ABUNDANCE, DISTRIBUTION AND CONSERVATION OF BIRDS IN THE VICINITY OF BOUNDARY BAY, BRITISH COLUMBIA

R.W. Butler (Editor)

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ABUNDANCE, DISTRIBUTION AND CONSERVATION OF BIRDS IN THE VICINITY OF BOUNDARY BAY BRITISH COLUMBIA[1]

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Abstract

The aims of this study were to determine the distribution of waterfowl, shorebirds, birds of prey and songbirds, and estimate the amount of land required to support these populations in the vicinity of Boundary Bay, British Columbia.

The estimated amount of food in Boundary Bay was insufficient to provide the energy needs of all American Wigeons (*Anas americana)*, Northern Pintails (*A. acuta*) and Mallards (*A. platyrhynchos*) after autumn. Large populations of these ducks remained in Boundary Bay during day and night in autumn and flew to farmlands to forage at night through the winter. In the Bay they ate mostly intertidal invertebrates, marsh plants, algae and eelgrass (*Zostera marina* and *Z. japonica*). In farmlands they ate wild seeds, grasses, corn, potatoes, cabbage and insects. Over three quarters of the farmlands were used by the three duck species with especially large concentrations near the northwest shore of Boundary Bay, along the Serpentine and Nicomekl rivers, and south of Ladner Village.

Black-bellied Plovers (*Pluvialis squatarola*) and Dunlins (*Calidris alpina*) foraged on beaches during low tide and roosted near the high tide line from April to October. From November to March they foraged on beaches during low tide and roosted on beaches or foraged in cultivated farmlands near Boundary Bay during high tides. Great Blue Herons (*Ardea herodias*) foraged on fish caught on beaches during low tides and roosted nearby during high tides from March to October. Some adults and most juvenile herons foraged on small mammals, principally Townsend's Vole (*Microtus townsendii*) caught in abandoned grasslands (old-fields) from November to February. Farmlands most frequently used by shorebirds and herons were within 2 km of the Bay and Brunswick Point.

Northern Harriers (*Circus cyaneus*) were most abundant in foreshore marshes and old-fields. Rough-legged Hawks (*Buteo lagopus*) were most common in old-fields and grasslands with shrubs. Red-tailed Hawks (*B. jamaicensis*) were abundant in old-fields and hay fields. The greatest numbers of these species were found near the Boundary Bay Airport. Barn Owls (*Tyto alba*) roosted and nested in barns throughout the study area. Short-eared Owls (*Asio flammeus*) roosted and nested on the ground in old-fields near the marshes on Brunswick Point and south of the Boundary Bay airport.

More species were present in hedgerows during the non-breeding season than

during the breeding season. However, greater densities occurred during the breeding season than the non-breeding season. Hedgerows with trees had more species and greater densities of birds than hedgerows without trees during the breeding and non-breeding seasons. The species of greatest conservation concern in hedgerows is the Cooper's Hawk (*Accipiter cooperii*).

To meet the goal of maintaining current populations of waterfowl, shorebirds, birds of prey and songbirds it is recommended that: 1) agricultural lands in Delta Municipality and in the Nicomekl and Serpentine river drainages in Surrey Municipality remain in the Agricultural Land Reserve, 2) the sub-tidal waters, beaches and mudflats in Boundary Bay, Mud Bay, Semiahmoo Bay and Roberts Bank be secured for the prime purpose of wildlife, 3) about 300 ha of farmland be secured for the prime use of dabbling ducks, shorebirds, nesting herons and birds of prey, and songbirds; and 600 ha of old-field habitat be secured for the prime purpose of birds of prey and herons, adjacent to Boundary Bay. Lastly, it is recommended that additional holdings be designated as Wildlife Areas if the habitat capability on the existing farmland declines below present levels.

Résumé

L'étude présentée ici consistait à déterminer la distribution des oiseaux aquatiques, des oiseaux de rivage, des oiseaux de proie et des oiseaux chanteurs et à estimer l'étendue du territoire nécessaire à la survie de ces populations dans les environs de la baie Boundary, en Colombie-Britannique.

D'après les estimations, les ressources alimentaires dans la baie Boundary ne peuvent suffire après l'automne aux besoins énergétiques des populations de canards siffleurs d'Amérique (*Anas americana*), de canards pilets (*A. acuta*) et de canards colverts (*A. platyrhynchos*). Ces canards demeurent dans la baie en grand nombre: en automne, ils y passent le jour et la nuit, tandis que durant l'hiver, ils vont se nourrir dans les terres agricoles la nuit. Les spécimens recueillis dans la baie se sont nourris principalement d'invertébrés intertidaux, de plantes palustres, d'algues et de zostères (*Zostera marina* et *Z. japonica*), tandis que ceux des terres agricoles ont mangé des graines de plantes sauvages, des graminées, due mais, des pommes de terre, des choux et des insectes. Plus des trois quarts des terres agricoles du secteur sont fréquentées par ces trois espèces de canards; il y a des concentrations particulièrement élevées près de la rive nord-ouest de la baie, sur les bords des rivières Serpentine et Nicomekl et au sud de Ladner Village.

Le pluvier argenté (*Pluvialis aquatarola*), le bécasseau d'Alaska (*Calidris mauri*) et le bécasseau variable (*Calidris alpina*) se nourrissent sur les plages à marée basse et se tiennent près de la ligne des hautes eaux ainsi que dans les terres agricoles. De novembre à mai, ils se nourrissent sur les plages à marée basse; à marée haute, il se tiennent sur la plage ou vont se nourrir dans les terres cultivées des environs de la baie. De mars à octobre, le grand héron (*Ardea hereodias*) se nourrit de poissons qu'il capture sur les plages à marée basse; à marée haute, il se tient à proximité de la plage. D'octobre à février, la plupart des juvéniles, ainsi que certains adultes, se nourrissent de petits mammifères, et plus particulièrement de campagnoles de Townsend (*Microtus townsendii*) qu'ils capturent dans les champs abandonnés. Les terres agricoles les plus fréquentées par les oiseaux de rivage et les hérons sont situées à 2 km, au maximum, de la baie et de Brunswick Point.

Le busard Saint-Martin (*Circus ovaneus*) abonde surtout dans les marais

intertidaux et dans les champs abandonnés. Quant à la buse pattue (*Buteu lagopus*), elle est surtout répandue dans les champs abandonnés et dans les prés de fauche. La buse à queue rousse (*Buteo jamaicensis*) abonde dans les champs abandonnés et dans les prés de fauche. Ces espèces sont surtout nombreuses près de l'aéroport de Boundary Bay. Quant à l'effraie des clochers (*Tyto alba*), qui se tient et niche dans les granges, on l'a trouvé partout dans la zone étudiée. Le hibou des marais (*Asio flammeus*) se tient et niche sur le sol, dans les champs abandonnés près des marais de Brunswick Point ainsi qu'au sud de l'aéroport de Boundary Bay.

En période de nidification, les haies abritent moins d'espèces qu'en dehors de la saison de reproduction. Toufefois, c'est pendant la reproduction que les densités de populations sont le plus élevées. Les haies arborées abritent un plus grand nombre d'espèces et des populations plus nombreuses que celles où il n'y pas d'arbres et ce, aussi bien pendant la nidification qu'en dehors de la période de reproduction. L'épervier de Cooper (*Accipiter cooperii*) est la plus fragile des espèces fréquentant les haies.

Pour maintenir les effectifs actuels chez les oiseaux aquatiques, les oiseaux de rivage, les oiseaux de proie et les oiseaux chanteurs, nous recommandons les mesures suivantes: 1) les terres agricoles de la municipalité de Delta ainsi que celles du bassin des rivières Nicomekl et Serpentine, dans la municipalité de Surrey, doivent continuer de faire partie de la réserve des terres agricoles; 2) toutes les eaux, plages et vasières infratidales des baies Boundary, Mud et Semiahmoo ainsi que celles du banc Roberts doivent être réservées pour la conservation de la faune; 3) il faut réserver environ 300 hectares de terres agricoles pour les canards de surface, les oiseaux de rivage, les hérons et oiseaux de proie nicheurs et les oiseaux chanteurs, en plus de 600 hectares de champs abandonnés pour les oiseaux de proie et les hérons, aux environs de la baie Boundary. Enfin, il est recommandé de constituer d'autres réserves fauniques si l'habitat actuel des terres agricoles se trouve réduit.

Preface

Stephen P. Wetmore

and

Bruce Cox

Boundary Bay and the nearby farmlands are of major importance to many birds using the Fraser River delta. The delta is perhaps the most important migration and winter habitat for many species of waterbirds on the Pacific Coast of Canada. The biological integrity of the Fraser River delta is dependent on maintaining the ecological functions of tidal beaches and marshes in Boundary Bay and adjacent farmlands.

On 28 July 1989, while visiting Vancouver, The Honourable Lucien Bouchard, then Minister of Environment called on federal, provincial and municipal governments to launch a study to determine the habitat requirements necessary to maintain internationally protected populations of migratory birds and other wildlife in the vicinity of Boundary Bay and Mud Bay. Following long public hearings, Delta Municipal Council unanimously defeated a plan on 8 August 1989 that would have turned 307 hectares on the Spetifore farm adjacent to Boundary Bay into a housing project. At the same time, Delta Municipal Council passed a motion for staff to draft guidelines for a multi-government environment study and area plan for non-industrialized floodplain areas adjacent to Boundary Bay.

It is apparent in statements made during the 14 November 1989 public meeting on the Boundary Bay environmental study that the public is concerned about wildlife, farming, planning and development issues. In addition, wildlife issues are sometimes a proxy for other issues such as lifestyle, open space and the retention of agricultural land. The public seems to be identifying their need for a mixture of high quality living space, working agricultural landscapes and natural wildlife areas.

Why is there such a high level of public and conservation agency concern for wildlife habitat and agricultural land near Boundary Bay?

1) The current planning processes do not recognize wildlife habitat as an equal partner to other interests in land use decision making;

2) Boundary Bay is not formally protected by governments although its

value to wildlife is well known (Butler and Campbell 1987);

3) The Agricultural Land Reserve (ALR) in the Municipality of Delta has eroded 4.7% between 1974 and 1991 (Klohn Leonoff *et al.* 1992);

4) Two-thirds of the agricultural land in commercial agricultural production in Delta Municipality is not owned by the individual who is farming the land (Klohn Leonoff *et al.* 1992);

5) The Government of British Columbia holds approximately 1600 hectares of agricultural land between Roberts Bank and Boundary Bay for industrial purposes and;

6) Golf courses were permitted as a legitimate use in the Agricultural Land Reserve resulting in numerous applications near Boundary Bay.

The wildlife studies that follow identify the location and estimate the amount of habitat required to support birds around Boundary Bay. A more general scientific symposium on the ecology of the Boundary Bay ecosystem is scheduled for the end of 1992.

This wildlife report is one of six parts of the Boundary Bay Area Study lead by the Corporation of Delta. Other studies on agriculture, foreshore planning, Delta rural land use, Surrey environmentally sensitive areas, and economic development and transportation are completed or in progress. A public review of all studies followed by land use planning and implementation processes is anticipated over the next several years.

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Chapter 1. Introduction, study area and approach

Robert W. Butler

Introduction

The Fraser River delta in southwestern British Columbia supports large populations of waterfowl, shorebirds and raptorial birds (Vermeer and Levings 1977, Butler and Campbell 1987, Butler and Vermeer 1989). In the last century about three-quarters of the marshes and seasonally-flooded grasslands on the delta were converted into farmlands (Butler and Campbell 1987). Many of the birds in Boundary Bay now forage for part of the year in the farmlands (Hirst and Easthope 1981, Butler and Cannings 1989). Concern for conservation of bird habitats in and around Boundary Bay (Butler and Campbell 1987, Moore 1990, Wetmore and Cox, this publ.) provided a specific stimulus for this study.

Fields planted with pasture grasses and discarded crops in the Nicomekl and Serpentine river drainages, and near Ladner, are used by large flocks of waterfowl during the day (Hirst and Easthope 1981, Jury 1981). Hirst and Easthope (1981) believed that farmland provided waterfowl with an alternate foraging habitat from beach habitats. However, other studies have shown that waterfowl deplete food in habitats before moving to new foraging sites (Goss-Custard and Charman 1976, see refs. in Chapter 3). This latter notion suggests that farmlands might provide additional feeding sites when food supplies are diminished in Boundary Bay rather than providing alternate foraging habitats, as hypothesized by Hirst and Easthope (1981).

Many of the raptorial bird species in British Columbia are abundant in farmlands near Boundary Bay, especially the Northern Harrier (*Circus cyaneus*), Rough-legged Hawk (*Buteo lagopus*) and Common Barn-Owl (*Tyto alba*) (Campbell *et al.* 1972, Campbell and Campbell 1983). The principal prey species of these raptors is the Townsend's Vole *(Microtus townsendii)*, a grassland rodent whose numbers can fluctuate widely in a year (Krebs 1979). Therefore, we believe that a close fit would be found between the distribution and abundance of raptorial birds and the grassland habitats where they foraged.

Dunlins (*Calidris alpina*) and Black-bellied Plovers (*Pluvialis squatarola*)

fly to farmlands in winter (Butler and Campbell 1987), but how they use farmlands has not been described. Other studies have shown that Dunlins roost during high tides, and feed on beaches during low tides (Senner *et al.* 1989). Great Blue Herons (*Ardea herodias*) forage for fish on beaches mostly in spring, summer and autumn. Adult herons fly to marshlands and riverbanks of the Fraser River to catch fish, and juveniles fly to grasslands to hunt small mammals in winter (Butler 1991).

Many species of songbird spend the non-breeding season in farmland hedgerows, forests and heath habitats near Boundary Bay. About 100 species of woodland birds use densely vegetated hedgerows on the Alaksen National Wildlife Area (Butler and Campbell 1987) but bird communities have not been described in the narrower hedgerows near Boundary Bay.

Goals of the study

The goals of our study were to: 1) determine the distribution of birds in habitats around Boundary Bay and 2) estimate the amount of land required to support the current populations of birds near Boundary Bay.

Study area

We studied birds from September 1989 to November 1991 on the intertidal beaches at Brunswick Point on Roberts Bank, and in Boundary Bay and Mud Bay, and in farmlands in the Municipality of Delta, and along the Serpentine and Nicomekl rivers in Surrey Municipality (Fig.1). Burns Bog was omitted from our study because we did not wish to duplicate a study of the distribution and abundance of songbirds and waterbirds that was investigated independently by TERA Consultants.

1. Climate

The climate in Boundary Bay is characterized by mild, wet winters and warm, dry summers. Annual daytime mean temperatures range from about 5°C in January to 22°C in July. Over 95% of the precipitation falls as rain and largely in the winter months. Fog occurs mostly in September and October.

Temperature and precipitation were near normal during most of the study. Exceptions occurred in February 1989 and 1990 when 3 and 6 times as much snow fell as on average, respectively, and in November and December 1990, when about 3 times as much rain fell as normal.

2. Habitats

2.1 Beaches and marshes - Sandflats and mudflats extend seaward 1-2 km from Brunswick Point and in Boundary Bay (Fig. 1). Mud Bay drains during very low tides. A narrow saltmarsh skirts the upper edge of most of the beach, and algal mats lie on the beach below the saltmarsh. Eelgrass (*Zostera japonica* and *Z. marina*) beds grow about 1 km from shore and extend into the subtidal (Swinbanks 1979).

Beaches are uncovered by two low tides about every 25 hours. The lowest of the two tides is followed by the highest tide. In addition to the lunar cycle, there are cycles of about 2 weeks duration and an annual cycle in which the lowest tides of the year occur at about midnight in December and midday in June. Tides affect birds that find their food on beaches by determining when and where they can feed. For example, from about November to February many of the lowest tides fall during the night so that shorebirds that feed along beaches must seek their food in darkness.

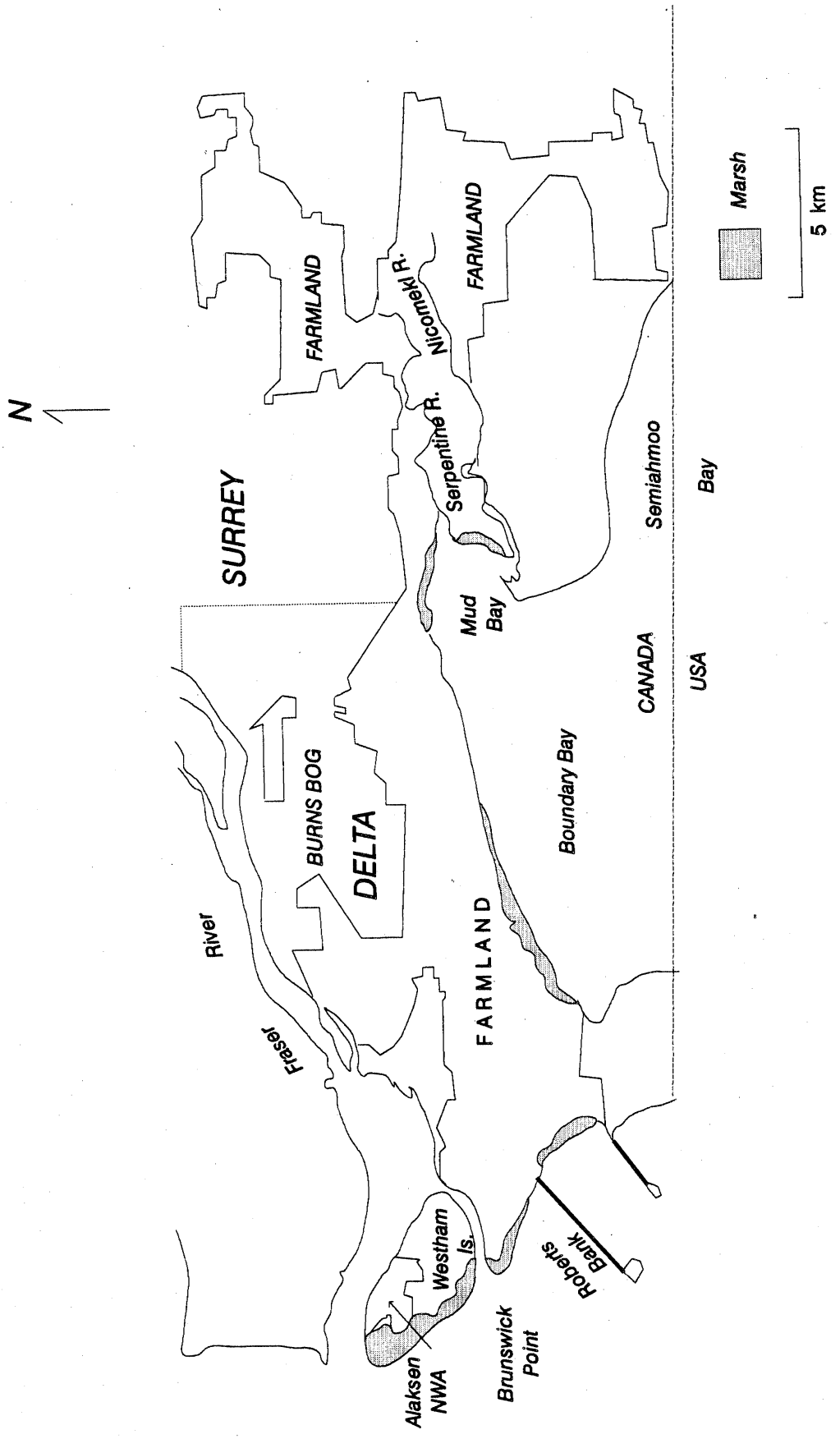

Figure 1. Distribution of major habitats in the study area.

2.2 Farmlands and hedgerows - Dikes along the upper beach prevent flooding of farmlands during high tides. A system of ditches and pumps drain fields of rainwater. Farmland crops currently include potatoes (24.1%), other processing and fresh vegetables (38.6%), hay, pasture, and silage (28.0%), grain (5.6%), berries (3.1%) and turf (0.6%) (Klohn Leonoff *et al.* 1992). Some fields are left fallow. Summer crops are harvested between June and October and fields are left barren or are planted with winter wheat or fall rye. Shrubs and trees form hedgerows along the perimeter of many fields.

The Approach

About 300 species of birds use beaches, marshlands, farmlands and forests in the vicinity of Boundary Bay. Our approach was to spend most effort on species and habitats of greatest conservation concern. Our criteria were to study species that: i) were rare, threatened, or endangered in Canada :Barn Owl (*Tyto alba*), Peregrine Falcon (*Falco peregrinus*), Cooper's Hawk (*Accipiter cooperi*), ii) occurred in internationally significant numbers: Western Sandpiper (*Calidris mauri*) and Dunlin (*C. alpina*); and whose populations had declined in North America: Mallard (*Anas platyrhynchos*), Northern Pintail (*A. acuta*) and American Wigeon (*A. americana*) or, iii) occurred in higher densities in Boundary Bay habitats compared to other similar habitats in British Columbia: Great Blue Heron (*Ardea herodias*), Northern Harrier (*Circus cyaneus*), Red-tailed Hawk (*Buteo jamaicensis*), Rough-legged Hawk (*B. lagopus*), Black-bellied Plover (*Pluvialis squatarola*) and Short-eared Owl (*Asio flammeus*). We also censused birds in hedgerows along farmlands and Great Blue Heron nesting colonies.

In Chapter 2, Breault and Butler estimated the number of Mallards, Northern Pintails and American Wigeons in the Fraser River delta that used farmlands near Boundary Bay, described how they used farmlands during day and night, and estimated the amount of farmland they used through their non-breeding season. Baldwin and Lovvorn described in Chapter 3 how Mallards, American Wigeons and Northern Pintails used Boundary Bay as food supplies changed with the season. Dunlin, Black-bellied Plover, Western Sandpiper and Great Blue Heron populations were estimated, and the location and types of farmlands they used was described by Butler in Chapter 4. Sullivan described the distribution of birds of prey in marshes and farmlands through the year, and estimated the area of each habitat

required to support them in Chapter 5. In Chapter 6, Butler described the summer and winter bird community in hedgerows. Finally, Butler and McKelvey synthesized the information from previous chapters and provided conservation recommendations in Chapter 7.

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Chapter 2. Abundance, distribution and habitat requirements of American Wigeons, Northern Pintails and Mallards in farmlands.

