Robert W. Butler
Kees Vermeer
(editors)

The abundance and distribution of estuarine birds in the Strait of Georgia, British Columbia

Occasional Paper
Number 83
Canadian Wildlife Service

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Dedication

This publication is dedicated to the late Michael Waldichuk, who heightened our awareness of the environmental sensitivity of British Columbia estuaries in the Special Estuary Series reports.

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Contents

Introduction

Robert W. Butler and Kees Vermeer

The present publication follows an earlier report by Vermeer and Butler (1989) that described the physical and biological environment, prey organisms, and ecology of waterbirds in the Strait of Georgia. Here, we compare the year-round abundance, distribution, and energy consumption of birds in five large estuaries and one small urban estuary in the Strait of Georgia. We use the traditional definition of an estuary: the lower deltaic portion of a river and the nearby shallow waters in the freshwater plume.

Some bird populations in the Fraser River estuary on the southeast shore of the Strait of Georgia exceed levels established in the Ramsar Convention to rank the ornithological significance of wetlands (Butler and Campbell 1987; Morrison et al. 1991). However, the significance of other estuaries to birds has not been assessed, although many have lost large amounts of bird habitat to human developments (Campbell Prentice and Boyd 1988). The use of estuarine habitats on the west coast of Canada has not been described for many species, and the role of birds in the energy flow of estuaries has received little attention. Moreover, the rapidly growing human population around the Strait of Georgia adds new pressure on bird habitats.

This publication provides information to assess the conservation significance of estuaries in the Strait of Georgia to waterbird populations on the Pacific coast. In addition, new information is provided on habitat requirements and population estimates of internationally significant populations of Trumpeter Swans *Cygnus buccinator*, Western Sandpipers *Calidris mauri*, and Dunlins *C. alpina*. Habitat use by waterbirds in one estuary and energy consumption by waterbirds at different trophic levels in six estuaries are described. We believe that the information will be useful for ornithologists and ecologists, as well as for coastal managers and members of conservation organizations.

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Comparison of seasonal shorebird and waterbird densities within Fraser River delta intertidal regions

Kees Vermeer, Robert W. Butler, and
Ken H. Morgan

1. Abstract

Densities of the most common shorebirds and waterbirds in the intertidal regions of the Fraser River delta were estimated during ground surveys for each month in 1988–89. Densities of ducks were highest in October–December. Both ducks and shorebirds had high densities in March–April. Ducks consisted mostly of American Wigeons *Anas americana*, Mallards *A. platyrhynchos*, and Northern Pintails *A. acuta*. Shorebirds were mostly Dunlins *Calidris alpina*. A minor peak, consisting chiefly of Western Sandpipers *C. mauri*, was observed in July. Of the whole Fraser River delta, Boundary Bay had the highest densities of ducks, gulls, and shorebirds. Roberts and Sturgeon banks had the highest densities of Trumpeter Swans *Cygnus buccinator* and three geese — Brant *Branta bernicla*, Canada Geese *B. canadensis*, and Lesser Snow Geese *Anser c. caerulescens*.

The distribution of shorebirds and waterbirds appears to be related to that of intertidal prey and to the presence of terrestrial food sources on adjacent farmlands (ducks and shorebirds) and landfills (gulls). Estuaries and nearby farmlands constitute important feeding habitats for shorebirds and waterbirds, and both should be preserved. Accurate boat censuses of bird populations should be conducted for reliable baseline information and monitoring.

2. Résumé

Au cours des inventaires terrestres des années 1988–1989, on a estimé tous les mois la densité des oiseaux de rivage et des oiseaux aquatiques les plus communs dans la zone intertidale du delta du fleuve Fraser. Entre octobre et décembre, la densité des populations de canards était à son niveau le plus élevé. En mars et avril, la densité des populations de canards et d'oiseaux de rivage était élevée. Les populations de canards se composaient en grande partie de Canards siffleurs d'Amérique *Anas americana*, de Canards colverts *A. platyrhynchos* et de Canards pilets *A. acuta*. Quant aux populations d'oiseaux de rivage, elles comprenaient surtout des Bécasseaux variables *Calidris alpina*. En juillet, on a observé un léger pic dans les effectifs des populations, principalement dû à la présence de Bécasseaux d'Alaska *C. mauri*. De tout le delta du fleuve Fraser, c'est dans la baie Boundary que l'on a observé les plus fortes densités de canards, de goélands et de mouettes et d'oiseaux de rivage. Les plus fortes densités de Cygnes trompettes *Cygnus buccinator*, de Bernaches cravants *Branta bernicla*, de Bernaches du Canada *B. canadensis* et de Petites Oies des neiges *Anser c. caerulescens* ont été observées dans les bancs Roberts et Sturgeon.

La répartition des oiseaux aquatiques et des oiseaux de rivage semble être liée à la répartition des proies intertidales ainsi qu'à la présence de sources de nourriture dans les terres agricoles adjacentes (canards et oiseaux de rivage) et de dépotoirs (goélands et mouettes). Les estuaires et les terres agricoles avoisinantes sont des habitats importants pour l'alimentation des oiseaux de rivage et des oiseaux aquatiques et devraient être préservés. Il y aurait lieu de faire des recensements exacts par bateau pour obtenir des données de base fiables sur les populations d'oiseaux et pour être en mesure d'exercer une surveillance adéquate.

3. Introduction

The Fraser River delta is the largest estuary on the Pacific coast of Canada. Butler and Campbell (1987) estimated that in some years as many as 1.4 million birds (300 000–750 000 waterfowl, 200 000–600 000 shorebirds, and 60 000 gulls) use the estuary and migrate through it. Between March 1988 and February 1989, members of the Vancouver Natural History Society (VNHS) conducted monthly censuses of estuarine birds along the upper tide line of the entire delta (Butler and Cannings 1989). We estimate bird densities based on those VNHS censuses and make species comparisons between three ecologically distinct intertidal areas. The objectives are to describe the spatial and temporal distributions of the most common species and to compare intra- and interspecific bird densities in the Fraser River estuary.

4. Study area

The physical nature, aquatic vegetation, and macrobenthos (important to diving ducks and shorebirds) of the Fraser River delta intertidal regions were described in some detail by Vermeer and Levings (1977) and are summarized briefly here. An overview of the shorebird and waterbird fauna of the Fraser River delta was given by Butler and Campbell (1987). The diets of dabbling and diving ducks have been investigated by Baldwin and Lovvorn (1992) and Vermeer and Levings (1977), respectively, and that of the most numerous shorebird, the Dunlin *Calidris alpina*, has been examined by McEwan and Fry (1981).

The intertidal flats of Boundary Bay and Roberts and Sturgeon banks consist of approximately 20 000 ha of alluvial deposits, sands, silts, and clays. The morphology and geology of the area have been described by Kellerhals and Murray (1969) and Luternauer and Murray (1973).

Marshes border the sea dikes of Boundary Bay and Roberts and Sturgeon banks. Marshes along Boundary Bay are dominated by salt-tolerant plant species, such as pickleweed *Salicornia virginica*, saltgrass *Distichlis spicata*, and arrow grass *Triglochin maritimum*. In contrast, marshes along Roberts and Sturgeon banks are dominated by brackish and freshwater plant species (Hutchinson 1982), mostly three-square bulrush *Scirpus americanus*, sea bulrush *S. maritimus*, Lyngby's sedge *Carex lyngbyei*, and cattail *Typha latifolia*. The predominance of saltwater marshes at Boundary Bay and brackish marshes at Roberts and Sturgeon banks is a consequence of the degree of mixing of fresh and salt water. Fresh water discharged by the various branches of the Fraser River runs through Roberts and Sturgeon banks. At Boundary Bay, that influence is greatly reduced.

Eelgrass beds (mostly *Zostera japonica* in the mid- and upper intertidal areas and *Z. marina* in the lower intertidal zone, down to about 1 m below lowest low water) cover approximately 3200 ha of Boundary and Mud bays. Eelgrass covers about 516 ha of tidal flats between the two terminal jetties on Roberts Bank and another 228 ha south of the ferry jetty (Ward 1992).

The macrobenthos of Roberts and Sturgeon banks has been investigated by Levings and Coustallin (1975), Northcote et al. (1976), Levings et al. (1978), and Chapman and Brinkhurst (1981). The highest macrobenthos biomass has been found in the muds adjacent to the sea dike marsh and in the eelgrass beds. Polychaetes (*Manayunkia aesturina*), amphipods (*Corophium salmonis*), and tanaids are major contributors to the invertebrate biomass there. In the lower intertidal zone, bivalves (*Macoma* spp.) dominate the biomass, except in eelgrass beds on southern Roberts Bank, where crustaceans and polychaetes are most abundant. Epifauna such as barnacles *Balanus glandula* and blue mussels *Mytilus edulis* are found on pilings, causeways, and jetties.

The macrobenthos of the intertidal mud- and sandflats of Boundary and Mud bays has been investigated by Kellerhals and Murray (1969), Patching (1972), O'Connell (1975), Swinbanks (1979), and McEwan and Gordon (1985). Of the epifauna, *Batillaria attramentaria* is the most abundant gastropod in the upper and middle intertidal zones. In the lower intertidal zone, the lean dogwhelk *Nassarius mendicus* is the dominant gastropod. The shore crab *Hemigrapsus oregonensis* is common in the upper intertidal area. Dungeness crab *Cancer magister* and rock crab *C. productus* predominate on the low intertidal and subtidal sandflats. Amphipods (*Anisogammarus* spp.) occur frequently in the upper and middle intertidal zones.

Of the infauna, the most abundant clam is the soft-shelled clam *Mya arenaria*, which occurs in the upper and middle intertidal areas. Butter clams *Saxidomus giganteus* are common in mid-intertidal gravel beds, whereas little-necked clams *Venerupis japonica* and *Protothaca staminea* occur in the lower intertidal zone in gravelly sediments. The heart cockle *Clinocardium nuttallii* is characteristic of muddy fine sand and eelgrass beds in the low intertidal and subtidal zones. Bentnose *Macoma nasuta* and sand *M. secta* clams occur in mud and sand, respectively, of the low intertidal and subtidal zones. The ghost shrimp *Callianassa californiensis* is common in the upper and abundant in the middle intertidal zones, whereas the blue mud shrimp *Upogebia pugettensis* is found in the eelgrass beds of the lower intertidal zone. The Pacific lugworm *Abarenicola pacifica* is abundant in sediments of the upper and middle intertidal areas. Other polychaetes, such as *Spio* spp., are abundant in the upper to lower intertidal transition, whereas *Nephtys caeca* and *Glycinde picta* are common in the middle and lower intertidal zones. In eelgrass beds, the most abundant polychaete is the bamboo worm *Praxillela affinis pacifica*.

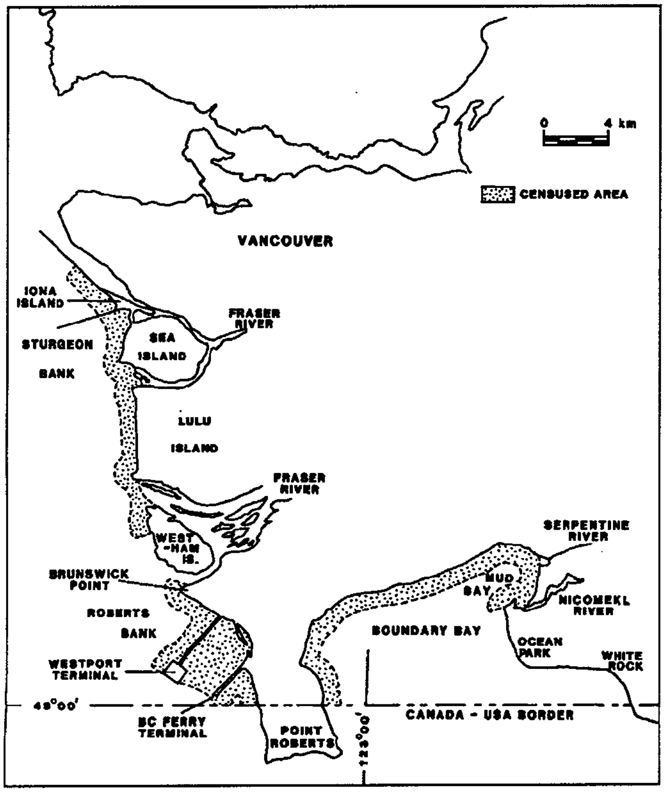
5. Methods

The VNHS census methods were described by Butler and Cannings (1989). Once a month, 17 teams of observers walked the dikes near the high tide line and recorded all bird species seen through binoculars or telescopes. All birds within about 1 km seaward of the high tide line were counted. The area between the British Columbia Ferry and Westport terminals was completely censused. The censused area (Fig. 1) represents only a fraction of the whole Fraser River intertidal zone, as birds beyond 1 km could not be identified. A portion of Boundary Bay near Ocean Park and White Rock was not counted regularly and is excluded from this report.

Three distinct areas were censused: (1) Boundary Bay; (2) southern Roberts Bank; and (3) Sturgeon Bank and the northern tip of Westham Island, which is part of Roberts Bank. Sturgeon Bank and the northern tip of Westham Island were combined, as they are characterized by brackish water marshes and as there was a distinct gap between that region and southern Roberts Bank (Fig. 1). For convenience, we name the censused area of Sturgeon Bank and Westham Island "North Bank," and that of southern Roberts Bank, "South Bank."

The censused areas of Boundary Bay, North Bank, and South Bank were calculated with a planimeter to be 23.9, 18.3, and 24.2 km^2. Bird densities were calculated by dividing the number of birds observed by the size of the censused areas. A few portions of the intertidal zone not surveyed in some months were not used for calculating bird densities. In this report, we have depicted the densities of the most numerous and conspicuous bird species in the Fraser River delta intertidal zone. Total counts of the major bird groups in the Fraser River delta intertidal zone are shown in Appendix 1.

Figure 1
Fraser River delta intertidal area; shaded area indicates the section censused by the Vancouver Natural History Society between March 1988 and February 1989



6. Results

6.1 Overall densities

The highest densities of shorebirds and waterbirds were observed from October through December, with a smaller peak in March and April (Table 1). The two peaks consisted mostly of fall and spring migrants, respectively. Ducks were the most numerous birds in October–December, followed by shorebirds, and both groups made up the majority of spring migrants. A minor peak, consisting chiefly of shorebirds, occurred in July. Of all birds, shorebirds and waterfowl were by far the most numerous, whereas loons, grebes, cormorants, swans, alcids, and herons made up only relatively small proportions. Herons, mostly Great Blue Herons *Ardea herodias*, peaked in August and September because of an influx of recently fledged young from nearby nesting colonies (Butler 1991).

The highest bird densities in both spring and fall were found in Boundary Bay (Fig. 2). Shorebirds were most numerous in spring, and both shorebirds and waterfowl contributed most to the high density of birds in the fall. In Boundary Bay and on the South Bank, most waterfowl were observed in the fall, with a minor peak occurring in the spring (Fig. 3). Larids (mostly gulls) peaked in late summer and again in winter (Fig. 3). Gull densities were generally higher in Boundary Bay than in the other two regions in all seasons. The seasonal patterns of shorebird abundance were similar in the three areas, but throughout the year shorebirds were far more numerous in Boundary Bay than over the banks (Fig. 3).

6.2 Species densities

6.2.1 Loons

Relatively few loons occurred in Boundary Bay compared with over the banks. The two most common species were the Pacific Loon *Gavia pacifica* and the Common Loon *G. immer*. Pacific Loons were seen mostly over the North Bank in spring, and Common Loons occurred mostly over the South Bank in fall (Fig. 4). The Red-throated Loon *G. stellata* was less numerous than the Common and Pacific loons, and the Yellow-billed Loon *G. adamsii* was seen only occasionally.

6.2.2 Grebes

Grebes were more numerous over the banks than in Boundary Bay (Fig. 5). Horned Grebes *Podiceps auritus* had their highest densities over the South Bank in both spring and fall, and Red-necked Grebes *P. grisegena* occurred most commonly at those times over both banks. The Western Grebe *Aechmophorus occidentalis* was the most numerous, with seasonal peak densities in August in Boundary Bay and in October over both banks. These differences suggest either that the area used by Western Grebes shifted over the seasons or that some of the grebes were offshore where they could not be seen. Eared *Podiceps nigricollis* and Pied-billed *Podilymbus podiceps* grebes were seen only occasionally.

6.2.3 Cormorants

The Double-crested Cormorant *Phalacrocorax auritus* was the most numerous cormorant. It had its highest density over the South Bank, followed by the North Bank and Boundary Bay (Fig. 6). The Pelagic Cormorant *P. pelagicus* was less common and occurred chiefly over the South Bank (Fig. 6). Brandt's Cormorant *P. penicillatus* was uncommon.

6.2.4 Swans and geese

The Trumpeter Swan *Cygnus buccinator* was the most common swan; few Tundra Swans *C. columbianus* were seen. Trumpeter Swans occurred mainly over the North Bank in fall and winter (Fig. 7). The Lesser Snow Goose *Anser c. caerulescens* was the most numerous goose, occurring chiefly over the North Bank in spring and fall (Fig. 7). Canada Geese *Branta canadensis* were most numerous over the North Bank in summer. Brant *B. bernicla* had their highest densities over the South Bank during their northward migration in April, with a minor peak occurring in Boundary Bay in the same month. The Greater White-fronted Goose *Anser albifrons* was seldom seen.

6.2.5 Dabbling ducks

The four most numerous dabbling ducks in the Fraser River delta intertidal zone were the Mallard *Anas platyrhynchos*, Northern Pintail *A. acuta*, American Wigeon *A. americana*, and Green-winged Teal *A. crecca carolinensis*. They had their highest densities in Boundary Bay in the fall (Fig. 8). In spring, Mallards, Northern Pintails, and American Wigeons were densest in Boundary Bay, whereas Green-winged Teals were densest over the North Bank (Fig. 8). The Gadwall *A. strepera* was most

Table 1
Overall densities of shorebirds and waterbirds observed in the censused Fraser River delta intertidal zone, March 1988 – February 1989

	No. of birds/km² [a]											
Bird groups	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Loons	2.04	3.54	12.72	0.03	0.03	1.43	4.70	2.09	2.98	1.77	1.14	1.55
Grebes	10.22	7.68	1.22	0	0.08	16.62	11.88	35.02	11.65	3.20	5.27	5.56
Cormorants	2.84	2.53	4.58	1.91	2.61	3.72	5.59	6.64	4.68	4.13	2.71	2.36
Swans	0.41	0	0	0	0	0	0	0.29	1.52	1.03	4.07	2.14
Geese	242.35	40.37	3.63	5.96	6.44	19.58	6.68	192.41	241.99	201.11	56.38	0.75
Ducks	1515.33	582.67	69.70	19.38	10.79	173.71	678.51	1769.03	2616.80	2266.34	1181.64	435.48
Larids	111.15	87.38	44.10	58.78	40.19	235.87	198.13	33.32	69.04	62.71	48.55	213.54
Alcids	0.07	0.11	0.12	0	0.02	0	0.07	0.02	0.26	0.03	0.02	0.33
Shorebirds	951.74	2337.34	53.95	49.47	895.03	87.23	132.13	1533.41	1229.41	935.30	1408.55	214.53
Herons	2.95	2.08	2.82	2.77	2.39	3.78	4.01	1.99	2.76	1.73	0.84	0.84
Total	2839.1	3063.7	192.8	138.3	957.6	541.9	1041.7	3574.2	4181.1	3477.4	2709.2	877.2

[a] The highest density is underlined for each bird group.

Figure 2
Seasonal changes in overall waterbird and shorebird densities on the banks and in Boundary Bay, 1988–89

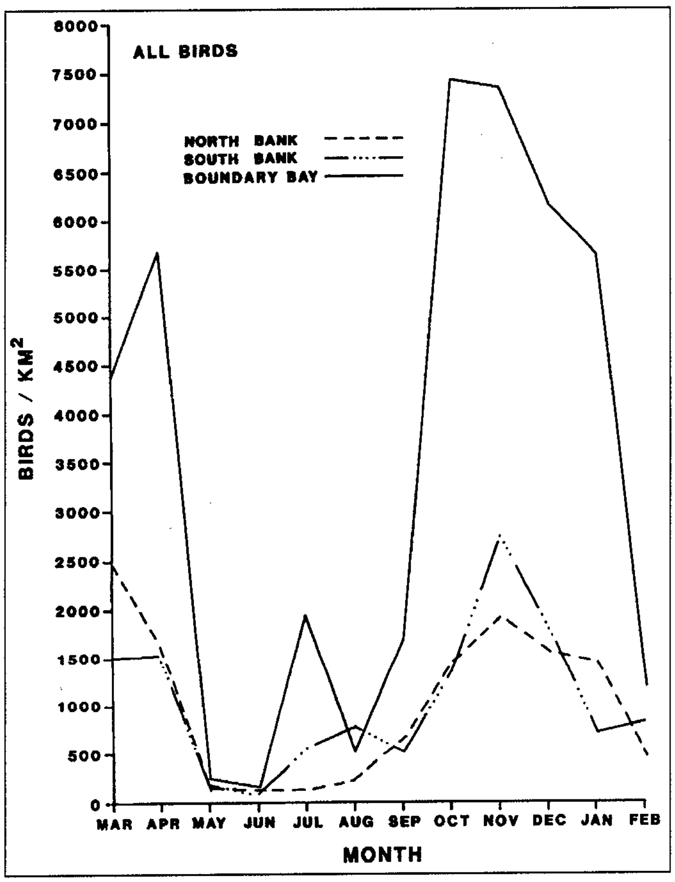
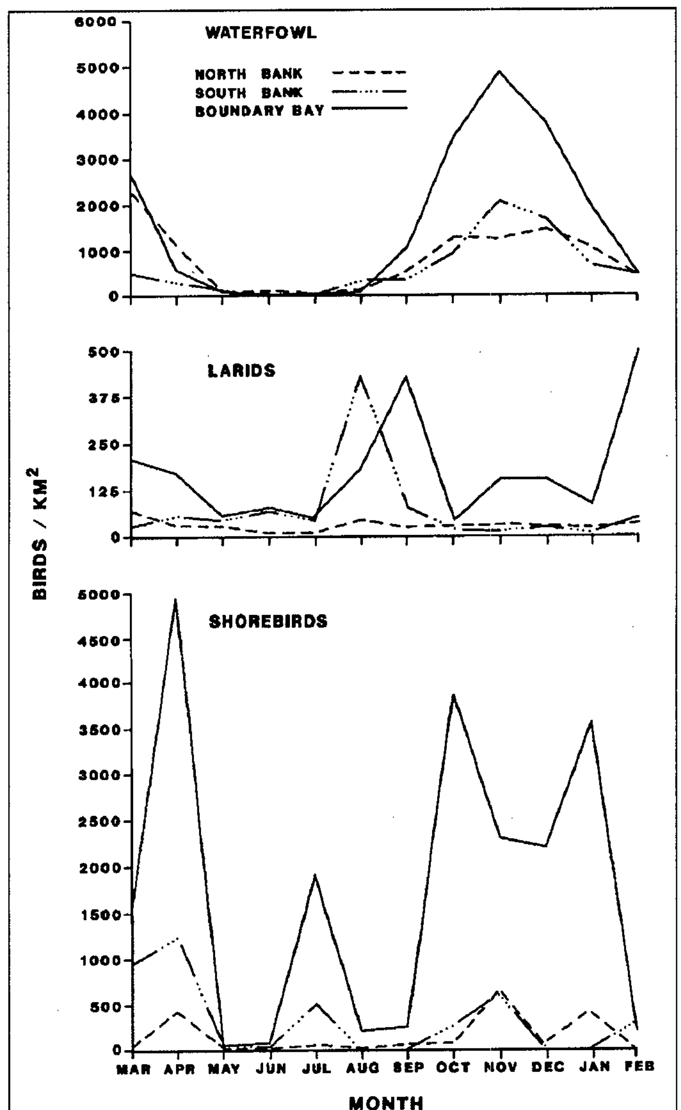


Figure 3
Seasonal changes in densities of waterfowl, larids (mostly gulls), and shorebirds on the banks and in Boundary Bay, 1988–89



numerous at Iona and Sea islands of the North Bank (Fig. 9). Gadwalls were abundant at Sea Island throughout the summer.

