	117	652	1228	2409	1763	252	45	93
Caspian Tern	0	0	0	0	32	60	26	238	39	0	0	0
Owls	3	0	0	0	0	0	0	0	0	0	0	0
Waterfowl	17463	9575	3728	3252	217	126	301	1458	2761	13977	9321	10989
Shorebirds	11660	11455	15910	40873	5350	143	998	983	259	3203	14049	20082
Gulls and terns	335	157	65	73	149	712	1255	2647	1802	252	45	93
All other birds	42	41	34	45	91	109	213	96	195	409	54	43
Total	29500	21227	19737	44243	5807	1089	2766	5184	5017	17841	23470	31207

Appendix 2. Flight observations Entered computer ..... Observer..... Date .....

Update every 15 minutes: Tide:Full/Falling/Rising/Low

Time:..... Cloud cover.....%,/ Fog patches/ Thick fog. Wind: Force .... Direct .... Ppt.: None/ Misty drizzle/ Drizzle/ Rain. Adjacent <30 m: mud/water. Tide .....

Appendix 3. Carcass Search Datasheet

Page ..... of .....

Date: ..... Time start:..... Time end: .....

Total search time (min): .....

Observer(s):.....

No. people searching .....

Sectors searched ..... to ..... Inner/Outer/Both

No. sectors searched : .....

Mean vegetation height (m): .....

Notes on conditions affecting search (tall veg. etc.)

Notes on scavengers/raptors seen:

Data on birds (use one line per bird)

Species code	Age	Sex	Section no.	Parallel dist. to pole (m)	Dist. to wire (m)	N or S of wire	Condition code	Estim. days dead	Scavenged Use codes	Details of injuries or broken bones	Likely wire kill? Y/Y?/ /N/U	Details of body parts found	Other notes

Codes: SEX: M = male; F = female; U = unknown.

AGE: Adult (AD); Immature (IM); First-, second- , third- year (FY, SY, TY); Unknown (U).

CONDITION: 0 = alive; 1 = very fresh, no smell (hours-1 day dead); 2 = slight decomposition (days - week);
3 = very decomposed (feathers falling off, maggots); 4 = mummified (many weeks - months dead); 5 = skeleton, feathers only

SCAVENGED: 0 = intact; 1 = 1-10% flesh eaten; 2 = 11-80% eaten; 3 = almost completely eaten (>80%); 999 = cannot tell if eaten.

LIKELY WIRE KILL (based on injuries& location): Y - seems very likely; Y? - possible; N - probably not; U - cannot guess.

Section number is based on the number of the shoreside pole.

Parallel distance to pole should be estimated from the shoreside pole of the section. Distance between poles is 60 m.

Appendix 4. Detailed chronology of conditions affecting carcass search, taken during weekly carcass search in Sectors 1-69, with additional general notes.

Date	Sectors affected	Direction from wire	Details
7 January	1-8	N	trailers, junk piles obscure area; vehicles have disturbed and trampled area
Construction on overpass is proceeding, with pile drivers, large trucks parking and driving at base of causeway, and large piles of gravel and sand dumped, stored and moved (until 31 May)			
28 January	1-5	N/S	sand and rail ties cover parts of search area; vehicles have disturbed and trampled area
4 February	1-8	N/S	junk, gravel and sand has been added, covering area
4 February	10-11	N	gravel and sand has been added, covering area
4 February	37	N	magnetic crane picks up large pile of debris, disturbing area
18 February	1-6	N/S	disturbed by construction, with some areas covered
25 February	1-6	N/S	disturbed by construction, with some areas covered
25 February	48-49	N/S	equipment and trucks trample and cover area
4 March	1-5	N/S	junk and gravel has been added, covering parts of area; vehicles have trampled parts of area
4 March	9-11	N	same
4 March	49-50	S	same
10 March	49	N/S	gravel has been added, covering area; vehicles have trampled area
10 March	1-8	S	vehicles and equipment have trampled area
15 March	4, 10-11	N	disturbed by construction
15 March	1-8	S	same

Appendix 4. (continued)

Date	Sectors affected	Direction from wire	Details
15 March	50	N/S	same
22 March	1-9	S	vehicles have trampled area; survey posts and concrete blocks have been added, covering parts of search area
22 March	1-5	N	same
31 March	1-9	S	gravel and rail ties have been added, covering parts of area; vehicles have trampled parts of area
31 March	1-5	N	same
5 April	1-7	S	disturbed by construction for installation of overhead light poles (until 24 December)
5 April	3-4	N	same
16 April	51-52	N	overhead light has been installed; vehicles have trampled area
24 April	1-9	S	disturbed by construction, survey posts
24 April	7	S	a fire in the road-cleaning truck, subsequent extinguisher foam and clean-up, has disturbed area
11 May	48	N/S	large pile of sand has been spread over area
17 May	50-69	S	paved road has been power-washed (seems to be a regular event)
22 May	1-6	S	heavy machinery; fill added to area south of road at base of causeway; road has been paved
31 May	4	N	junk has been spread around to other areas

Construction has ended at base of causeway and overpass is complete.

Appendix 4. (continued)

Date	Sectors affected	Direction from wire	Details
6 June	12,25	S	disturbance from survey crews; gravel has been pushed around, covering some areas
6 June	65-69	N	tractors move piles of sand and gravel around
14 June	49-50	N/S	tall vegetation has been cut and left on top of area
23 June	4-52	N	vehicle has disturbed whole area, compressing substrate and destroying American Wigeon nest
7 July	4,6	N	three large piles of soil have been added, covering parts of area
26 September	47-50	N	disturbance from construction
26 September	49	S	same
26 September	33-38	N	bulldozer is pushing piles of soil along section, grading and covering over whole area
5 October	4-6	N	gravel has been added and graded
5 October	48-50	N/S	area disturbed by digging for light standard insertion; area has been graded and soil added
10 October	1-8	N	crews have been working on wires and have placed large piles of equipment in places
10 October	48-50	N/S	gravel and vegetation has been skimmed off top and pushed against Pole 49, removing/covering area
17 October	1-30	on	cross-beams have now been added
23 October	1-52	N/S	heavy machinery tramples area; falling debris covers parts of area below wires

Appendix 4. (continued)

Date	Sectors affected	Direction from wire	Details
Cross-beams are now up to Pole 48; Sector 2 (south of wire) has hydro poles lying in ditch, covering search area. A new, shorter pole has been placed near Pole 1, as well as several poles north of Sector 1. Two new wires (approximately 2m and 4m below previously lowest wire) have been placed from Pole 1 to 50. Pole 48 has a new cross wire going to the south, and a yellow plastic angled pole in search area.			
14 November	1-25	N	vehicle has trampled area
2 December	1-51	N	new dirt, sand and gravel is being added and graded to whole area, covering original area
10 December	1-50	N	same
17 December	1-14	N	survey crews have disturbed area and installed wooden posts
24 December	1-8	S	installation of light poles is complete
31 December	1-5	N	heavy trucks with machinery trample area; a new shed on wooden risers has been placed north of Sector 1
31 December	49-50	N	heavy trucks with machinery trample area