André M. Breault and Robert W. Butler

Introduction

As many as 25,000 ducks have been counted in farmlands in the Fraser River delta during the day, and up to 50,000 ducks have been counted there with a spot-light at night (Jury 1981). During the day, American Wigeons (*Anas americana*), Mallards (*A. platyrhynchos*) and Northern Pintails (*A. acuta*) settled on flooded pastures and fields with discarded crops in south Delta, and near the Nicomekl and Serpentine rivers (Jury 1981, Hirst and Easthope 1981, Duynstee 1992). However, most ducks foraged in farmlands at night. The accuracy of Jury's (1981) estimates of ducks in fields at night might be low because his spot-light did not illuminate distant fields, and it frightened ducks within the light beam.

The objectives of this study were to: 1) estimate the numbers of ducks that use farmlands, 2) describe the habitats they use and, 3) estimate the amount of farmland needed to support American Wigeons, Northern Pintails and Mallards in the lower Fraser River delta.

Study area and methods

1. Fieldwork and study area

Fieldwork was done from 28 September 1989 to 11 April 1990, and 22 October 1990 to 16 March 1991. These two field seasons are referred in this paper as year one and year two, respectively. The study area included the beaches and marshes on the Fraser River delta, and farmlands south of the South Arm of the Fraser River and along the Nicomekl and Serpentine rivers (Fig. 1). Beaches are mostly sand and mud with saltmarshes and brackish marshes along the high elevations. Dykes prevent high tides from flooding the delta's farmlands that are mostly covered by pastures and cultivated for growing vegetables. These habitats are described in detail by Butler and Campbell (1987) and in Chapter 1. Statistical analyses were made with Systat 5.01 computer software (Wilkinson 1990).

2. Estimating the area of habitat used by ducks

The area of farmland habitat used by American Wigeons, Northern Pintails and Mallards was estimated using the formula:

$$H = n \times d \times N$$

where H is the area in hectares of farmland habitat used by ducks, n is the mean number of ducks supported on 1 ha of a habitat for 1 day, d is the median number of days that ducks foraged in the same field and N is the number of ducks using farmlands in autumn, winter and spring. Each of these factors is now described in detail:

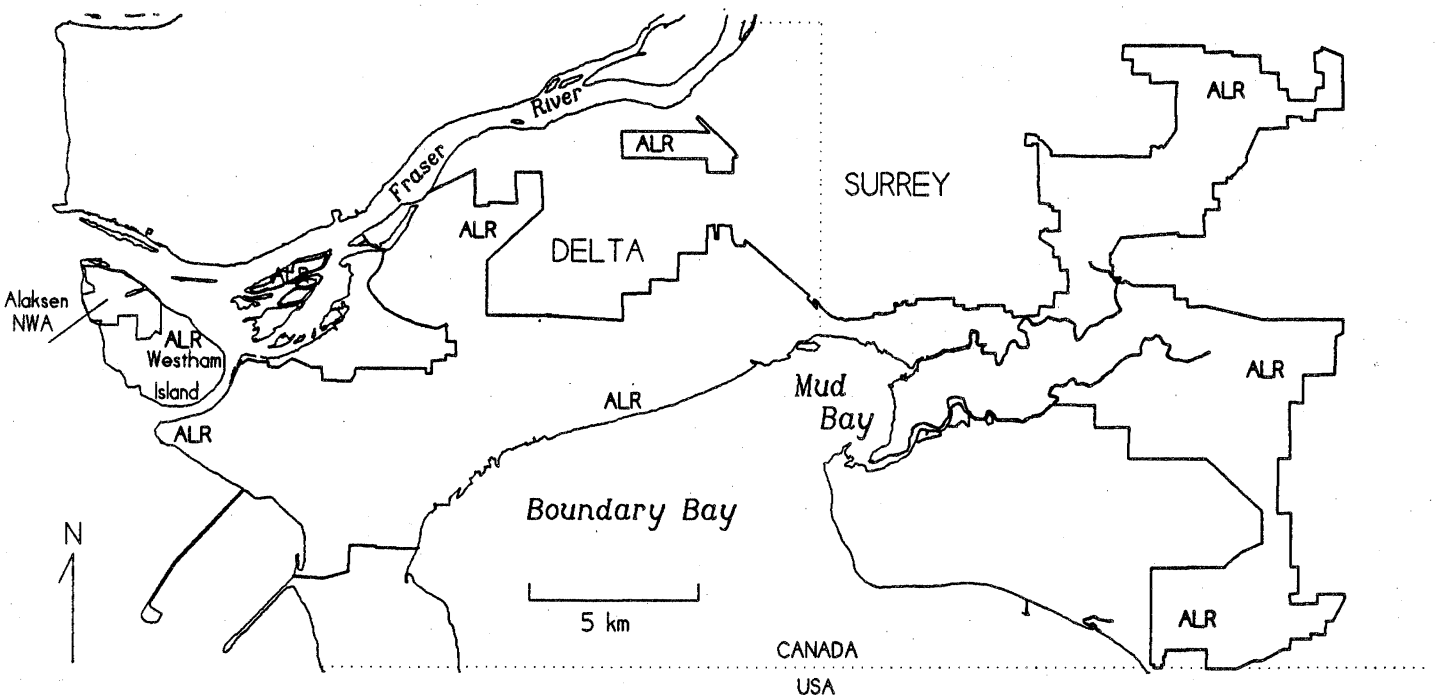

Figure 1. The location of farmlands (ALR), Boundary Bay, Mud Bay, Westham Island and the Fraser River estuary.

Number of Ducks per Hectare per Day (n)

American Wigeons, Northern Pintails and Mallards (referred to as ducks, hereafter) were counted from a vehicle driven along a farmland survey route (Fig.2) on one day and night each week from 1 November 1990 to 22 March 1991. The farmland survey passed pastures, grass cover crops, harvested potatoes, harvested corn, and ploughed fields covering 11% and 15% of the entire farmland in the study area in year one and two, respectively. The types of fields are called habitats in this study.

Ducks were counted and identified to species in each field through binoculars and telescopes during the day, and 2.7X and 6.0X night-vision telescopes (Department of National Defense, night vision equipment AN-PVS-501 and AN-TVS-502) at night. Ducks could be easily seen and identified in fields at night with the night-vision equipment. One of five habitats was assigned to each field along the farmland survey in September, and the field area was measured from a satellite image taken in June 1991. The average number of American Wigeons, Northern Pintails and Mallards that used 1 ha of each habitat was calculated by totalling the numbers of each species counted in each field on each day and night census, and dividing by the area of the field. The mean density of all ducks in each of the five habitats was then calculated.

Residency Time in Fields (d)

The median number of days that ducks foraged in fields was estimated by: i) calculating the median number of farmland surveys (from 1 to 19) on which each species was present in all fields, ii) dividing by the total number of farmland surveys (N=19) and, iii) multiplying by the 150 days that ducks were seen in farmlands (1 November to 31 March).

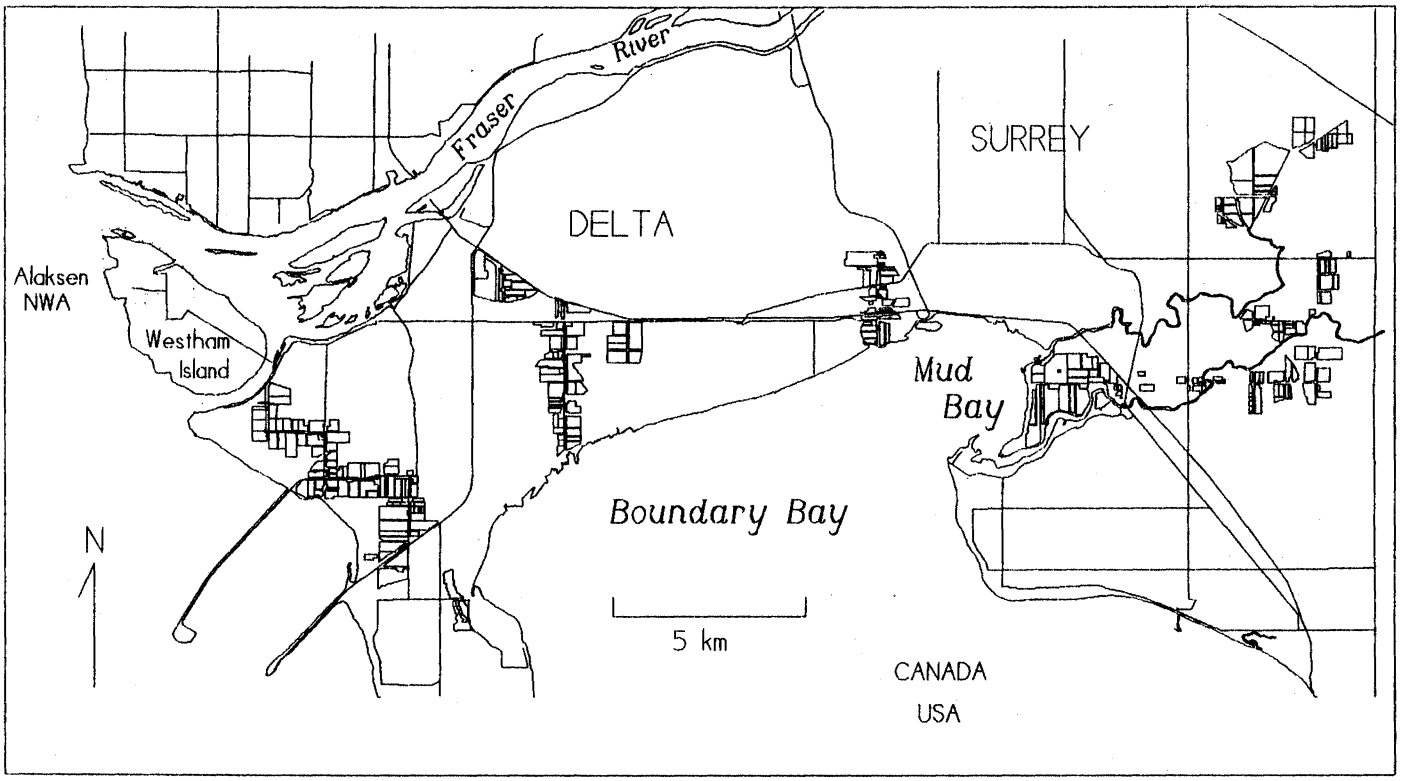

Figure 2. Location of fields along farmland survey routes in the vicinity of Boundary Bay.

Numbers of Ducks Using Farmlands (N)

All American Wigeons, Northern Pintails and Mallards in the Fraser River delta were assumed to use farmlands in every 24h period from 1 November to 31 March because about 70 ducks fitted with transmitters in farmlands and on beaches in Boundary Bay spent most of the day in the Fraser River marshes and Boundary Bay and flew to farmlands each day or night during this period (J. Baldwin, pers. comm.). Therefore, the numbers of ducks using farmlands was estimated by counting all ducks on the beaches and farmlands on Fraser River delta during the day. The numbers of ducks in Boundary Bay and Alaksen National Wildlife Area were estimated through a 20X telescope from a vehicle driven along dykes and roads when the tide was high once each week from 1 November 1989 to 31 March 1990 and 1 November 1990 to 16 March 1991. Each duck was counted in flocks with fewer than about 400 ducks and estimated by summing the number of groupings of 100 birds in larger flocks. The estimated error using the latter method was $\pm$ 14.9% (Appendix 1). Species composition was determined by periodically counting the numbers of American Wigeons, Mallards and Northern Pintails in sample flocks during surveys in Boundary Bay and in farmlands. During the study, it was discovered that ducks fitted with transmitters moved between Boundary Bay, Roberts Bank, Sturgeon Bank and the farmlands (J. Baldwin, pers. comm.). We used counts of ducks made on foot along dykes at high tide once each month from November 1988 to March 1989 (Butler and Cannings 1989) to estimate the numbers of ducks on Roberts Bank and Sturgeon Bank. The numbers of ducks in farmlands during the day was estimated by assuming that the density of ducks in the entire farmland was the same as the density of ducks counted during daytime farmland censuses. This assumption seems reasonable because 8.3% of all ducks counted on one survey of the entire farmland in January 1990 were found on the farmland survey route which covered about 11% of the entire farmland.

3. Distribution of ducks in farmland

The location and size of daytime flocks of ducks was mapped during 10 flights over the entire farmland in a Cessna 172 flown at an altitude of about 150m between 23 January and 6 April 1990.

RESULTS

1. Density of ducks in habitats

American Wigeons, Mallards and Northern Pintails used all five farmland habitats (Table 1). The American Wigeon was densest during the day in pastures in year one and vegetable fields in year two (Table 1). At night, the American Wigeon was densest in vegetable and ploughed fields. The Mallard was densest in potato and corn fields in year one and vegetable fields in year two during the day (Table 1). At night, Mallards were densest in potato fields. The daytime density of the Northern Pintail was highest in ploughed fields in year one and vegetable fields in year two. Potato fields held the highest nighttime densities (Table 1).

There was no significant difference between the daytime and nighttime densities of each species in most habitats (Table 1). Exceptions were American Wigeons that were significantly more dense in ploughed fields at night than during the day in year two and Mallards that were significantly more dense at night than during the day in potato fields (Table 1).

Table 1. Mean (±SE) American Wigeon, Mallard and Northern Pintail daytime and nighttime densities per survey in six crop types.

Species/crop	Duck Densities ±SE (no. of ducks/ha/visit)								
	Daytime		Daytime		U test	p	Nighttime		U test	p
	Year 1	(n)	Year 2	(n)	stat[a]		Year 2	(n)	stat[b]	
American Wigeon										
Pasture	22.6 ± 9.2	(15)	21.1 ± 4.2	(69)	579	0.47	16.7 ± 3.2	(60)	1891	0.40
Corn	12.9 ± 7.7	(6)	8.7 ± 5.1	(7)	22	0.89	7.1 ± 4.5	(8)	32	0.64
Potato	5.7 ± 3.3	(4)	13.5 ± 6.1	(28)	51	0.78	12.8 ± 3.5	(26)	321	0.46
Ploughed	4.5 ± 1.9	(5)	19.4 ± 17.6	(12)	37	0.46	33.4 ± 12.8	(9)	25	0.04
Vegetable	3.1 ± 1.2	(3)	29.0 ± 9.7	(8)	4	0.08	39.4 ± 37.4	(3)	14	0.68
Grass cover crops	-		13.8 ± 6.3	(18)	-	-	7.4 ± 3.2	(15)	148	0.64

Mallard

Pasture	3.3 ± 0.9 (39)	4.5 ± 0.7 (124)	2030	0.13	3.2 ± 0.8 (47)	3403	0.09
Corn	7.3 ± 2.3 (30)	3.3 ± 1.5 (27)	496	0.15	3.7 ± 2.1 (18)	207	0.41
Potato	7.5 ± 1.8 (18)	19.0 ± 3.0 (84)	545	0.06	26.5 ± 17.6 (41)	2276	0.01
Ploughed	4.6 ± 1.7 (20)	5.0 ± 1.3 (62)	695	0.42	15.8 ± 7.5 (15)	340	0.11
Vegetable	6.1 ± 2.4 (21)	36.0 ± 26.0 (25)	219	0.34	5.3 ± 3.9 (5)	76	0.45
Grass cover crops	-	12.4 ± 3.2 (55)	-	-	5.2 ± 1.9 (24)	863	0.03

Northern Pintail

Pasture	6.3 ± 2.0 (15)	18.3 ± 4.8 (56)	331	0.21	12.1 ± 4.0 (21)	606	0.84
Corn	19.3 ± 9.9 (9)	10.5 ± 3.2 (8)	36	1.00	1.1 (1)	7	0.25
Potato	16.1 ± 10.3 (7)	21.2 ± 6.3 (24)	74	0.64	41.6 ± 22.4 (21)	228	0.59
Ploughed	41.1 ± 36.1 (8)	23.8 ± 16.9 (25)	108	0.74	19.6 ± 8.0 (10)	80	0.10
Vegetable	2.4 ± 0.8 (8)	34.7 ± 16.8 (15)	36	0.13	12.2 ± 8.7 (2)	12	0.66
Grass cover crops	-	15.0 ± 5.8 (18)	-	-	12.3 ± 5.6 (7)	66	0.86

a: Mann-Whitney U-test between daytime densities in the year 1 and year 2 of the study.

b: Mann-Whitney U-test between daytime and nighttime densities during year 2 of the study.

2. Residency time in a field

The median probability that a field was used more than once was (8.1 sightings/19 censuses=) 0.43. Therefore, the median number of days a field was used between 1 November and 31 March was estimated to be (0.43 X 150 d=) 64.5 days. This estimate seems reasonable because pasture grasses and grass cover crops grow through the winter and seeds, corn, potatoes and insect larvae become easier to dig from fields flooded with water beginning about November.

3. Numbers of ducks on the Fraser River delta

The number of all species of ducks in the Fraser River delta in year one and year two rose from about 100,000 ducks in early October to about 175,000 from November to mid-January (Fig. 3). However, in year one the numbers of ducks declined in February followed by a second peak in March whereas in year two the decline occurred in the last half of January followed by a second peak in February (Fig. 3). American Wigeons were the most numerous duck and outnumbered Mallards and Northern Pintails from November to March (Table 2). An average of about 115,000 ducks were on the entire Fraser River delta between 1 November to 31 March (Table 2).

4. Numbers of ducks in farmlands

The sum of the mean densities of ducks in five habitats containing pasture, corn, potato, ploughed, and grass cover crops was 93.3 ducks in 5 ha or 18.7 ducks/ ha (Table 3). The median residency time was 64.5 days in a field. Therefore, if one hectare of habitat supports 18.7 ducks for 64.5 days then 115,000 ducks will need (115,000/18.7 X 150d/64.5d=) 14302 ha for 150 days. This accounts for about 75% of the 19078 ha of farmland in the study area.

Table 2. Estimated numbers of American Wigeons, Northern Pintails and Mallards in the Fraser River delta in November 1990 to March 1991.

Month	American Wigeon	Northern Pintail	Mallard
November	73,000	50,000	29,000
December	65,000	41,000	32,000
January	40,000	27,000	32,000
February	36,000	33,000	33,000
March	37,000	22,000	22,000

Table 3. Mean densities of American Wigeons, Northern Pintails and Mallards in five habitat types.

Habitat Types	Mean Densities (no. ducks/ha)
Pasture	18.4
Corn	6.8
Potato	30.8
Ploughed	18.3
Grass cover crops	19.0
TOTAL	93.3

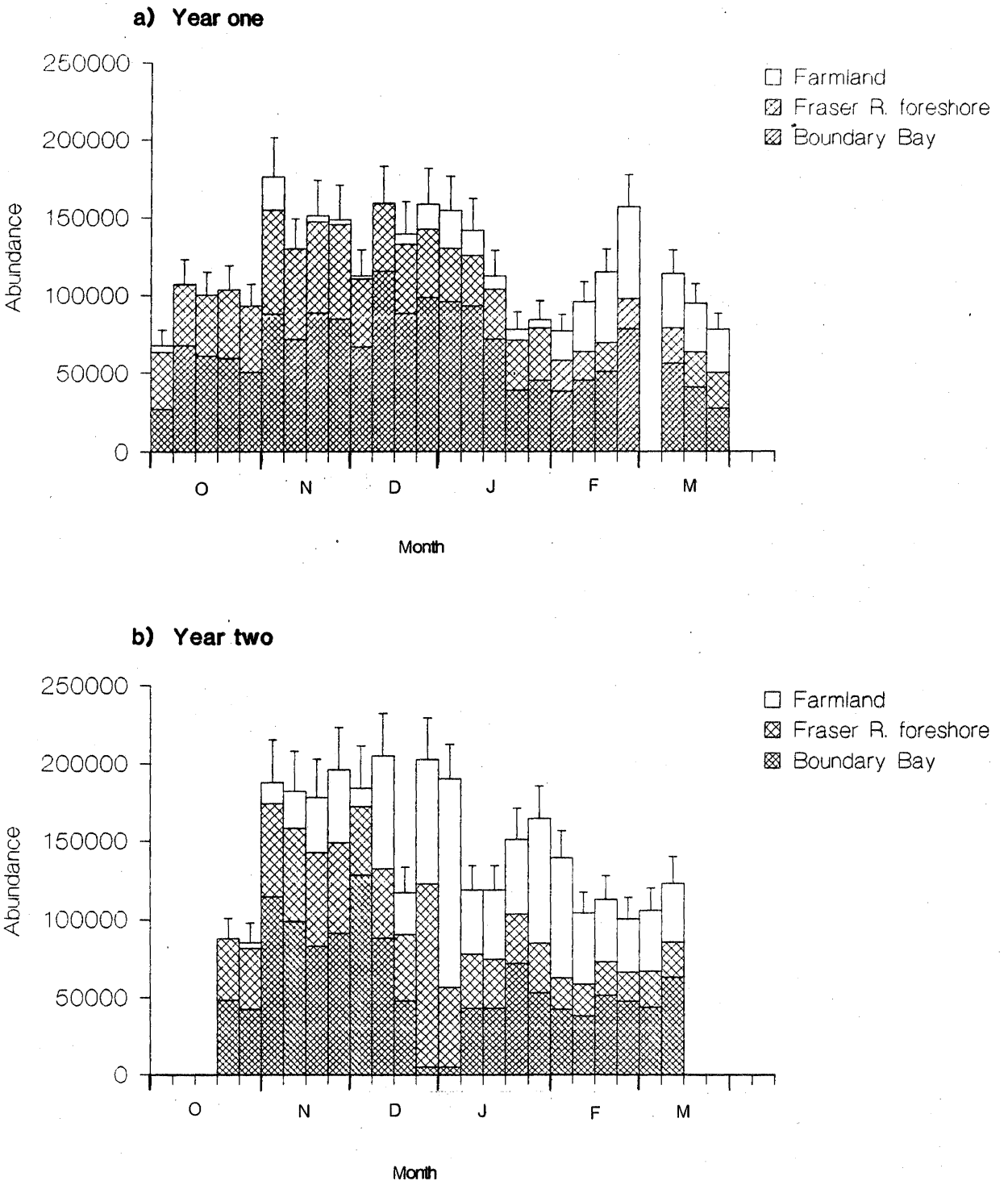

Figure 3. Estimated numbers of all species of ducks on farmland, on the Fraser River foreshore and in Boundary Bay, by week in year one and year two.

5. Daytime distribution of ducks in farmlands

Ducks used farmlands throughout the delta. The most frequently used farmlands along the Serpentine and Nicomekl rivers, the northwest corner of Boundary Bay south of Highway 17 and, south of Ladner Village and west of Highway 17 (Fig. 4).