6.2.6 *Diving ducks*

The four major diving duck species were the Greater Scaup *Aythya marila*, Surf Scoter *Melanitta perspicillata*, White-winged Scoter *M. fusca*, and Bufflehead *Bucephala albeola*. They had their highest densities in the spring, were scarce in summer, and became numerous again in fall and winter (Fig. 10). Greater Scaups, White-winged Scoters, and Buffleheads were at higher densities in Boundary Bay and over the South Bank than over the North Bank (Fig. 10). Surf Scoters had their highest density over the North Bank in the spring but were most common over the South Bank and in Boundary Bay in fall and winter. The Ruddy Duck *Oxyura jamaicensis* was found chiefly at Iona Island on

Figure 4
Seasonal changes in densities of Pacific and Common loons on the banks and in Boundary Bay, 1988–89

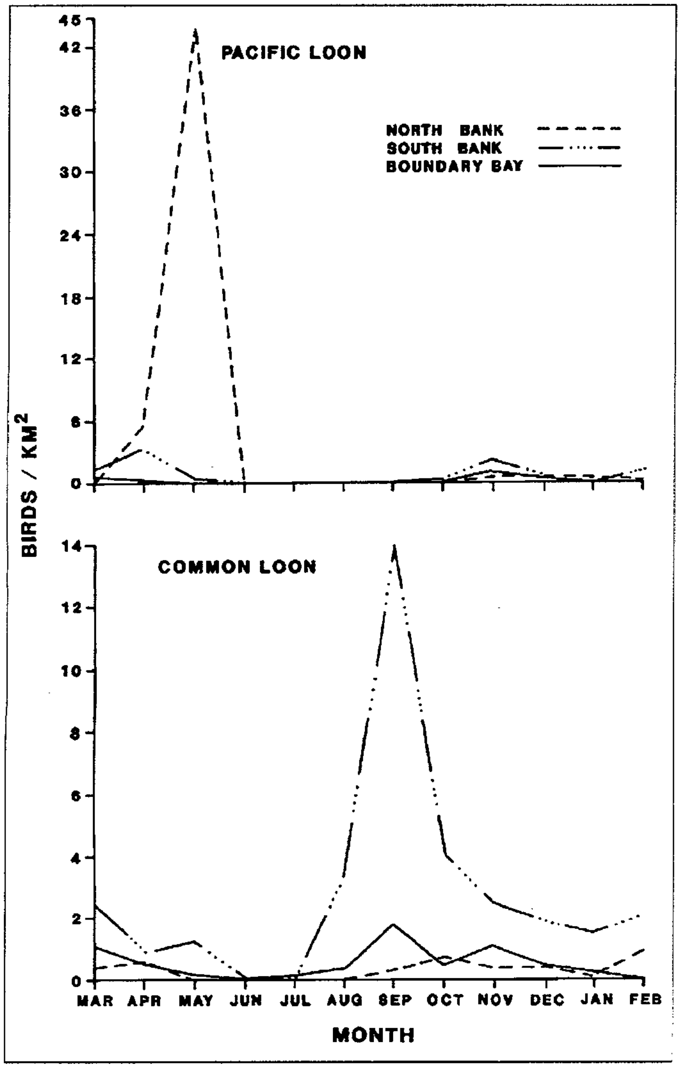
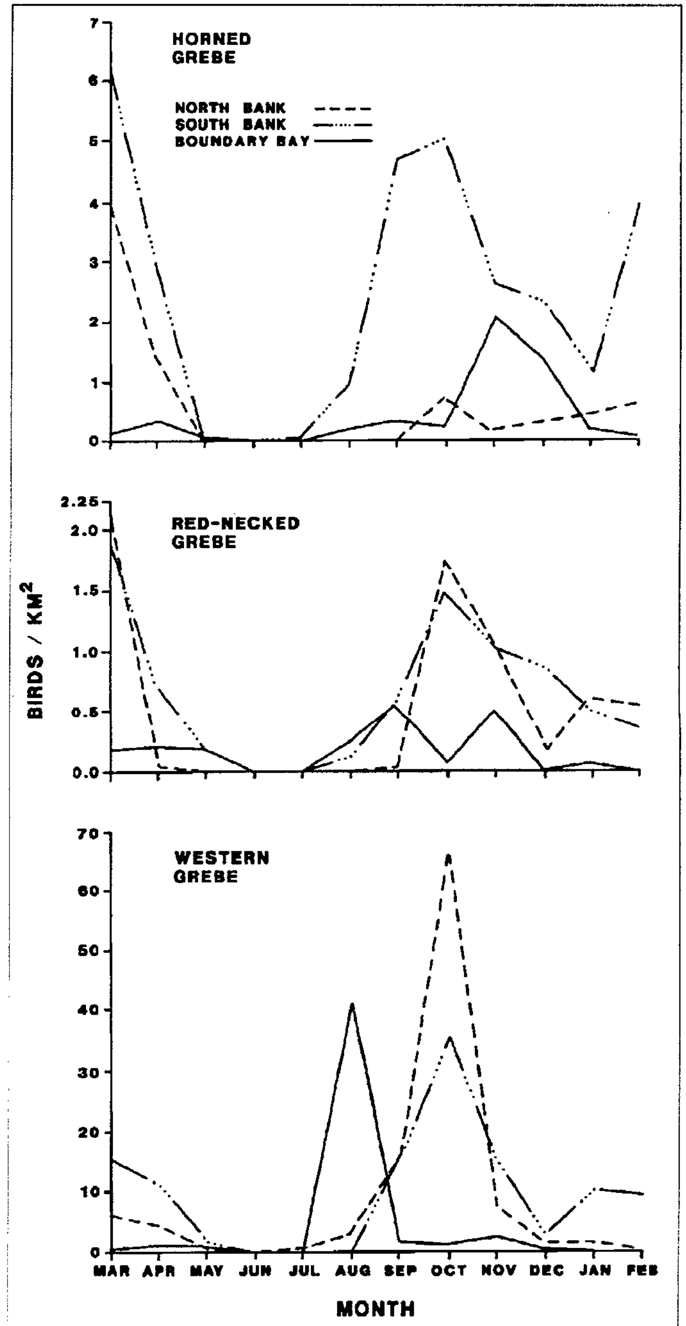


Figure 5
Seasonal changes in densities of Horned, Red-necked, and Western grebes on the banks and in Boundary Bay, 1988–89



the North Bank (Fig. 9). The Canvasback *Aythya valisineria* was common over the North Bank in spring and numerous over the South Bank in fall. Other duck species visit (Butler and Campbell 1987), but all were less numerous in 1988–89 than those discussed here.

6.2.7 Gulls

The three most numerous gulls were the Glaucous-winged Gull *Larus glaucescens*, Mew Gull *L. canus*, and Bonaparte's Gull *L. philadelphia* (Fig. 11). The first two were most numerous in Boundary Bay, whereas Bonaparte's Gull was common in all three regions. Glaucous-winged Gulls, which nest throughout the Strait of Georgia, were present throughout the year. The density of Glaucous-winged Gulls peaked in February. Mew Gulls were most dense in March in Boundary Bay (Fig. 11). Three successive density peaks of Bonaparte's Gulls occurred in Boundary Bay and over the two banks from summer through fall (Fig. 11).

Gulls that were common or abundant at only one time of the year were the California Gull *Larus californicus*, Ring-billed Gull *L. delawarensis*, Herring Gull *L. argentatus*, and Thayer's Gull *L. thayeri*. As it was difficult to distinguish between Herring and Thayer's gulls, their numbers were grouped. California, Herring, and Thayer's gulls were most common in Boundary Bay in September, whereas Ring-billed Gulls were most numerous over the South Bank in August (Fig. 12).

6.2.8 Shorebirds and herons

The two most numerous shorebirds were the Dunlin and Western Sandpiper *Calidris mauri*. Dunlin numbers peaked in April and again in October, whereas the Western Sandpiper peaked only in July (Fig. 13). Both species were by far most numerous in Boundary Bay. Many other shorebirds visit the Fraser River delta intertidal zone (Butler and Campbell 1987), but in

Figure 6
Seasonal changes in densities of Double-crested and Pelagic cormorants on the banks and in Boundary Bay, 1988–89

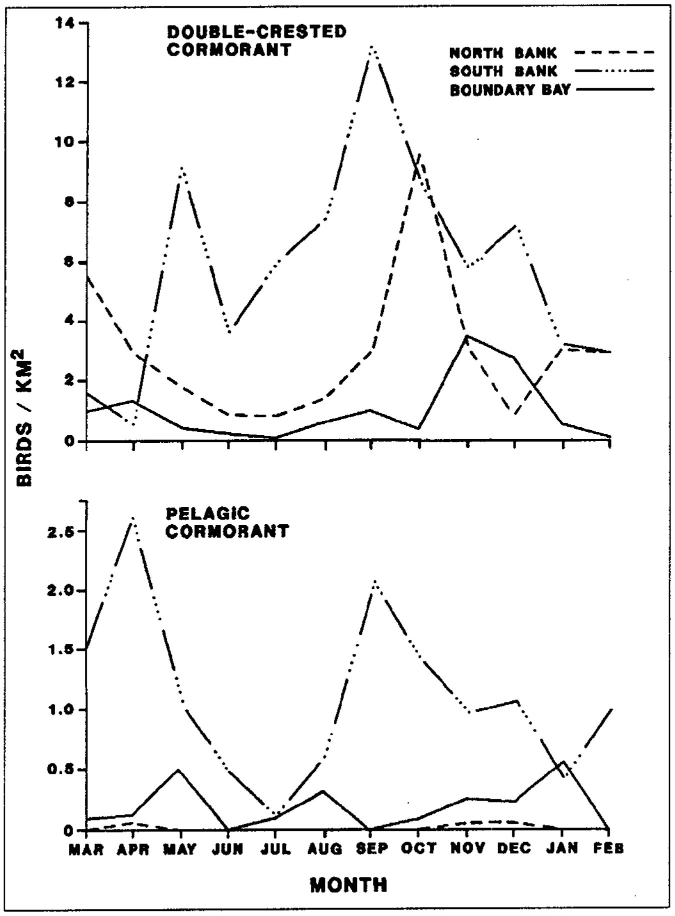
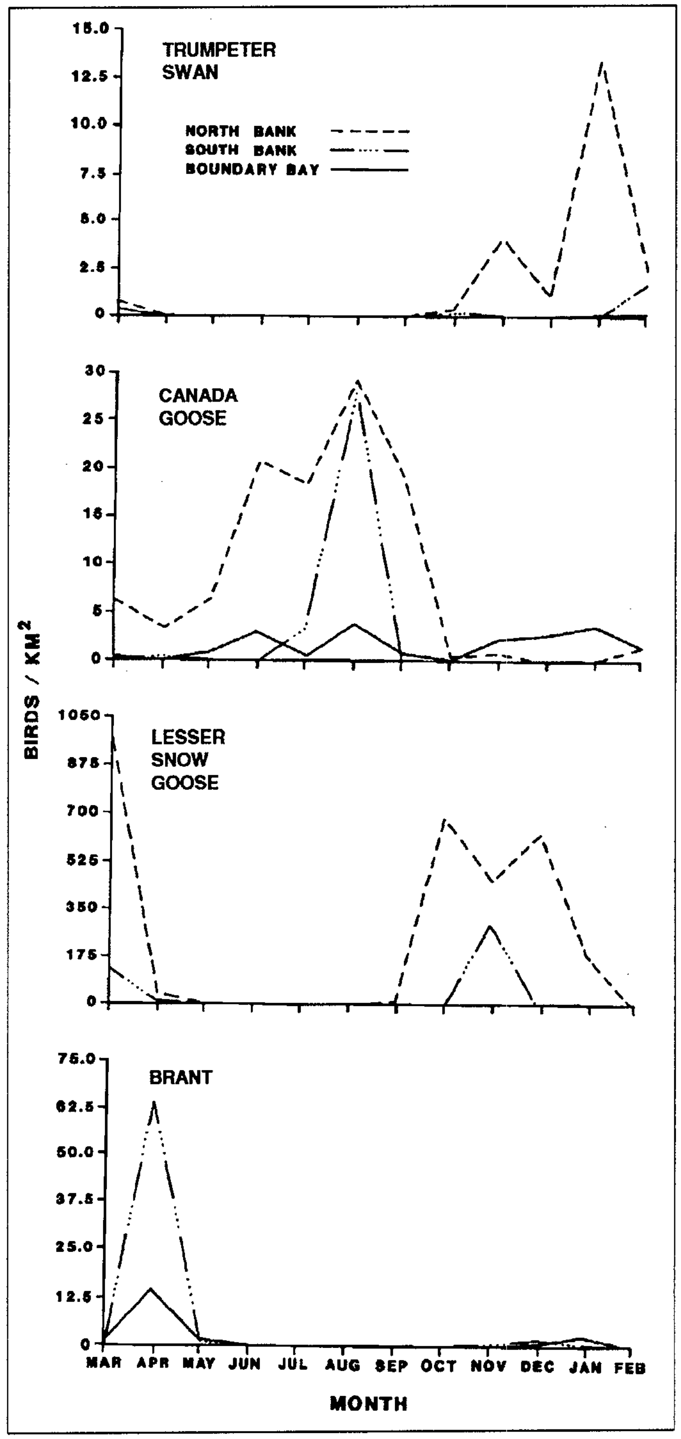


Figure 7
Seasonal changes in densities of Trumpeter Swans, Canada Geese, Lesser Snow Geese, and Brant on the banks and in Boundary Bay, 1988–89



1988–89 all were less numerous than the Dunlin and Western Sandpiper. The Great Blue Heron was present all year and was most numerous over the North Bank and in Boundary Bay (Fig. 14).

7. Discussion

7.1 Comparisons of regions

7.1.1 Densities in Boundary Bay

The high bird densities seen in Boundary Bay most likely relate to an abundance of intertidal prey and nearby terrestrial food sources (McEwan and Gordon 1985; Baldwin and Lovvorn 1992). One physical factor that determines the composition and abundance of intertidal prey is salinity, which ranges from 28‰ in Boundary Bay to 20‰ on the South Bank in autumn (Levings and Coustallin 1975; Swinbanks 1979). McEwan and Gordon (1985) observed higher benthic invertebrate densities in Boundary Bay than on the South Bank and noted that certain species were either absent from or present in lower numbers on the South Bank compared with Boundary Bay.

The presence of extensive eelgrass beds and their associated marine invertebrate community, as well as large tracts of nearby farmlands, attracts tens of thousands of Mallards, Northern Pintails, and American Wigeons to Boundary Bay in autumn. The ducks forage mostly on eelgrass, but also on amphipods and snails (Northern Pintails), sea lettuce (American Wigeons), and wild seeds (Mallards), from September through November (Baldwin and Lovvorn 1992). By mid-November, ducks shift to farmlands to eat wild seeds, corn, grasses, potatoes, cabbage, and insects (Baldwin and Lovvorn 1992; Breault and Butler 1992).

Of the shorebirds, Dunlins were most numerous in Boundary Bay in winter, and Western Sandpipers in summer (Fig. 13). Both are also numerous on their northward migration in spring. The spring migration peak

Figure 8
Seasonal changes in densities of Mallards, Northern Pintails, Green-winged Teals, and American Wigeons on the banks and in Boundary Bay, 1988–89

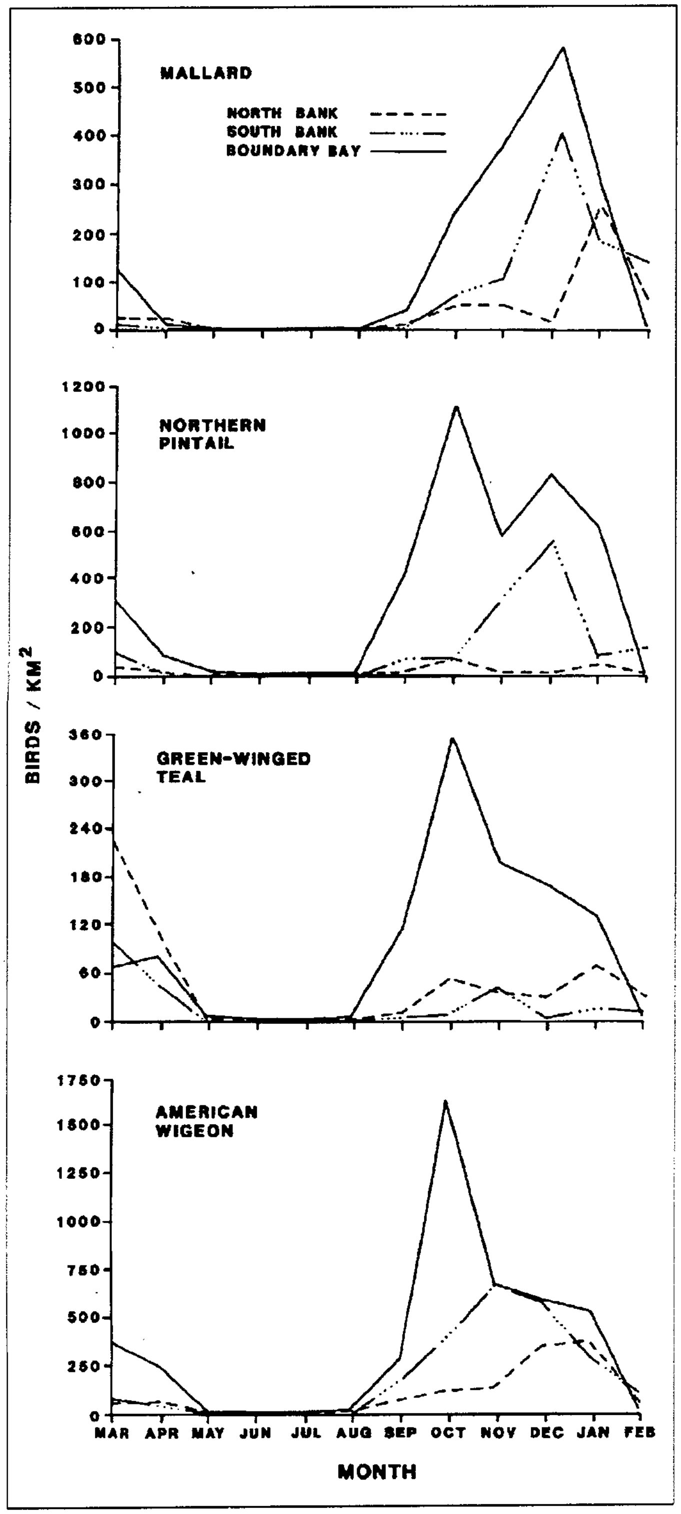
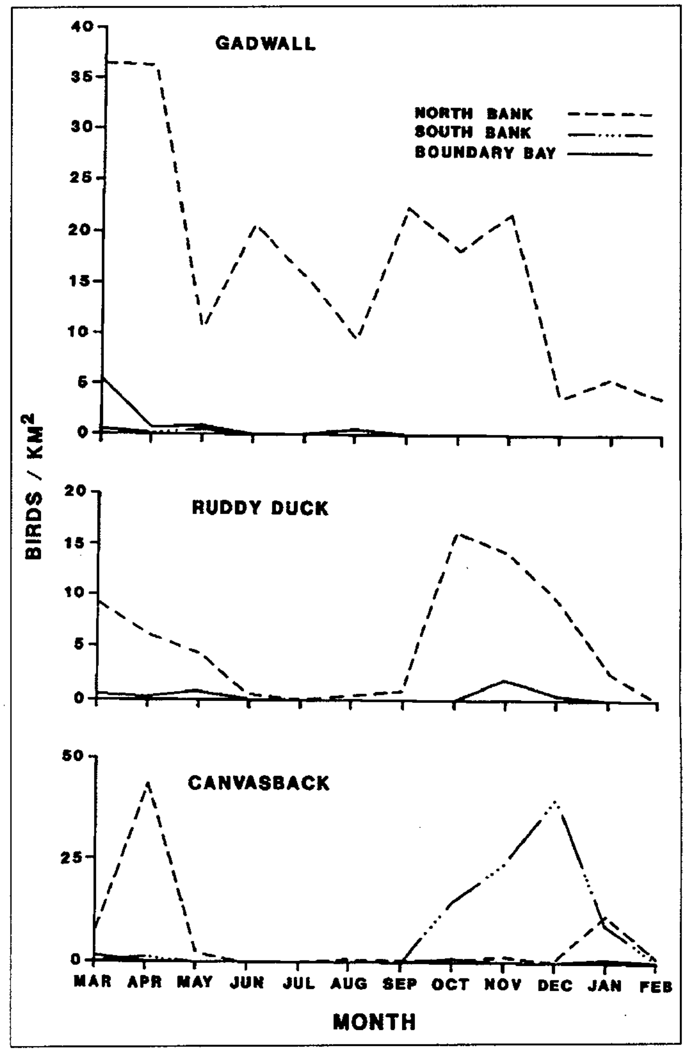


Figure 9
Seasonal changes in densities of Gadwalls, Ruddy Ducks, and Canvasbacks on the banks and in Boundary Bay, 1988–89



of Western Sandpipers is brief and was missed in this study. Butler (this volume) observed tens of thousands of both shorebird species passing through Boundary Bay and Brunswick Point in the spring of 1991 and 1992. Dunlins winter in Boundary Bay possibly because of an abundance of marine snails. Snails were observed to be a major prey of Dunlins in Boundary Bay, but not at Brunswick Point (KV, unpubl. data). Another attraction for Dunlins, in addition to intertidal feeding in Boundary Bay, is adjacent farmland. Dunlins feed extensively on ploughed and unploughed fields and on pastures during winter (Butler 1992).

The presence of human refuse at a nearby landfill likely encourages gulls to visit and roost in Boundary Bay. The Greater Vancouver garbage dump is visited by tens of thousands of Glaucous-winged and Thayer's gulls during winter (KV, unpubl. data).