Discussion

Comparison with other studies

The numbers of ducks estimated on the Fraser River delta in this study were similar to those made by Vermeer and Levings (1977) and McKelvey and Summers (1990). Hirst and Easthope (1981) and Jury (1981) found small numbers of ducks on farmland during the day. The present study located large numbers of ducks during the daytime in farmland in the same study areas as Hirst and Easthope (1981) and Jury (1981). The increase in daytime use of farmland by ducks might indicate reduced hunting pressure in recent years.

The distribution of American Wigeons, Northern Pintails and Mallards in farmland habitats during the day in this study agree with results from similar studies made by Hirst and Easthope (1981) during the day. An exception was the high densities of ducks in vegetable fields in the second year of the study (46.4 ducks/ha). This behaviour occurred in January possibly because deep snows prevented ducks from foraging in other habitats. The ducks moved into the other habitats when the snow melted in February.

This study is the first to show that the day and night densities of ducks were not significantly different between most habitats (Table 1). However, the sample sizes were small so the power of most comparisons might have been too low to reveal a significant difference.

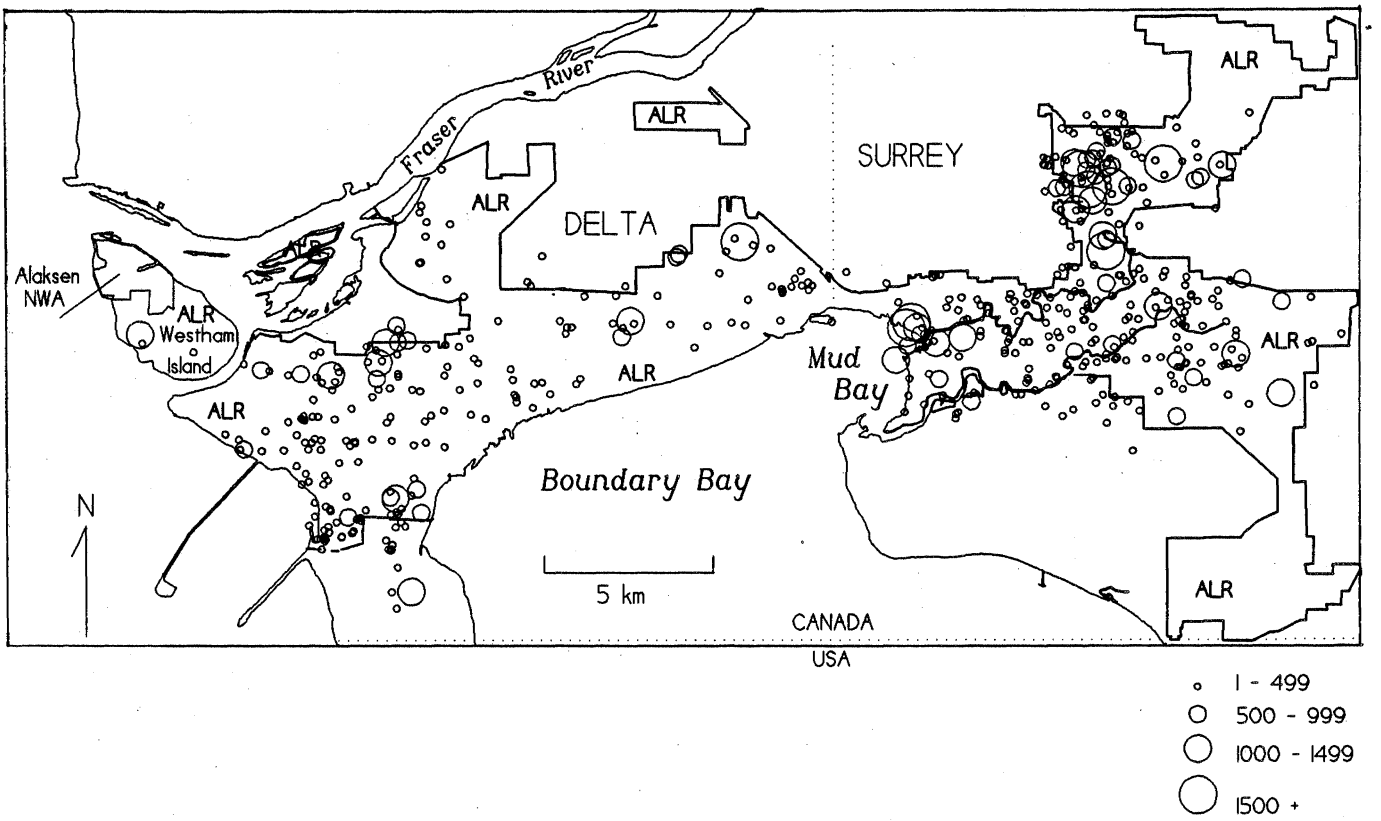

Figure 4. Distribution and abundance of flocks of ducks seen on 10 aerial surveys of entire farmlands between 23 January and 6 April 1990.

Sensitivity analysis of the estimates

The accuracy of the estimates is dependent on the observer's ability to estimate the numbers of ducks in the Fraser River delta, their distribution in different farmlands during the day and night and the length of time ducks spent in each field. Each of these estimates adds error to our calculations of the amount of farmland required by ducks. The estimated amount of land required by ducks changes by 4.0% for every unit change in the density estimates, by 1.6% for every change of one day in the residency time spent in a field and 0.9% for every change of 1000 ducks in the populations estimates. The average error around the mean density of ducks in five habitats (18.7 ducks/ha) was about 31%. Therefore, the mean densities of ducks ranged from 12.9-24.5 ducks/ha. If 24.5 ducks/ha is used in place of the mean (18.7 ducks/ha) in the equation (see *2.2* above), then more (20732 ha) than the available farmland (19078 ha) would be required. Clearly, these densities are too high. On the other hand, an estimated 10916 ha, or 57.2% of the available land would be required if the lower value (12.9 ducks/ha) are used in the calculations. The 57.2% estimate is probably too low since ducks were very widespread in farmlands in Jury's (1981), Duynstee's (1992) and this study (Fig. 4). The error in the population estimates was about 15% (Appendix 1), so the amount of land required by ducks might be about (0.9%. X 15% error=) 13.5% higher or lower than the 14302 ha estimate. Neither of these differences is large enough to greatly change the conclusion that ducks use most of the farmland.

Conservation of ducks around Boundary Bay

These findings show that large numbers of ducks use farmlands around Boundary Bay, and suggest that a loss in farmland will result in a decline in their populations. The best farmlands for waterfowl are in the Serpentine and Nicomekl river drainage, near the northwest corner of Boundary Bay, and south of Ladner Village (Fig.4)

Acknowledgments

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Appendix 1. Error associated with flock size estimates

The formula presented in Cochran (1977) was used to calculate the total error around estimates of flock size:

$$Error = \sqrt{(Accuracy)^2+(Precision)^2}$$

Repeated counts of a sample of flocks were used to quantify accuracy and precision of flock size estimates. Accuracy was derived from flocks for which the number of birds was both estimated (see methods) and then counted one-by-one. Precision was derived from repeated estimates of isolated flocks. The overall error was calculated from the following formula (Cochran 1977):

$$Total\ Error = \sqrt{(Accuracy)^2+(Precision)^2}$$

1. Estimating accuracy

Five observers surveyed 155 flocks of ducks ranging in size from 10 to 620 individuals between October 1989 and November 1990. Accuracy around each estimate was calculated as the difference between the estimate and count, divided by counted flock size.

The accuracy varied between observers was determined by regressing accuracy on calculated group size for each observer and for pooled observers. An F-test was used to compare the sum of individual observer's residual sum-of-squares (ssq) with the ssq of pooled observers (Appendix Table 1). The difference between ssq was not significant ($F_{155,145,0.05}$=1.14, p>0.05), so all observations in subsequent analyses were pooled.

An ANOVA was used to examine whether accuracy varied with estimated group size. Although not statistically significant, a plot of residuals obtained from the regression of accuracy against estimated group sizes suggested both normal

distribution and homogeneity of variances. Accuracy did not vary significantly with group size (r^2=0.01, n=155, p=0.45), but the power of the test may be too low to detect significant variations.

Overall survey accuracy was calculated as the mean (±SE) error between estimated and counts where birds were individually counted. Observers underestimated the number of birds in counted flocks by 1.1% to 15.7% (Appendix Table 1). Pooled observations indicated that flock sizes were underestimated by an average of 9.7 ± 0.01% (n=155).

Appendix Table 1. Precision (±SE) of flock size estimates.

Observer	*No. of Paired surveys*	*Percent (±SE) error around counts**	*Residual sum-of-squares*
1	*66*	*-10.5% ± 0.02*	*1.50*
2	*9*	*- 1.8% ± 0.04*	*0.12*
3	*33*	*-15.7% ± 0.02*	*0.44*
4	*19*	*-13.0% ± 0.05*	*0.87*
5	*28*	*- 1.1% ± 0.03*	*0.56*
All observers combined	*155*	*- 9.7% ± 0.01*	*4.25*

*: - = *underestimate*

\+ = *overestimate*

2) Estimate of precision

Precision was examined by comparing two repeated estimates of the size of 82 separate flocks ranging in size from 800 to 25,000 individuals. The estimates were collected by one observer between October 1990 and March 1991 using the methods outlined in the first chapter [i.e. each estimate was based on the area covered by a group of known size (100 birds)]. Precision was calculated as the difference between the two estimates divided by the first estimate.

A Kruskal-Wallis ANOVA was used to examine whether precision varied with calculated group size because of non-normality and non-homogeneity of variance of the residuals. Estimated precision did not vary significantly with group size (Kruskal-Wallis ANOVA, p=0.72).

Overall estimated precision was calculated as the mean (±SE) of individual estimate precision. Overall precision was calculated at 11.3 ± 0.01% (Appendix Table 2).

Appendix Table 2. Precision of flock size estimates.

Number of surveys	Percent error between subsequent estimates of flock size		
	Maximum error	Minimum error	Mean (±SE) error
82	50%	0%	11.3±0.01%

3. Measuring total error around estimates

The values calculated in the preceding section were used to estimate total error. By replacing accuracy and precision in Equation 1 by their calculated values, the calculated total error was:

$$Error = \sqrt{(-9.7\%)^2+(11.3\%)^2}$$

$$= \sqrt{221.78}$$

$$= 14.89$$

This calculated error (14.89%) is used in the next sections as the error around flock size estimates.

The calculations of total error associated with flock size estimates depend on numerous untested assumptions. Accuracy and precision were calculated from different flock sizes (respectively 10-620 and 800-2500 individuals), and precision and accuracy errors were assumed to be independent from flock size. A plot of precision error against calculated flock size showed a non-significant increase in precision variance with flock size, suggesting that the assumption

is wrong. Repeated estimates of the size of a flock were assumed to be independent (i.e. no pseudoreplication). Finally, it was assumed that there were no significant differences between calculated flock size (one-by-one count) and real flock size. Further work is in progress to better estimate the margin of error around flock size estimates.

Chapter 3. Populations, diet, food availability and food requirements of dabbling ducks in Boundary Bay.

John R. Baldwin

and

James R. Lovvorn

Introduction

Boundary Bay, in the southern Fraser River Delta of British Columbia, is an important resting and feeding area for migratory birds (Leach 1972, Butler and Campbell 1987). The Bay has extensive tidal flats with large portions covered by eelgrass (*Zostera spp.*) which provides habitat for many invertebrates. Eamer (1985) suggested that estuarine habitats such as Boundary Bay are valuable feeding areas for dabbling ducks in fall and early winter. Previous food habits studies in the Fraser Delta described use of emergent marsh vegetation (*Carex sp.* and *Scirpus* spp.) along the delta foreshore (Burgess 1970) and use of agricultural lands adjacent to Mud Bay (Hirst and Easthope 1981). While important, these studies are inadequate for determining the contribution of Boundary Bay to population food requirements for dabbling ducks.

Boundary Bay research, described in this study, has focused on the question of how much upland habitat is necessary to maintain current populations of birds. Deciding how much upland habitat is necessary requires knowledge of the contribution to the diet provided by tidal habitats. Waterfowl can deplete a large portion of available food (Madsen 1988, Van Eerden 1984), and habitat shifts by Wigeon (Madsen 1988), geese (Drent and Swierstra 1977, Charman 1979, Drent et al. 1978, Lorenzen and Madsen 1985), and Canvasbacks (*Aythya valisineria*, Lovvorn 1989) have occurred when available food was depleted below levels that allow profitable foraging. An early-winter shift by ducks from Boundary Bay to upland habitats may result from declining food availability in the bay.

In this study, our objectives were to:

1) determine the diets of American Wigeon (*Anas americana*), Northern Pintails (*A. acuta*), and Mallards (*A. platyrhynchos*) in tidal habitats of Boundary Bay and nearby uplands;

2) document temporal patterns in the availability of important foods in tidal habitats and;

3) estimate population food requirements of the three duck species, and to evaluate the contribution of tidal habitats toward fulfilling these requirements.

Methods.

1.Estimates of the numbers of ducks.

Numbers of dabbling ducks in Boundary Bay were estimated every 7-10 days from September 1990 through March 1991. Duck numbers were estimated with a 20-60X spotting scope from points along the dike road (112th Street to Beach Grove). Estimates were calibrated regularly by estimating numbers of birds in discrete flocks of 50-100, then counting each bird and adjusting the "mental image" if necessary. Large flocks were estimated by counting from left to right and then repeating the count estimate from right to left. If the difference in estimates was greater than 10% the procedure was repeated. Estimates for flocks in excess of about 5,000 ducks were repeated several times and averaged. We attempted to standardize tide and weather conditions during bay counts. Tide heights of 3-4.3 m (9-13 feet) above LLW (Canadian Hydrographic Service 1990) were best to eliminate ducks hidden by vegetation at high tide (>4.5 m) and to decrease numbers of ducks too far away at low tide (the intertidal zone is about 2.5-3.5 km across at low tide). Calm days with minimum wave action and no rain or fog were necessary for adequate visibility. Counts were made between 0900-1600 PST to reduce numbers of ducks returning to or leaving the Bay during crepuscular periods.

Observations in the uplands and telemetry data to be reported elsewhere

indicated that, after late November, most dabblers fed in uplands at night and returned to the Bay during the day. Thus, daytime counts in the Bay were used to calculate duck-use days for the area. Daily duck-use days (the presence of one duck in the area for one day) were linearly interpolated from counts on consecutive census days in Boundary Bay. Use-days were summed for each month and for all months combined. Estimates of duck species composition were averaged for each month to calculate use-days by species.

2. Estimates of prey abundance.

2.1 Core samples in tidal flats

Core samples were taken along two transects in the Bay in mid-October, mid-December, and mid-February 1990-91. Transects extended from the edge of the salt marsh perpendicular to shore at 72nd Street (transect 1) and 96th Street (transect 2). Sampling stations were marked with stakes at 100-m intervals for 2.1 km on transect 1 and 2.5 km on transect 2. Three cores per station were taken during each sampling period. A galvanized-steel, hand-held sampler (10-cm radius) was forced into the substrate to a depth of 5-6 cm. The substrate to one side of the corer was then dug away and a flat shovel slid under the sampler to prevent the sandy core from dropping out when removed. Samples were later washed through a 0.5 mm screen, organisms sorted by species, and numerical densities of invertebrates and grams dry mass of eelgrass were recorded.

2.2 Estimates of eelgrass abundance

Three transects were established within a monotypic stand of *Z.japonica*. The transects were approximately 400 m from and parallel to Centennial Beach (Fig. 1).

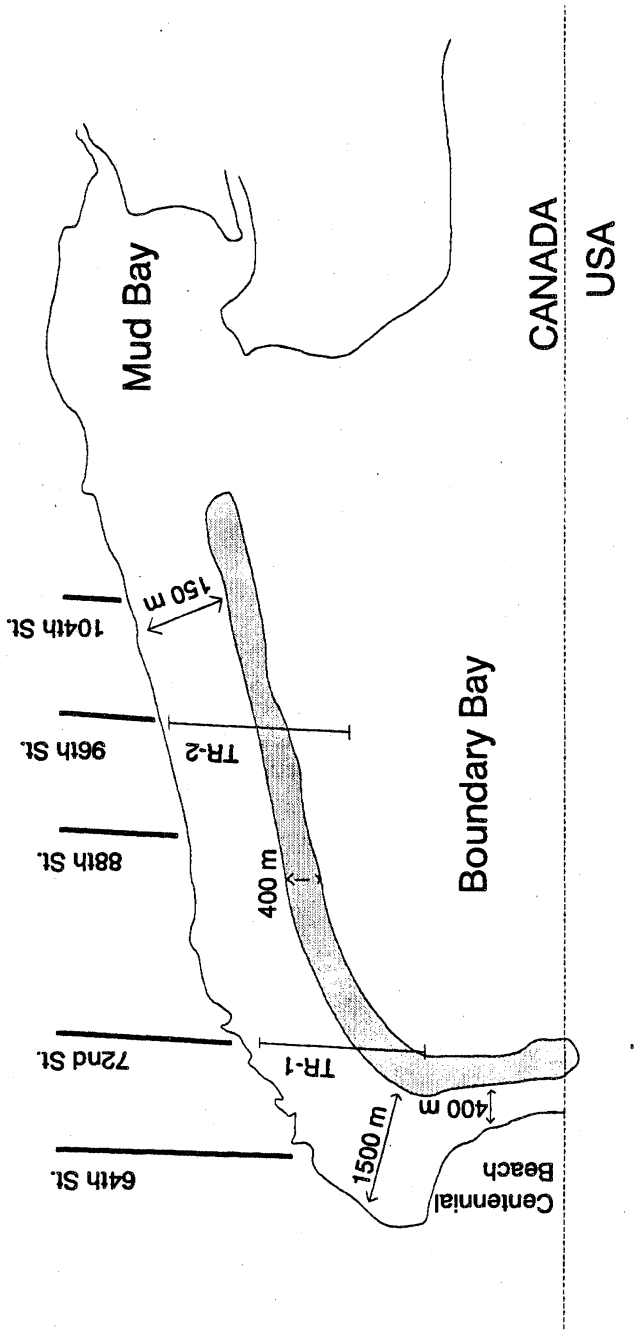

Figure 1. Estimated minimum coverage of *Zostera japonica* in October 1990 (shaded area). Core transects TR-1 and TR-2 are also shown.

Transects were 50 m apart, and each had 20 stations at 10m intervals. Percent cover within a 0.1-m^2 rectangular frame was estimated at each station in mid-October before most ducks arrived and in mid-January when ducks were abundant. Biomass of *Z. japonica* in the entire Bay was extrapolated from its average biomass in core samples containing *Z.japonica*. An estimate of total areal coverage was mapped on a Generic CADD (1989) image of Boundary Bay.

3. Duck foraging behaviour on tidal flats.

Foraging behaviour of Wigeon, Pintails, and Mallards in Boundary Bay was observed from 1 October through 7 December 1990. Daylight hours were divided into four equal parts, and ducks were observed for two 30-min periods, once a week, during each of the four daylight periods. Tide heights ranged from 1.5-4.7 m above LLW. A focal bird (Altmann 1974) was randomly selected and observed for 20 sec (n=1128 focal individuals) to quantify percent time spent feeding. These data were not normally distributed, so 15-85% quantiles are used to delimit the same proportion of the distribution (68%) enclosed by ± 1 standard deviation.

4. Diets of dabbling ducks.

Wigeon, Pintails, and Mallards were collected from October 1990 through January 1991. Ducks were collected in Boundary Bay from a blind approximately 400 m seaward of the dike at 72nd Street. Foraging ducks were collected between Ladner Village to 112th Street.

Esophagus contents were immediately preserved with ethyl alcohol and later frozen (n=99) or allowed to freeze outdoors (n=16). Food items were sorted and oven-dried at 56°C for 48 hours and weighed to the nearest mg. Percent dry mass were calculated for each esophageal sample (Swanson et al. 1974), and then aggregate percentages were calculated for the major food groups of each species.

5. Estimates of population food requirements.

The estimated mass of food required by Wigeon, Pintails, and Mallards in winter was estimated as follows: 1) each food item found in the esophagus and crop was converted into percent dry weight, 2) the dry weight of each food item was converted into units (kJ) of metabolizable energy and, 3) the additional mass of each food item required by a Wigeon, Pintail, and Mallard to reach published estimates of their daily energy requirements was calculated. The estimated mass

of food required each day by a Wigeon, Pintail, and Mallard was multiplied by the number of duck-days that each species spent in the Bay to arrive at an estimate of the amount of food required to support these species from September to March. Each of these steps is described in detail now.

Population food requirements (PFR) over the winter (1 September 1990 to 31 March 1991) for Wigeon, Pintails, and Mallards were calculated by the formula:

PFR = [(DF X DEE) / AME] X DD

where the diet fraction (DF) is the aggregate fraction (average fraction for all esophagi) of dry mass for each food species, calculated separately for each duck species. Estimated daily energy expenditure (DEE) from published values was 631 kJ per day for a Wigeon (Mayhew 1988), 660 kJ per day for a Pintail (interpolated for a body mass of 900 g from values for Wigeon and Mallard), and 683 kJ per day for a Mallard (Morton et al. 1989). Apparent metabolizable energy (AME) is the percent of gross ingested energy that is assimilated by a duck (see definitions in Miller and Reinecke 1984) and was obtained from the literature (Appendix 1). Methods to estimate duck-use days (DD) were provided earlier (see section *2.1* above). A 25% confidence bound on population size was used to calculate a minimum and maximum population estimate from which to estimate a range of population food requirements. To estimate food intake from tidal versus upland habitats, we assumed that ducks obtained 90% of their daily energy needs from the Bay until the end of November, after which 90% of energy needs were obtained from surrounding uplands. This assumption seems reasonable because most ducks flew to uplands at night after November when low tides exposed the feeding habitats in the Bay (J. Baldwin, unpubl. data).

Results

1. Estimates of duck numbers.

Numbers of ducks in Boundary Bay climbed steadily from mid-September to a high of about 80,000 in mid-December (Fig. 2). The Bay was completely frozen from 17 December 1990 to 10 January 1991. Numbers of ducks in the Bay dropped to <100

during this period and then gradually returned to about 40,000 when the ice thawed in mid-January.

Wigeon (48.7%), Pintails (37.6%) and Mallards (12.8%) made up over 99% of dabbling ducks counted in Boundary Bay (Table 1). Approximately 6.7 million duck-use days was estimated for Boundary Bay from September 1990 to March 1991 (Table 2). Pintails declined through winter, whereas numbers of Wigeon and Mallards were more variable (Table 2).

2. Duck foraging behaviour on tidal flats.

All species spent most of their time feeding at tide heights below 2.3 m LLW (Table 3). Although feeding was observed at all tide heights, median time spent feeding decreased to near zero at tide heights above 2.6 m. The extent of night feeding in the Bay throughout the intertidal zone has not been documented, but is thought to be negligible after late November. McKelvey et. al. (1985) recorded minimal feeding at night by dabblers in the upper intertidal area south of Boundary Bay airport.

3. Diet of dabbling ducks.

Zostera spp. (>98% *Z. japonica*) comprised the largest percentage of the diet in all three species of ducks collected in the Bay (Table 4). Wigeon fed on the leaves of *Zostera* spp., Pintails ate the seeds and rhizomes, and Mallards ate the seeds. Amphipods were eaten by Pintails, whereas wild seeds (*Atriplex patula*, *Salicornia* spp., *Juncus* sp., *Chenopodium glaucum*, *Echinochloa spp.*, and *Polygonum* spp.) were eaten by all three species. Sea lettuce (*Ulva* sp.) was eaten by Wigeon, and gastropods were eaten mostly by Pintails.

Table 1. Average percent species composition of American Wigeons, Northern Pintails and Mallards among all dabbling ducks[1] estimated from September 1990 to March 1991 in Boundary Bay.

Month	Wigeon	Pintail	Mallard
September	46	44	9
October	43	50	6
November	46	42	11
December	55	35	10
January	26	46	27
February	54	26	20
March	62	24	13
Mean	48.7	37.6	12.8

[1] Green-winged Teal (*Anas crecca*), Northern Shoveler (*A. clypeata*) and Eurasian Wigeon (*A. penelope*) made up about 1% of the total of all dabbling ducks.

Table 2. Estimated duck-use days[1] by American Wigeons, Northern Pintails and Mallards of Boundary Bay between September 1990 and March 1991.

Month	Wigeon	Pintail	Mallard	Total
September	153,366	146,698	30,006	333,405
October	416,425	479,227	61,836	966,184
November	810,035	749,901	192,781	1,768,635
December	707,380	448,740	125,440	1,293,200
January	140,036	249,135	148,178	542,777
February	472,191	225,983	174,104	879,313
March	553,218	211,132	118,483	890,851
Total	3,252,653	2,510,817	850,829	6,674,365

1- one duck-use day is defined as the presence of one duck for one day.

Table 3. Median percentages of time that American Wigeons, Northern Pintails and Mallards spent foraging during the day at different tide heights in Boundary Bay between 1 October and 7 December 1990. 15-85% quantiles are shown in parentheses. For medians without ranges there was no variation.

Tide height (m)	Wigeon	Pintail	Mallard
1.5-2.0	100	100	100(0-100)
2.0-2.3	100	100	75(0-100)
2.3-2.6	25(0-100)	100(65-100)	80(0-100)
2.6-2.9	<1(0-100)	<1(0-100)	<1(0-100)
2.9-3.2	<1(0-100)	<1(0-30)	0
3.2-4.7	0	0	0

Table 4. Aggregate percent dry mass of the foods of ducks collected in Boundary Bay. Foods representing <0.5% of the diet are omitted.

Food	Wigeon (n=14)	Pintail (n=19)	Mallard (n=3)
Plant			
Zostera spp.	67.1	35.2	73.5
Ulva sp.	18.6	0	0
Wild seeds	7.1	8.2	23.0
Animal			
Amphipoda	0	24.7	0
Gastropoda	0	13.7	2
Insecta	0	2.7	1.5
Bivalvia	0	2.7	0

In the uplands, wild seeds comprised an important portion of the diet for all species (Table 5). Corn was eaten primarily by Mallards. The 7% corn diet for Wigeon is probably an overestimate, as it occurred in esophagi only when most pasture areas were covered with several centimetres of snow. The same bias probably applies to cabbage eaten by Pintails and Mallards (Table 5). Wigeon relied mostly on grass and pasture species (wheat, clover, rye, and various grasses). Mallards relied on agricultural crops such as potatoes, corn, and cabbage and wild seeds provided 30% of the their diet. Seeds of *Polygonum* spp. were the single largest component of Mallard and Pintail diets in the uplands.

Wigeons obtained most of their food energy in farmlands from grass and pasture and in the Bay from eelgrass and seaweed (Appendixes 2 and 3). Most of the food energy required by Pintails in the Bay was derived from eating gastropods, amphipods, and plant seeds (Appendix 2) although *Z. japonica* provided a large portion of the Pintail diet (41 tons). Mallards obtained their food energy more evenly among food items (Appendices 2,3) in fields, but not in the Bay, than Wigeons or Pintails. *Zostera* spp. seeds were the largest fraction of the Mallard diet in the Bay (Table 4, Appendix 2).

4. Prey abundance.

4.1 Core samples on tidal flats.

Figure 3 shows the abundances of seven of the most common invertebrates in the tidal flats above MLLW in the Bay, as well as of *Zostera marina* and *Zostera japonica*. *Zostera marina* contributed >95% of the eelgrass biomass in core samples. *Z. japonica* occurred in only trace amounts in some areas where feeding by ducks had occurred. Results from samples taken in the autumn suggested that *Z. japonica* had already declined before our first sample in October 1990. Coverage of *Zostera* spp. decreased by 94% between October 1990 and mid-February 1991. Invertebrates of all species declined from October to February. The gastropod *Haminoea vesicula* showed the most dramatic decline (Fig. 3). *H. vesicula* was less than 0.5% of the diet for Pintails and Mallards; however, this may have been due to small sample size and rapid digestion because of the thin

Table 5. Aggregate percent dry mass of the foods of ducks collected in uplands. Foods representing <0.5% of the diet are omitted.

Food	Wigeon (n=14)	Pintail (n=6)	Mallard (n=24)
Plant			
Wild seeds[1]	14.6	72.9	30.5
Pasture and grass foliage	72.3	0	0
Corn	7.0	0	23.8
Potatoes	0	0	20.8
Cabbage	0	16.7	13.2
Insecta	0.8	10.5	3.5
Unidentified	4.1	0	5.2

[1] *Echinochloa* spp., *Rubus laciniatus*, *Atriplex patula*, *Polygonum* spp., and *Juncus* sp.Table 5

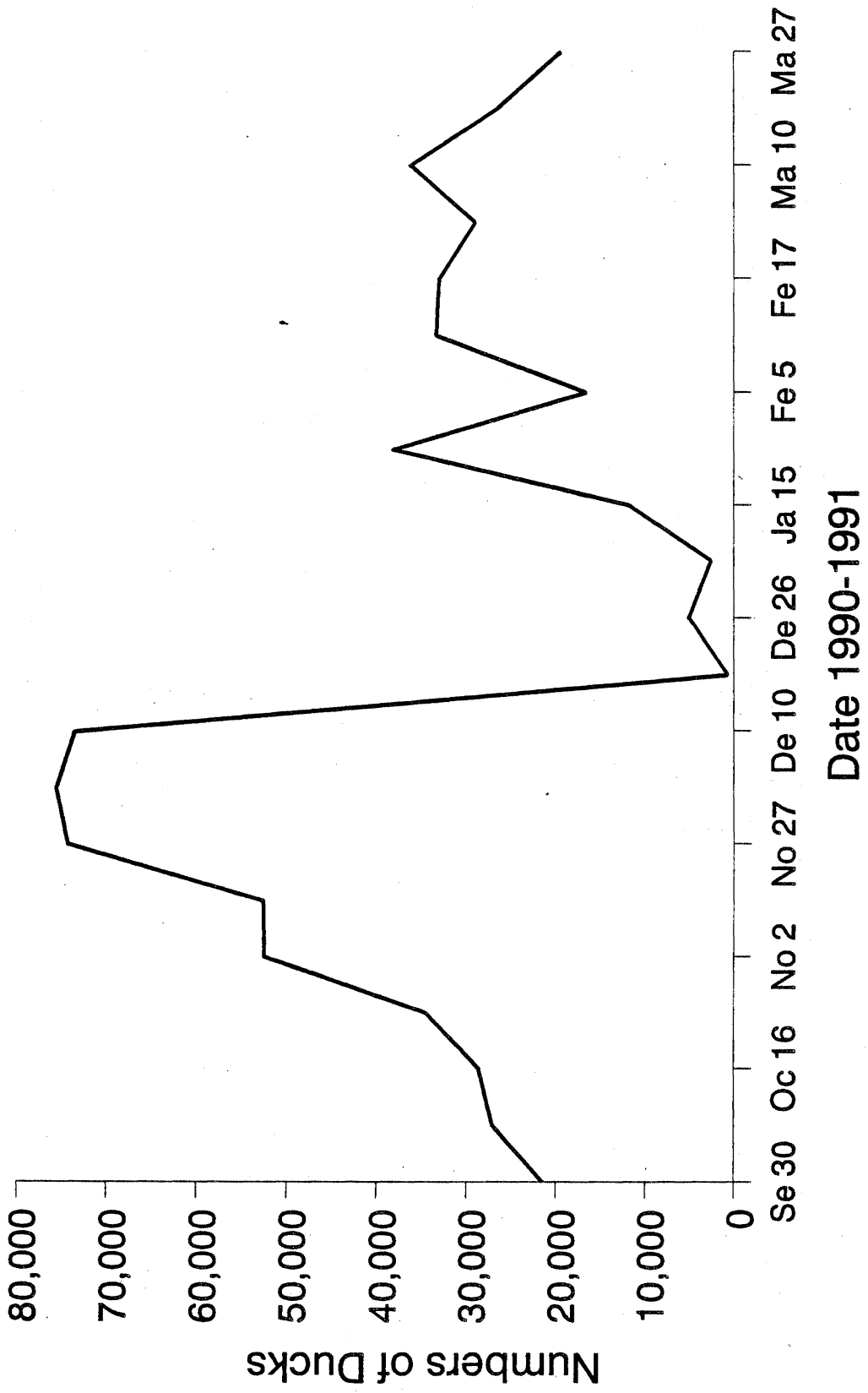

Figure 2. Estimated numbers of dabbling ducks in Boundary Bay 1990-91.

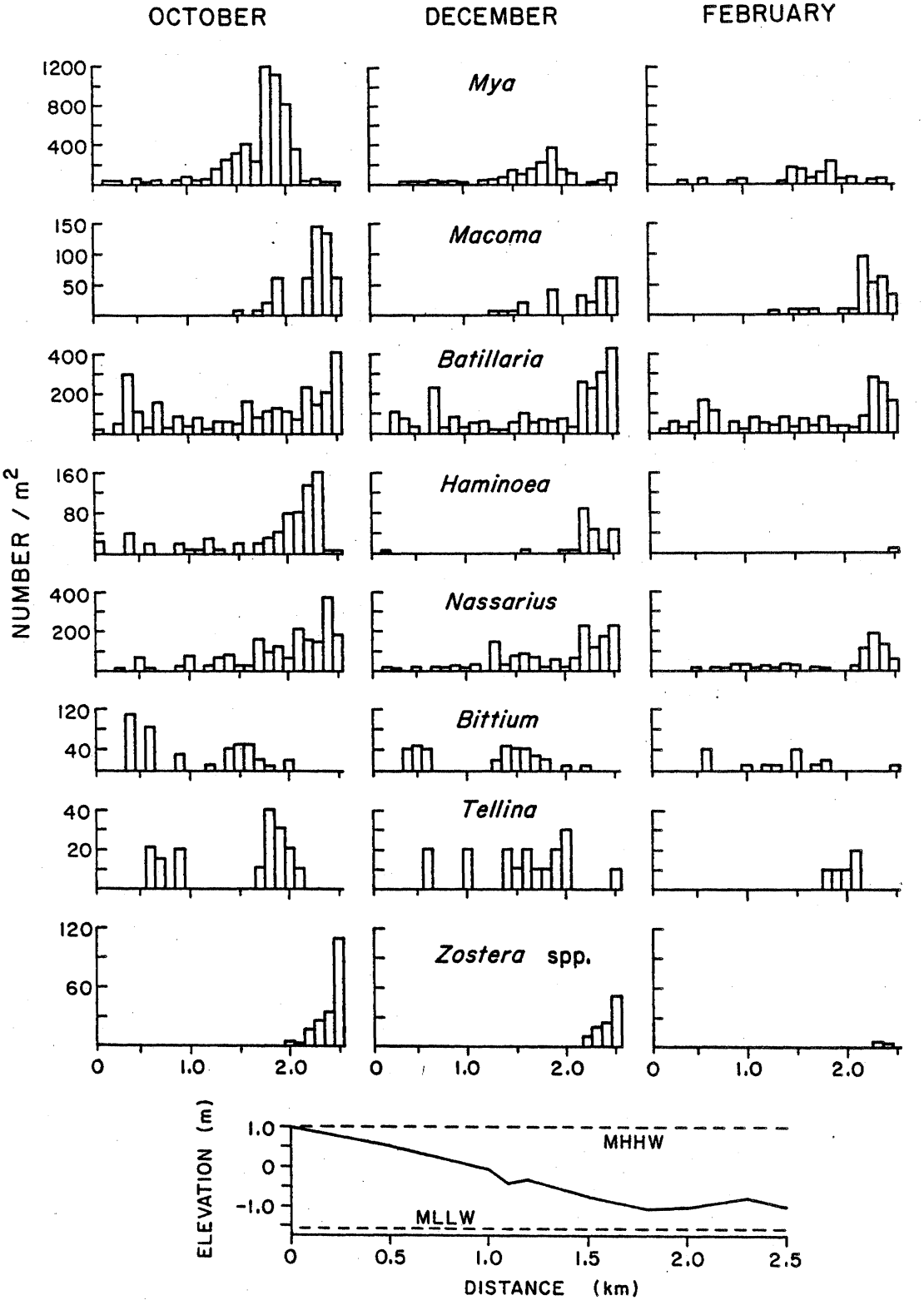

Figure 3. Densities of invertebrates (number/m^2) and *Zostera* spp. (g dry mass/m^2) in Boundary Bay, 1990-91. The 25 stations were 100 m apart along a transect perpendicular to shore, starting at the edge of the salt marsh at 96th Street. The elevational gradient is from Swinbanks (1979).

fragile shell. Soft-shelled clams *Mya arenaria* declined 86%, and the snail *Batillaria zonalis* showed the smallest decline at 33%. *B. zonalis* over 1 cm long were not eaten by Wigeon, Pintails, or Mallards.

4.3 Eelgrass transects on tidal flats.

The estimated minimum coverage of the Bay by *Zostera japonica* in October 1990 (Fig. 1) was 551 ha. Average dry mass was 30.6 m^{-2} (SD=12.5) in core samples. The estimated standing crop in October was 168.6 (SD= 68.9) dry tonnes. Cover of eelgrass along 3 transects through a monotypic stand of *Z. japonica* decreased an average 88% between 15 October 1990 and 15 January 1991 (Table 6). Ice covered large portions of the transect area from about 19 December until 15 January and might have uprooted large amounts of *Zostera*.

Estimated food requirements of duck population.

In Boundary Bay, Wigeon relied heavily on the exotic eelgrass *Z. japonica* during the fall (Table 4) and grazed an estimated 83% of the biomass (140 tonnes, Appendix 2). The largest estimated biomass of food eaten by Wigeons (204 tonnes) came from upland grassland and pasture (Appendix 3). Fifty tonnes of Wigeon forage were provided by algae, primarily *Ulva* spp. with small amounts of filamentous (*Enteromorpha* sp.) and unidentified species.

Table 6. Average percent cover for *Zostera japonica* at 60 stations on 3 transects in Boundary Bay. One standard deviation is shown in parentheses.

	Percent cover		
Transect	October	January	Percent loss
1	17.3 (13.7)	2.2 (1.1)	87.3 (11.9)
2	10.7 (10.6)	1.2 (1.4)	89.2 (8.2)
3	6.0 (4.0)	0.7 (0.4)	88.2 (10.7)

Table 7. Percentage contribution to the estimated daily food requirements (tonnes) of American Wigeon, Northern Pintails and Mallards from tidal flats and uplands between 1 September 1990 and 31 March 1991. Data are shown in Appendix 2 and 3.

	Percentage of food requirements		
	Wigeon	Pintail	Mallard
Tidal flats	42.6	69.9	5.3
Uplands	57.4	30.1	94.7

Table 7 shows the percentage of food obtained (tonnes) by each species in intertidal and upland habitats over the winter (1 September 1990 to 31 March 1991). Only Pintails obtained a larger percentage of their energy from the Bay than uplands.

Discussion.

1. Estimates of duck abundance.

Our calculations of the food requirements of dabbling ducks rely heavily on estimates of the population size of different duck species. Numbers of ducks using the Bay vary between months and years. Past estimates of duck numbers were made by different observers, under different weather and tidal conditions, and from both the ground and the air (Burgess 1970, Leach 1972, and McKelvey et al. 1985). Aerial censuses often grossly underestimate total numbers (Caughley 1974), and ground counts under suboptimal conditions also tend to be underestimates (Vermeer and Levings 1977). We used only ground counts by one person under standardized conditions for calculating duck-use days and population food requirements. More importantly, our estimates are not greatly different from others and would not change our conclusion that Boundary Bay cannot supply enough food to support all dabbling ducks through winter.

2. Effects of ice cover.

During the freezing period from 18 December 1990 to 11 January 1991, ice gradually extended outward from the dike to cover most of Boundary Bay. Ducks normally using the Bay for resting and/or feeding dispersed to the Fraser Delta foreshore, islands in the Strait of Georgia, the northeast coast of Puget Sound between Samish Bay and Port Susan, or areas farther south (unpubl. data). Flooded upland feeding sites were also frozen during this period. Impacts of ice on availability of upland foods was exacerbated by unusually heavy rainfall before the freezing period: precipitation for October through December 1990 was 11.5 cm above normal. High rainfall coupled with below-normal temperatures and at times

heavy snowfall contributed to making most foods in both tidal and upland habitats unavailable for several weeks. These harsh conditions probably resulted in unusual feeding behaviour. For example, the crops of several ducks collected at that time had a mixture of mud and decaying cabbage. This was the only time cabbage was found in collected birds and inaccurately inflated its fraction of the diet (Table 2, Appendix 3).

3. Importance of tidal flats as feeding habitat.

Vermeer and Levings (1977) suggested that dabbling ducks used Boundary Bay only for resting. Our research indicates, however, that American Wigeon, Northern Pintails, and Mallards feed extensively on the tidal flats of Boundary Bay from arrival in early September through late November. Starting in mid-November, these dabbling ducks gradually shifted their feeding activity from the Bay to nearby uplands. Thereafter, uplands provided most of the food for ducks. The Bay continued to provide some food but became more important for resting and loafing site as winter progressed.

Two other possible motivations for this habitat shift were apparent, both related to the onset of winter storms and precipitation. First, with the beginning of heavy winter rains in late November, poorly-drained upland fields become flooded. This seasonal flooding coincides with the first seasonal use of these fields by Wigeon that eat winter cover crops and pasture grasses, Pintails that eat mostly invertebrates, and Mallards that eat both plant and animal foods (Hirst and Easthope 1981, Appendix 3). Second, extensive beds of eelgrass *Zostera* spp. (Fig. 1) are uprooted and removed from the intertidal zone by early-winter storms (Harrison 1979). The leaves of *Z. japonica* provide most food biomass for Wigeon and are an important habitat for bivalves and amphipods eaten by Pintails and Mallards. This major habitat change suggests, contrary to previous belief (Eamer 1985, Hirst and Easthope 1981), that the habitat shift might not be mostly a function of flooding of upland fields but, rather, reflect inferior or inadequate food resources in Boundary Bay beginning in early winter.

The dramatic decrease in *Z. japonica* in late fall may result from several factors: grazing, ice scouring, wave action, and senescence. Harrison (1979,

1982) noted that *Z. japonica* is primarily an annual, establishing each year from an extensive seed bank. Our estimates (Appendix 2) indicate that Wigeon may remove as much as 83% of the standing crop. Wigeon grazed the leaves of *Z. japonica*, whereas Pintails ate both seeds and rhizomes and Mallards ate just the seeds (Table 4).

Regardless of the reason for the biomass loss of *Z. japonica*, its availability was clearly inadequate to support populations of Wigeon through the winter. Our samples in the Bay were insufficient to estimate the relative contribution of the total invertebrate biomass to the population food requirements of Pintails and Mallards. However, the winter decline of invertebrates in the Bay probably contributed to the shift to upland feeding by these species. In addition, strong wind and waves after November at times forced dabbling ducks out of the Bay (unpubl. data). During windy conditions at night, many thousands of ducks used farmland ditches and farmlands adjacent to the dike to escape the wind. During the day, ducks would most likely be forced to find refuge elsewhere under similar weather conditions because of disturbance from humans walking on the dikes and hunting nearby. Ducks equipped with radio-transmitters used Boundary Bay, Roberts Bank and Sturgeon Bank during the day and flew to farmlands at night.

4. Conclusions.

The exotic eelgrass *Zostera japonica*, which has colonized formerly bare tidal flats only since the late 1950's (Harrison and Bigley 1982), has become an important source of plant and invertebrate foods for dabbling ducks in the Fraser River Delta (see also Posey 1988). Boundary Bay is exposed to heavy winter waves which rip up the shallow-rooted *Z. japonica* which is eaten by dabbling ducks and especially Wigeon after early winter. Both tidal and upland habitats are essential to supporting current numbers of dabbling ducks in the Fraser River Delta.

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Appendix 1. Gross energy (GE, kJ/g dry mass) and metabolizable energy coefficients (fraction of GE assimilated, MEC) for duck foods.