7.1.2 Densities on the banks

Trumpeter Swans and Lesser Snow Geese are present mostly over the North Bank, where there are large beds of bulrushes and sedges in the tidal marshes (Boyd, this volume). Their preferred food in these marshes is bulrush rhizomes (Burton 1977; S. Boyd, pers. commun.). During high tide, Trumpeter Swans and Lesser Snow Geese eat potatoes, grasses, and winter wheat and rye on nearby farmlands (S. Boyd, pers. commun.). Trumpeter Swans have recently begun to eat potatoes in farmlands near Boundary Bay, but swans are seldom seen in the bay. High densities of Canada Geese over the North Bank in summer and of Brant over the South Bank in spring may

Figure 10
Seasonal changes in densities of Greater Scaups, Surf and White-winged scoters, and Buffleheads on the banks and in Boundary Bay, 1988–89

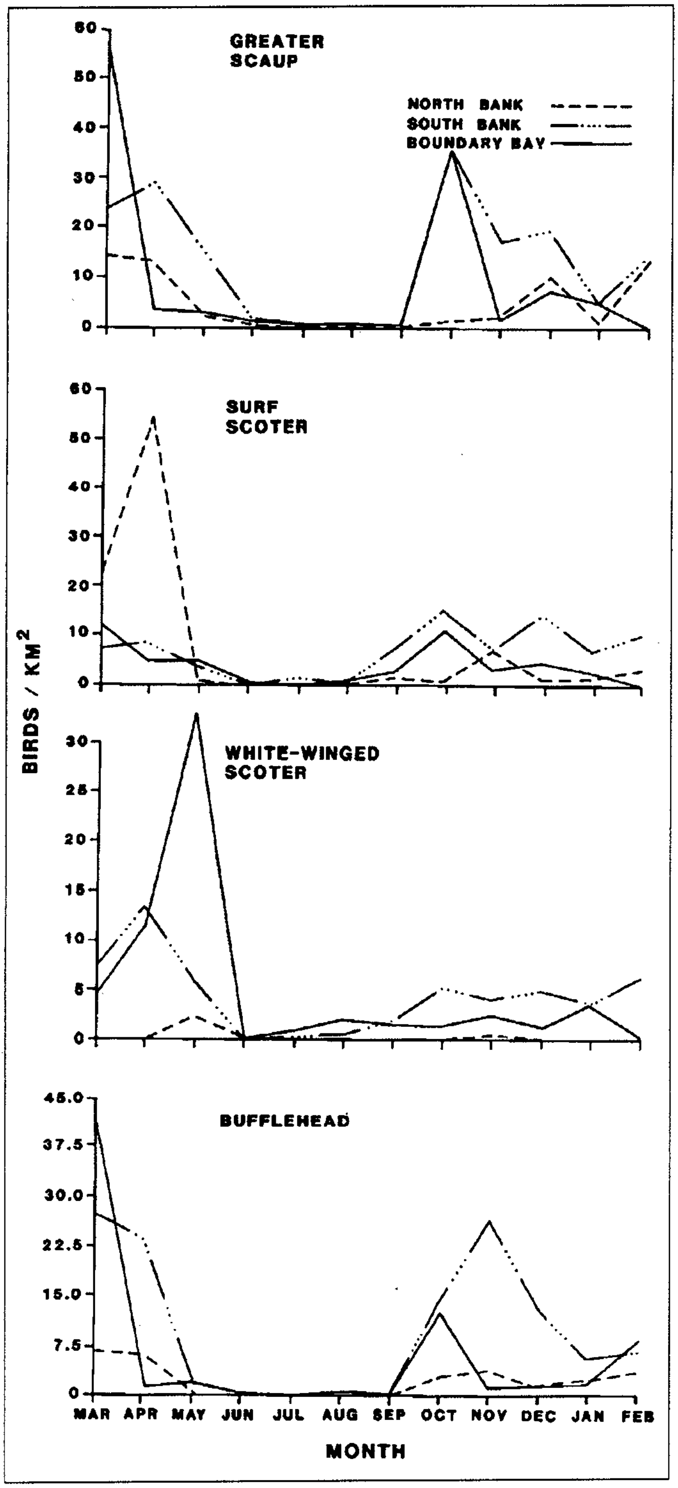
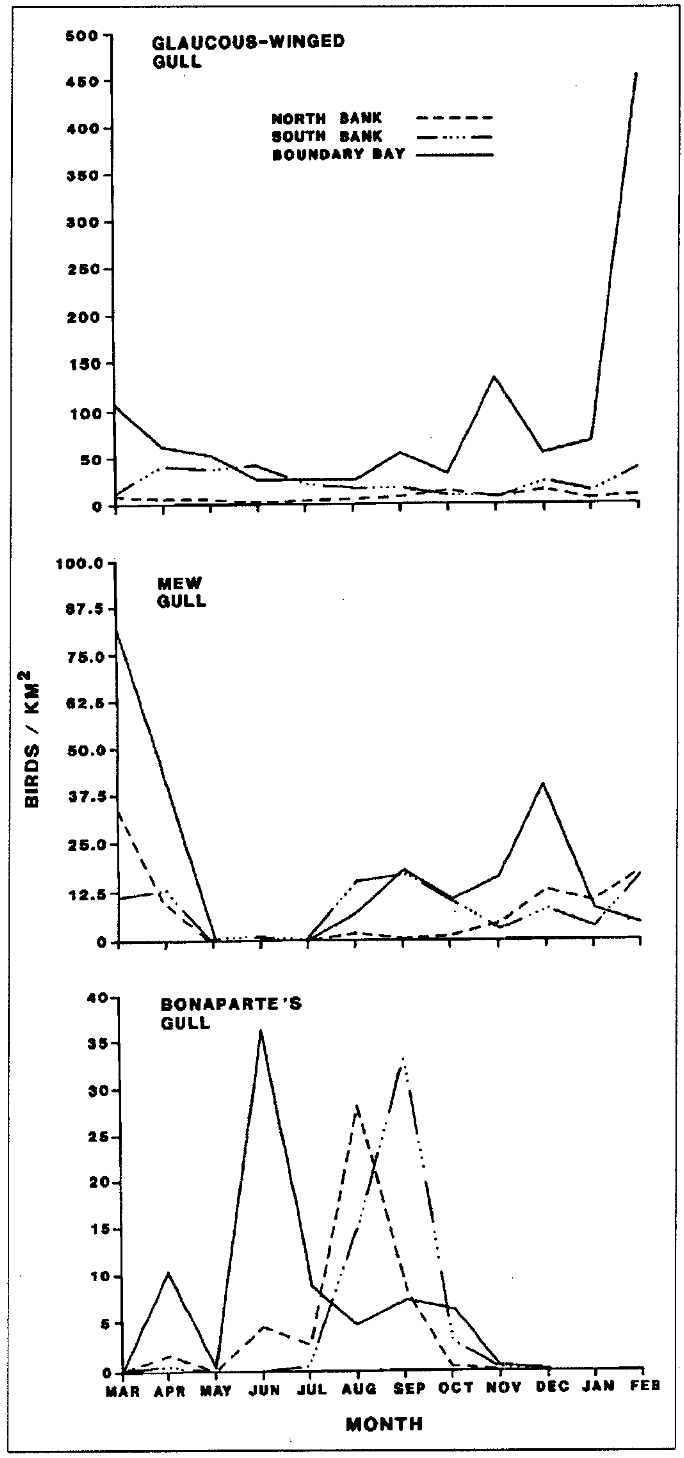


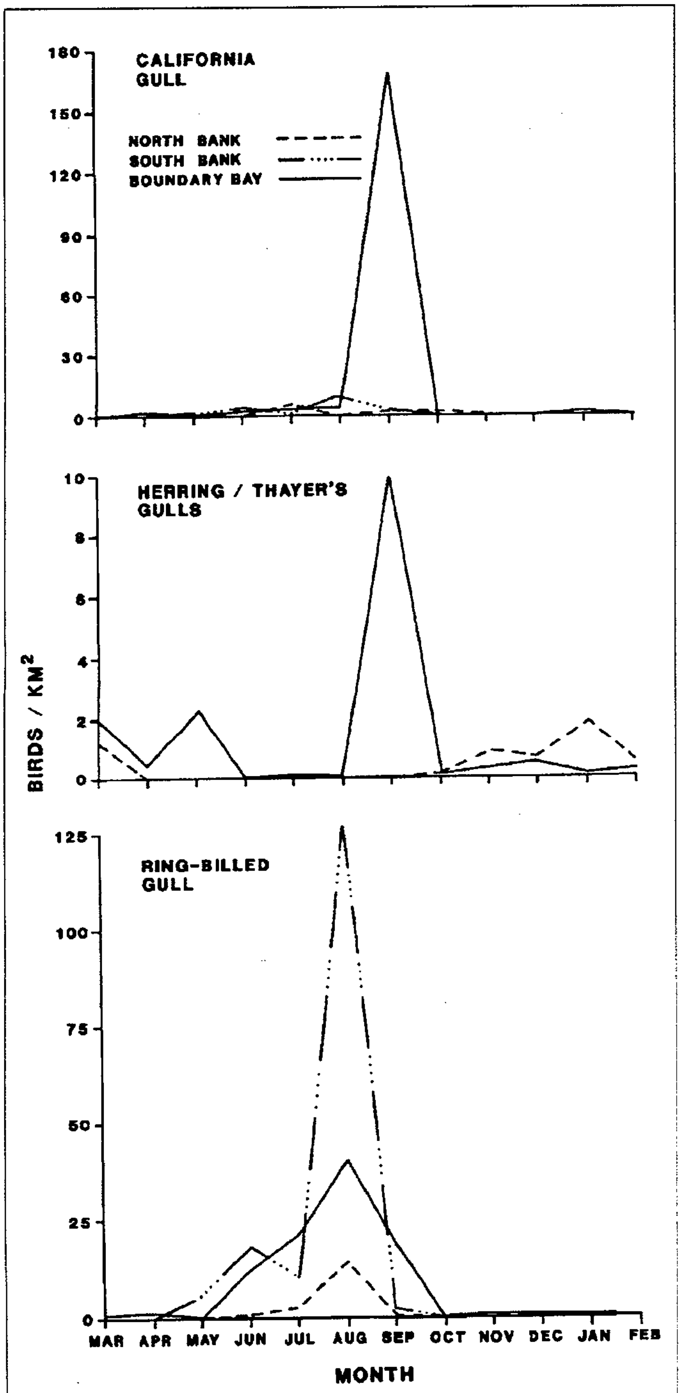
Figure 11
Seasonal changes in densities of Glaucous-winged, Mew, and Bonaparte's gulls on the banks and in Boundary Bay, 1988–89



reflect the distribution of their preferred foods. Canada Geese eat bulrush rhizomes and sedges in the brackish tidal water marsh over the North Bank, and Brant eat eelgrass between the British Columbia Ferry and Westport terminals. The eelgrass beds expanded and became denser after the creation of the Westport Terminal (Levings 1985; S. Boyd, pers. commun.). Brant also forage upon eelgrass in Boundary Bay in early spring.

Three species of ducks — Canvasbacks, Gadwalls, and Ruddy Ducks — were more common over the North Bank than elsewhere (Fig. 9). Little is known of the feeding habits of these three species in the Fraser River delta intertidal zone. Canvasbacks and Ruddy Ducks might be attracted to the Iona Island area because of the presence of the Iona sewage lagoon, as they have been observed to frequent areas where there is eutrophication (Vermeer, "The Gorge estuary," this volume). The Gadwall is common over the North Bank in summer

Figure 12
Seasonal changes in densities of California, Herring/Thayer's, and Ring-billed gulls on the banks and in Boundary Bay, 1988–89



because it nests nearby on Iona and Sea islands (Butler and Campbell 1987).

Loons, grebes, cormorants, and alcids made up a small proportion of the total waterbird population. The higher densities of loons, grebes, and cormorants observed over the banks compared with in Boundary Bay may relate to the greater availability of fish in areas of deeper water near the banks. The higher densities of Double-crested and Pelagic cormorants at Roberts Bank may relate to the large number of pilings and breakwaters

Figure 13
Seasonal changes in densities of Western Sandpipers and Dunlins on the banks and in Boundary Bay, 1988–89

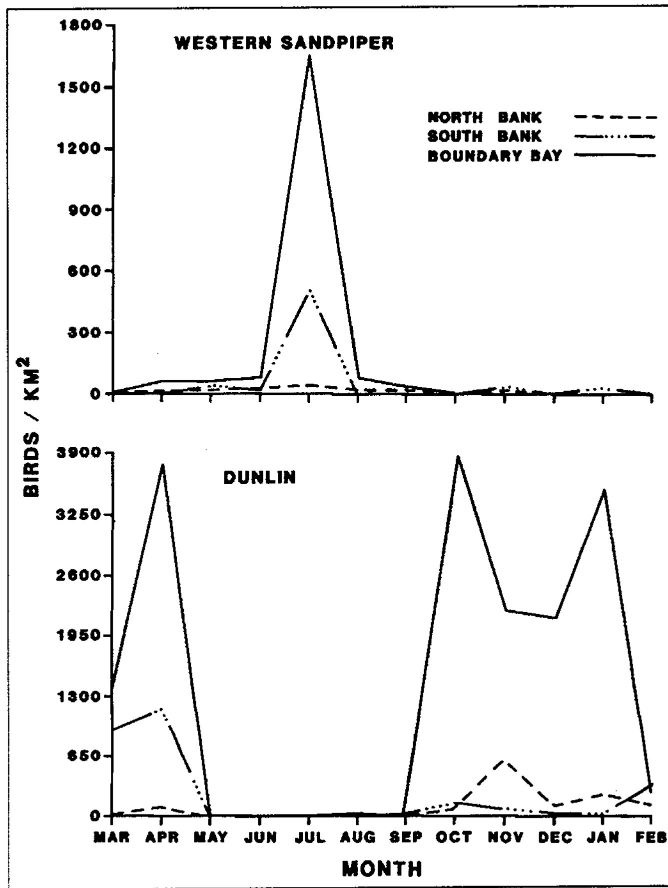
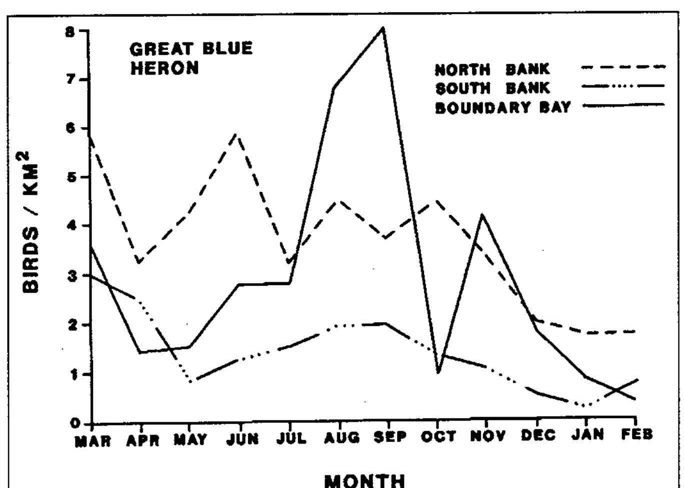


Figure 14
Seasonal changes in densities of Great Blue Herons on the banks and in Boundary Bay, 1988–89



located there. Cormorants spend much time on exposed perches, such as pilings, to dry their plumage and rest.

Great Blue Herons are widespread in all months of the year. One of us (RWB) has seen as many as 400 herons foraging in eelgrass beds between the terminal jetties on the South Bank in May. The numbers of herons feeding in eelgrass beds decrease between August and February, while they increase in marshes on the banks

(Butler 1991). The pattern is reversed after February. Many Great Blue Herons nest near their foraging grounds in Boundary Bay and on the banks.

7.2 Comparison with other estuaries; estuary preservation

As for other estuaries in British Columbia, the Fraser River delta intertidal zone is used by birds mostly from autumn to spring, with waterfowl and gulls being most numerous (Vermeer et al. 1992; Vermeer, both papers, this volume; Vermeer, Bentley, and Morgan, this volume). The Fraser River delta intertidal zone has far more migrant and wintering shorebirds, and higher densities of wintering ducks and geese, than other British Columbia estuaries (Vermeer and Levings 1977; Vermeer et al. 1983, 1992; Butler et al. 1989; Vermeer, Bentley, and Morgan, this volume). The reason may be the vast expanse of intertidal mudflats inhabited by a diverse benthic invertebrate fauna (Bawden et al. 1973; Levings and Coustallin 1975; McEwan and Gordon 1985), extensive marshes and eelgrass beds, and the presence of large tracts of nearby farmlands containing pasture grasses and vegetables for ducks and geese and earthworms and insects for shorebirds.

Other British Columbia estuaries appear to have distinct bird populations, even when those estuaries are within the same region (Vermeer et al. 1992; Vermeer, Bentley, and Morgan, this volume). Several estuaries are chemically polluted, as are parts of the Fraser River delta intertidal zone (Vermeer and Peakall 1979). Such pollution may reduce the abundance of marine invertebrates, which in turn affects the diversity of the waterbird fauna (Vermeer et al. 1992).

Many shorebirds and waterfowl feed in farmlands adjacent to British Columbia estuaries. Baldwin and Lovvorn (1992) suggested that the intertidal zone in Boundary Bay cannot by itself supply the food requirements for waterfowl populations present throughout the winter. The combination of observed declines of stored body fat in Dunlins and their initiation of extensive feeding in Fraser River delta intertidal farmlands after December (McEwan and Whitehead 1984; Butler 1992) also suggests that the large numbers of Dunlins need the addition of terrestrial foods for survival. Therefore, in addition to protecting estuaries, farmlands adjacent to estuaries need to be preserved.

7.3 Shortcomings of methods and recommendations

Aerial surveys of waterbird populations in the Fraser River delta intertidal zone have been conducted with a selective bias towards waterfowl (see Vermeer and Levings 1977; McKelvey et al. 1985; Savard 1985; McKelvey and Summers 1990). In aerial surveys, many small dark-coloured birds may be missed, and large conspicuous ones may be overrepresented in the data. Error in aerial surveys is caused by poor visibility, plane angle, weather conditions, position of sun, wave action, observer inexperience, fatigue, and other factors. Savard (1982) estimated that only half the birds present are observed during aerial surveys. Ground surveys may suffer from some of the same limitations, but generally birds are more easily identified in ground surveys.

The VNHS censuses are the first year-round ground surveys of the entire Fraser River delta intertidal zone. They also have their biases. Because they were conducted once a month, rapidly migrating bird populations were missed or underestimated. Observers had great difficulties with identifying birds seen farther offshore, resulting in many ducks and gulls being reported as unidentified. As only the area within the first kilometre from shore was censused, diving ducks, loons, grebes, cormorants, and alcids occurring beyond that distance were likely underrepresented.

We recommend that bimonthly censuses of bird populations and species composition in the Fraser River delta intertidal zone be conducted with shallow-draft boats at high tide throughout the entire intertidal zone by one boat operator and one observer. The senior author (KV) had much success with this method when censusing bird populations in Vancouver Island estuaries. Because of the vastness of the Fraser River delta intertidal zone, several boat teams should be employed simultaneously. A series of markers should be established at known distances from shore, preferably at a maximum distance of 1 km from shore and from each other. The markers would allow observers to know exactly which intertidal segment they were censusing and thereby reduce duplication. Boat censuses should be conducted only on calm days to maintain good visibility. Large congregations of birds, which may be difficult to survey from the water, should be simultaneously counted and photographed from the air. For the purpose of monitoring Fraser River delta intertidal bird populations, accurate censuses (perhaps conducted initially at one year and later at five-year intervals) are essential for data reliability. The establishment and execution of accurate census methods are necessary to detect population trends.

Besides conducting censuses of the whole Fraser River delta intertidal zone, specific habitats such as salt and brackish marshes, eelgrass beds, and mudflats should be censused to determine habitat use by different species. These habitats should be censused frequently to determine variability in species usage of habitats according to season, weather conditions, and tidal level. Observations on feeding activities by waterbirds should accompany those censuses to determine the extent of foraging and loafing by individual species within each habitat.

8. Acknowledgements

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Appendix 1
Overall numbers of shorebirds and waterbirds observed in the censused Fraser River delta intertidal zone, March 1988 – February 1989

	No. of birds											
Bird groups	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Loons	114	235	845	2	2	95	274	139	198	103	76	103
Grebes	571	510	81	0	5	1 104	693	2 326	774	187	350	369
Cormorants	159	168	304	119	173	247	326	441	311	241	180	157
Swans	23	0	0	0	0	0	0	12	101	60	270	142
Geese	13 545	2 681	241	372	428	1 300	390	12 778	16 071	11 735	3 744	50
Ducks	84 693	38 695	4 629	1 210	717	11 536	39 591	117 481	173 782	132 241	78 473	28 920
Larids	6 212	5 803	2 929	3 669	2 669	15 664	11 561	2 213	4 585	3 659	3 224	14 181
Alcids	4	7	8	0	1	0	4	1	17	2	1	22
Shorebirds	53 193	155 223	3 583	3 088	59 439	5 793	7 710	101 834	81 645	54 575	93 542	14 247
Herons	165	138	187	173	159	251	234	132	183	101	56	56
Total no. of birds	158 679	203 460	12 807	8 633	63 593	35 990	60 783	237 364	277 667	202 904	179 916	58 247
Surface area (km^2)[a]	55.89	66.41	66.41	62.42	66.41	66.41	58.35	66.41	66.41	58.35	66.41	66.41

[a] Used to calculate densities of shorebirds and waterbirds in Table 1.

Distribution and abundance of Western Sandpipers, Dunlins, and Black-bellied Plovers in the Fraser River estuary

Robert W. Butler

1. Abstract

At least half a million, and perhaps as many as one million, Western Sandpipers *Calidris mauri* were estimated on a single day in 1992 on the Fraser River estuary, and up to 62 000 Dunlins *C. alpina* and 2300 Black-bellied Plovers *Pluvialis squatarola* were counted in 1989–91. Western Sandpipers migrated northward through the estuary from mid-April to mid-May and southward from late June until October. They used the entire estuary and were most numerous in late April on Brunswick Point. Large numbers of Dunlins arrived in the estuary in October and departed by mid-May. The largest numbers occurred in November in Boundary Bay. Black-bellied Plovers were present in the estuary throughout the year and were most numerous in Boundary Bay. Their winter population varied between 800 and 1800 individuals, and the nonbreeding population was about 180 individuals. The three species roosted in fields during some high tides, and some Dunlins and Black-bellied Plovers foraged there mostly from November to March.

2. Résumé

Dans l'estuaire du fleuve Fraser, il y a eu, en 1992, au moins cinq cent mille et peut-être jusqu'à un million de Bécasseaux d'Alaska *Calidris mauri* en une seule journée, selon les estimations, et de 1989 à 1991, on a dénombré jusqu'à 62 000 Bécasseaux variables *C. alpina* et 2 300 Pluviers argentés *Pluvialis squatarola*. De la mi-avril à la mi-mai 1992, la population de Bécasseaux d'Alaska a migré vers le nord, en passant par l'estuaire, et de la fin de juin jusqu'en octobre, elle a migré vers le sud. On a observé des Bécasseaux d'Alaska dans tout l'estuaire, et à la fin d'avril, ils étaient les plus nombreux à la pointe Brunswick. Les Bécasseaux variables sont arrivés en grand nombre dans l'estuaire en octobre et sont repartis à la mi-mai. On a observé les effectifs les plus élevés en novembre, dans la baie Boundary. La population de Pluviers argentés a été présente dans l'estuaire toute l'année, et les effectifs étaient surtout élevés dans la baie Boundary. En hiver, la population variait entre 800 et 1 800 individus; environ 180 individus formaient la population non reproductrice. Les trois espèces se sont rendues dans les champs pendant certaines marées hautes. Des Bécasseaux variables et des Pluviers argentés se sont nourris dans ces champs, surtout de novembre à mars.

3. Introduction

The Fraser River estuary supports the largest numbers of shorebirds of any estuary on the Pacific coast of Canada (Butler and Campbell 1987). Dunlins *Calidris alpina* and Black-bellied Plovers *Pluvialis squatarola* dominate the shorebird fauna from October to March. In April and May, they are joined by great numbers of migrating Western Sandpipers *Calidris mauri.* Small numbers of all three species use the estuary in June. From July through September, the estuary supports large numbers of postbreeding Western Sandpipers and Black-bellied Plovers migrating south for the winter.

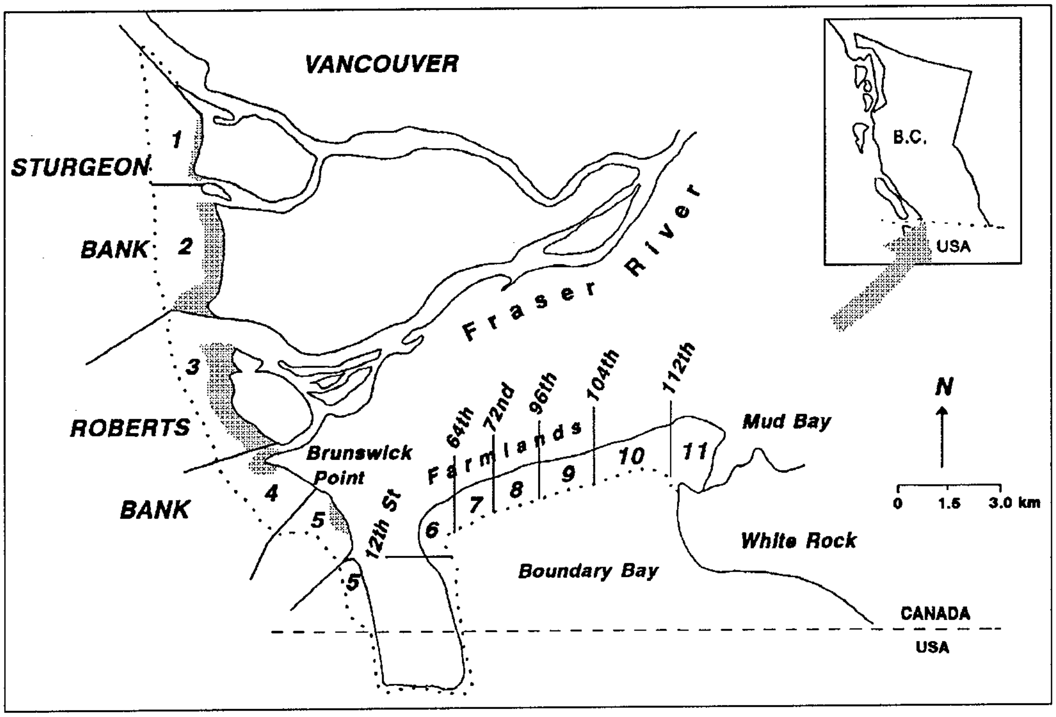
Although the Fraser River estuary qualifies as an important site under international conservation programs (Butler and Campbell 1987; Morrison et al. 1991), information on the distribution and abundance of shorebirds is limited. Vermeer, Butler, and Morgan (this volume) show that Dunlins and Western Sandpipers are more numerous in Boundary Bay than on Roberts or Sturgeon Bank and provide information on the seasonal distribution of these species in the estuary, based on once-a-month censuses. The objective here is to describe the distribution and abundance of Western Sandpipers, Dunlins, and Black-bellied Plovers on the Fraser River estuary in greater detail.