Species	GE	MEC	Source[1]
Plant			
Callitriche pallustris	14.655	0.33	Estimate
Corn	18.900	0.80	Karasov(1990)
Echinochloa crusgalli	18.255	0.66	Miller(1984)
Poaceae (leaves)	18.640	0.29	Mayhew(1988)
Polygonum spp.(seeds)			
Mallard	19.302	0.23	Hoffman and Bookhout(1985)
Pintail	19.302	0.27	"
Potatoes	17.300	0.56	Karasov(1990)
Trifolium sp.	14.655	0.33	Bailey(1969),Karasov(1990)
Ulva sp.	20.516	0.33	Sugden(1973),Karasov(1990)
Wild Seeds			
Spergula, Atriplex, Stellaria, Juncus, Rubus, Salicornia	12.400	0.59	Karasov(1990)
Zostera japonica			
Leaves	17.745	0.30	Duynstee(Unpubl. data), Mayhew(1988),Ricklefs(1974)
Seeds	21.000	0.59	Karasov(1990)
Rhizomes	14.952	0.56	McRoy(1970),Karasov(1990)
Zostera marina			
Leaves	17.630	0.30	Mayhew(1988)
Seeds	21.000	0.59	Karasov(1990)
Animal			
Amphipoda	20.300	0.77	Dauvin and Joncourt(1989), Karasov(1990)
Bivalvia			
Mya arenaria	18.297	0.21	Jorde and Owen(1988)
Mytilus edulis	16.748	0.31	Jorde and Owen(1988)
Crepidula sp.	15.070	0.06	Estimate[2]
Gastropoda			
Nassarius mendicus	19.430	0.06	"
Batillaria zonalis	19.430	0.06	"
Bittium attenuatum	19.430	0.06	"
Phytia myosotis	21.785	0.44	Sugden(1973)
Assiminea californica	21.785	0.44	Sugden(1973)
Insecta			
Coleoptera	26.340	0.77	Driver et.al.(1974), Driver(1981),Karasov(1990)
Diptera	22.335	0.77	"
Chironomidae	22.335	0.77	"

[1] If two references: the first is for GE, the second is for MEC.
[2] Estimated for dry mass from similar thick-shelled species (Sugden 1973).

Appendix 2. Estimated range[1] of the population food requirements (tonnes) of Wigeon, Pintails, and Mallards in Boundary Bay from 1 September to 31 March 1991.

	Wigeon		Pintail		Mallard	
Food	Low	High	Low	High	Low	High
Zostera spp.[2]	84.220	140.366	24.931	41.556	1.898	3.163
Atriplex patula	0	0	34.62	57.701	0.595	0.992
Salicornia spp.	0	0	4.365	7.275	0	0
Algae[3]	30.157	50.243	0	0	0	0
Gastropoda[4]	0	0	49.288	82.146	0	0
Amphipoda[5]	0	0	10.738	17.896	0	0
Bivalvia[6]	0	0	3.537	5.895	0	0

[1] >98% *Zostera japonica*.

[2] Based on ± 25% of use-day estimate (Table 3).

[3] Predominantly *Ulva* sp.; also includes 4.1% unidentified algae.

[4] *Bittium* sp., *Nassarius mendicus*, *Phytia myosotis*, *Assiminea californica*, *Crepidula* sp.

[5] Primarily *Eogammarus confervicolus*.

[6] *Mya arenaria*.

Appendix 3. Estimated range[1] of the population food requirements (tonnes) of Wigeon, Pintails, and Mallards in uplands.

	Wigeon		Pintail		Mallard	
Food	Low	High	Low	High	Low	High
Corn[2]	4.112	6.853	0	0	6.306	10.512
Grass & pasture[3]	122.781	204.635	0	0	0.904	1.507
Wild Seeds[4]	0	0	0	0	1.309	2.181
Echinochloa spp.	5.233	8.723	10.692	17.821	4.48	17.469
Juncus sp.	0	0	3.250	5.418	2.262	3.770
Polygonum spp.	21.677	36.129	19.281	32.135	10.104	16.839
Cabbage[5]	0	0	17.621	29.370	9.894	16.488
Potato	0	0	0	0	8.631	14.385
Insecta	0.309	0.516	3.946	10.520	0.736	1.225

[1] Based on ± 25% of use-day estimate (Table 3).

[2] Taken by Wigeon only during severe freezing and snow conditions.

[3] Includes wheat, rye, clover, and Poaceae family.

[4] Includes seeds of *Spergula arvensis*, *Stellaria media*, *Chenopodium glaucum*, *Atriplex patula*, and *Rubus laciniatus*.

[5] Probably overestimated, taken only during severe freezing and snow conditions.

Chapter 4. Populations, distribution and habitat requirements of Western Sandpipers, Dunlins, Black-bellied Plovers and Great Blue Herons.

Robert W. Butler

Introduction

The Fraser River delta, including Boundary Bay, supports the largest known migrant populations of Western Sandpipers (*Calidris mauri*) and the largest winter populations of Dunlins (*C. alpina*), Black-bellied Plovers (*Pluvialis squatarola*) and Great Blue Herons (*Ardea herodias*) in Canada (Butler and Campbell 1987). Dunlins frequent Boundary Bay from about October to May, Western Sandpipers are present in April and May, and July to October (Butler and Campbell 1987). Black-bellied Plovers are present in the Bay around the year (Price 1990) but are most abundant from August to May. Great Blue Herons are year-round residents of Boundary Bay. Up to 92,000 Dunlin, 4300 Black-bellied Plover and 60,000 Western Sandpipers have been counted in Boundary Bay on a single day (Butler and Campbell 1987, Butler and Cannings 1989).

Butler and Campbell (1987) and Butler (1991) indicated that herons and shorebirds foraged and rested on beaches and farmlands near Boundary Bay. Herons frequent grasslands to prey on small mammals (Butler 1991). Shorebirds might settle in sparsely vegetated and ploughed fields where they can see approaching predators or find invertebrate prey.

The purpose of this chapter is to: 1) estimate the size of shorebird and heron populations on beaches and in farmlands and, 2) describe the time of year, locations and types of farmlands and beaches used for feeding and roosting Dunlins, Black-bellied Plovers, Western Sandpipers and Great Blue Herons.

Methods and study area.

1. Fieldwork.

Western Sandpipers, Dunlins and Black-bellied Plovers, which are referred to as shorebirds in this chapter, were studied from 29 June 1990 to 11 May 1991 on the intertidal marshes, and sand- and mudflats in Mud Bay, Boundary Bay, and on south Roberts Bank and on farmland in Delta Municipality and at the lower drainage of the Nicomekl and Serpentine rivers in the Municipality of Surrey (Fig. 1). Information presented here on Great Blue Herons was collected by Butler (1991) in 1987-1990. Detailed methods can be found in his thesis.

2. Population estimates.

Shorebird numbers were estimated from a vehicle driven on a dike along the shore of Boundary Bay, and between the British Columbia Ferry Terminal jetty near Tsawwassen and Brunswick Point. Censuses of shorebirds were made on every second, third or fourth day in the periods: 29 June - 14 September 1990, 22 October 1990 - 30 March 1991, and 22 - 29 April 1991, and on every day from 2-11 May 1991. Counts made during extremely cold weather in January 1991 were eliminated from the population estimates because they were very low. Herons were counted from Brunswick Point to Mud Bay in all months except March, April and August. The maximum numbers counted from 11 aircraft surveys from September to February 1986-88 and in May 1988 and from 2 vehicle surveys on a dike in June and July 1990, were used to estimate the heron population on beaches. All surveys were made on calm days when tides were about 2.5m high.

3. Use of beaches and farmlands.

Beaches and farmlands used by Dunlins and Black-bellied Plovers at high tide were located by following their flights through binoculars from the beaches to farmlands between 22 October 1990 and 6 March 1991. The numbers of each species, whether the field was ploughed or covered by turf grass and pasture, and the percentage of the flock that was feeding and resting was recorded.

Heron roosts were located in farmlands and on beaches by driving dikes and farmfields around Boundary Bay and Mud Bay during high tides through the year (see methods in Butler 1991).

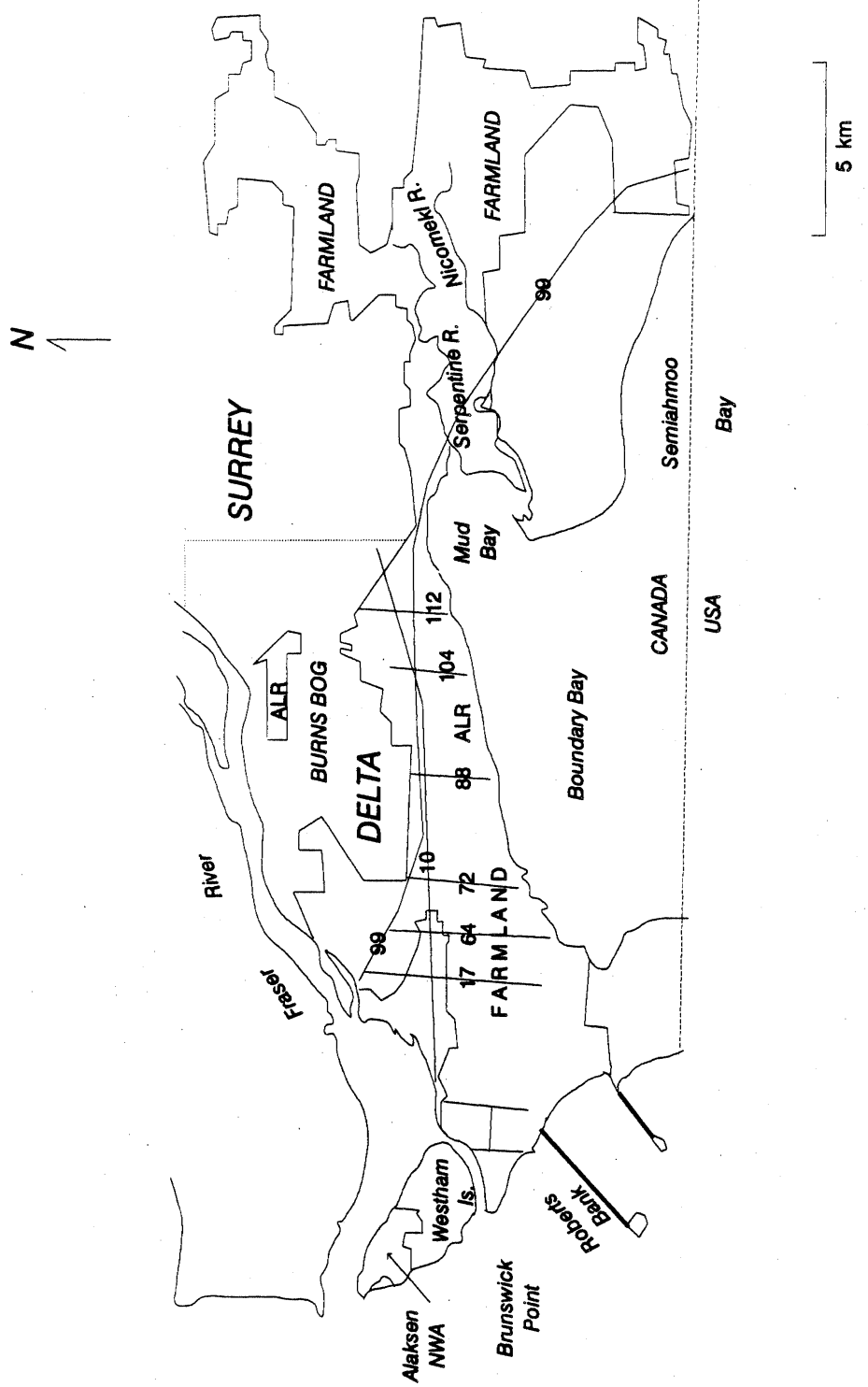

Figure 1. Place names used in the text. Farmlands lie within the Agricultural Land Reserve (ALR).

Results

1. Numbers of wading birds on beaches

About 32,000 Dunlins were counted on average in the winter of 1989-90 and 1990-91. About 40,000 were counted on average during autumn, and 26,000 in spring (Table 1). About 600 Black-bellied Plovers were counted on an average winter day, 1600 in spring migration, 1200 in autumn, and about 300 in summer (Table 1). The largest number of plovers on beaches was seen during their southward migration in July 1990 when 1855 individuals were present.

The number of Western Sandpipers that used Boundary Bay on an average day was about 56,000 birds during the northward migration, and about 15,000 during the southward migration (Table 1). The largest number counted was about 100,000 in the last week of April 1991. The largest number of Great Blue Herons was seen on beaches in May, and the fewest number was counted in December (Table 2).

2. Use of beaches and farmlands.

Western Sandpipers roosted on beaches, in saltmarshes, on dikes and floating debris in Mud Bay, Boundary Bay, between the BC Ferry Terminal and Westport Coal Terminal jetties and on Brunswick Point. When high tides covered the entire beach, flocks flew to fields with Dunlins. About 100,000 sandpipers roosted on Brunswick Point beach and along the western side of the Westport Coal Terminal jetty at Brunswick Point in April 1991.

Table 1. Average number of Dunlins, Black-bellied Plovers and Western Sandpipers at different times of the year in Boundary Bay and Brunswick Point.

Species	Year	Period	Mean	S.E.	N	Range
Dunlin	1989-90	Winter[a]	30422	4529	10	13497-57735
	1990-91	Winter[a]	33688	3481	6	20800-44100
	1991	Spring[b]	26114	3896	7	15295-41000
	1990	Autumn[f]	39633	5012	6	26800-56350
Black-bellied Plover	1989-90	Winter[a]	548	154	10	75-1440
	1990-91	Winter[a]	613	88	6	330-948
	1990&91	Spring[b]	1606	397	6	600-2840
	1990&91	Summer[d]	333	97	28	0-1855
	1990	Autumn[g]	1194	285	9	240-2885
Western Sandpiper	1991	Spring[c]	55740	15659	12	830-18800
	1990	Summer[e]	14801	3639	21	0-55075

Dates are as follows: a = 1 December - 15 February, b = 16 February - 30 April, c = 22 April - 11 May, d = 1 May - 31 August, e = 29 June - 14 September, f = 22 October - 1 December, g = 1 September - 30 November.

Table 2. Maximum number of Great Blue Herons counted from aircraft and from the ground near high tide in Boundary Bay and Brunswick Point.

Year	Month	Census method	Maximum number
1986	January	Air	37
1988	January	Air	43
1986	February	Air	97
1988	February	Air	65
	March-April	no census	
1988	May	Air	434
1990	June	Ground	256
1990	July	Ground	232
1990	August	Ground	71
1986	September	Air	237
1987	September	Air	184
1986	October	Air	168
1987	October	Air	160
1986	November	Air	127
1986	December	Air	41

From the end of October to early May, Dunlins and Black-bellied Plovers roosted on beaches and saltmarshes and in farmland (Fig. 2). Plovers departed for roosts about 30 mins. earlier, and returned to beaches about 30 mins. later than Dunlins.

Western Sandpipers, Dunlins and Black-bellied Plovers settled in farmlands mostly within 2 km of their beach roosts on Brunswick Point and along Boundary Bay (Table 3, Fig. 2). The median size of 28 roosting flocks on beaches (6450 birds, range = 900 to 12,000) was nearly 13 times greater than the median size of 48 farmland flocks (507 birds, range = 8 to 7900). The greatest number of shorebirds counted in farmlands on a single day was 11,600 Dunlins on 9 November 1990, and 7108 plovers on 27 October 1990.

Most shorebirds rested in farmlands from October to December and foraged there between December and March (Table 4). Dunlin and Black-bellied Plover flocks were seen significantly more often on ploughed fields than on turf and pasture fields (Table 5).

Heron roosts in Mud Bay and the Tsawwassen Indian Reserve (Fig. 2) held over 100 herons each, only in August. Most herons roosted alone or in flocks of <20 herons on beaches and in farmlands. A greater proportion of juveniles roosted in farmlands than adults (Table 6). The median distance from the bay of 981 herons found in farmlands between September 1987 and March 1988 was 491m. Juvenile herons were found significantly farther from the beach than adult herons (Median test Chi-square=41.3, $p<0.001$). Great Blue Herons fed in ditches (n=110 herons) and grasslands (n=508 herons) between 25 August 1987 and 31 March 1988.

Table 3. Number of Dunlins and Black-bellied Plovers counted at roosts versus the distance (m) from the nearest beach.

Distance to nearest beach	Dunlin		Black-bellied Plover	
	Number	%	Number	%
0-500	7992	22.7	6692	41.5
501-1000	2490	7.1	1060	6.6
1001-1500	10634	30.2	4515	28.0
1501-2000	9386	26.6	2151	13.3
>2000	4733	13.4	1696	10.5
	35235		16114	

Table 4. Percentage of Dunlin and Black-bellied Plovers feeding versus resting in farmfields.

	Percent feeding			
Date	Dunlin	N	Black-bellied Plover	N
Oct 22-31	6.6	753	0.0	3492
Nov 1-14	41.7	12640	6.1	3420
15-30	43.7	13090	69.9	2160
Dec 1-14	94.3	4031	83.1	1065
Jan 1-14	60.1	17532	78.3	387
15-31	100.0	50	100.0	120
Feb 1-14	100.0	75	0	6
15-28	ND	ND	ND	ND
Mar 1-7	100.0	10	100.0	350

Table 5. Number of flocks of Dunlins and Black-bellied Plovers seen in turf and pastures and ploughed fields.

Field	No. of fields	No. of flocks
Turf and pasture	116	9
Ploughed	97	18

$\chi^2 = 11.9$, $p<0.01$, d.f.= 1

Table 6. Numbers of adults and juvenile Great Blue Herons on beaches and saltmarsh roosts versus farmland roosts.

	Beaches and saltmarshes	Farmlands
Adults	378	415
Juveniles	39	149

$\chi^2 = 44.0$, $p<0.01$

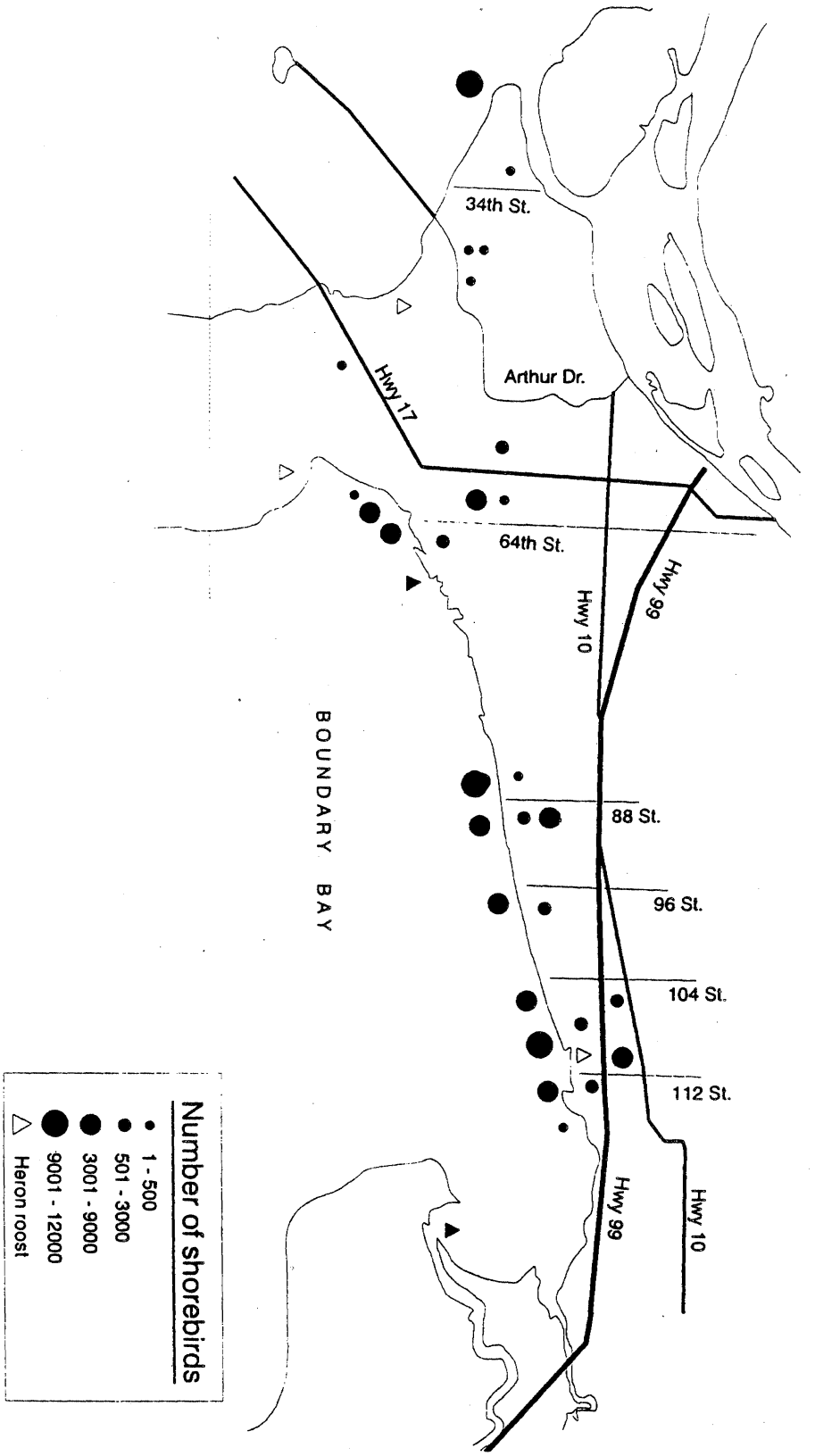

Figure 2. Location of shorebird (solid circles) and Great Blue Heron (solid triangle) roosts in the vicinity of Boundary Bay.

Discussion

1. Population estimates.

The numbers of Western Sandpipers and Great Blue Herons counted in this study fall within the range reported by Butler and Cannings (1989). However, fewer Dunlins and Black-bellied Plovers were counted in my study than by Butler and Cannings (1989). These differences might result from population fluctuations between years (e.g. Have *et al.* 1984, Goss-Custard and Moser 1988) and the abilities of observers to accurately estimate numbers of shorebirds (Rappoldt *et al.* 1985). Annual variation in numbers of Black-bellied Plovers, Dunlins and Western Sandpipers in two estuaries in Puget Sound, Washington was 22.2%, 33.2% and 53.0%, respectively (Buchanan 1988). Errors in estimating flocks of Dunlins have been estimated to be as great as 37% (Rappoldt *et al.* 1985). In my study, observers refined their skills by correcting for bias by comparing their estimates to a known number of shorebirds.

2. Beach roosts.

Shorebirds and herons roosted on beaches throughout the year. Saltmarshes and beaches were used as roost sites at high tide by shorebirds in this and other studies (Goss-Custard *et al.* 1977, Shuford *et al.* 1989). The roosts sites most frequently used by shorebirds from October to May, were near the farmlands where they rested and foraged (Fig. 2). This suggests that Western Sandpipers, Dunlins and Black-bellied Plovers might prefer to roost along stretches of beach nearest the farmlands where they forage.

3. Use of farmlands

Western Sandpipers, Dunlins and Black-bellied Plovers rested and foraged in farmlands within 2 km of the beach from October to May. Great Blue Herons mostly used farmlands from October to March. Butler (1991) showed that juvenile herons flew to grasslands in the Fraser River delta to prey on small mammals from October to March because juveniles could not catch enough food on beaches during these months. Dunlins in Boundary Bay lose weight after December (McEwan and Whitehead 1984) when most began to feed in farmlands (Table 4). This suggests that shorebirds that feed in farmlands around Boundary Bay might be inefficient

foraging juveniles (e.g. Heppleston 1971, Groves 1978, Burger 1980). On the other hand, winter tides are often high during the day when humans and their dogs walk the dykes and shorebirds are at beach roosts. Shorebirds abandoned roost sites in Britain when disturbance from dogs, horseriders and walkers increased on the Dee estuary (Mitchell *et al.* 1988). These types of disturbance, as well as low-flying helicopters, occur in Boundary Bay.

Dunlins leave estuaries for farmlands when heavy precipitation falls in California (Shuford *et al.* 1989). However, my study is the first to show that Dunlins and Black-bellied Plovers forage regularly in farmlands. The stomachs and oesophagii of Dunlins shot at the Vancouver Airport contained earthworms and insects (unpubl. data, CWS files).

The amount of food that a shorebird attains from the beach will be largely determined by the rate that it can catch its prey and the amount of time that tides uncover the beaches. The amount of stored fat on Dunlins in Boundary Bay reaches a peak in December and then declines until March (McEwan and Whitehead 1984). The autumn increase might be an adaptation to poorer foraging success in January and February when most low tides occur at night and invertebrate prey densities are probably low. Farmlands near Boundary Bay might provide alternate foraging habitats for individuals that could not find sufficient food to meet their daily energy needs on the beach.

4. Implications for conservation

Wading birds require beaches in Boundary Bay and on Roberts Bank as feeding and roosting sites throughout the year, and farmlands within 2km of the beach from October to May. Three important farmland areas for Western Sandpipers, Dunlins and Black-bellied Plovers are near Brunswick Point, along 64th Street, and between 88th and 112th Streets near Boundary Bay (Fig. 2).

The long term outlook for Great Blue Herons in Boundary Bay is bleak. Herons require grasslands and ditches for feeding sites in autumn and winter and beaches throughout the year and suitable nesting places in spring and summer. About 350 pairs of herons nest in an alder forest on Point Roberts and about 50 pairs breed in a grove of spruce trees in farmland near the Nicomekl River

(Butler 1989). The forest used by the Point Roberts colony will be reduced to a remanant by an approved golf course and subdivision and inadequate buffering might be provided. The Nicomekl colony has moved several times in the past 20 years and several of the trees have fallen. No obviously suitable alternative sites are left near Boundary Bay.

Acknowledgements

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Chapter 5. Populations, distribution and habitat requirements of birds of prey.

Terrance M. Sullivan

Introduction

The lower Fraser River valley is used by 22 species of birds of prey in fall and winter (Butler and Campbell 1987) and 12 species in summer (Grass and Grass 1978). Northern Harriers (*Circus cyaneus*), Red-tailed Hawks (*Buteo jamaicensis*), Rough-legged Hawks (*Buteo lagopus*), Bald Eagles (*Haliaeetus leucocephalus*), Short-eared Owls (*Asio flammeus*) and Barn Owls (*Tyto alba*) are the most abundant species. The Cooper's Hawk (*Accipiter cooperii*) and Peregrine Falcon (*Falco peregrinus*) are common winter residents in small numbers (Campbell *et al.* 1972). The lower Fraser River Valley has high densities of breeding Red-tailed Hawks (Runyan 1987) and most of the remnant breeding population of Barn Owls in Canada (Campbell and Campbell 1983). Of the remaining summer residents, an additional 8 are known to breed here. Most other species depart for northern breeding grounds or remain in lower numbers than in winter.

The species studied here were the Northern Harrier, Red-tailed Hawk, Rough-legged Hawk, Short-eared Owl and Barn Owl and are referred to as 'birds of prey' throughout this paper. They were chosen because they all prey upon small mammals, principally Townsend's Voles (*Microtus townsendii*). These microtine rodents are found in old-field habitats, which are declining in area (Moore 1990). Barn Owls are listed as vulnerable (COSEWIC 1991) and there is concern that their population levels are declining. The habitats used by falcons and accipiters is described in Chapter 6.

The objectives of this study were to: (1) determine the distribution of birds of prey and their habitats and, (2) estimate the amount of each habitat required to maintain populations of birds of prey near Boundary Bay.

Study area and methods

1. Fieldwork and study area

In 1989-90, the study area included farmland and foreshore habitats bounded by 64th Street, 88th Street, Boundary Bay foreshore and Highway No. 10. In 1990-91, the study area was expanded and divided into 2 sites, *Boundary Bay Airport* and *Boundary Bay West*. In addition, two other sites were added to the study area: *Boundary Bay East* and *Brunswick Point* (Fig. 1). These four study sites were chosen based on the relative amounts of field and foreshore habitats and abundant populations of birds of prey (Campbell *et al.* 1972, Grass and Grass 1978). In the summer of 1991, barns were surveyed for the presence of Barn Owls (Fig. 2).

2. Distribution of habitats

Surveyed fields were identified on the ditches map (Corp. of Delta Map No. 1799) and areas measured on a graphics table. Fields in the four study sites were classified as: cultivated, hay and pasture, overgrown pasture and old-fields. *Cultivated* fields were covered with crops or were recently harvested. *Hay* fields were covered with grasses that were periodically cut to short grass from late spring to early fall. *Pasture* fields were covered with grasses grazed by livestock. *Overgrown pasture* fields held combinations of short grass cropped by grazing animals, tall grasses and shrubs. *Old-fields* were covered in grasses < 50 cm tall and a litter mat >10 cm deep. Some old-fields also had patches of shrubs and forbs. The foreshore habitat was considered to be the marsh between the dike and high water mark.

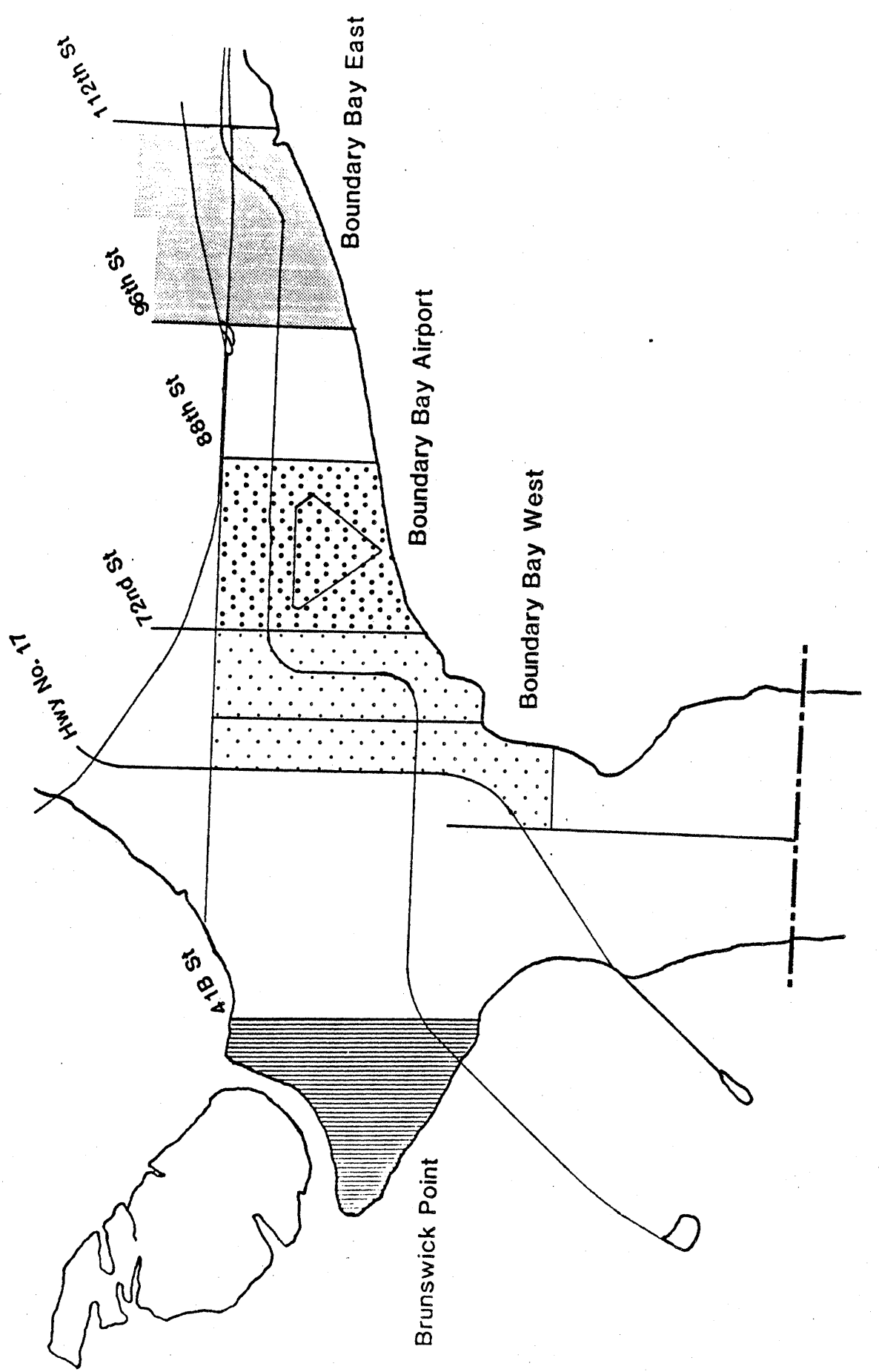

Figure 1. Locations of four sites where birds of prey were studied near Boundary Bay.

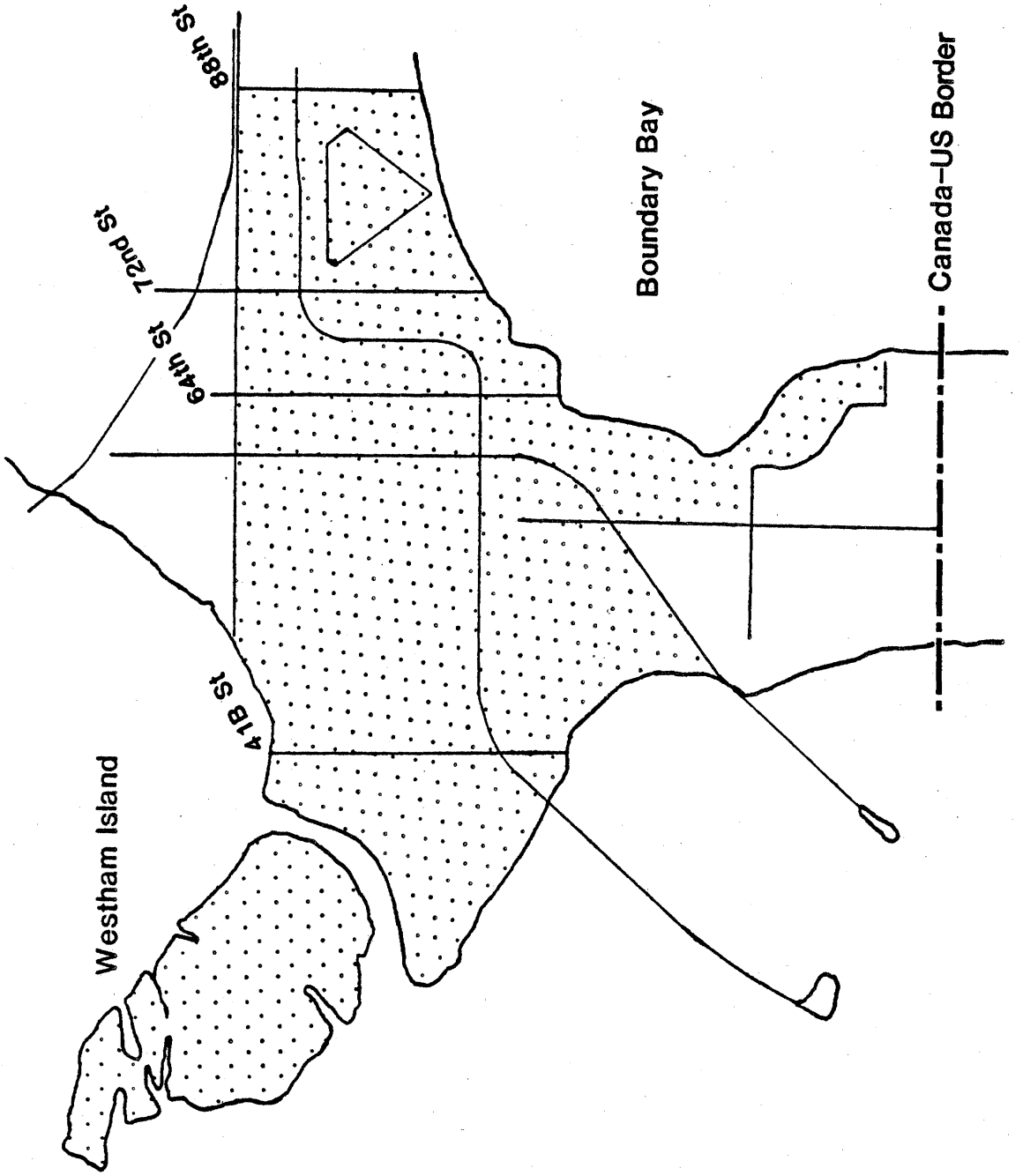

Figure 2. Location of farmland habitat examined for the presence of Barn Owls.

3. Distribution of birds of prey

3.1 Comparison between study sites

Censuses of diurnal birds of prey were made at least once per week from 7 November 1989 to 27 March 1990, 13 June to 29 August 1990, 25 October 1990 to 24 April 1991 and 13 May 1991 to 27 June 1991 between 0800 and 1800h PST. All roads and dikes were driven by vehicle in each survey site with stops of 1-2 mins every 0.5 km. At each stop, the numbers and locations of all birds of prey were marked on a map. Barns west of 88th Street were searched for the presence or signs of Barn Owls. A barn was considered to have been used in the past if regurgitated pellets were found. The number of owls, eggs and owlets was recorded. The size of populations of birds of prey was estimated using the maximum numbers of each species in each study site. The winter density of birds of prey was calculated by dividing the maximum numbers of each species seen by the total area of all habitats in each study site.

3.2 Comparison between habitats

The null hypothesis that foraging Northern Harriers, Red-tailed Hawks and Rough-legged Hawks used habitats in equal proportion to their area was tested for each survey site. Each habitat (5 types of field or marsh; *see 2., above*) in which a bird of prey was sighted was scored 1.0 and those sighted along the boundaries of two habitat types scored 0.5 for each habitat type. Ground perched birds of prey were considered resting and excluded from the analysis. The null hypothesis was rejected if the birds of prey were not evenly distributed between all habitats. In this case, the attraction or avoidance of that habitat was determined using Neu *et al.*'s (1974) method. This method compares 95% confidence intervals for the proportion of birds of prey seen in each habitat to the proportion of each habitat present in each study site. A habitat preference index for each species was calculated by dividing the number of sightings in each habitat by the expected number if all birds of prey were evenly distributed through the habitats. An index value of 1.0 means that the habitat was used in

proportion to its occurrence, a value of <1.0 means the habitat was under-utilized (avoided) and a value of >1.0 indicated that birds of prey utilized that habitat more than expected (attracted).

3.3 Effect of field area and location

A step-wise multiple regression was used to examine the effect of the distance of fields from Boundary Bay and the size of fields on the average number, and density, of birds of prey observed.

3.4 Roosting habitats

Short-eared Owl roosts were located in November and December 1991 by dragging a weighted 20 m rope through tall grass fields and foreshore habitats. Areas surveyed included the foreshore on Brunswick Point, the foreshore west of 88th St. and fields to the north and south of the Boundary Bay Airport. The flight path of Northern Harriers, Red-tailed Hawks and Rough-legged Hawks were recorded twice each week between 1 December and 30 January 1991, 0.5 h before sunset until dark and 0.5 h before dawn until 1 hr after dawn.

3.5 Effect of vole numbers on the numbers of birds of prey

The abundance of Townsend's Vole (*Microtus townsendii*) was determined on 5 trapping grids near the Boundary Bay Airport and 2 grids on Westham Island, detailed methods are provided by Taitt (1990, 1991, 1991a). Briefly, 49 Longworth live-traps placed 5 m apart were pre-baited for a month. Traps were set and checked for two days each week. All voles caught in traps were marked with eartags and released. The density of voles was calculated using Minimum Number Alive and multiplied by a factor of 5 to calculate the density of voles per hectare (Taitt 1990, 1991, 1991a). These estimates were compared to the number of birds of prey found in winter and summer near the Boundary Bay Airport.

Results

Distribution of habitats

Over half of the habitat in the four survey sites was cultivated fields and about one-quarter was hay and pasture fields (Table 1). The remaining area was covered by old-fields (8.1%), marshes (6.2%) and overgrown pasture fields (4.4%)(Table 1). Brunswick Point had the largest amount of cultivated land (691

(691 ha), Boundary Bay East had the largest area of hay and pasture fields (409 ha), Boundary Bay West had the largest area of overgrown pasture fields (96 ha) and Boundary Bay Airport had the largest area of old-fields (270 ha). A *salicornia-Triglochin* community dominates the marsh in Boundary Bay and a *Typha-Carex* marsh dominates on Brunswick Point (Yamanaka 1978).

Distribution of birds of prey

1. Comparison between study sites

Northern Harriers, Red-tailed Hawks and Rough-legged Hawks were seen in all survey sites but they were not equally abundant. Over half of the Northern Harriers and Red-tailed Hawks and about three fifths of the Rough-legged Hawks were found in the Boundary Bay Airport survey area (Table 2). More importantly, the densities of Northern Harriers, Red-tailed Hawks and Rough-legged Hawks were up to 3-fold times greater in the Boundary Bay Airport study site than any other study site (Table 3). Large numbers and high densities of Northern Harriers also occurred in the Boundary Bay West study site (Tables 2 and 3).

Twenty-nine barns were occupied by Barn Owls, 13 held old pellets and 3 held neither owls nor pellets. The highest percentage of occupied barns and the most owls observed were found between Highway No. 17 and 88th St (Table 4). A total of 37 Barn Owls were found in 45 barns surveyed.

2. Comparison between habitats

Northern Harriers, Red-tailed Hawks and Rough-legged Hawks were not evenly distributed between marsh and four field habitats (Appendix 1). The habitat selection of these 3 species varied depending on the relative amounts of old-field habitat present. The Boundary Bay Airport survey area had the largest area of old-field as well as the best representation of all five habitat types (Table 1). The three other survey areas had little of no old-field habitat present. Regardless of the amount of old-field habitat, Northern Harriers, Red-tailed Hawks and Rough-legged Hawks significantly avoided cultivated fields (Table 5), the predominant field type in all survey areas (Table 1).

Within the Boundary Bay survey area, Northern Harriers, Red-tailed Hawks and Rough-legged Hawks were all significantly attracted to old-field habitats (Table 5). All other habitats were significantly avoided except for 1 habitat for each species. Northern Harriers used the foreshore habitat in proportion to its occurrence while Red-tailed Hawks and Rough-legged Hawks used overgrown pastures in higher proportion than expected.

In contrast, habitat selection of birds of prey differed where there was little or no old-field. There was a higher use of hay/pasture, overgrown pasture and foreshore habitats than in areas with abundant old-field (Table 5).

Table 1. Percent and area (ha) of habitat types in four sites surveyed for birds of prey.

Survey site	Cultivated % (Area)	Hay/pasture % (Area)	Overgrown Pasture % (Area)	Old-field % (Area)	Marsh % Area
Boundary Bay Airport	31.5 (292)	23.9 (221)	7.0 (65)	29.1 (270)	8.6 (80)
Boundary Bay West	59.0 (686)	22.7 (264)	8.2 (96)	3.0 (35)	7.1 (83)
Boundary Bay East	55.5 (518)	43.8 (409)	0 (0)	0.5 (5)	0.2 (2)
Brunswick Point	84.8 (691)	4.8 (39)	1.2 (10)	0.3 (3)	9.0 (73)
Average	56.0 (2187)	24.3 (932)	4.4 (170)	8.1 (312)	6.2 (237)

Table 2. Maximum numbers (percentage) of birds of prey in survey sites in winter 1991.

Survey Sites	Northern Harrier	Red-tailed Hawk	Rough-legged Hawk
Boundary Bay Airport	37 (52.9%)	24 (53.3%)	21 (61.8%)
Boundary Bay West	17 (24.3%)	7 (15.6%)	8 (23.5%)
Boundary Bay East	8 (11.4%)	10 (22.2%)	4 (11.8%)
Brunswick Point	8 (11.4%)	4 (8.9%)	1 (2.9%)
Total	70	45	34

Table 3. Mean number of birds of prey per hectare in all fields in four survey sites in 1990/91

Survey site	Northern Harriers	Red-tailed Hawks	Rough-legged Hawks	Total
Boundary Bay Airport	2.0	1.5	1.1	4.6
Boundary Bay West	1.2	0.5	0.5	2.1
Boundary Bay East	0.6	0.5	0.2	1.3
Brunswick Point	0.7	0.3	0.04	1.1

Table 4. Common Barn-Owl use of barns 1991.

Survey location	Number of barns visited	Number of barns with pellets	Number of barns with owls	Number of owls
Westham Island	9	1	8	10
Brunswick Point	9	2	7	7
41B St to Hwy # 17	16	9	5	6
Hwy # 17 to 88th St	11	1	9	14
Total	45	13	29	37

Table 5. Habitat selection index of three birds of prey in five habitats

	Cultivated fields	Hay/Pasture fields	Overgrown pasture	Old fields	Foreshore
Northern Harrier					
Boundary Bay Airport	**0.73***	**0.50***	**0.40***	**1.81****	0.93
Boundary Bay West	**0.57***	0.89	1.91	-	**3.07****
Boundary Bay East	0.81	0.76	-	-	**1.14****
Brunswick Point	**0.34***	-	-	-	**7.44****
Red-tailed Hawk					
Boundary Bay Airport	**0.64***	**0.67***	1.23	**1.73****	**0.45***
Boundary Bay West	**0.62***	**2.00****	1.83	-	2.09
Boundary Bay East	0.77	1.11	-	-	42.5
Brunswick Point	0.75	-	-	-	2.08
Rough-legged Hawk					
Boundary Bay Airport	**0.72***	**0.40***	1.23	**2.12****	**0.19***
Boundary Bay West	**0.45***	1.16	**3.20****	-	2.09
Boundary Bay East	1.00	0.99	-	-	-
Brunswick Point	-	-	-	-	-

* indicates that significantly ($p<0.05$) fewer individuals were seen in the habitat than expected by chance, ** indicates that more significantly ($p<0.05$) more individuals were seen in the habitat than expected by chance and, - indicates that too few individuals or too little habitat were available for analysis.