4. Study area and methods

4.1 Shorebird habitats in the Fraser River estuary

The Fraser River estuary is described by Butler and Campbell (1987). The intertidal area extending through Boundary Bay, Mud Bay, Roberts Bank, and Sturgeon Bank was divided into 11 census areas by extending an imaginary line from major roads that ended at the beach (Fig. 1). The upper intertidal zone near the dikes where shorebirds were censused was mostly fine mud on Sturgeon Bank and Roberts Bank, mostly sand in west Boundary Bay, and fine mud in east Boundary Bay and Mud Bay (Swinbanks 1979).

Figure 1
The Fraser River delta, showing the 11 areas censused for shorebirds



4.2 Distribution and abundance of shorebirds

The distribution of small sandpipers (mostly Dunlins and Western Sandpipers) was mapped on 15 days between 17 April and 5 May 1992 by the same observer in a Cessna airplane flown at an altitude of about 130 m. Censuses were flown at a 2.8-m tide. All flocks were estimated and marked on maps of the estuary. The amount of exposed intertidal zone in each census area was estimated by tracing the area of exposed mudflat between the marshes and the 2.8-m tide line on nautical charts (Kellerhals and Murray 1969; Swinbanks 1979; Hutchinson 1982; Ward et al. 1992).

The proportions of Western Sandpipers and Dunlins in sample flocks were estimated from the dikes every 1–3 days. I assumed that the proportions of each species in flocks censused from the airplane and the ground were the same.

Previous ground and air surveys had indicated that few Dunlins and Black-bellied Plovers use Sturgeon Bank (Butler and Cannings 1989; K. Summers, pers. commun.). Therefore, ground counts for these species were confined to Roberts Bank and Boundary Bay, where over 95% of Dunlins and 99% of Black-bellied Plovers were counted (Butler and Cannings 1989). The numbers of shorebirds using Boundary Bay and Roberts Bank were estimated by counting them through a telescope from dikes near the high tide line. All Black-bellied Plovers and flocks of fewer than 200 Dunlins and Western Sandpipers were counted directly. Numbers in flocks of 200–10 000 Western Sandpipers and Dunlins were counted by estimating the number of shorebirds in each successive field of view of a telescope until the entire flock had been counted. Very large flocks (>10 000) were estimated by multiplying the number of square metres of beach covered by the flock by the average number of sandpipers in several 1-m^2 plots estimated by eye. The dimensions of flocks were estimated by eye or with an odometer in a vehicle driven along the dike parallel to the flock. The accuracy of these census methods is discussed later. Ground censuses were made at least once each week in the following periods: 28 September 1989 – 11 April 1990, 29 June 1990 – 30 March 1991, and 22 April – 11 May 1991.

4.3 Accuracy of the estimates

There are at least two sources of error in the estimates of shorebird numbers. First, it was difficult to identify the species in large or distant flocks. This problem was greatest in spring, when Western Sandpipers, Least Sandpipers *Calidris minutilla*, and Dunlins were in the estuary. Least Sandpipers were disregarded in this study because they occurred in relatively small numbers. I assumed that the proportions of Dunlins and Western Sandpipers seen on the ground near the dike and during air censuses were the same: most air and ground censuses were conducted simultaneously.

The second source of error was the ability to detect and estimate shorebird flocks. Dispersed flocks of sandpipers could have been overlooked and underestimated. For example, flocks seen by observers on the ground were sometimes missed by the observer in the airplane. I assumed that the biases inherent in estimating shorebird numbers from the airplane were constant across the estuary and used the numbers to determine relative distribution in the estuary. Observers on the ground compared their estimated numbers and individually counted numbers of sandpipers about five times during most censuses. These comparisons were used by all observers to correct their tendencies to over- or underestimate the numbers of birds in flocks. The error in

Table 1
Total numbers of Western Sandpipers and Dunlins estimated from an airplane above the Fraser River estuary during spring migration, 1992

Date	Total no.	Estimated no. Western Sandpipers	Dunlins[a]
17 April	5 200	1 500	3 700
18 April	16 600	5 500	11 100
19 April	34 000	12 600	21 400
20 April	35 000	14 000	21 000
21 April	66 000	30 000	36 000
22 April	84 000	41 000	43 000
23 April	69 000	36 000	33 000
24 April	73 000	41 000	32 000
25 April	63 100	38 000	25 100
26 April	118 200	76 000	42 200
27 April	126 900	87 000	39 900
29 April	114 500	87 000	27 500
3 May	8 600	7 500	1 100
4 May	15 500	14 200	1 300
5 May	9 800	9 200	600

[a] The proportion of Dunlins was estimated from a regression equation using parameter P, derived from period counts of flocks near dikes between 16 April and 6 May, and date D, where 16 April = day 1: $P = 74.7 - 3.9\ D$, $r^2 = 0.75$, $p < 0.01$.

this method was about ±20% when estimated flock sizes were plotted against known flock sizes. The error in estimating the numbers of shorebirds in very large flocks is unknown and probably large, especially when the estimate is made from an airplane.

5. Results

5.1 Western Sandpiper

In 1992, most Western Sandpipers migrated northward through the Fraser River estuary between 19 April and 5 May. The greatest numbers in the estuary were seen between 26 and 29 April, when over 43% of all 839 400 birds censused were present (Table 1). The greatest numbers in Boundary Bay occurred between 22 and 28 April, on Roberts Bank on 28 April, and on Sturgeon Bank on 28–29 April.

All census areas in the estuary were used by sandpipers. The greatest densities each day shifted between Boundary Bay (seven days), Roberts Bank (six days), and Sturgeon Bank (three days). The greatest overall densities occurred on Roberts Bank (census areas 4 and 5), west Boundary Bay (census area 6), and Sea Island (census area 1) (Table 2).

Censuses from dikes at Boundary Bay and Brunswick Point tallied at least 500 000 sandpipers on 29 April 1992 (Table 3). Numbers declined rapidly through May, so that by 10 May nearly all sandpipers had departed the estuary. Small numbers of Western Sandpipers were present again in late June during the southward migration, and the numbers increased rapidly through July, reaching a peak of over 45 000 in August (Table 3). Fewer than 200 were counted in the estuary in September.

5.2 Dunlin

The first Dunlin flocks arrived in the Fraser River estuary in mid-September, but most arrived in October, November, and December (Tables 3 and 4). The maximum number occurred in November 1991, when 62 000

Table 2
Densities of spring migrant Western Sandpipers in 11 census areas surveyed from aircraft in April and May 1992

Census area[a]	Maximum density (no. of birds/ha)	% of maximum
1	162.7	14.9
2	32.0	2.9
3	28.6	2.6
4	215.3	19.7
5	164.9	15.1
6	207.2	18.9
7	59.7	5.5
8	46.9	4.3
9	36.1	3.3
10	58.3	5.3
11	82.1	7.5

[a] Census areas correspond to numbered areas shown in Figure 1.

Dunlins were tallied (Table 3). The winter population was estimated at 25 000–35 000 individuals.

Between 7000 and 13 000 Dunlins used fields between October and February (Table 3). Numbers declined in April, when Dunlins migrated out of the estuary (Table 3).

The average number of Dunlins per census area in Boundary Bay and on Brunswick Point followed a similar seasonal distribution as their overall numbers in the estuary: numbers were greatest in November and lowest in September (Table 4). Dunlins used the entire length of Boundary Bay (Table 5) and were most numerous and occurred in the greatest density in west Boundary Bay (census areas 8–10 in Tables 5 and 6).

5.3 Black-bellied Plover

Black-bellied Plovers used the Fraser River estuary throughout the year. They were numerous in April during their northward migration, in July and August when they flew south, and in November (Table 3). The winter (December–February) population was about 1600–1800 individuals, and the nonbreeding summer population was about 180 individuals (Table 3).

The number of plovers on beaches during the nonbreeding season (September–April) was greatest in April and lowest in February (Table 4). All census areas in Boundary Bay were used by plovers (Table 5), and densities were greatest in west Boundary Bay (census areas 8–10) (Table 6). Black-bellied Plovers departed from the estuary to fly to fields during high tides between November and March (Table 3).

6. Discussion

6.1 Seasonal abundance of shorebirds

6.1.1 Western Sandpiper

My estimate of at least 500 000 Western Sandpipers in late April is likely to be low because it was derived by multiplying the lowest estimates of the area of beach covered by the flock by the lowest density of individuals per square metre made by two independent observers. When maximum estimates were used, as many as one million Western Sandpipers might have been present. These single-day estimates in April are of the

Table 3
Maximum numbers of Dunlins, Black-bellied Plovers, and Western Sandpipers counted from the ground each month on beaches and fields on Brunswick Point and Boundary Bay, 1989–91

	Dunlins			Black-bellied Plovers			Western Sandpipers
Month	Fields	Estuary	Total	Fields	Estuary	Total	Estuary
January	13 400	12 000	25 400	340	469	809	0
February	11 000	16 000	27 000	1 405	150	1 555	0
March	1 000	17 000	18 000	360	1 035	1 395	0
April	0	12 000	12 000	0	2 300	2 300	>500 000
May	0	0	0	0	262	262	110 000
June	0	0	0	0	178	178	335
July	0	0	0	0	1 825	1 825	21 300
August	0	0	0	0	1 650	1 650	45 300
September	0	0	0	0	970	970	140
October	10 000	18 000	28 000	0	1 180	1 180	0
November	7 000	55 000	62 000	900	1 250	2 150	0
December	7 000	28 000	35 000	700	1 075	1 775	0

Table 4
Average numbers of Dunlins and Black-bellied Plovers counted in all census areas each month in Boundary Bay, 1990–91

	Dunlin			Black-bellied Plover		
Month	Mean	SE	No. of censuses	Mean	SE	No. of censuses
September	<100	–	–	213.3	146.2	3
October	3300	2500	7	499.8	193.1	6
November	9700	3600	15	388.3	192.7	6
December	7400	1500	26	327.7	85.9	15
January	3400	1000	12	303.5	73.5	4
February	5800	1900	8	90.0	29.4	4
March	5300	2100	8	203.6	80.2	12
April	2900	1100	10	809.4	178.3	12

Table 5
Average numbers of Dunlins and Black-bellied Plovers counted from vehicles in Boundary Bay from October 1989 to April 1990

	Dunlin			Black-bellied Plover		
Census area[a]	Mean	SE	No. of times seen	Mean	SE	No. of times seen
4	5290	1072	15	24	11	5
5	1950	550	17	156	97	6
6	2500	550	24	394	157	5
7	4800	1000	33	249	95	7
8	9900	3400	16	265	110	15
9	5700	1250	18	79	35	12
10	6100	1500	22	317	173	10

[a] Census areas correspond to numbered areas shown in Figure 1.

Table 6
Average densities of Dunlins and Black-bellied Plovers in Boundary Bay from October 1989 to April 1990

	Dunlin			Black-bellied Plover		
Census area[a]	Mean	SE	No. of times seen	Mean	SE	No. of times seen
4	21.7	4.4	15	1.0	<0.1	5
5	16.1	4.5	17	1.3	0.8	6
6	19.4	4.1	24	2.7	1.0	5
7	27.6	5.8	33	1.1	0.3	7
8	79.1	26.9	16	4.3	1.8	15
9	70.4	15.6	18	5.9	2.4	12
10	65.3	16.0	22	4.6	1.0	10

[a] Census areas correspond to numbered areas shown in Figure 1.

same order of magnitude as estimates for this species at other large mudflats along the Pacific coast of the United States (Herman and Bulger 1981; Page et al. 1990). Large numbers also stop at the Stikine River (pers. obs.) and Copper River deltas in Alaska (Senner 1979).

Adult Western Sandpipers migrate over the Fraser River estuary in late June through early August; juveniles occur from late July to mid-September (Butler et al. 1987). The maximum number of adults in July was lower than the maximum number of juveniles in August (Table 3). Spring migration was brief, with a rapid increase from mid-April to a peak in the last few days of April followed by a rapid decline in early May. This pattern of a sudden influx of migrants also occurs in California (Shuford et al. 1989), Oregon (Widrig 1979), Washington (Herman and Bulger 1981; Buchanan 1988), and Alaska (Senner 1979).

Most Western Sandpipers on the Pacific coast spend the winter on mudflats from California (Page et al. 1979; Shuford et al. 1989) to Peru (American Ornithologists' Union 1983). Small numbers spend the winter in Oregon (Widrig 1979), and a few stay through the winter in the Fraser River estuary (Butler and Campbell 1987). During migration, Western Sandpipers that had been marked in the winter as far away as Peru, Panama, and California passed over the Fraser River estuary within a two-week period in April (unpubl. data).

6.1.2 *Dunlin*

The seasonal occurrences of Dunlins in the Fraser River estuary (Table 3) and on the Washington (Buchanan 1988) and California (Page et al. 1979; Shuford et al. 1989) coasts appear similar. Dunlins increased rapidly in October to a peak in November and declined rapidly in April. Dunlins marked in Alaska were observed to make a 24- to 28-hour flight from Alaska to Oregon and California in autumn (R. Gill, Jr., pers. commun.).

During the winter, Dunlin numbers declined after November in California (Shuford et al. 1989) and in the Fraser River estuary (this study). Holmes (1966) suggested that their decline between mid-January and mid-February in California resulted from a slow, northward movement along the coast. Dunlins were observed to be most numerous on the Oregon coast in February (Widrig 1979), which supports Holmes's (1966) hypothesis. However, an increase was not detected in Puget Sound, Washington (Buchanan 1988), or in the Fraser River estuary (Table 3). Alternatively, Page (1974) and Gerstenberg (1979) showed that the midwinter declines of Dunlins on the coast of California resulted from movements to inland areas rather than from their northward migration along the coast. Dunlins in the present study shifted to upland foraging sites in winter, consistent with Page's (1974) observations. However, Dunlins vacated the estuary and uplands of the Fraser River estuary during about two weeks in February 1991 when the estuary was covered in ice and returned in March (pers. obs.). Therefore, Dunlins seem capable of shifts of at least several kilometres in their distribution during the winter.

6.1.3 Black-bellied Plover

The seasonal abundance of Black-bellied Plovers during southward migration on the Pacific coast is not consistent between sites. In the Fraser River estuary, plover numbers peaked in July, August, and November (Table 3). In Washington, plovers increased each month from June through February (Buchanan 1988), whereas in Oregon, plover numbers peaked in August, September, and October (Widrig 1979). In California, plovers were numerous in August, September, and October (Shuford et al. 1989). The greatest abundance during the year occurred in April in both the Fraser River estuary (Table 3) and Bolinas Lagoon, California (Shuford et al. 1989), during October in Oregon, and during February in Washington (Buchanan 1988).

Black-bellied Plovers flew to farmlands when high tides inundated intertidal areas in November through March (Table 3). Plovers roosted and foraged mostly in ploughed fields within 2 km of the estuary (Butler 1992). The percentage of foraging individuals increased to a peak in the last two weeks of January, which suggests that plovers rely on fields as foraging habitat in winter (Butler 1992).

6.2 Distribution of shorebirds

The Western Sandpiper, Dunlin, and Black-bellied Plover are found mostly on mudflats and sandflats across their range (Gerstenberg 1979; Page et al. 1979; Cramp and Simmons 1983; Buchanan 1988). In the Fraser River estuary, Vermeer, Butler, and Morgan (this volume) found that Western Sandpipers and Dunlins were widespread on Sturgeon Bank, on Roberts Bank, and in Boundary Bay, with greatest densities in Boundary Bay. In this more detailed study, the Western Sandpipers were found on all mudflats, including those adjacent to brackish marshes on Sturgeon Bank and Roberts Bank and adjacent to salt marshes in Boundary Bay and Mud Bay. However, the species was most numerous and present in greatest densities on beaches on Brunswick Point, followed by those in Boundary Bay. Dunlins and Black-bellied Plovers were most numerous and present in greatest densities in Boundary Bay.

The mudflats on Sturgeon Bank are uncovered by ebbing tides later than mudflats elsewhere in the estuary. This might explain why shorebirds were less numerous on Sturgeon Bank. Roberts Bank consists mostly of very fine mud and clay and supports large numbers of amphipods (Swinbanks 1979), which are the principal prey of Western Sandpipers (K. Vermeer, unpubl. data). The beaches in Boundary Bay are a mixture of sand and mud (Luternauer 1976; Swinbanks 1979) and support large numbers of gastropods, bivalves, and marine worms (Swinbanks 1979), which are eaten by Dunlins (E. McEwan and K. Fry, unpubl. data). The diet of Black-bellied Plovers in the Fraser River estuary has not been studied, but elsewhere they eat chiefly polychaetes, molluscs, and crustaceans (Cramp and Simmons 1983). Sturgeon Bank is mostly sand except for a narrow band of mud near the marshes. Western Sandpipers and Dunlins might find difficulty in distinguishing between prey items and similar-sized grains of sand (Quammen 1982).

7. Acknowledgements

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Abundance patterns of Trumpeter and Tundra swans on the Fraser River delta, B.C.

W. Sean Boyd

1. Abstract

Swan populations in the Pacific Northwest increased exponentially at 7% per year during the 1970s and 1980s. Trumpeter Swans *Cygnus buccinator* accounted for most of the increase. Swan numbers near Ladner on the Fraser River delta grew at 15% per year, from 50 birds in the early 1970s to over 700 in the early 1990s. Recruitment of young (at 20%) probably accounted for much of the observed increase. I estimate that swans are responsible for 6–8% of the current grubbing impact on the bulrush *Scirpus americanus* zone on the Fraser River delta. Lesser Snow Geese *Anser c. caerulescens* account for the rest. At their present rate of increase, however, swans could reach 4000 birds by the year 2006 and account for 32–38% of all grubbing. In addition, total foraging intensity would increase by 38–50% over the present level. Bulrush mass would be reduced further, and swans and Lesser Snow Geese might be forced to disperse out of the area or to rely increasingly on farm crops. Studies are proposed to monitor swan abundance and movements and the interaction between swans and their preferred habitats on the delta.

2. Résumé

Les populations de cygnes du nord-ouest du Pacifique ont augmenté exponentiellement de 7 % par année durant les années 1970 et les années 1980. La plus grande partie de cette augmentation est due au Cygne trompette *Cygnus buccinator*. La population de cygnes près de Ladner dans le delta du fleuve Fraser a augmenté de 15 % par année; de 50 individus au début des années 1970, elle est passée à plus de 700 au début des années 1990. Le recrutement de jeunes (20 %) compte probablement pour beaucoup dans l'augmentation observée. Nous estimons que les cygnes sont responsables de 6 à 8 % du déracinement du scirpe d'Amérique *Scirpus americanus* dans le delta du fleuve Fraser; la Petite Oie des neiges *Anser c. caerulescens* est responsable du reste. Cependant, à ce taux d'accroissement, la population de cygnes pourrait atteindre 4 000 individus d'ici l'an 2006 et être ainsi responsable de 32 à 38 % du déracinement. De plus, le broutage total pourrait être de 38 à 50 % supérieur à ce qu'il est actuellement. La biomasse de scirpes diminuerait d'autant, ce qui forcerait les cygnes et les Petites Oies des neiges à se disperser en dehors de cette zone ou à augmenter leur consommation de plantes cultivées. On propose de faire des études pour surveiller l'abondance des cygnes et les déplacements des populations ainsi que les interactions entre les cygnes et les habitats qu'ils préfèrent dans le delta.

3. Introduction

Trumpeter Swan *Cygnus buccinator* numbers in North America declined to a historical low in the 1930s as a result of excessive hunting (Pacific Flyway Council, unpubl. data in the 1992 Trumpeter Swan management plan). The species was classified as threatened, conservation efforts were initiated, and Trumpeter Swans responded by increasing in abundance throughout their range.

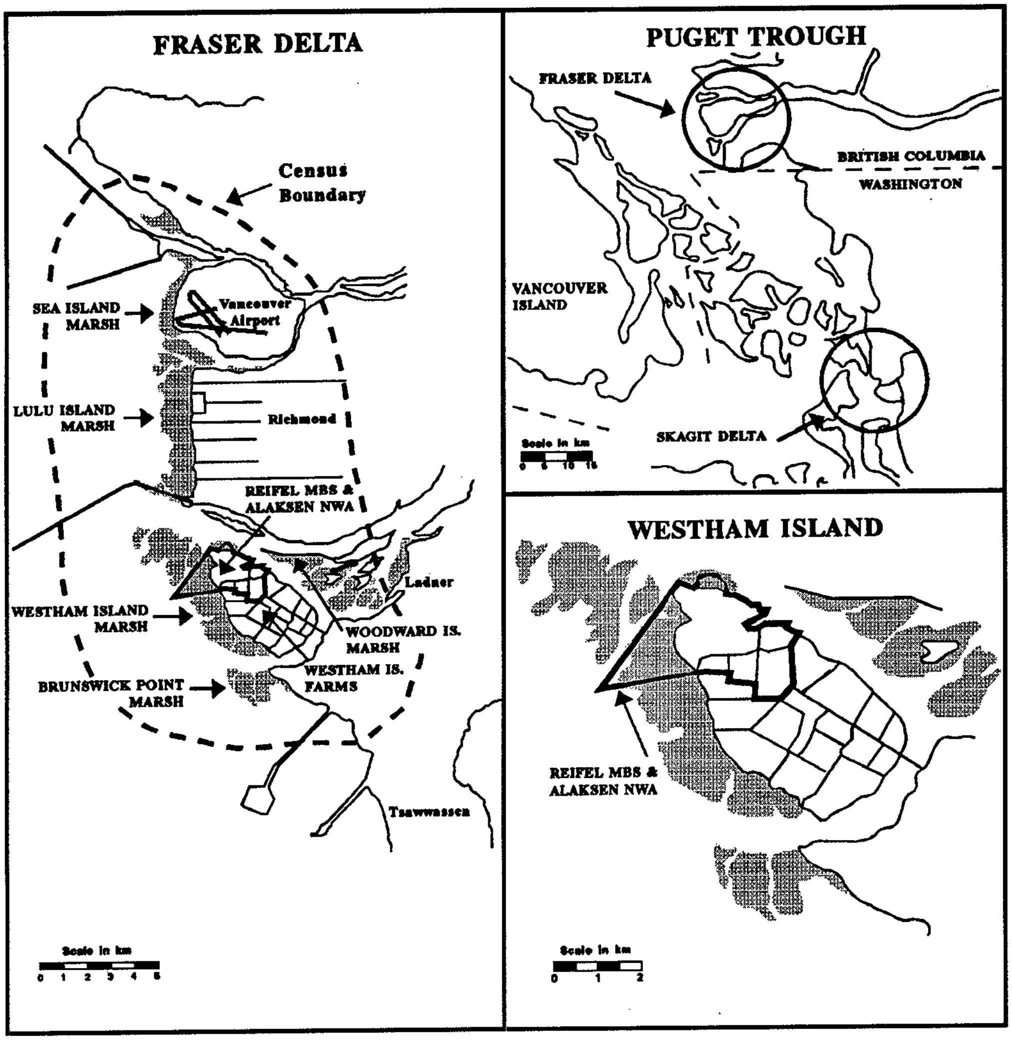
Trumpeter Swans, Tundra Swans *Cygnus columbianus*, and Lesser Snow Geese *Anser c. caerulescens* overwinter on the Fraser River delta. The birds eat cover crops and waste potatoes during the day and forage on bulrush *Scirpus americanus* rhizomes on the foreshore marshes at night. Rhizomes have already been depleted in some parts of the delta. Large and increasing populations of grubbing herbivores like swans and geese will decrease plant biomass further. That, in turn, could affect abundance and habitat use patterns on the delta.