3. Effect of field size and location

The number and density of Northern Harriers increased significantly with the proximity of fields to foreshore habitats (Table 6). Neither Red-tailed Hawk nor Rough-legged Hawk numbers or density were affected by the proximity to foreshore habitats. The numbers, but not the density, of these three species increased in proportion as the area of the field increased (Table 6).

4. Roosting habitats

A total of 57 Short-eared Owls were found in 5 communal ground roosts in the foreshore habitats and one in a grove of plum trees in an old-field in the Boundary Bay Airport study site. Northern Harriers flew east pat 80th St. prior to dusk and returned at sunrise but no roost was found. Red-tailed Hawks and Rough-legged Hawks roosted in coniferous trees in Burns Bog and on the Surrey Bluffs.

5. Effect of vole densities on abundance of birds of prey

The numbers of Northern Harriers, Red-tailed Hawks, Rough-legged Hawks and Short-eared Owls tracked the abundance of Townsend's Voles near the Boundary Bay Airport. The numbers of voles and birds of prey was lower in the first winter than in the second winter (Fig.3). Similar fluctuations in the numbers of birds of prey have been recorded over many years (Fig.4).

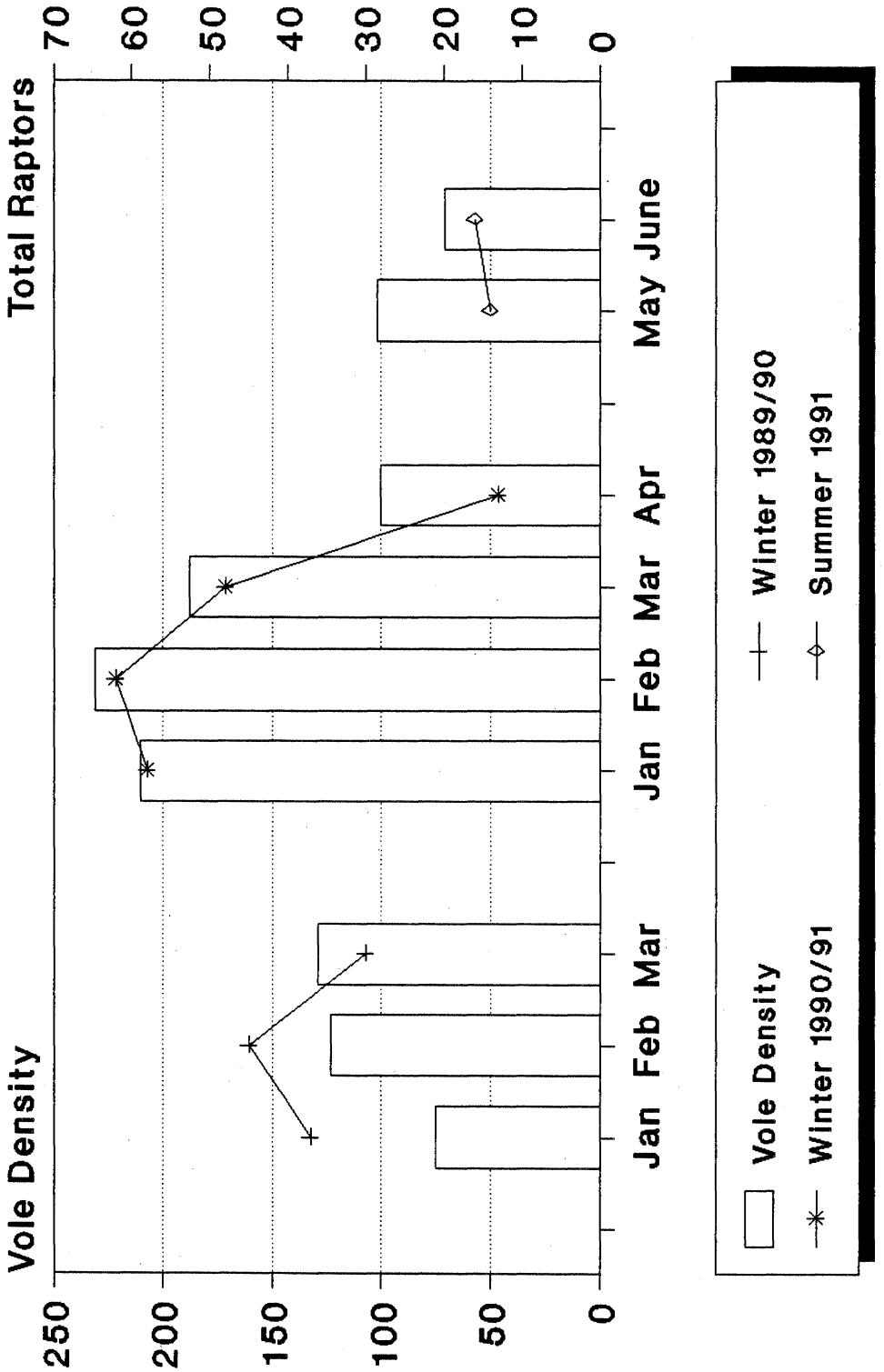

Figure 3. Density of Townsend's Voles and the number of raptorial birds in the vicinity of Boundary Bay.

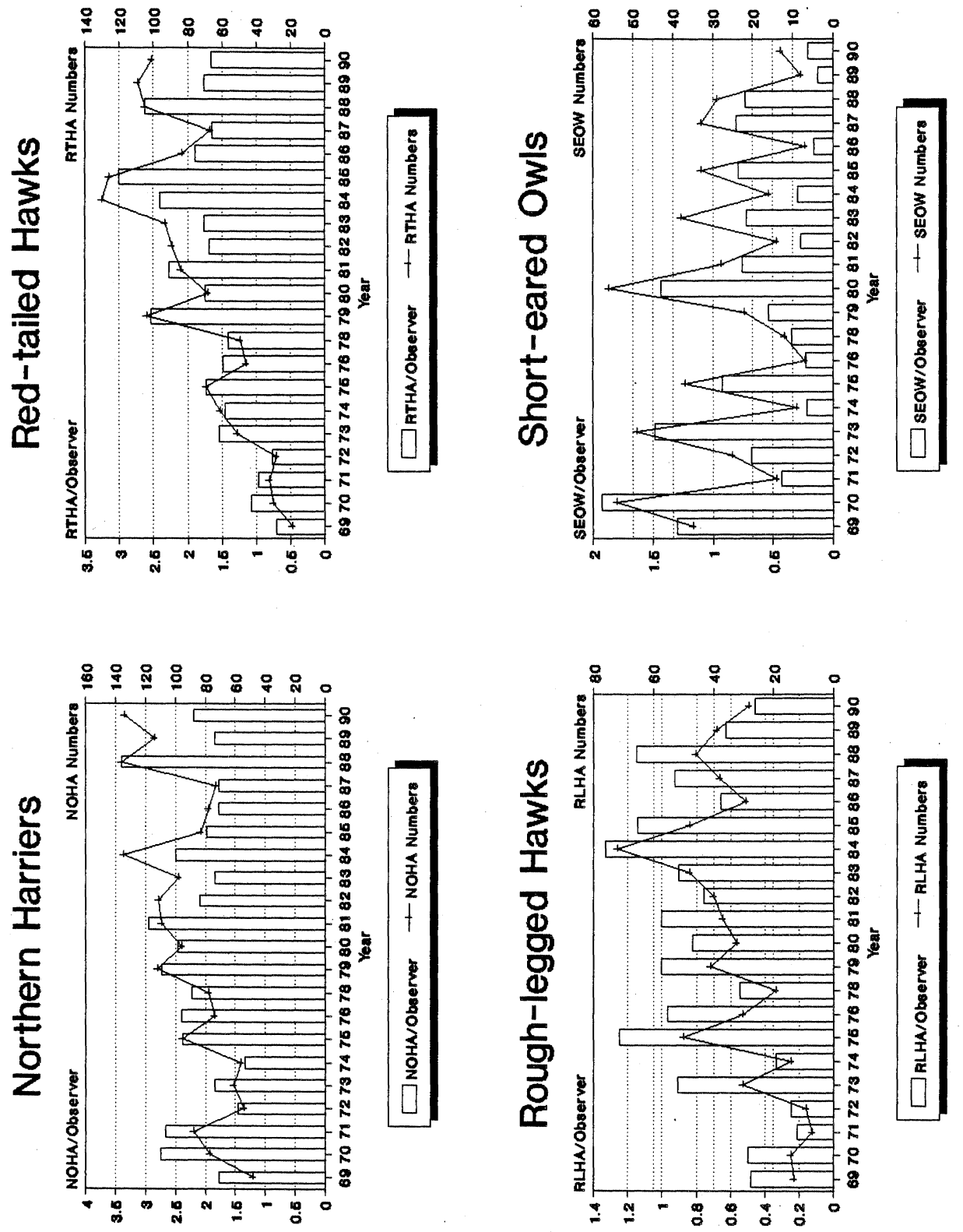

Figure 4. Number of four species of birds of prey seen per observer on Ladner Christmas Bird Counts from 1969 to 1990.

Table 6. Regression equations of numbers and density of birds of prey and area (ha) and distance (km) of fields from beaches.

Numbers (y)	Area of field (x)	p value	Distance to beach (x)	p value
Northern Harriers	y= 0.028x + 0.254	<0.001	y=-0.75x + 0.254	0.03
Red-tailed Hawks	y= 0.035x - 0.129	<0.001	ns	>0.05
Rough-legged Hawks	y= 0.016x - 0.002	0.007	ns	>0.05
Density				
Northern Harriers	ns	>0.05	y=-0.008x + 0.062	<0.05
Red-tailed Hawks	ns	>0.05	ns	>0.05
Rough-legged Hawks	ns	>0.05	ns	>0.05

ns indicates a non-significant (>0.05) relationship between variables y and x

Discussion

General conclusions

There were three main conclusions from this study. First, the largest numbers and densities of Northern Harriers, Rough-legged Hawks and Red-tailed Hawks (Table 2 and 3) were found in the Boundary Bay Airport survey site where the largest area of old-field habitat occurred (Table 1). The second highest number and density of birds of prey were found in Boundary Bay West survey site where the largest area of overgrown pasture was found (Table 1). Campbell et al. (1972) found birds of prey were abundant in the vicinity of Boundary Bay and J. Stroman (unpubl. ms.) found the greatest abundance near the Boundary Bay Airport.

The second conclusion was that the habitat selection of birds of prey was affected by the relative amounts of old-field habitat. Where present in relatively large amounts, birds of prey were found in the highest numbers and density (Tables 2 and 3) and chose old-field habitats over all others (Table 5). Where there was little or no old-field habitats, hay/pasture, overgrown pasture and foreshore habitats were used in higher proportion. However, there was also a marked decline in the number and density of birds of prey in these sites. Regardless of the amount of old-field present, Northern Harriers, Red-tailed Hawks and Rough-legged Hawks significantly avoided cultivated fields (Table 5). These findings indicate that the best habitats for Northern Harriers, Rough-legged Hawks and Red-tailed Hawks are old-field and overgrown pasture habitats.

The third conclusion was that the densities of Northern Harriers were significantly greater on fields near Boundary Bay than farther away (Table 6) whereas Red-tailed and Rough-legged Hawks were distributed throughout. The Northern Harrier is a hawk of marshes and grasslands (Hamerstrom 1986) whereas the Rough-legged Hawk and Red-tailed Hawk are open country species (Beebe 1974).

Barn Owl distribution

Barn Owls are using or have used all but 3 barns throughout the study area. However, thirteen of these barns, which had previous use, were unoccupied. Barn Owls are cavity nesters (Marti 1991), are year round residents in the Lower Fraser Valley and can breed in any month of the year (Campbell and Campbell 1983). However, vacant nesting sites are uncommon in cavity nesting birds, which suggests that foraging habitat may be limiting the population of Barn Owls.

Effect of small mammal populations

Grasslands around Boundary Bay support abundant small mammal populations, specifically Townsend's Voles (Krebs 1979, Taitt and Krebs 1983). During this study, old-field habitats had the highest densities of Townsend's Voles compared to other grasslands (Sullivan unpubl. data). Small mammals are the principal prey of Northern Harriers (Hamerstrom 1986, Bildstein 1987), Rough-legged Hawks (Craighead and Craighead 1956), Short-eared Owls (Clark 1975, , Sullivan, unpubl. data) and Barn Owls (Campbell *et al*. 1987). Red-tailed Hawks are more generalist in their diet but also prey on small mammals (Beebe 1974). Therefore, the distribution of birds of prey, in this study, is supported by other studies which showed that high densities of birds of prey occurred where there was high densities of prey (Craighead and Craighead 1956; Village 1982, 1987; Baker and Brooks 1981; Korpimaki and Norrdahl 1991; Preston 1990).

Habitat requirements of non-breeders

This study showed that Northern Harriers, Rough-legged Hawks and Red-tailed Hawks were most often found in either old-fields, overgrown pasture or marshes (Table 5). There is a linear relationship between the area of field and the number of birds of prey utilizing them. Therefore, these results indicate that any loss of old-field, overgrown pasture and marsh habitats will result in a decline in the population levels of birds of prey. In addition, a loss of barns would likely result in a decline in Barn Owl populations. There are about 330 ha of old-field and 275 ha of overgrown pasture habitats between 112th Street and Brunswick Point. Approximately 40 ha of old-field is managed co-operatively for birds of prey near the Boundary Bay Airport. There are four barns on the Alaksen

National Wildlife Area. In addition, Great Blue Herons (*Ardea herodias*) use old-field habitats (Chapter 4) and marsh habitats throughout the study area (Butler and Campbell 1987). About 100 Bald Eagles were seen on the beaches in Boundary Bay in February. These beaches were also used each year by Peregrine Flacons, Gyrfalcons (*Falco rusticolus*) and Merlins (*Falco columbarius*).

Habitat requirements of breeders

Birds of prey that breed near Boundary Bay include the Red-tailed Hawk and Bald Eagle, Northern Harrier, Short-eared Owl and Barn Owl. The nest-site requirements of the Red-tailed Hawk and Bald Eagle can be met by maintaining large cottonwoods (*Populus trichocarpa*). Old-field and marsh habitats used by winter populations of birds of prey will also provide nesting habitat for Northern Harriers and Short-eared Owls. Barn Owls need access to barns or nest-boxes in secluded woodlots near areas of suitable foraging habitat.

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Appendix 1. Summary of chi-square values between the observed and expected densities of three birds of prey and the area of habitats in four study sites.

Study site	Species[1]	Chi-square	df	Significant[2]
Airport				
	NOHA	260.1	4	Yes
	RTHA	98.0	4	Yes
	RLHA	142.0	4	Yes
Brunswick Point	NOHA	172.2	2	Yes
	RTHA	8.9	2	No
Boundary Bay				
West	NOHA	53.5	3	Yes
	RTHA	12.3	2	Yes
	RLHA	30.7	3	Yes
East	NOHA	896.6	2	Yes
	RTHA	143.2	2	Yes
	RLHA	<0.1	1	No

1- Species abbreviations are as follows: NOHA is Northern Harrier, RTHA is Red-tailed Hawk and RLHA is Rough-legged Hawk.

2- The probability of a significant relationship occurring by chance is <0.05.

Chapter 6. Comparison between breeding season and non-breeding season bird species in farmland hedgerows near Boundary Bay

Robert W. Butler

Introduction

Slightly more than half of Delta Municipality is agricultural land (Butler and Campbell 1987), and many of the farm fields are bordered by hedgerows. Very little is known about the hedgerow bird community or its threats near Boundary Bay. Weber (unpubl. data) determined the species composition and abundance of spring migrant and breeding birds in mostly treed hedgerows on the Alaksen National Wildlife Area about 10 km west of Boundary Bay. Different species assemblages might use the mostly shrub-hedgerows near Boundary Bay than the mostly treed hedgerows on Alaksen (O'Connor and Shrubb 1986).

The purpose of this study is to describe the frequency and abundance of species in shrub-hedgerows and treed-hedgerows, compare the breeding bird communities in hedgerows near Boundary Bay and on the Alaksen National Wildlife Area, and discuss the importance of hedgerow to birds in the Boundary Bay ecosystem.

Study area and methods

Birds were censused in shrub hedgerows with few trees and with many trees. I refer to these respective hedgerows as shrub- and tree-hedgerows.

Shrub-hedgerows were about 3-5m wide and contained mostly blackberry (*Rubus* spp.) and rose (*Rosa* sp.). Tree-hedgerows paralleled mostly cultivated fields and a road. Tree-hedgerows were 1-5m wide, and contained hawthorn (*Crataegus* sp.), crabapple (*Malus* spp.), cottonwood and poplars (*Populus* spp.), rose (*Rosa* sp.), blackberry (*Rubus* spp.) and waxberry (*Symphoricarpus alba*).

Bird abundance was estimated using the Variable Circular-plot method (Reynolds *et al.* 1980). Stations were established every 75 m along the hedgerows. All birds detected during a 12 min. stop at each station were recorded. Eight stations along large-hedgerows were censused 20 times (about once each week) from 31 October 1990 to 31 March 1991, and on 27, 29, 30 June, and 1 and 2 July 1991. Four stations were censused 15 times from 27 October 1990 to 30 March 1991 and on 30 June, 1 and 2 July 1991.

Locations of all Cooper's Hawks (*Accipiter cooperii*), Sharp-shinned Hawks (*A. striatus*), Merlins (*Falco columbarius*) and Northern Shrikes (*Lanius excubitor*) were mapped during censuses, while travelling between transects and along beaches during high tides when raptors mostly hunt shorebirds (Bijlsma 1990) once each week.

Data are presented for the breeding season (June and July) and non-breeding season (October to March).

RESULTS

About 43% and 35% more species used shrub- and tree-hedgerows, respectively, in the non-breeding season than in the breeding season (Table 1). However, the average number of birds seen at census points was more than twice as great in shrub-hedgerows and about 23% higher in tree-hedgerows in the breeding season compared to the non-breeding season (Table 1).

Table 1. Number of species recorded and average number of birds detected per census point in shrub- and tree-hedgerows during the breeding and non-breeding season.

	Breeding		Non-breeding	
	Shrub-hedgerow	Tree-hedgerow	Shrub-hedgerow	Tree-hedgerow
No. of species	17	26	30	40
No. of birds per census point	16.0	23.3	7.9	18.0

Summer community

The tree-hedgerows held all but one species found in shrub-hedgerows (Tables 1 and 2). Six of the 26 species seen in tree-hedgerows but not seen in shrub-hedgerows, were the Black-capped Chickadee (*Parus atricapillus*), Rufous Hummingbird (*Selasphorus rufus*), Bald Eagle (*Haliaeetus leucocephalus*), House Sparrow (*Passer domesticus*), Cliff Swallow (*Hirundo pyrrhonota*) and Rock Dove (*Columba livia*). A single Northern Rough-winged Swallow (*Stelgidopteryx serripennis*) was the only species found exclusively in shrub-hedgerows. Six species common to both types of hedgerow were the Song Sparrow (*Melospiza melodia*), Rufous-sided Towhee (*Pipilio erythrophthalmus*), Common Bushtit (*Psaltriparus minimus*), Red-winged Blackbird (*Aeglius phoenicus*), House Finch (*Carpodacus mexicanus*) and Bewick's Wren (*Thyromanes bewickii*).

The European Starling (*Sturnus vulgaris*) was the most abundant species in shrub- and tree-hedgerows (Tables 2 and 3). The Song Sparrow and House Sparrow were the second most abundant species in shrub-hedgerows and tree-hedgerows, respectively (Tables 2 and 3).

The most frequently seen species were usually the most abundant (Tables 2 and 3). Exceptions were flocking species that were abundant but infrequently seen, such as the European Starling and House Sparrow in shrub- and tree-hedgerows and Brewer's Blackbirds (*Euphagus cyanocephalus*) in shrub-hedgerows.

Species seen in hedgerows mostly in summer included the Rufous Hummingbird, Common Yellowthroat (*Geothypis trichas*), Savannah Sparrow (*Passerculus sandwichensis*), Barn Swallow (*Hirundo rustica*), Cliff Swallow, and Cedar Waxwing (*Bombycilla cedorum*).

Table 2. Relative frequency and abundance of birds detected in shrub-hedgerows during the breeding season.

Species	Relative frequency: Number detected	Relative frequency: Percent	Relative abundance: Number detected	Relative abundance: Percent
European Starling	5	83.3	29	30.2
Song Sparrow	5	83.3	10	10.4
Common Yellowthroat	5	83.3	9	9.4
American Robin	5	83.3	7	7.3
Barn Swallow	4	66.6	6	6.3
Brown-headed Cowbird	3	50.0	5	5.2
Savannah Sparrow	3	50.0	5	5.2
Brewer's Blackbird	2	33.3	6	6.3
Common Bushtit	2	33.3	4	4.2
Red-winged Blackbird	2	33.3	4	4.2
Northwestern Crow	2	33.3	3	3.1
Bewick's Wren	1	16.7	1	1.0
Marsh Wren	1	16.7	1	1.0
Mallard	1	16.7	2	2.1
Rufous-sided Towhee	1	16.7	2	2.1
House Finch	1	16.7	1	1.0
Rough-winged Swallow	1	16.7	1	1.0
Total	44		96	

Table 3. Frequency and abundance of birds detected in tree-hedgerows during the breeding season.

Species	Relative frequency		Relative abundance	
	Number detected	Percent	Number detected	Percent
Northwestern Crow	31	75.6	66	66.9
American Robin	30	73.2	43	4.5
Starling	29	70.7	255	26.7
Barn Swallow	29	70.7	86	9.0
Savannah Sparrow	28	68.3	71	7.4
Common Yellowthroat	23	56.1	43	4.5
Brewer's Blackbird	19	46.3	53	5.5
Ring-necked Pheasant	17	41.5	21	2.2
American Goldfinch	17	41.5	23	2.4
Brown-headed Cowbird	14	34.2	21	2.2
Song Sparrow	12	29.3	29	3.0
House Sparrow	12	29.3	101	10.6
Red-winged Blackbird	12	29.3	19	2.0
Black-capped Chickadee	11	26.8	18	1.9
House Finch	8	19.5	19	2.0
Cliff Swallow	7	17.1	18	1.9
Common Bushtit	5	12.2	13	1.4
Mallard	5	12.2	6	0.6
Rufous-sided Towhee	1	2.4	1	0.1
Bald Eagle	4	9.8	5	0.5
Rock Dove	3	7.3	24	2.5
Rufous Hummingbird	3	7.3	3	0.3
Marsh Wren	2	4.9	2	0.2
Cedar Waxwing	2	4.9	2	0.2
Bewick's Wren	1	2.4	1	0.1
Northern Harrier	1	2.4	1	0.1
Total			956	

Non-breeding season community

Thirty species were recorded in shrub-hedgerows and 40 in tree- hedgerows (Table 1). The Cedar Waxwing and Bohemian Waxwing (*Bombycilla garrulus*) were found only in shrub-hedgerows (Table 4). Species found only in tree-hedgerows were: American Goldfinch (*Carduelis tristis*), Golden-crowned Sparrow (*Zonotrichia atricapilla*), Winter Wren (*Troglodytes troglodytes*), Rough-legged Hawk (*Buteo lagopus*), Brown-headed Cowbird (*Molothrus ater*) , Rock Dove (*Columba livia*), Sharp-shinned Hawk, Northern Shrike, Norther Flicker (*Colaptes auratus*), Mourning Dove (*Zenaida macroura*), Long-eared Owl (*Asio otus*), and American Kestrel (*Falco sparverius*).

Twenty-eight out of 45 (62.2%) species were common to both types of hedgerows. The Song Sparrow, American Robin (*Turdus migratorius*) and White-crowned Sparrow (*Zonotrichia leucophrys*) were among the 4 most abundant and frequently seen species (>25% of all census points) in tree- and shrub-hedgerows (Tables 4 and 5). The European Starling was the most abundant species in tree-hedgerows (Table 5). Tall trees in tree-hedgerows attracted species that fed in adjacent habitats. Several species that forage mostly in open country were only seen in tree-hedgerows. They include the Northwestern Crow (*Corvus caurinus*), Rough-legged Hawk, Rock Dove, Bald Eagle, Northern Shrike and American Kestrel. Several forest species were attracted to tree-hedgerows including the Sharp-shinned Hawk, and Long-eared Owl. The Northern Shrike was seen mostly along hedgerows (70.0%), and less often over farm fields (25.0%) and beaches (5.0%; n=42 sightings). Cooper's Hawks were seen mostly along hedgerows (59.4%), followed by farm fields (37.5%), and once on beaches (3.1%; n=32 sightings). Comparative figures for 9 sightings of Sharp-shinned Hawks were 55.6% along hedgerows, 22.2% over farm fields and 22.2% over beaches. The Merlin (*Falco sparverius*) was seen 19 times of which 21.0% were in hedgerows, 36.8% were on farmland and 42.1% were on beaches.

Hedgerows provided habitats for several species only during the non-breeding season including the Golden-crowned Kinglet (*Regulus satrapa*), Ruby-crowned Kinglet (*R. calendula*), Fox Sparrow (*Passerella iliaca*), Dark-eyed Junco

(*Junco hyemalis oreganus*), Downy Woodpecker (*Picoides pubescens*), Bohemian Waxwing, Golden-crowned Sparrow, Rough-legged Hawk and Northern Shrike. These species mostly breed away from Boundary Bay (Butler and Campbell 1987).

Discussion

1. Comparison with other studies

The species composition of breeding birds between Weber's (unpubl) study on the Alaksen National Wildlife Area and mine reflects the more forested hedgerows on Alaksen. The Pacific Slope Flycatcher (*Empidonax difficilis*), Warbling Vireo (*Vireo gilvus*), Northern Oriole (*Icterus galbula*), Tree Swallow (*Tachycineta bicolor*) and Black-headed Grosbeak (*Phoeneticus melanocephalus*) present at Alaksen were absent from my study. Hedgerows with trees attracted more forest species than hedgerows without trees in Britain (O'Connor and Shrubb 1986).

The American Robin, European Starling and Song Sparrow were the most abundant breeding species in Weber's study and mine. They are probably attracted to hedgerows for nest sites and plentiful food in nearby farmlands (robin and starling) and in hedgerows (sparrow).

Table 4. Relative frequency and abundance of birds detected in shrub-hedgerows during the non-breeding season.

Species	Relative frequency		Relative abundance	
	Number detected	Percent	Number detected	Percent
Song Sparrow	131	67.5	241	15.8
White-crowned Sparrow	82	42.3	265	17.3
American Robin	55	28.4	292	19.1
Fox Sparrow	29	15.0	31	2.0
Rufous-sided Towhee	27	13.9	31	2.0
Golden-crowned Kinglet	20	10.3	40	2.6
House Finch	16	8.3	38	2.5
Red-winged Blackbird	10	5.2	42	2.8
Brewer's Blackbird	9	4.6	213	13.9
Bewick's Wren	8	4.1	9	0.6
Black-capped Chickadee	8	4.1	11	0.7
Ruby-crowned Kinglet	6	3.1	11	0.7
European Starling	5	2.6	219	14.3
Northern Harrier	4	2.1	5	0.3
Red-tailed Hawk	4	2.1	5	0.3
Ring-necked Pheasant	3	1.6	4	0.3
Purple Finch	3	1.6	3	0.2
Dark-eyed Junco	3	1.6	14	0.9
Western Meadowlark	3	1.6	27	1.8
Bald Eagle	2	1.0	2	0.1
Common Bushtit	2	1.0	11	0.7
Yellow-rumped Warbler	2	1.0	3	0.2
Downy Woodpecker	2	1.0	2	0.1
Common Barn-Owl	1	0.5	1	<0.1
Lincoln's Sparrow	1	0.5	1	<0.1
Cedar Waxwing	1	0.5	3	0.2
Merlin	1	0.5	1	<0.1
Cooper's Hawk	1	0.5	1	<0.1
Northwestern Crow	1	0.5	2	0.1
Bohemian Waxwing	1	0.5	2	0.1
Total			1530	

Table 5. Relative frequency and abundance of birds detected in tree-hedgerows during the non-breeding season.

Species	Relative frequency		Relative adundance	
	Number detected	Percent	Number detected	Percent
Song Sparrow	133	70.7	354	10.5
American Robin	64	34.0	420	12.4
White-crowned Sparrow	53	28.2	372	11.0
European Starling	48	25.5	1194	35.3
Rufous-sided Towhee	40	21.3	56	1.7
Dark-eyed Junco	32	17.0	224	6.6
House Finch	29	15.4	144	4.3
Northwestern Crow	26	13.8	48	1.4
Black-capped Chickadee	22	11.7	41	1.2
Golden-crowned Kinglet	22	11.7	68	2.0
Common Bushtit	15	8.0	61	1.8
Golden-crowned Sparrow	12	6.4	27	0.8
Red-winged Blackbird	11	5.9	24	0.7
Bald Eagle	10	5.3	16	4.7
Fox Sparrow	9	4.8	14	0.4
Brewer's Blackbird	9	4.8	190	5.6
Red-tailed Hawk	8	4.3	8	0.2
Long-eared Owl	6	3.2	10	0.3
Northern Shrike	5	2.7	5	0.2
Northern Harrier	5	2.7	5	0.1
Red-necked Pheasant	5	2.7	16	4.7
Northern Flicker	5	2.7	5	1.4
Bewick's Wren	4	2.1	4	<0.1
American Goldfinch	3	1.6	31	0.9
Western Meadowlark	3	1.6	9	0.3

Cooper's Hawk	2	1.1	2	<0.1
Ruby-crowned Kinglet	2	1.1	3	<0.1
Winter Wren	2	1.1	2	<0.1
Yellow-rumped Warbler	2	1.1	2	<0.1
Sharp-shinned Hawk	2	1.1	2	<0.1
Merlin	2	1.1	2	<0.1
Rough-legged Hawk	2	1.1	2	<0.1
Common Barn Owl	3	1.6	4	<0.1
Lincoln's Sparrow	1	0.5	1	<0.1
Brown-headed Cowbird	1	0.5	2	<0.1
Rock Dove	1	0.5	6	1.8
Purple Finch	1	0.5	1	<0.1
Downy Woodpecker	1	0.5	1	<0.1
Mourning Dove	1	0.5	1	<0.1
American Kestrel	1	0.5	1	<0.1
Total				3378

Species richness of breeding season birds in my study is similar to studies of hedgerow birds in Britain (24-35 species; Williamson 1967).

2. Comparison between seasons

My study is the first that compared hedgerow use by birds in the Fraser River delta in summer and winter. There were more species in winter than in summer (Table 1). The species with the greatest relative abundance in summer were the European Starling, House Sparrow and Song Sparrow. The European Starling, Song Sparrow, American Robin, White-crowned Sparrow and Brewer's Blackbird were more abundant in the non-breeding season.

Songbirds in winter are probably attracted to hedgerows near Boundary Bay because of the mild climate, abundant food supplies and shelter provided in and near hedgerows. Winter temperatures around Boundary Bay seldom fall below freezing for long spells. Berries linger on hawthorn, crabapple and blackberry into winter and discarded crops and soil invertebrates are eaten by birds through winter in nearby farmlands. Dense shrubs provide roost sites against inclement weather. The large numbers of songbirds in hedgerows attract predators such as the Cooper's Hawk, Sharp-shinned Hawk and Merlin.

3. Comparison between habitats

Species richness and bird densities are greatest in hedges with trees and the diversity of shrub species is high (O'Connor and Shrubb 1986, Mills *et al.* 1991). My study supports these findings: tree-hedgerows held more species of birds in winter and summer than shrub-hedgerows (Table 1).

Northern Shrikes, Cooper's Hawks and Sharp-shinned Hawks were mostly seen along hedgerows. Merlins also used hedgerows, but were seen more often in farmfields and over beaches. The sample sizes are not large (n=42, 32, 9 and 19 sightings, respectively), and my method did not provide equal time to search each of the 3 habitats. However, the result is not unexpected. Shrikes and accipiters feed on mostly songbirds, whereas Merlins eat songbirds and shorebirds. The Cooper's Hawk and Sharp-shinned Hawk ambush their prey along forest and shrub edges, whereas the Merlin catches its prey by fast pursuit in open country.

4. Conservation of hedgerows

Species that are most dependent on hedgerow habitats near Boundary Bay include the Cooper's Hawk, Northern Shrike, Ring-necked Pheasant (*Phasianus colchicus*) and Bewick's Wren. The year-round distribution of these four species in British Columbia is restricted to lowland riparian habitats (Campbell *et al.* 1990).

The Cooper's Hawk has declined in eastern North America (Tate 1986) and is considered 'rare' in Canada by the Committee on the Status of Endangered Wildlife in Canada (Cook and Muir 1984). Its status in British Columbia is unknown. Destruction of riparian habitats (Cadman *et al.* 1987) and organochlorine pesticides used in agriculture, were implicated in the decline of this species in Ontario (Penak 1981). Similar problems might impact this species in British Columbia, especially in the Boundary Bay farmlands where many Cooper's Hawks spend the winter (Campbell *et al.* 1990).

Ring-necked Pheasants were first introduced into the farmlands near Boundary Bay about a century ago, and are widespread today (Butler and Campbell 1987). The status of the Bewick's Wren and Northern Shrike are unknown. Both species are widespread in the Fraser River delta, but are nowhere abundant (Butler and Campbell 1987).

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Chapter 7. Conclusions and recommendations for the conservation of the birds of Boundary Bay

Robert W. Butler and Richard W. McKelvey

Introduction

The aim of this research was to describe and estimate the amount of habitat required to maintain bird species of greatest conservation concern in the vicinity of Boundary Bay. The main conclusions of previous chapters are discussed and integrated in recommendations for the conservation of birds in the vicinity of Boundary Bay.

Abundance of birds

Similar average numbers of birds were counted in this study (Chapter 2 & 4) and a 1988-89 study by Butler and Cannings (1989). The present study tallied an average of about 115,000 dabbling ducks per day between October and April on the intertidal and farmland habitats of the Fraser River delta. Butler and Cannings (1989) tallied about 123,000 dabbling ducks in the intertidal habitats in the same area in 1988-89. Dunlins (*Calidris alpina*), American Wigeons (*Anas americana*), Northern Pintails (*A. acuta*) and Mallards (*A. platyrhynchos*) were abundant in this study (Table 1) and Butler and Cannings (1989) study. Bald Eagles (*Haliaeetus leucocephalus*) were not counted in our study but Butler and Cannings (1989) tallied 241 individuals in Boundary Bay over a 12 month period.

Habitats used by birds

Dabbling ducks in our study (Chapter 2) used the same farmland habitats during day and night as in Hirst and Easthope's (1981) daytime study. The principal habitats of dabbling ducks near Boundary Bay were cultivated fields, pastures, mudflats and eelgrass beds (Table 2).

Table 1. Average numbers of common dabbling ducks, shorebirds, and large birds of prey in Boundary Bay and nearby farmlands per day in the month of greatest abundance in 1989-90. Data from chapters 2, 4 & 5.

Dabbling Ducks	Average per Day in the Month of Greatest Abundance
American Wigeon	73,000
Northern Pintail	50,000
Mallard	33,000
Total	156,000
Shorebirds	
Western Sandpiper	56,000
Dunlin	39,000
Black-bellied Plover	1600
Great Blue Heron	434
Total	97,034
Large birds of prey	
Northern Harrier	70
Short-eared Owl	57
Red-tailed Hawk	45
Barn Owl	37
Rough-legged Hawk	34
Total	243
Grand Total	253,277

Table 2. Principal habitats used by waterfowl, shorebirds, birds of prey and songbirds near Boundary Bay. Data are contained in previous chapters.

Habitats	Dabbling ducks	Shorebirds and Herons	Birds of prey	Songbirds
Farmlands				
old field		+	+	+
overgrown pasture			+	+
cultivated field	+	+		+
pasture	+	+	+	+
hedgerows & trees		+	+	+
Beach				
mudflat	+	+	+	
saltmarsh	+	+	+	
eelgrass	+	+		

Ours is the first study to describe the habitats of shorebirds, birds of prey and songbirds in farmlands near Boundary Bay. Shorebirds used old-fields,cultivated fields, pastures, mudflats, marshes and eelgrass beds (Table 2). Birds of prey used old-fields, overgrown pastures, pastures including hay fields, hedgerows and trees, mudflats and marshes (Table 2). Songbirds used old-fields, overgrown pastures, cultivated fields, pastures, hedgerows and trees (Table 2).

Distribution of bird habitats

Day and nighttime distributions of waterfowl (Chapter 2) was similar to the daytime distribution in farmlands around Boundary Bay found by Jury (1981). Waterfowl were abundant on intertidal habitats in Boundary Bay, Roberts Bank, and Sturgeon Bank. Some farmlands were used by waterfowl through the autumn, winter and spring. These farmlands lay in the Serpentine and Nicomekl River drainage basins, near the northwest corner of Boundary Bay, and south of Ladner Village In contrast, farmlands on the Spetifore farm in Tsawwassen and near 96th and 112th Streets, were used by large flocks of ducks for a few days or weeks. This is the first study to show that most shorebirds (Chapter 4) and large birds of prey (Chapter 5) used habitats generally within 2 km of Boundary Bay and Brunswick Point.

Implications of changing farmland practices on birds

Our analyses suggest that a loss of the current variety of farmland habitats in the study area will result in a decline in populations of dabbling ducks, birds of prey and shorebirds. The intertidal area of Boundary Bay cannot supply the food requirements of waterfowl through the winter (Chapter 3). Many shorebirds feed in farmlands after November (Chapter 4) and birds of prey occur in high densities in the old-field habitat near the Bay (Chapter 5).

Recommendations

The findings of this research indicate that preservation of intertidal beaches and large tracts of land with mixed farming is necessary to maintain the current population levels of waterfowl, shorebirds and birds of prey in the vicinity of Boundary Bay. However, waterfowl can cause serious damage to some

crops and farming practices are likely to change in the future (Klohn Leonoff *et al.* 1992). Therefore, to achieve the goal of maintaining current population levels of birds, we require a conservation plan that protects birds from imminent threats and future changes, while recognizing the potential threat of waterfowl on farming activities. We recommended that:

1) the sub-tidal waters, beaches, mudflats and marshes in Boundary Bay, Mud Bay, Semiahmoo Bay and on Roberts Bank be secured for the prime purpose of wildlife conservation;

2) the current Agricultural Land Reserve (ALR) in Delta Municipality and in the drainage basins of the Nicomekl and Serpentine Rivers be retained;

3) crop damage prevention programs such as the Greenfields Project (Duynstee 1992), be continued;

4) a core of habitat managed for waterfowl, shorebirds and herons, and birds of prey of greatest conservation concern be secured adjacent to Boundary Bay;

5) additional holdings be secured near Boundary Bay, in the Serpentine and Nicomekl River drainage, on Brunswick Point for the primary use of wildlife if the habitat capability on present farmland declines.

Justification for these recommendations is now provided.

Securing the bays, beaches and marshes for wildlife

Large populations of waterbirds move across the entire foreshore of the Fraser River delta in search of food and shelter. Hence, the first step in maintaining the present populations of waterbirds in Boundary Bay requires securing their habitats in the Bay and on nearby beaches and marshes. Some important habitats include subtidal and intertidal eelgrass beds, intertidal mudflats and saltmarshes. It is important to realize that the loss or degradation of one of these aquatic habitats might reduce the value to birds of nearby habitats. Therefore, it is important that all of the subtidal, beaches, mudflats and marshes be secured.

Agricultural Land Reserve and crop damage prevention

Many of the birds in the vicinity of Boundary Bay forage and rest in nearby farmlands. Hence, the retention of these farmlands in the ALR will continue to

benefit many species of birds. Programs that reduce conflicts between the farming industry and birds that feed there provide an opportunity to explore ways to minimize damage.

Securing a core of wildlife habitat

The numbers and species of birds that use agricultural lands depends on farming practices which are likely to change (Klohn Leonoff *et al.* 1992). For example, golf course developments and greenhouses on farmlands have reduced the value of those agricultural lands to many wildlife species. Manipulations of farmland habitat to make them more attractive to waterfowl and shorebirds can be undertaken in a few months if land is available. However, land is expensive and might not be for sale. Moreover, hedgerows, old-fields and tall trees take years to become established. Losses of these habitats could result in declines in the abundance of many species including "vulnerable" populations of Barn Owls (Campbell and Campbell 1983) and "rare" populations of Cooper's Hawks (Cook and Muir 1984). Therefore, it is important that a nucleus of habitat be secured that will be managed for waterfowl, shorebirds, birds of prey and songbirds.

1. Farmland habitats

The size of core Wildlife Areas should be large enough to provide a mix of farmland habitats required by waterfowl and shorebirds, hedgerows for songbirds and forests for nesting herons and birds of prey. The 300 ha Alaksen National Wildlife Area is about the right minimum size because it is sufficiently large to support internationally significant populations of waterfowl as well as large numbers of shorebirds, songbirds and nesting birds of prey.

The Wildlife Areas should be located in areas where habitats can be created that are suitable to birds. As well, Wildlife Areas near Boundary Bay could provide benefits such as public viewing, nature interpretation, lure cropping and opportunities to manage habitat for other flora and fauna. Waterfowl use much of the delta (Chapter 2) and can be lured to farmlands when food and resting sites are provided (Hatfield 1992). In contrast, shorebirds, herons and birds of prey used farmlands mostly near the Bay (Chapters 4 & 5) although similar habitats were present elsewhere in the delta. Specifically, habitats for Northern Harriers should be adjacent to the marshes of Boundary Bay (Chapter 5), shorebird

and heron habitats should be within 2 km of the Bay (Chapter 4). Therefore, the most suitable location of Wildlife Areas for waterfowl, shorebirds, herons and birds of prey is near Boundary Bay.

2. Old-field habitats

Old-field habitats should be large enough to provide foraging sites for birds of prey and herons in the non-breeding season, and foraging and nesting sites for Northern Harriers and Short-eared Owls in the breeding season. In addition, Barn Owl populations require nest-sites such as in barns, large trees near old-fields.

The maximum densities of birds of prey that can be supported on intensively managed old-field and overgrown pasture habitat is unknown. Therefore, an area equivalent to the approximately 600 ha of old-field and overgrown pasture in the study area must be secured to support current populations of birds of prey.

Size and location of additional holdings

Additional holdings for Wildlife Areas should offset the reduced habitat capability of lands in the study area. Densities of waterfowl, shorebirds, birds of prey, and songbirds can be increased by making their habitats more attractive. For example, the densities of waterfowl and shorebirds on the Alaksen National Wildlife Area increased after fields were flooded with shallow water (Hatfield 1990). Moreover, more species of songbirds used hedgerows containing trees than hedgerows without trees (Chapter 6) and maintaining the height of grasses in old-fields makes them more attractive to birds of prey than if the grasses are allowed to grow tall (Chapter 5).

The acquisition of more holdings should match the decline in habitat capability on lands in the study area. Additional holdings of intensively managed land required to support all of the estimated 115,000 ducks that use farmlands (Chapter 2) at the same densities reported by Hatfield (1991) on the Alaksen National Wildlife Area is estimated to be (115,000 ducks/ 32.4 ducks/ha =) about 3500 ha. Habitat capability for waterfowl can be assessed by multiplying the area of farmland covered by different crop types by the mean densities of waterfowl in those different crop types. Alternate locations for additional holdings and Wildlife Areas for waterfowl include farmlands in the Serpentine and Nicomekl

River drainage, near the northwest corner of Boundary Bay and south of Ladner Village (Chapter 2). Alternate locations for habitat purchases suitable to shorebirds, herons and birds of prey are on farmlands adjacent to Brunswick Point.

Future Directions

Future work might examine the strength of Hatfield's (1992) density estimate of the area of farmland required to support each species of duck. Food manipulations of wild and captive ducks offer the best prospects. The question of the significance of farmlands as foraging habitats to individual Dunlins and Black-bellied Plovers needs to be examined. Tracking individual shorebirds equipped with radio transmitters might provide answers. Variation in small mammal densities between fields and years probably influences the distribution and reproductive success of some large birds of prey. Hence, the optimum balance between the density of small mammals and their availability to large birds of prey needs to be examined. Manipulations of cover on fields with small mammals and the distribution and reproductive success of Barn Owls might be rewarding.

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