The objectives of this paper are to (1) describe the temporal and spatial patterns of abundance of swans; (2) compare their rate of population growth with that in other areas in the Pacific Northwest; (3) estimate the recruitment rate of young into the population; and (4) forecast abundance and potential grubbing intensity on the Fraser River delta.

4. Methods

From early October 1987 to late April 1992, I conducted weekly aerial surveys of swans on the Fraser River delta (Fig. 1). Flocks of more than 30 birds were photographed, and estimates were made of smaller groups and family units. Photos were taken with a 110-mm lens from a Cessna 180 flown at an altitude of 400 m. I also used the photos to determine the number of immatures (grey birds) and adults (white birds) in the population.

Figure 1
Fraser River delta. The study area includes the subunits outlined plus adjacent farmland at Brunswick Point, Richmond, and Sea Island (MBS = Migratory Bird Sanctuary; NWA = National Wildlife Area).



To estimate peak populations, I used a distance-weighted least squares function (Wilkinson 1990) to smooth plots of bird abundance against Julian date.

I assumed that swan abundance remained constant between surveys and calculated the number of swan-days with the following formula:

$$\Sigma N_i \frac{(D_{i+1} - D_{i-1})}{2}$$

where N_i = population at day i, D_{i+1} = next survey date (day), and D_{i-1} = previous survey date. Swan-days corresponded to the intensity of use of the delta; for example, 10 swan-days was equivalent to one swan present on the delta for 10 days or 10 swans present for one day.

Historical population trends in the Pacific Northwest were determined from data collected during Christmas Bird Counts (CBCs) (National Audubon Society 1974–91) and unpublished data from the Pacific Flyway Council's 1992 Trumpeter Swan management plan. I regressed the natural logarithm of abundance against year. The slope of the regression corresponded to the growth rate of the population (Begon and Mortimer 1986).

I tested for differences in the proportion of juveniles across years and across the Fraser River delta. Each proportion was computed using a combined ratio estimate (Cochran 1977). Pair-wise comparisons were made using the Behrens-Fisher test modified with Bonferroni's method (Zar 1984).

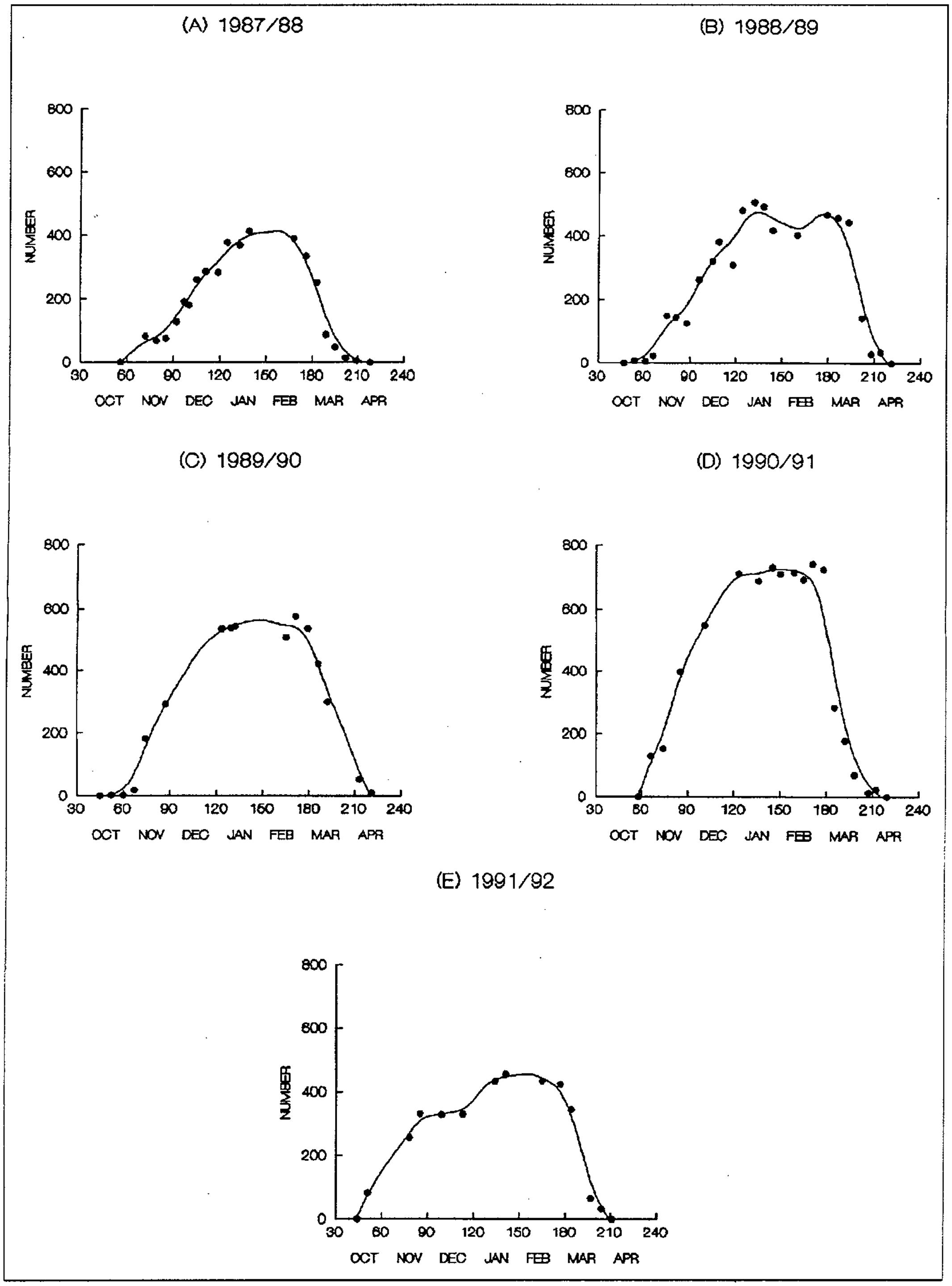
5. Results and discussion

5.1 Temporal and spatial patterns

Swans arrived on the Fraser River delta in early November (Fig. 2; Appendix 1). Numbers peaked by early to mid-January, remained stable to the end of February, and then declined by early March. By the end of March, all swans had left the delta.

Marshes at Brunswick Point, Westham Island, and Lulu Island each supported between 15% and 20% of the mean number of swan-days on the delta (Fig. 3E; Appendix 1). Farms at Westham Island supported most of the swan-days (45%). Swans partially shifted from the marshes at Brunswick Point and along Westham Island to Westham Island farms in 1988–89 (Fig. 3A–D). The shift

Figure 2
Swan counts on the Fraser River delta by year: (A) 1987–88, (B) 1988–89, (C) 1989–90, (D) 1990–91, and (E) 1991–92. Day after 1 September and months are given on the horizontal axis.



corresponded to the first winter (1988–89) in which large numbers of swans foraged on waste potatoes, a behaviour that continued for the remainder of the study period (pers. obs.).

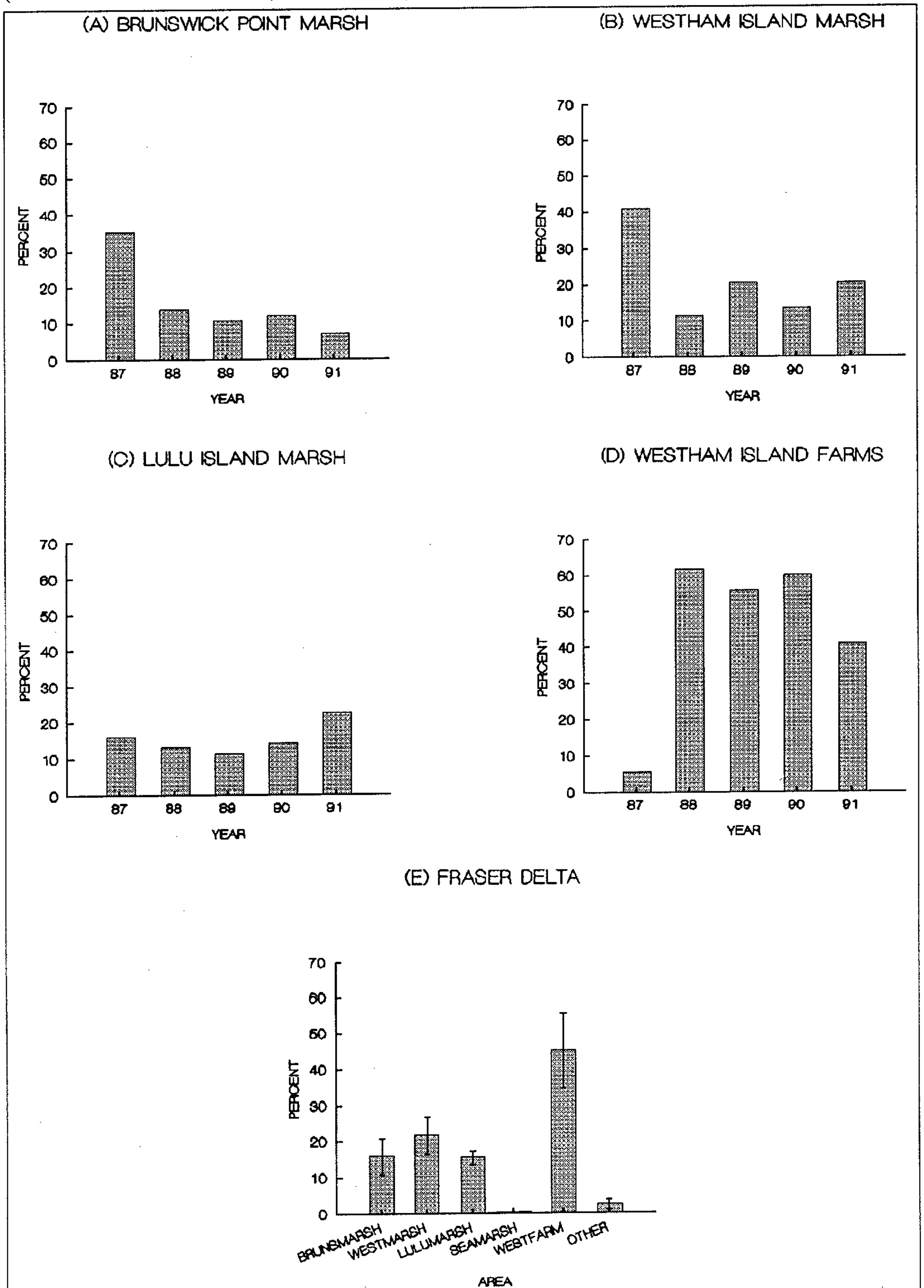
5.2 Abundance and trend

Peak midwinter counts of swans on the Fraser River delta rose steadily from 413 in 1987–88 to a high of 730 in 1990–91 (Fig. 4A). The reason for the decline to 456 swans in 1991–92 is unknown, but I suspect that mild weather throughout the winter resulted in some birds dispersing inland.

Swan-days followed the same pattern as peak abundance (Fig. 4A and B). A linear regression describing the relation was highly significant ($r^2 = 0.99$, $p < 0.001$, $n = 5$; Fig. 4C), suggesting that the temporal pattern of abundance on the delta was consistent across years. It also means that peak abundance is probably a good predictor of swan foraging intensity over the entire winter.

Only 50 swans were recorded during CBCs at Ladner on the Fraser River delta in the early 1970s, but

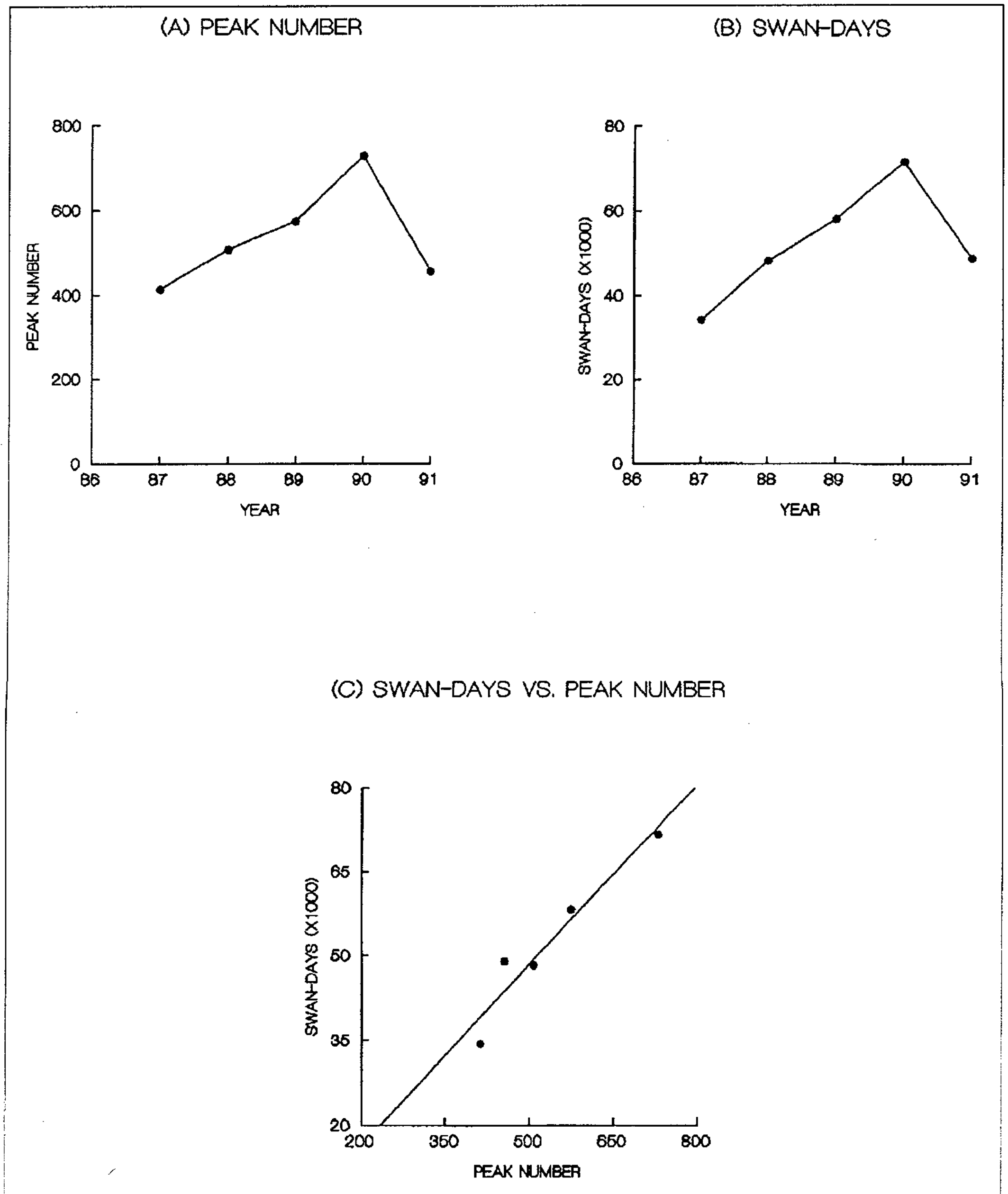
Figure 3
Proportion of total swan-days in different areas of the delta by year: (A) Brunswick Point marsh (Brunsmarsh), (B) Westham Island marsh (Westmarsh), (C) Lulu Island marsh (Lulumarsh), and (D) Westham Island farms (Westfarm). (E) Means (± SE) for the above areas across all years (Seamarsh = Sea Island marsh). Notation for years: 87 = 1987–88, 88 = 1988–89, etc.



almost 600 birds were present by the early 1990s (Fig. 5A). The Ladner counts from 1987–88 to 1990–91 were lower than my counts because the census areas did not coincide. Also, in some years the CBC (late December) occurred before swan numbers had peaked. Aerial surveys recorded only 87 and 69 swans on the delta during two January 1977 surveys (G. Kaiser and R. McKelvey, pers. commun.); those numbers were close to the Ladner CBC (Fig. 5A).

Swan numbers at Comox on Vancouver Island and at Bellingham (Wash.) increased throughout the 1970s and 1980s (Fig. 5B). Numbers increased rapidly on the Skagit River delta in the late 1980s, from 30 birds in 1986–87 to 1262 birds in 1988–89.

Figure 4
(A) Peak number of swans, (B) number of swan-days, and (C) linear relationship between the two indices on the Fraser River delta. Notation for years: 87 = 1987–88, 88 = 1988–89, etc.



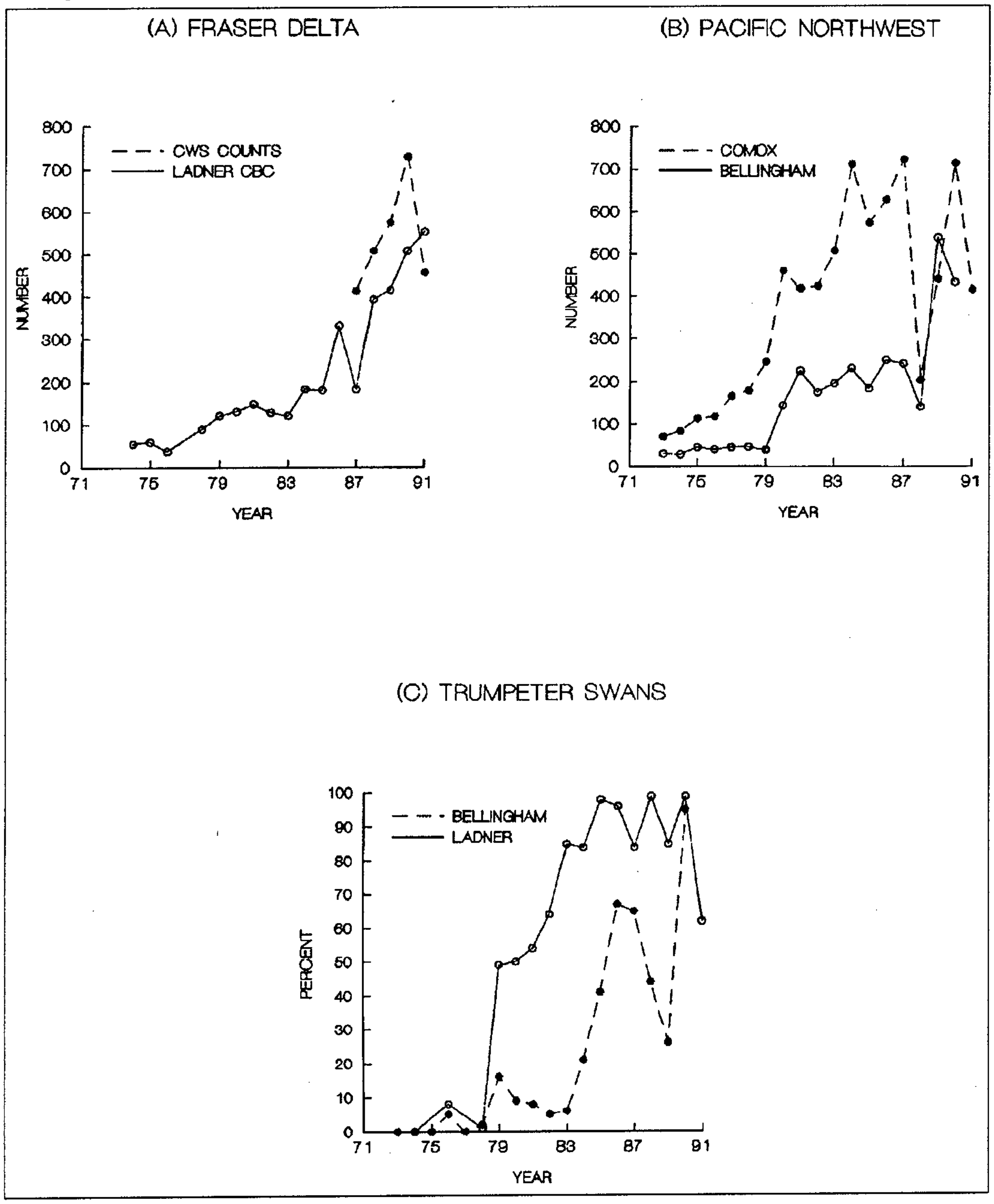
Trumpeter Swans accounted for most of the increase in swan numbers. They always comprised close to 100% of the birds at Comox, and their proportions at Ladner and Bellingham increased substantially in the 1980s (Fig. 5C). R. McKelvey (unpubl. data) estimated that Trumpeter Swans comprised 92% of one flock of swans on the Alaksen National Wildlife Area (NWA) in March 1989 ($n = 277$) and 70% of several flocks on Westham Island in December 1989 and January 1990 ($n = 1433$).

Trumpeter Swan populations have increased throughout the Pacific Northwest in recent years. Winter counts coordinated by the Washington State Department of Wildlife showed a 250% increase on the Skagit River delta between 1978–79 and 1990–91 (Pacific Flyway Council, unpubl. data). On Vancouver Island, McKelvey et al. (1991) recorded a 300% increase between 1970–71 and 1988–89. Surveys by the U.S. Fish and Wildlife Service in Alaska revealed a 450% increase in the postbreeding population between 1968 and 1990.

Plots of the natural logarithm of abundance against year were linear, suggesting that the above Trumpeter Swan populations increased exponentially during the 1970s and 1980s (Fig. 6A). All regressions were highly significant, and all suggested the same growth rate of 7% per year (Table 1). CBCs of swans conducted over smaller areas showed higher but more variable growth rates (from 12 to 18%) (Fig. 6B–D; Table 1). The swan population on the Fraser River delta grew at 15% per year.

Swans may have reached the carrying capacity of the Comox CBC census area by the mid-1980s (Fig. 6D). A linear model was significant for the first 12 years of counts ($r^2 = 0.97$, $p < 0.001$, slope = 23%), but numbers did not increase after 1984. The entire data set was best

Figure 5
(A) Swan numbers at Ladner from Christmas Bird Counts (CBCs) plus Canadian Wildlife Service peak counts (note: Ladner CBC for 1977 was not available), (B) swan numbers from the CBCs at Comox and Bellingham, and (C) the proportion of Trumpeter Swans in the counts at Ladner and Bellingham. Notation for years: 75 = 1975–76, 79 = 1979–80, etc.



described by a quadratic model with an asymptote of about 600 birds ($r^2 = 0.85$, $p < 0.001$, $n = 19$).

5.3 Recruitment

The mean proportion of immatures in the swan population on the Fraser River delta (weighted by sample size) ranged from 16.3 to 23.7% over the study period (overall mean ± SE = 19.6 ± 1.1%, n = 5 years) (Fig. 7A and B; Appendix 2). Recruitment was similar for Trumpeter Swans on the Skagit River delta, on Vancouver Island, and in Alaska (Table 2). A recruitment rate of about 20% minus a natural mortality rate of 5% could have accounted for most of the population growth observed on the Fraser River delta (15%).

The proportion of young differed across the delta and across years. Swans had fewer immatures at Lulu Island than at other parts of the delta (Fig. 7A; $p < 0.05$, years pooled), and 1990–91 had a lower proportion than 1991–92 (Fig. 7B; $p < 0.05$, areas pooled).

5.4 Forecast

By the year 2006, the best estimate of swan abundance in the Ladner CBC is 4000 birds, provided the population continues to grow at 15% per year (i.e., no density-dependent factors emerge) (Fig. 8A and B). Swans are responsible for 6–8% of the current grubbing impact on bulrush (see Appendix 3 for calculations). If the above forecast is realized and Lesser Snow Goose numbers

Figure 6
(A) Linear regression of (log) numbers against year using census data for three different Trumpeter Swan populations in the Pacific Northwest (Alaska, Vancouver Island, and Skagit). (B)–(D) Log numbers plotted against year using CBC data for Ladner, Bellingham, and Comox. Notation for years: 75 = 1975–76, 79 = 1979–80, etc.

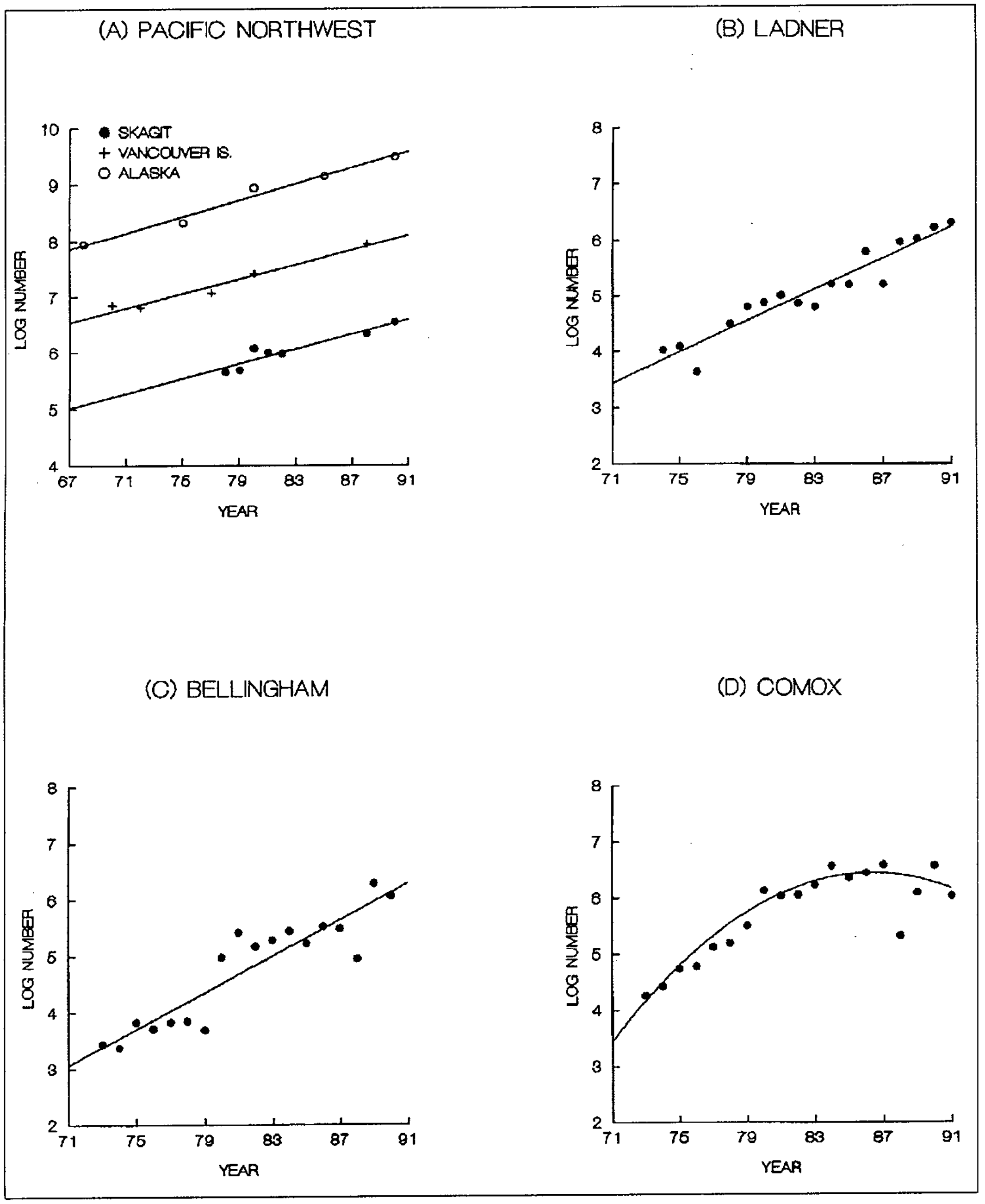


Table 1
Linear regressions of the logarithm of swan abundance against year for populations in the Pacific Northwest

Location (and type of count)	No. of years	r^2	p	R^a (%)	Period
Skagit (winter)	7	0.88	0.002	7	1978–79 to 1990–91
Vancouver (winter)	5	0.96	0.003	7	1970–71 to 1988–89
Alaska (breeding ground)	5	0.98	0.001	7	1968 to 1990
Ladner (Christmas)	17	0.91	<0.001	15	1973–74 to 1991–92
Comox (Christmas)	19	0.64	<0.001	12[b]	1973–74 to 1991–92
Bellingham (Christmas)	18	0.83	<0.001	18	1973–74 to 1990–91

[a] R is the estimated annual rate of population growth (see Methods).
[b] This estimate of R includes all years; the data were split into two parts — a growth phase (R = 23%) between 1973–74 and 1984–85 and a stable phase (R = 0%) from 1985–86 to 1991–92.

Figure 7
Percent young in the swan population on the Fraser River delta (A) by area and (B) by year. Lowercase letters denote significant differences at $p < 0.05$. Notation for years: 87 = 1987–88, 88 = 1988–89, etc.

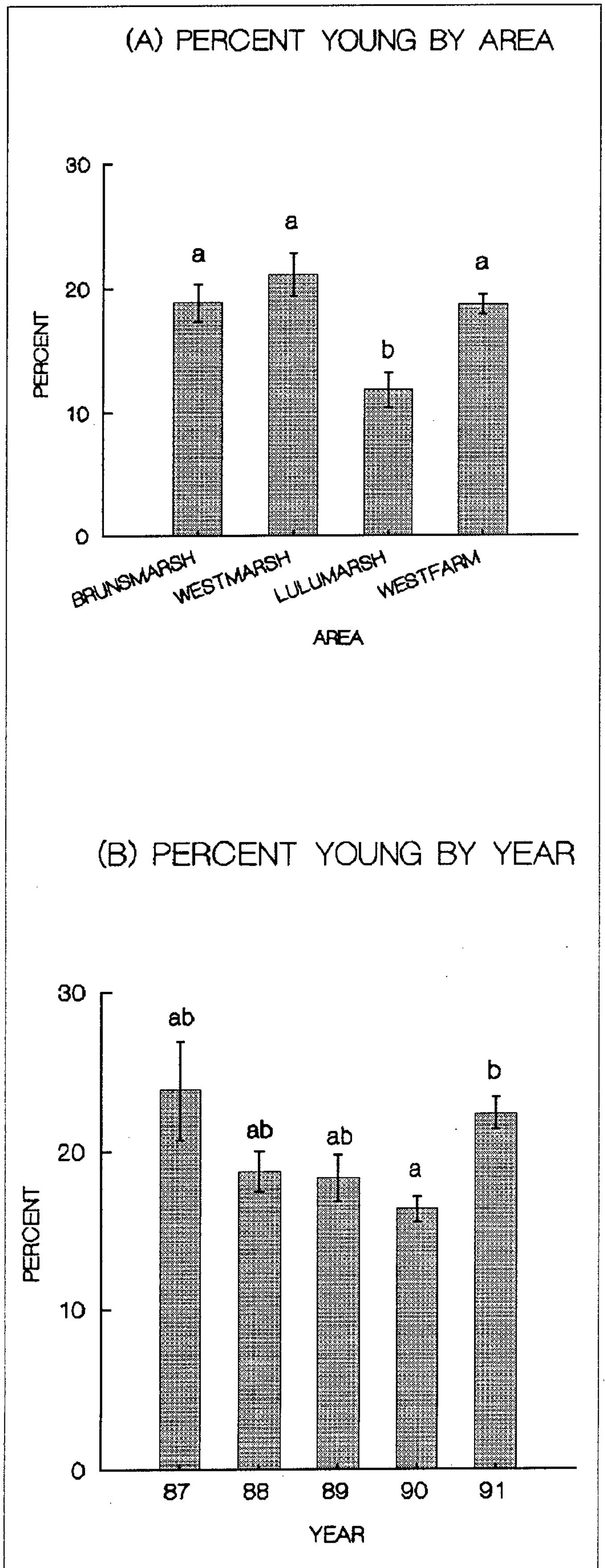
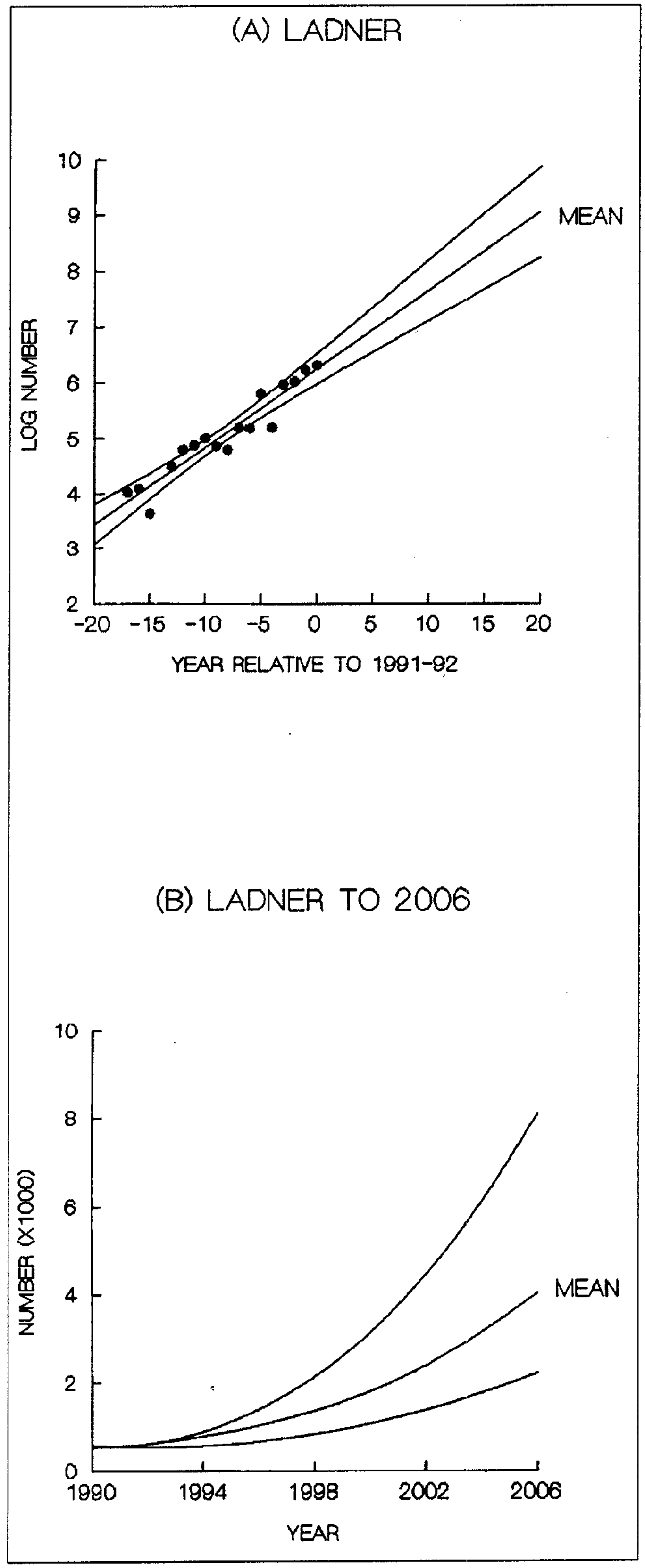


Figure 8
The potential future trend in swan numbers on the Fraser River delta: (A) extension of the linear regression of (log) numbers against year (plus 95% confidence limits), and (B) predicted mean with upper and lower 95% confidence limits



remain constant, swans could account for 32–38% of all grubbing on the delta by the year 2006. Also, total

Table 2
Proportion of young in different wintering populations of Trumpeter Swans[a]

	% young ($\bar{x} \pm$ SE)[b]	
Location	Recent (1987–88 to 1991–92)	Long-term (1977–78 to 1991–92)
Fraser River delta	19.6 ± 1.1 (5)	N/A
Vancouver Island	17.1 ± 1.8 (5)	18.8 ± 1.9 (12)
Skagit River delta	19.1 ± 2.3 (5)	20.5 ± 1.6 (15)
Alaska	22.9 ± 0.5 (5)	23.8 ± 2.1 (12)

N/A = not available

[a] All data from Groves and Conant (1991).
[b] Number of years is shown in parentheses.

foraging intensity on bulrush rhizomes would increase by 38–50% over the present level. Bulrush mass would decline, and that, in turn, could result in increased foraging on local farms, dispersion out of the study area, or lower recruitment and survival rates. Abundance patterns and habitat interactions must therefore be understood before we can develop management prescriptions for swans and geese on the Fraser River delta.

6. Recommendations

The following studies are recommended to further our understanding of the wintering ecology of swans on the Fraser River delta:

1. Monitor peak swan populations and swan recruitment rates. Continue to census swans during the January–February period. The proportion of young and the proportion of Trumpeter Swans in the population should also be determined.
2. Monitor the interaction between swans, Lesser Snow Geese, and bulrush rhizomes. Plant data should be collected from permanent stations in the marsh. The trend in rhizome mass will indicate if consumption exceeds plant production. Detailed observations of swan grubbing versus goose grubbing (locations and depths in the bulrush zone, timing, etc.) are needed to assess differences in foraging impact.
3. Determine the amount of swan movement between the study area and other locations in the Puget Trough. A banding effort using neck bands or radio transmitters would be required. Site fidelity within and between years and habitat use should be assessed.
4. Monitor the interaction between swans and farm crops. Types and locations of preferred crops and the effect of swan foraging should be measured.
5. Enhancement techniques, such as fertilization and transplanting, should be investigated to determine the potential for increasing the carrying capacity of the bulrush zone.

7. Acknowledgements

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Appendix 1

Swan numbers on the Fraser River delta by date and area, and the proportion of swans counted off air photos, 1987–88 to 1991–92

	No. of swans												
Date	Brunswick Point fields	Westham Island fields	Alaksen NWA fields	Brunswick Point marsh	Westham Island marsh	Reifel Refuge marsh	Outer Island marsh	Lulu (S) Island marsh	Lulu (N) Island marsh	Sea Island marsh	Total count	Total no. of swans from photos	% of total count from photos
1987–88													
27 Oct. 1987											0	0	0
12 Nov. 1987				42	17			12	11		82	42	51
19 Nov. 1987				60	6	1					67	0	0
25 Nov. 1987				25	10	10			30		75	0	0
02 Dec. 1987				41	60	10	6	7	3		127	0	0
07 Dec. 1987	25	5		40	65	9		44	3		191	0	0
10 Dec. 1987	35	103		17	4	12		4	5		180	0	0
15 Dec. 1987		35		78	58	20		70			261	0	0
21 Dec. 1987				97	110	14		63	3		287	97	33
29 Dec. 1987				106	100	32		46			284	106	37
04 Jan. 1988				135	186			56			377	0	0
12 Jan. 1988		4		120	137	50		31	26	1	369	0	0
18 Jan. 1988		28		110	202	10		42	13	8	413	352	85
16 Feb. 1988		27		205	93	11		48	6		390	205	52
24 Feb. 1988				150	95	40		14	37		336	0	0
02 Mar. 1988		10		24	145	35		29	9		252	145	57
08 Mar. 1988	22			45	18	2					87	0	0
14 Mar. 1988				40	6	2					48	0	0
21 Mar. 1988				14							14	0	0
28 Mar. 1988				4		2					6	0	0
06 Apr. 1988											0	0	0
1988–89													
24 Oct. 1988							8				8	0	0
31 Oct. 1988				6							6	0	0
06 Nov. 1988		10		7				3	3		23	0	0
15 Nov. 1988		35		40	11			41	22		149	0	0
21 Nov. 1988		40	4	52		5		43			144	0	0
28 Nov. 1988		36		38	10			20	21		125	0	0
06 Dec. 1988		125		53	36	2		5	42		263	0	0
15 Dec. 1988		169		70	36	4			44		323	275	85
19 Dec. 1988	6	266		33	19	2			56		382	266	69
28 Dec. 1988		228		39		2			41		310	228	73
03 Jan. 1989	7	353	17	38	12	4		3	49		483	440	91
11 Jan. 1989		342		80	27	4		24	31		508	369	72
17 Jan. 1989		411		32	1	4		34	13		495	443	89
23 Jan. 1989		72		110	185	4		28	20		419	419	100
08 Feb. 1989				147	175	39		43			404	404	100
27 Feb. 1989	19	274	95	7	17	1		53	3		469	274	58
06 Mar. 1989		332	97	4	13			12	2		460	429	93
13 Mar. 1989		82	321		5			23	14		445	403	90
22 Mar. 1989		73	65	5							143	138	96
28 Mar. 1989			7	16		4		2	1		30	0	0
03 Apr. 1989									35		35	0	0
10 Apr. 1989											0	0	0
1989–90													
23 Oct. 1989						2					2	0	0
31 Oct. 1989						2					2	0	0
07 Nov. 1989				12				7			19	0	0
14 Nov. 1989	13	102	31	12	22	2					182	0	0
27 Nov. 1989		210	18	15	5			22	22		292	228	78
02 Jan. 1990		116	187	80	113			20	19		535	535	100
08 Jan. 1990	10	400	59		16	2		32	19		538	514	95
11 Jan. 1990	7	424		32	15			50	16		544	488	89
13 Feb. 1990	36	244	12	19	128		6	52	10		507	462	91
19 Feb. 1990				219	270	2		72	12		575	561	97
27 Feb. 1990	8	219	11	42	190	2		57	7		536	451	84
06 Mar. 1990	5	349		20	4	2	12	19	9		420	349	83
12 Mar. 1990		134		24	141						299	275	91
02 Apr. 1990								27	28		55	0	0
10 Apr. 1990								5	5		10	0	0
01 May 1990								1	1		2	0	0

Continued

Appendix 1 *(continued)*
Swan numbers on the Fraser River delta by date and area, and the proportion of swans counted off air photos, 1987–88 to 1991–92

	No. of swans												
Date	Brunswick Point fields	Westham Island fields	Alaksen NWA fields	Brunswick Point marsh	Westham Island marsh	Reifel Refuge marsh	Outer Island marsh	Lulu (S) Island marsh	Lulu (N) Island marsh	Sea Island marsh	Total count	Total no. of swans from photos	% of total count from photos
1990–91													
29 Oct. 1990											0	0	0
06 Nov. 1990			80	12	6			16	16		130	32	25
14 Nov. 1990		90		19		40		2	2		153	129	84
26 Nov. 1990		337		12	20			27	2		398	337	85
11 Dec. 1990		481		30	17	4		16			548	510	93
02 Jan. 1991	30	505		14	12	60		87	4		712	697	98
15 Jan. 1991		542		9	52	2		40	41	2	688	680	99
24 Jan. 1991		580		23		32		92	2	2	731	714	98
29 Jan. 1991		58		302	249			101			710	710	100
08 Feb. 1991		562		20	51			31	51		715	712	99
13 Feb. 1991		477		55	55	17		18	71		693	693	100
19 Feb. 1991		634		2	21	2		78	3	2	742	730	98
26 Feb. 1991		73		223		275		76	76	2	725	708	98
05 Mar. 1991		96		69		52		32	32	3	284	244	86
12 Mar. 1991			13	46	23	13		43	41		179	173	97
18 Mar. 1991				36				18	17		71	71	100
27 Mar. 1991				7				4	2		13	13	100
02 Apr. 1991				10		5		5	5		25	0	0
09 Apr. 1991											0	0	0
1991–92													
15 Oct. 1991											0	0	0
22 Oct. 1991					12			5	66		83	83	100
18 Nov. 1991		116		50	12			40	39		257	245	95
25 Nov. 1991		228						52	52		332	328	99
09 Dec. 1991		241				11		38	39		329	319	97
23 Dec. 1991		199		9	7	31		10	75		331	301	88
13 Jan. 1992	118	173		9	27	33	3	4	66		433	285	66
20 Jan. 1992	110			18	169	69		47	43		456	425	93
13 Feb. 1992	39	205		20		29		28	75	39	435	407	94
25 Feb. 1992		252	22	65	4	19		9	53		424	387	91
03 Mar. 1992			3	44	50	243	2	2	2		346	330	95
16 Mar. 1992	2		7	28		3		13	13		66	16	24
23 Mar. 1992				2	10				20		32	0	0
06 Apr. 1992											0	0	0

NWA = National Wildlife Area

Appendix 2
Proportion of young in the swan population on the Fraser River delta by date and area, 1987–88 to 1991–92

Date	% young[a] Westham Island fields	Brunswick Point marsh	Westham Island marsh	Lulu Island marsh	Other	Fraser River delta
1987–88						
21 Dec. 1987		18.6 (97)				18.6 (97)
18 Jan. 1988		9.0 (78)	32.0 (175)	18.2 (44)		23.9 (297)
16 Feb. 1988		22.4 (205)				22.4 (205)
02 Mar. 1988			28.8 (146)			28.8 (146)
1988–89						
15 Dec. 1988	30.8 (169)		37.8 (37)	3.2 (31)		28.3 (237)
19 Dec. 1988	16.5 (266)					16.5 (266)
28 Dec. 1988	19.8 (167)					19.8 (167)
03 Jan. 1989	13.4 (351)			17.6 (34)		13.8 (385)
11 Jan. 1989	19.8 (342)	13.1 (84)		10.5 (19)		18.2 (445)
17 Jan. 1989	18.0 (412)	18.8 (32)	50.0 (4)			18.3 (448)
23 Jan. 1989	20.8 (72)	7.1 (14)	12.7 (189)	11.5 (26)		14.3 (301)
08 Feb. 1989		18.5 (27)	22.4 (143)			21.8 (170)
06 Mar. 1989	21.5 (429)		28.6 (7)			21.6 (436)
1989–90						
27 Nov. 1989	24.3 (144)					24.3 (144)
02 Jan. 1990	18.2 (296)	20.6 (68)	28.2 (85)			20.5 (449)
08 Jan. 1990	18.8 (462)			0.0 (35)		17.5 (497)
11 Jan. 1990	14.2 (424)	9.5 (21)		6.3 (32)		13.4 (477)
13 Feb. 1990	22.2 (63)		31.6 (19)	5.9 (51)		17.3 (133)
27 Feb. 1990	17.6 (255)	9.5 (21)	21.2 (80)			18.0 (356)
06 Mar. 1990	16.3 (349)					16.3 (349)
12 Mar. 1990	39.8 (133)		10.3 (117)			26.0 (250)
1990–91						
26 Nov. 1990	18.7 (337)					18.7 (337)
11 Dec. 1990	17.1 (481)	0.0 (9)	25.0 (12)			16.9 (502)
02 Jan. 1991	17.2 (505)	28.6 (14)	25.0 (72)	7.7 (91)	30.0 (30)	17.6 (712)
15 Jan. 1991		22.2 (9)	24.1 (54)	8.4 (83)		15.1 (146)
24 Jan. 1991	19.0 (580)	27.3 (11)	15.6 (32)	18.7 (91)		18.9 (714)
29 Jan. 1991	15.5 (58)	21.2 (99)	17.1 (234)	7.6 (79)		16.2 (470)
08 Feb. 1991	13.0 (562)	25.0 (20)	10.4 (48)	13.4 (82)		13.2 (712)
13 Feb. 1991	13.8 (477)	29.1 (55)	8.5 (59)	11.2 (89)		14.3 (680)
19 Feb. 1991	15.1 (634)		52.4 (21)	13.3 (75)		16.0 (730)
26 Feb. 1991	8.2 (73)	24.2 (219)	16.7 (264)	7.2 (152)		16.1 (708)
05 Mar. 1991	30.2 (96)	12.1 (66)	16.3 (43)	0.0 (39)		18.0 (244)
1991–92						
18 Nov. 1991	27.6 (116)	14.0 (50)		11.4 (79)		19.6 (245)
25 Nov. 1991	25.0 (228)					25.0 (228)
09 Dec. 1991	24.9 (241)		54.5 (11)	15.9 (69)		24.0 (321)
23 Dec. 1991	19.2 (193)		20.6 (34)	28.2 (71)		21.5 (298)
06 Jan. 1992	25.0 (52)		18.2 (44)			21.9 (96)
13 Jan. 1992	21.4 (173)		30.2 (63)	7.1 (70)	17.8 (118)	19.3 (424)
20 Jan. 1992		0.0 (7)	21.2 (236)	18.1 (72)	27.3 (110)	21.9 (425)
13 Feb. 1992	25.4 (205)	0.0 (20)	17.8 (28)	0.0 (9)	33.3 (39)	23.3 (301)
25 Feb. 1992	25.6 (250)	21.5 (65)	31.6 (19)	24.6 (53)		25.1 (387)

[a] Sample sizes are given in parentheses.

Appendix 3
Relative grubbing impact of swans

In order to estimate the current and future impacts of swan grubbing on the bulrush zone compared with total grubbing (swans plus Lesser Snow Geese), I assumed that only the number of bird-days and the relative weights of the birds (Table A3.1) were important in the calculations. Bird mass to 0.75 power was assumed to correspond to food intake rate or basal metabolic rate.[1] I also assumed that mode, location, and time spent grubbing were similar between species. Those assumptions were probably not correct, but information was lacking and only rough estimates were sought.

Table A3.1
Relative weights[a]

Species	Male (kg)	Female (kg)	Mean (kg)	$Mean^{0.75}$ (kg)
Trumpeter Swans	12.7	10.5	11.6	6.3
Tundra Swans	6.8	6.4	6.6	4.1
Lesser Snow Geese	2.7	2.5	2.6	2.1

[a] From Terres, J. 1980. The Audubon Society encyclopedia of North American birds. A. Knopf, New York. 1109 pp.

Current

- Mean number of swan-days per year on the Fraser River delta between 1987–88 and 1991–92 was 53 000. Because Trumpeter Swans made up about 90% of the swan population, they were responsible for 53 000 × 0.90 = 47 700 swan-days. Tundra Swans were responsible for the remainder (53 000 – 47 700 = 5300).
- Most of the grubbing impact by Lesser Snow Geese on the Fraser River delta occurs in the fall/early winter period (unpubl. data), but some does occur in spring (pers. obs.). Hence, two different estimates were used. Between 1987–88 and 1991–92, the mean number of goose-days during the fall/early winter period was 1 850 000; from fall to spring, the mean number was 2 506 000 (unpubl. data).
- Number of swan grubbing equivalents:
  - Trumpeter Swans: 47 700 days × 6.3 kg = 300 510
  - Tundra Swans: 5 300 days × 4.1 kg = 21 730

  Total = 322 240
- Number of goose grubbing equivalents:
  (1) Fall/early winter: 1 850 000 days × 2.1 kg = 3 885 000
  (2) Fall to spring: 2 506 000 days × 2.1 kg = 5 262 600
- Current proportion of swan grubbing impact of total:
  (1) (322 240/[322 240 + 3 885 000]) = 0.08 or 8%
  (2) (322 240/[322 240 + 5 262 600]) = 0.06 or 6%

Future (2006 AD)

- A population of 4000 swans translates into 400 000 swan-days by extending the linear relationship shown in Figure 4C. Trumpeter Swans would account for 360 000 days at their current proportion of 90%. Tundra Swans would account for 40 000 days.
- Number of swan grubbing equivalents:
  - Trumpeter Swans: 360 000 days × 6.3 kg = 2 268 000
  - Tundra Swans 40 000 days × 4.1 kg = 164 000

  Total = 2 432 000
- Number of goose grubbing equivalents (same as current level):
  (1) Fall/early winter: 3 885 000
  (2) Fall to spring: 5 262 600
- Future proportion of swan grubbing impact of total:
  (1) (2 432 000/[2 432 000 + 3 885 000]) = 0.38 or 38%
  (2) (2 432 000/[2 432 000 + 5 262 600]) = 0.32 or 32%
- Increase in total grubbing impact of swans and Lesser Snow Geese over current level:
  (1) ([2 432 000 + 3 885 000]/[322 240 + 3 885 000]) = 1.50 or 50%
  (2) ([2 432 000 + 5 262 600]/[322 240 + 5 262 600]) = 1.38 or 38%

[1] Drent, R.; Ebbinge, B.; Weijand, B. 1979. Balancing the energy budgets of arctic-breeding geese throughout the annual cycle: a progress report. Verh. orn. Ges. Bayern 23: 239–264.

Seasonal changes in waterbird composition and population of the Gorge, an urban estuary

Kees Vermeer

1. Abstract

The waterbird population in the Gorge estuary was censused once each month in 1989. Seasonal changes in the bird population were similar to those in other Vancouver Island estuaries, but the species composition and densities differed. Pied-billed Grebes *Podilymbus podiceps*, Double-crested Cormorants *Phalacrocorax auritus*, Canada Geese *Branta canadensis*, Buffleheads *Bucephala albeola*, Greater Scaups *Aythya marila*, Ruddy Ducks *Oxyura jamaicensis*, Canvasbacks *Aythya valisineria*, Hooded Mergansers *Lophodytes cucullatus*, and American Coots *Fulica americana* had higher densities and were more common in the Gorge than in other Vancouver Island estuaries.

Piscivores such as Double-crested Cormorants, Common Mergansers *Mergus merganser*, and Hooded Mergansers were widespread at all water depths, whereas other fish-eating species such as Common Murres *Uria aalge*, Marbled Murrelets *Brachyramphus marmoratus*, Red-necked Grebes *Podiceps grisegena*, and Pelagic Cormorants *Phalacrocorax pelagicus* were confined to deep, saline waters. Nonpiscivorous waterfowl, such as Canada Geese, dabbling and diving duck species, and coots, on the other hand, had their highest densities in shallow water areas with a high freshwater output.

The Gorge has suffered from much eutrophication and pollution, which has affected Pacific herring *Clupea pallasi*, coho salmon *Oncorhynchus kisutch*, and cutthroat trout *O. clarki* stocks, and possibly also some piscivorous bird species. Those fish stocks have recently recovered. Reducing the input of raw sewage, halting most wastewater and effluent disposal, removing heavy industry, and restoring the foreshore have likely contributed to the recovery. It is recommended that to totally restore the ecological conditions of the past, the storm drainage system entering the Gorge must be halted.

2. Résumé

En 1989, on a recensé la population d'oiseaux aquatiques de l'estuaire The Gorge une fois par mois. Les changements saisonniers de la population d'oiseaux étaient semblables à ceux observés dans d'autres estuaires de l'île de Vancouver; seules la composition en espèces et les densités différaient. Les populations de Grèbes à bec bigarré *Podilymbus podiceps*, de Cormorans à aigrettes *Phalacrocorax auritus*, de Bernaches du Canada *Branta canadensis*, de Petits Garrots *Bucephala albeola*, de Grands Morillons *Aythya marila*, de Canards roux *Oxyura jamaicensis*, de Morillons à dos blanc *Aythya valisineria*, de Becs-scies couronnés *Lophodytes cucullatus* et de Foulques d'Amérique *Fulica americana* étaient plus denses et plus communes dans l'estuaire The Gorge que dans d'autres estuaires de l'île de Vancouver.

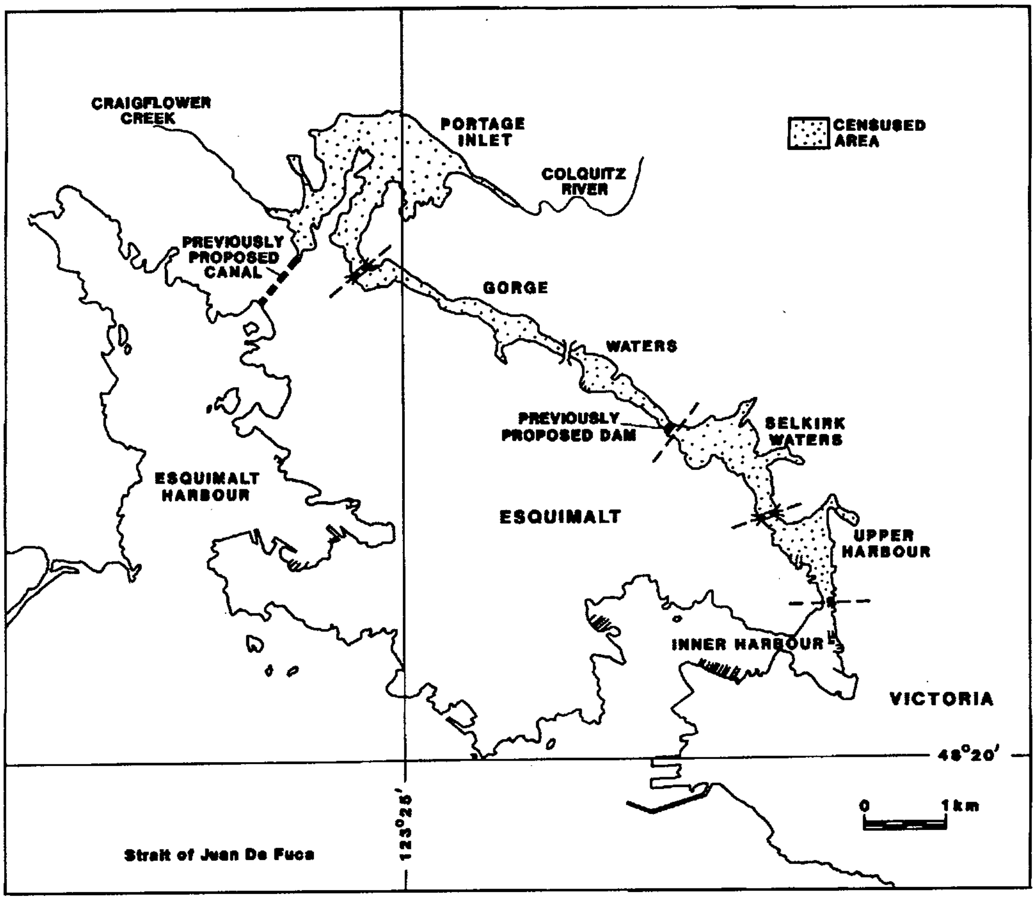
Certaines espèces piscivores, comme le Cormoran à aigrettes, le Grand Bec-scie *Mergus merganser* et le Bec-scie couronné, étaient répandues à tous les niveaux de profondeur des eaux, alors que d'autres, comme la Marmette de Troïl *Uria aalge*, l'Alque marbrée *Brachyramphus marmoratus*, le Grèbe jougris *Podiceps grisegena* et le Cormoran pélagique *Phalacrocorax pelagicus* étaient confinées aux zones d'eaux salées profondes. Les espèces aquatiques non piscivores, comme la Bernache du Canada, les canards de surface, les canards plongeurs et les foulques, étaient les plus denses dans les zones peu profondes où les apports d'eau douce sont importants.

L'estuaire The Gorge a subi les effets d'une eutrophisation et d'une pollution importantes, lesquelles ont eu des répercussions sur les stocks de harengs du Pacifique *Clupea pallasi*, de saumons coho *Oncorhynchus kisutch* et de truites fardées *O. clarki* et peut-être aussi sur certaines espèces d'oiseaux piscivores. Ces stocks de poissons se sont récemment rétablis. Il semble que la réduction des rejets d'eaux d'égouts non traitées, l'arrêt des déversements d'eaux usées et d'effluents, la disparition des industries lourdes et la restauration des rives ont contribué à ce rétablissement. Pour restaurer complètement les conditions écologiques de l'estuaire The Gorge, on recommande que le réseau de collecte des eaux pluviales ne soit plus évacué dans celui-ci.

3. Introduction

Comparisons of waterbird populations in Vancouver Island estuaries have been recently made by Butler et al. (1989) and Vermeer et al. (1992), but no detailed description has been made of the waterbird composition of the Gorge estuary, on the southern tip of Vancouver Island. In contrast to other estuaries on Vancouver Island, the Gorge is entirely an urban estuary,

Figure 1
The Gorge estuary and its sections (Portage Inlet, Gorge Waters, Selkirk Waters, and Upper Harbour) that were censused for waterbirds throughout 1989



surrounded by the municipalities of Esquimalt and Victoria. The Gorge has also suffered from more eutrophication than other Vancouver Island estuaries (Waldichuk 1969). Because of its urban nature and eutrophication, I investigated the aquatic avifauna, except shorebirds (i.e., sandpipers, plovers, etc.), of the Gorge to determine if it differed from that of Vancouver Island estuaries that have suffered less from eutrophication. A second objective was to describe the species distribution along a salinity and water depth gradient extending the length of the Gorge's waterway.

4. Study area and methods

The Gorge estuary is defined here as the connected water bodies between the Inner Harbour of Victoria and Portage Inlet. The four water bodies censused in the estuary were the Upper Harbour, Selkirk Waters, Gorge Waters, and Portage Inlet (Fig. 1). The Upper Harbour and Selkirk Waters are about 10 m deep, the Gorge Waters 3–4 m, and Portage Inlet 1–3 m. The Upper Harbour and Selkirk Waters are used by coastal vessels, whereas the Gorge Waters and Portage Inlet are accessible only to small craft.

The physical and chemical oceanography and tidal characteristics of Victoria Harbour and the Gorge estuary have been described by Waldichuk (1969) and Ages (1973), respectively. Various aspects of the aquatic biology of the Gorge waterway system have been discussed by Brown et al. (1966), Godkin and Gustus (1966), Knoke and Rauchert (1966), and Lambert (1967).

The flow characteristics in the Gorge are predominantly tidal. The maximum tidal amplitude is about 2.5 m in Victoria Harbour and between 1.0 and 1.5 m in Portage Inlet, with a delay of approximately 3–4 hours (Waldichuk 1969). Fresh water enters the Gorge by the Colquitz River and Craigflower Creek (Fig. 1). The waters of the Gorge are well mixed vertically. Lowest salinities occur from December through March, approaching 0 ‰ in Portage Inlet in January (Waldichuk 1969). Waldichuk (1969) observed very little variation in salinity in summer and fall, but in winter there was a distinct decline from Victoria Harbour to the Selkirk Waters, and from the Selkirk Waters to the Gorge Waters and Portage Inlet.

The waterbird population of the Gorge was censused once each month from January through December 1989 by the same two observers from a small boat. Censuses were conducted in calm weather and lasted from two to three hours, depending on the number of birds encountered. Data from each water body were analyzed separately. The surface areas of Portage Inlet, the Gorge Waters, the Selkirk Waters, and the Upper Harbour were determined (by planimeter from a hydrographic chart) to be 0.90, 0.40, 0.33, and 0.23 km^2, respectively, for a total of 1.86 km^2. Overall counts of all waterbirds censused in the Gorge are shown in Appendix 1.

Figure 2
Seasonal changes in numbers and percentages of the major waterbird groups in the Gorge, 1989

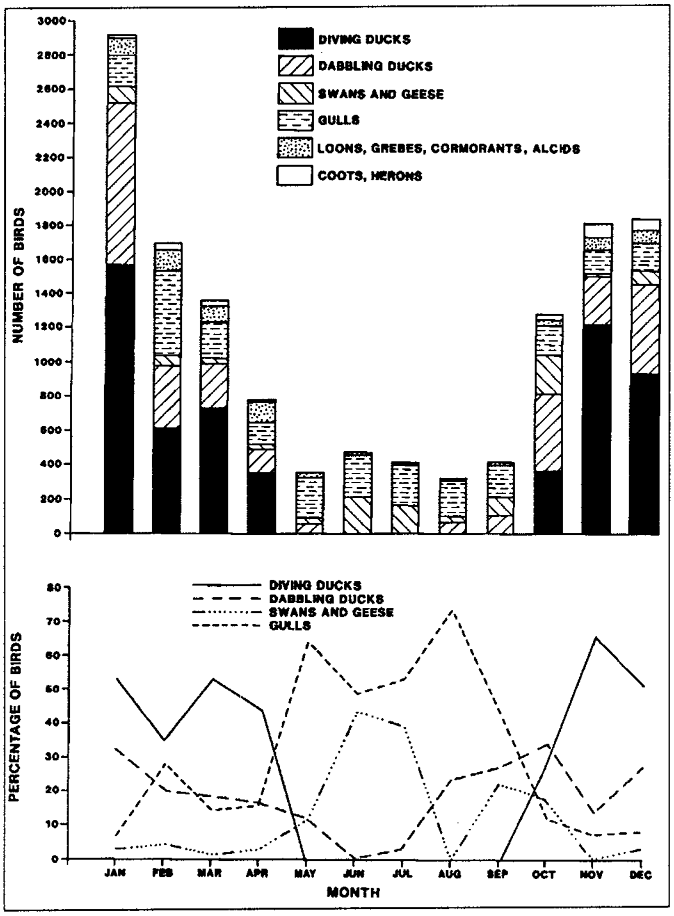
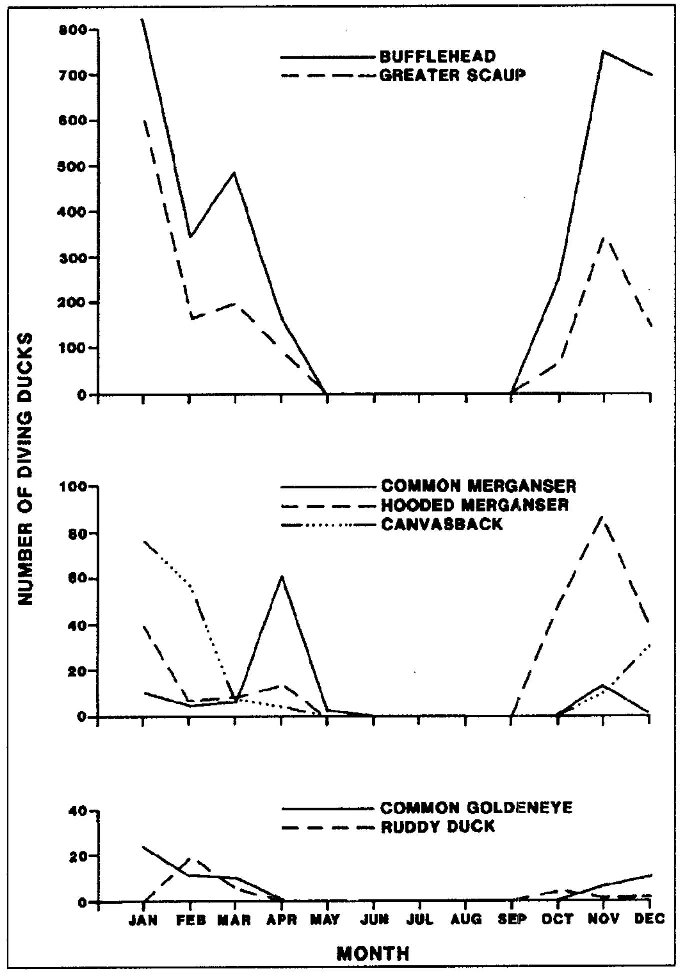


Figure 3
Seasonal changes in numbers of diving ducks in the Gorge, 1989



5. Results

5.1 Seasonal changes in bird composition

The highest numbers of waterbirds in the Gorge were observed from October through April. Diving and dabbling ducks predominated (Fig. 2). The lowest numbers of birds were present from May through September, during which time gulls and geese were predominant.

Diving ducks were most numerous from November through April (Fig. 2). The most abundant species were the Bufflehead *Bucephala albeola* and Greater Scaup *Aythya marila*, with lower numbers of Common *Mergus merganser* and Hooded *Lophodytes cucullatus* mergansers, Canvasback *Aythya valisineria*, Common Goldeneye *Bucephala clangula*, and Ruddy Duck *Oxyura jamaicensis* (Fig. 3). Other diving ducks occasionally seen were the Lesser Scaup *Aythya affinis*, Surf *Melanitta perspicillata* and White-winged *M. fusca* scoters, and Red-breasted Merganser *Mergus serrator* (Appendix 1).

Feral populations of Mute Swans *Cygnus olor* and Canada Geese *Branta canadensis* reside year-round. Mallards *Anas platyrhynchos* and American Wigeons *A. americana* were the most abundant dabbling ducks. Northern Pintails *A. acuta* were common only during fall and winter (Fig. 4). Other less common dabblers were Green-winged Teals *A. crecca*, Gadwalls *A. strepera*, and Eurasian Wigeons *A. penelope*.

Glaucous-winged Gulls were present all year and were most numerous in summer (Fig. 5). Mew Gulls *Larus canus* were the second most common gulls, but they occurred mainly in spring and fall (Fig. 5). Thayer's Gulls *L. thayeri* were seen only in February, and California Gulls *L. californicus* only in August and September (Fig. 5). Bonaparte's *L. philadelphia*, Herring *L. argentatus*, and Ring-billed *L. delawarensis* gulls were seen only occasionally (Appendix 1).

The fish-eating birds in the Gorge consisted of cormorants, grebes, and murrelets, of which Double-crested Cormorants *Phalacrocorax auritus* were by far the most numerous (Fig. 6). The Red-necked Grebe *Podiceps grisegena* was the most common species of grebe. Other fish-eating birds included Pelagic Cormorants *Phalacrocorax pelagicus*, Pied-billed Grebes *Podilymbus podiceps*, and Marbled Murrelets *Brachyramphus marmoratus* (Fig. 6), whereas Western Grebes *Aechmophorus occidentalis* and Common Murres *Uria aalge* were encountered only once (Appendix 1).

5.2 Differences in bird composition within the Gorge

Common Murres and Marbled Murrelets were seen only in the Upper Harbour, and Pelagic Cormorants were chiefly confined to that area (Table 1). Red-necked Grebes were seen only in the deeper parts of the Selkirk Waters

Figure 4
Seasonal changes in numbers of swans, geese, dabbling ducks, and coots in the Gorge, 1989

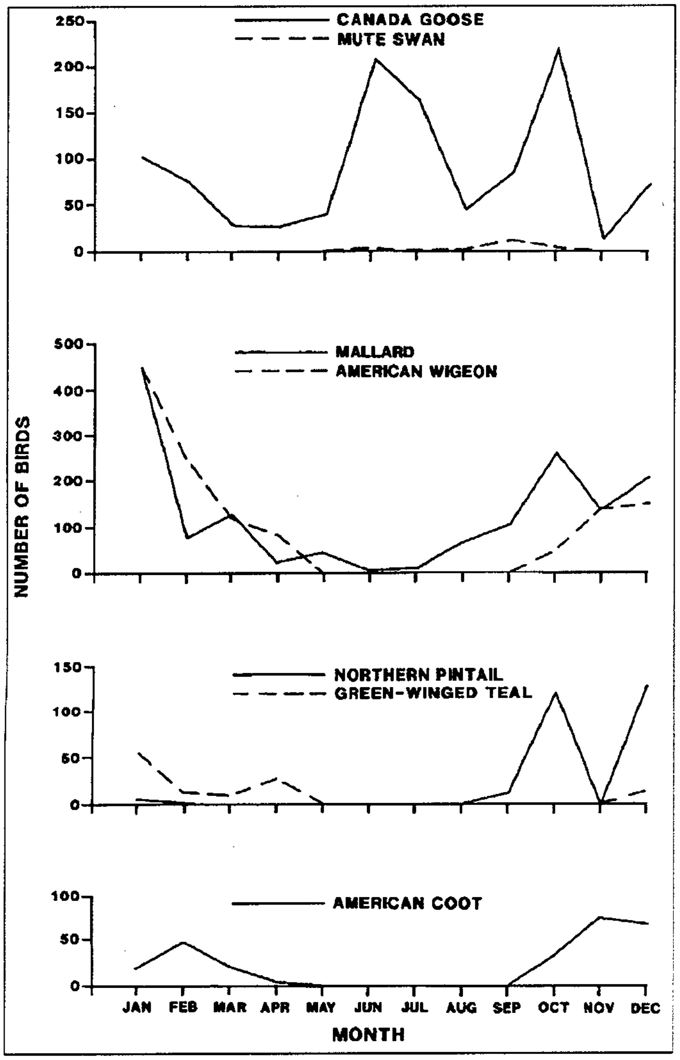


Figure 5
Seasonal changes in numbers of four gull species in the Gorge, 1989

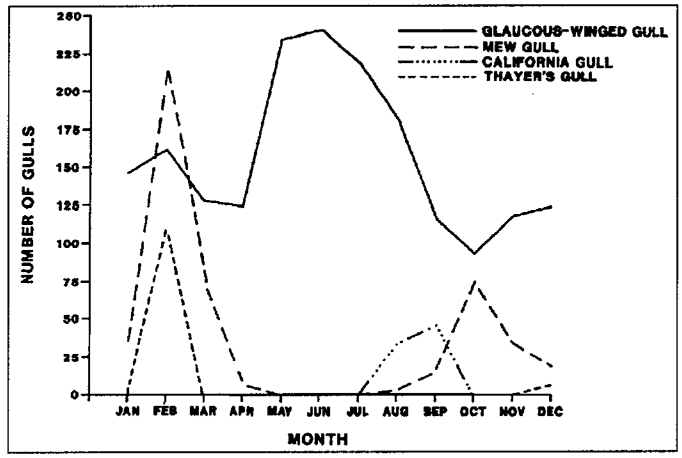
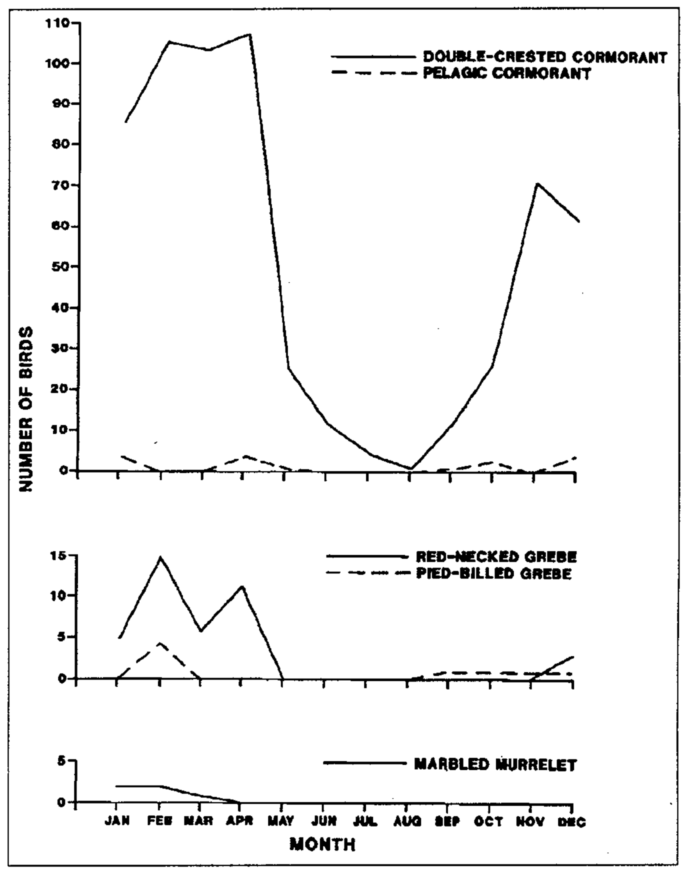


Figure 6
Seasonal changes in numbers of cormorants, grebes, and murrelets in the Gorge, 1989



and Upper Harbour, but Common and Hooded mergansers and Double-crested Cormorants were widespread throughout all water depths. In contrast, all nonpiscivorous waterfowl species had higher densities in the more shallow Portage Inlet and Gorge Waters (Table 1). Northern Pintails, Canvasbacks, and Ruddy Ducks were mostly confined to Portage Inlet.

6. Discussion

6.1 Bird composition in the Gorge compared with other estuaries

The seasonal changes in the waterbird population in the Gorge were similar to those observed in four other estuaries on the southeast coast of Vancouver Island (Vermeer, Bentley, and Morgan, this volume), as well as those seen in eight estuaries on the west coast of Vancouver Island (Vermeer et al. 1992). The bird species composition of the Gorge, however, was very different from that of those 12 estuaries. In the Gorge, nine species (Pied-billed Grebes, Double-crested Cormorants, Canada Geese, Buffleheads, Greater Scaups, Canvasbacks, Hooded Mergansers, Ruddy Ducks, American Coots) had higher densities than in any of the other 12 estuaries.

One possible explanation for the distinct bird community in the Gorge is the diverse food supply. Ten species of fish have been found in the Gorge, of which the Pacific herring *Clupea pallasi* is perhaps the most abundant. Although there are two distinct runs of herring (September–October and March–April), herring are usually present in the Gorge from mid-December until late April (Brown et al. 1966). Double-crested Cormorants

Table 1
Maximal densities of some fish-eating and waterfowl species at Portage Inlet, the Gorge and Selkirk waters, and the Upper Harbour, January–December 1989

Species	No. of birds/km² [a] Portage Inlet		Gorge Waters		Selkirk Waters		Upper Harbour	
Fish-eating species								
Red-necked Grebe	0		0		9.1	(3)	65.2	(5)
Double-crested Cormorant	34.4	(10)	187.5	(12)	184.8	(10)	213.0	(10)
Pelagic Cormorant	0		0		3.0	(1)	17.4	(5)
Common Murre	0		0		0		4.3	(1)
Marbled Murrelet	0		0		0		8.7	(3)
Common Merganser	63.3	(6)	2.5	(1)	33.3	(5)	4.3	(1)
Hooded Merganser	36.7	(7)	87.5	(5)	45.5	(5)	34.8	(5)
Nonpiscivorous waterfowl								
Canada Goose	221.1	(12)	367.5	(9)	3.0	(1)	0	
Mallard	327.8	(12)	375.0	(10)	36.4	(6)	4.3	(2)
American Wigeon	233.3	(7)	550.0	(6)	106.1	(6)	0	
Green-winged Teal	55.6	(6)	12.5	(3)	9.1	(2)	0	
Northern Pintail	144.4	(5)	0		0		0	
Greater Scaup	394.4	(8)	1250.0	(4)	54.5	(3)	52.2	(2)
Bufflehead	778.9	(7)	1537.5	(6)	181.8	(5)	4.3	(1)
Canvasback	83.3	(6)	2.5	(1)	0		0	
Ruddy Duck	21.1	(6)	2.5	(1)	0		0	
American Coot	83.3	(7)	50.0	(7)	0		0	

[a] The number of months birds were present is shown in parentheses.

were most numerous in the Gorge during those periods when herring were present; this suggests a possible relationship between the two. Brown et al. (1966) reported that large numbers of cormorants fed upon schools of herring in Portage Inlet. Alternative or additional attractants for cormorants may have been the numerous pilings and wharves and the trees lining the Gorge. Cormorants were frequently seen resting and drying their feathers in such locations.

The threespine stickleback *Gasterosteus aculeatus* is one of the most abundant small fish in the Gorge (Brown et al. 1966). The presence of high numbers of sticklebacks may have attracted Common and Hooded mergansers to the Gorge. The diet of Common Mergansers on the British Columbia coast consists mainly of sculpins, sticklebacks, and salmonids (Munro and Clemens 1932). No information on the diet of Hooded Mergansers in British Columbia is available, but Cottam and Uhler (1937) found that they fed extensively upon small, noncommercial species of fish.

Canada Geese were often seen grazing on lawns bordering the Gorge, and they were frequently fed by people. This additional food may explain their high densities at the Gorge. American Wigeons and Greater Scaups, whose diets consist mainly of green algae (Vermeer and Levings 1977), may have been attracted to the Gorge by the presence of extensive beds of algae (*Enteromorpha intestinales* and *E. clathrara*, with lesser amounts of *Ulva lactuca*). American Wigeons and Mallards were also seen feeding and loafing on lawns. The very high density of Buffleheads in the Gorge may be related to the presence of shrimp, snails, and vascular plant seeds, which appear to make up their main diet in southern British Columbia (Vermeer 1982). The presence of herring eggs in late fall and early spring may also have attracted Buffleheads and Greater Scaups to the Gorge. Both species feed extensively upon herring eggs when the eggs are available (Vermeer 1981).

Surf and White-winged scoters were scarce in the Gorge, in marked contrast to their typically high numbers in other British Columbia estuaries (Butler et al. 1989; Vermeer et al. 1992; Vermeer, Bentley, and Morgan, this volume). Surf Scoters forage mostly on blue mussels *Mytilus edulis*, and White-winged Scoters feed primarily on a variety of clam species in British Columbia waters (Vermeer 1981; Vermeer and Bourne 1984). Blue mussels and clams may be scarce in the Gorge.

6.2 Differences in bird composition within the Gorge

Variation in species densities throughout the Gorge may relate to differences in water depths and/or salinity. Different water types may to a large extent determine the composition, abundance, and accessibility of prey. The fact that Common Murres and Marbled Murrelets were seen only in the Upper Harbour suggests that those species prefer deeper, more saline waters. In other Vancouver Island estuaries, those two species were absent from shallow, brackish waters, occurring predominantly over deep, saline waters. In addition, both species may have been attracted to the Gorge by the presence of herring, one of their main prey species (Vermeer 1992).

Pelagic Cormorants, unlike Double-crested Cormorants, were mostly confined to the Upper Harbour. This is not unusual, as the Pelagic Cormorant is an exclusively marine cormorant, whereas the Double-crested Cormorant forages in marine, estuarine, and freshwater habitats.

That the highest densities of Canada Geese and dabbling ducks occurred in shallow waters may possibly relate to the accessibility of aquatic foods and to some extent to the presence of lawns bordering those waters. High densities of Greater Scaup in Portage Inlet and the adjacent Gorge Waters may relate to an abundance of *Enteromorpha* and *Ulva* spp. High densities of Bufflehead in those waters may have been a result of a rich marine invertebrate fauna within the extensive eelgrass (*Zostera* spp.) community there.

American Coots, Canvasbacks, and Ruddy Ducks were seen only in Portage Inlet and the Gorge Waters.

Those three species primarily inhabit freshwater habitats; when present in estuaries, they are seen mostly in areas with a high freshwater output (Cottam 1939; pers. obs.). Hence, their presence in Portage Inlet and in the adjacent Gorge Waters is not surprising, as those water bodies have the lowest salinity content in the Gorge. An additional factor may be the nature of the bottom substrate in those waters, which consists of a 30-cm-deep layer of organic mud (Marshall 1969). The three species mentioned above are often seen over muddy bottoms (pers. obs.), and Cottam (1939) stated that Ruddy Ducks frequently feed on bottom ooze. Canvasbacks are known to feed on *Macoma* spp. (Cottam 1939), which are associated with Portage Inlet muds (Brown et al. 1966).

6.3 Environmental perturbations

During the 1960s, the Gorge was highly polluted owing to the clearance of effluents from primary wastewater treatment plants, untreated wastes, and seepage from septic tanks from surrounding residential areas (Waldichuk 1969), which resulted in eutrophication. Spawning runs of cutthroat trout *Oncorhynchus clarki*, coho salmon *O. kisutch*, and Pacific herring had essentially ceased, partially because of the pollution (Waldichuk 1969), and the beaches were so polluted that they remained closed to swimming for extended periods (Ages 1973).

In response to this pollution problem, a number of schemes were proposed to improve the water quality of the upper basin of the Gorge (Portage Inlet and the Gorge Waters). Two of those proposals involved the construction of a dam between Victoria Harbour and the Gorge to prevent entry of polluted harbour waters and the construction of a canal between Portage Inlet and Esquimalt Harbour to flush the basin and to scour out the polluted Portage Inlet (Fig. 1). Neither proposal was accepted because of the possible unacceptable impacts upon the estuary.

Untreated water and effluents from wastewater plants are no longer discharged into the Gorge. Since the late 1970s and early 1980s, all residential areas around the Gorge have had sewage treatment (L. Potter, pers. commun.). Herring stocks have recovered, creating a popular recreational fishery (R. Kehl, pers. commun.). There is now recreational fishing for cutthroat trout, and moderate numbers (150–200) of coho salmon again spawn in Craigflower Creek (R. Kehl, pers. commun.). However, coho salmon returning to spawn in the Colquitz River have declined from about 200 to 25 individuals over the last decade. Agricultural and other developments are thought to be the major reasons for the decline, exacerbated by the frequent leakages of faulty furnace oil tanks (R. Kehl, pers. commun.).

Much of the heavy industry has recently moved away from the Gorge, and its foreshore is restored, where possible, to its natural state. Raw sewage, however, still enters the Gorge from overflows from sanitary sewers, house sewers incorrectly connected to storm drains, and runoff from land containing animal feces (Times Colonist, 4 March 1993). The main source of pollution is storm drains that have been contaminated by fecal matter. Rerouting waste from storm drains away from the Gorge would greatly accelerate the rejuvenation of its estuary. The accessibility of this estuary to the municipalities of Victoria and Esquimalt provides much educational and recreational potential.

7. Acknowledgements

M. Bentley assisted with the census of birds in the Gorge. D.V. Ellis provided access to unpublished manuscripts on various aspects of the Gorge, and R. Kehl provided information on the trends of recent commercial fish stocks. R.W. Butler, R.W. Elner, K.H. Morgan, and N.A.M. Verbeek read the manuscript and made pertinent comments. S. Bucknell typed the manuscript.

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Appendix 1
Number of waterbirds observed (for a total of 37 species) in the Gorge from January through December 1989

	No. of birds											
Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Common Loon				1								
Western Grebe	1											
Red-necked Grebe	5	15	6	11								
Pied-billed Grebe		4							1	1	1	1
Double-crested Cormorant	86	105	103	107	26	12	5	1	12	27	71	62
Pelagic Cormorant	4			4	1				1	3		2
Brandt's Cormorant	1	1										
Mute Swan					2	2	2	2	8	4	5	6
Canada Goose	101	76	27	29	40	210	166	46	84	224	12	73
Mallard	448	77	129	23	47	7	17	73	103	272	139	213
American Wigeon	444	256	121	84						48	143	162
Eurasian Wigeon		2									1	1
Northern Pintail	3								13	122		13
Green-winged Teal	58	16	9	29				1		2		15
Gadwall											2	
Greater Scaup	601	165	197	95					1	67	355	156
Lesser Scaup		5										
Canvasback	76	57	8	5							10	30
Surf Scoter											1	
White-winged Scoter			7									
Common Goldeneye	24	11	10								7	10
Bufflehead	815	344	489	162						250	745	703
Common Merganser	10	4	6	60	3						13	
Red-breasted Merganser		1		13								
Hooded Merganser	40	6	8	14						49	87	40
Ruddy Duck		20	6	1						4	1	1
American Coot	20	49	22	5						34	75	69
Glaucous-winged Gull	147	162	129	125	236	241	219	181	115	93	119	149
Herring Gull										2		
Thayer's Gull		110										7
California Gull								34	46			
Mew Gull	35	218	75	7				4	17	74	36	21
Ring-billed Gull								2		1		
Bonaparte's Gull								2	10			
Common Murre	1											
Marbled Murrelet	2	2	1									
Great Blue Heron	6	6	7	8	10	8	11	4		5	5	1
Total	2928	1712	1360	783	365	480	420	350	411	1282	1828	1852
No. of birds/km^2	1574	940	731	421	196	258	226	138	221	689	983	996

Comparison of the waterbird populations of the Chemainus, Cowichan, and Nanaimo river estuaries

Kees Vermeer, Michael Bentley, and Ken H. Morgan

1. Abstract

Comparisons of the compositions and densities of waterbird populations were made for the Chemainus, Cowichan, and Nanaimo river estuaries, censused in 1989. In all three estuaries, highest densities occurred from October through April. The Nanaimo River estuary had low densities of swans and diving ducks but high densities of Glaucous-winged Gulls *Larus glaucescens*. The Cowichan River estuary had higher densities of piscivorous birds, ducks in the genus *Bucephala*, and Mew *Larus canus* and Ring-billed *L. delawarensis* gulls. It was also the only estuary used extensively by Mute Swans *Cygnus olor*. The Chemainus River estuary had relatively high densities of Greater Scaups *Aythya marila*, Surf Scoters *Melanitta perspicillata*, White-winged Scoters *M. fusca*, and Bonaparte's *Larus philadelphia* and California *L. californicus* gulls. Differences in bird composition between estuaries are thought to be related to food availability, nearness of human refuse, effects of log storage, and adjacent nesting habitat.

Waterbird densities were compared between these three Vancouver Island estuaries and the Fraser River estuary, the largest estuary in British Columbia. The Fraser River estuary had much higher densities of geese and ducks, probably because of the presence of extensive brackish water marshes, eelgrass beds, and nearby farmlands on which waterfowl feed.

2. Résumé

On a comparé la composition et la densité des populations d'oiseaux aquatiques de l'estuaire des rivières Chemainus, Cowichan et Nanaimo en se basant sur des recensements de 1989. Dans les trois estuaires, les plus fortes densités de population ont été observées d'octobre à avril. Dans l'estuaire de la rivière Nanaimo, on a trouvé de faibles densités de cygnes et de canards plongeurs mais de fortes densités de Goélands à ailes grises *Larus glaucescens*. Dans l'estuaire de la Cowichan, on a observé de plus fortes densités d'oiseaux piscivores, de canards du genre *Bucephala*, de Goélands cendrés *Larus canus* et de Goélands à bec cerclé *L. delawarensis*. C'est aussi le seul estuaire largement utilisé par le Cygne tuberculé *Cygnus olor*. Dans l'estuaire de la Chemainus, on a trouvé des densités relativement élevées de Grands Morillons *Aythya marila*, de Macreuses à front blanc *Melanitta perspicillata*, de Macreuses à ailes blanches *M. fusca*, de Mouettes de Bonaparte *Larus philadelphia* et de Goélands de Californie *L. californicus*. On croit que les différences dans la composition en espèces des populations d'oiseaux des différents estuaires sont liées à l'abondance des ressources alimentaires, à la proximité de dépotoirs, aux effets des billes en stockage et à la présence d'habitats de nidification dans les environs.

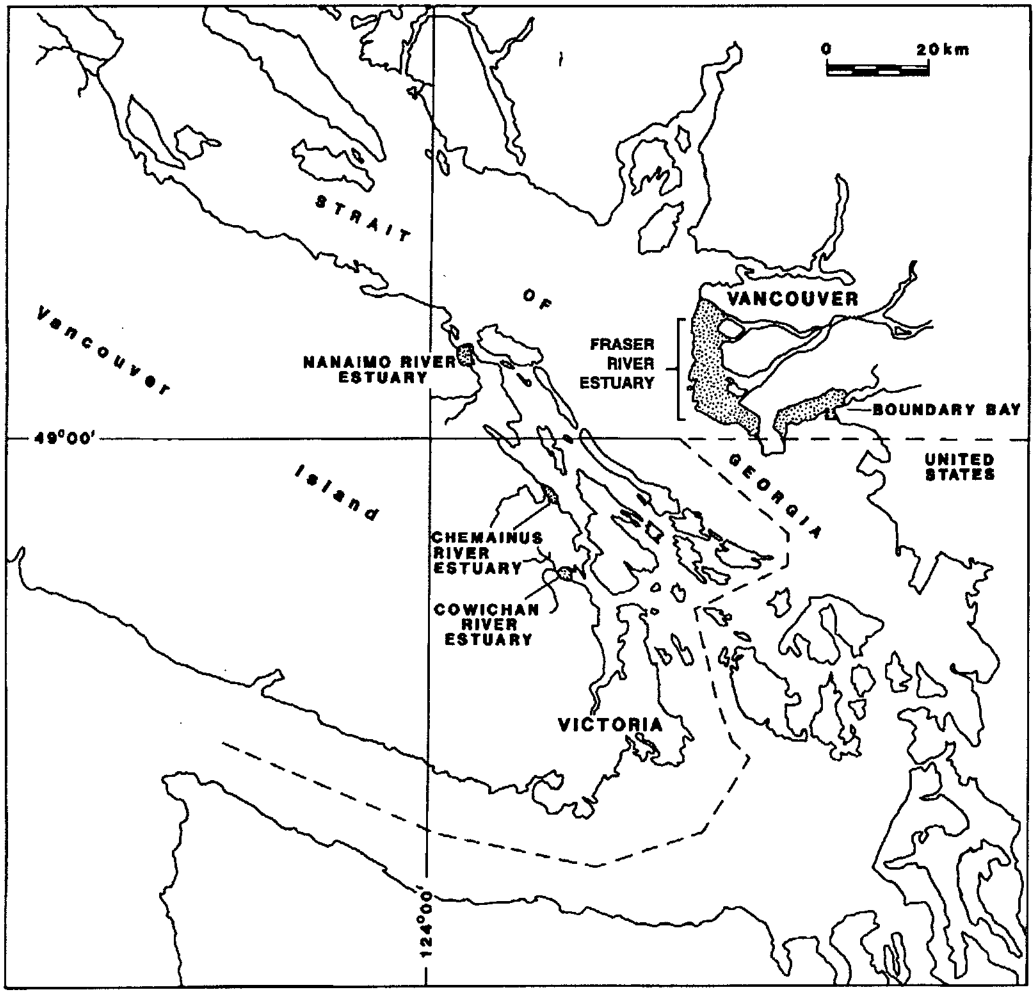
On a comparé la densité des populations d'oiseaux aquatiques de ces trois estuaires de l'île de Vancouver avec celle des populations de l'estuaire du fleuve Fraser, le plus grand estuaire en Colombie-Britannique. Les populations d'oies et bernaches et de canards sont beaucoup plus denses dans l'estuaire du Fraser, probablement en raison de la présence de grands marais d'eau saumâtre et de prairies de zostères marines et de la proximité de terres agricoles, où les oiseaux aquatiques se nourrissent.

3. Introduction

Waterbirds in the Chemainus, Cowichan, and Nanaimo river estuaries (hereafter Chemainus, Cowichan, and Nanaimo estuaries) were censused for the first time by Vaudry and Land (1973) and Blood et al. (1975, 1976). Butler et al. (1989) compared the waterbird compositions of two of those estuaries (Cowichan and Nanaimo) and four others on Vancouver Island with that of the Fraser River, the largest estuary in British Columbia. They found that the Fraser River estuary (hereafter Fraser estuary) supported most of the waterfowl, wading birds, and gulls, whereas the Cowichan estuary had most of the fish eaters, mostly Western Grebes *Aechmophorus occidentalis*. However, that analysis was based on censuses made only for the November–March period by different observers in different years. Moreover, censuses for the Cowichan and Nanaimo estuaries were conducted over much larger areas than the estuaries themselves. We attempt here to correct the shortcomings of the earlier studies.

The objectives of this study were to make inter-estuarine comparisons on a bird density basis among the Chemainus, Cowichan, and Nanaimo estuaries, and between those three estuaries and that of the Fraser River, over the course of a year. The Chemainus, Cowichan, and Nanaimo estuaries were selected for comparison with the

Figure 1
Location of the Chemainus, Cowichan, Fraser, and Nanaimo river estuaries in the Strait of Georgia



Fraser estuary because they are all located at similar latitudes in the Strait of Georgia (Fig. 1).

4. Study area and methods

The geology, soils, climate, aquatic vegetation, invertebrate biology, fisheries, and wildlife of the Chemainus, Cowichan, and Nanaimo estuaries have been reviewed by Bell and Kallman (1976a, 1976b).

The three estuaries were censused over a period of one year (1989), on the same day each month (Chemainus and Cowichan estuaries) and on the following day (Nanaimo estuary) in order to make comparisons of the bird compositions and populations between the estuaries as relevant as possible. All waterbirds other than shorebirds (i.e., sandpipers, plovers, etc.) were counted with the aid of binoculars by two observers from a small boat at mid- to high tides. Counts in each estuary lasted between two and four hours, depending on the number of birds present and the area of each estuary (Fig. 2). Although two rivers enter Cowichan Bay (the Cowichan and Koksilah rivers), the estuary has been called the Cowichan estuary for convenience. The censused areas for the Chemainus (8.26 km^2), Cowichan (3.99 km^2), and Nanaimo (8.60 km^2) estuaries were calculated with a planimeter from 1:20 000 hydrographic charts. Overall counts of all waterbirds censused in those estuaries are shown in Appendices 1, 2, and 3.

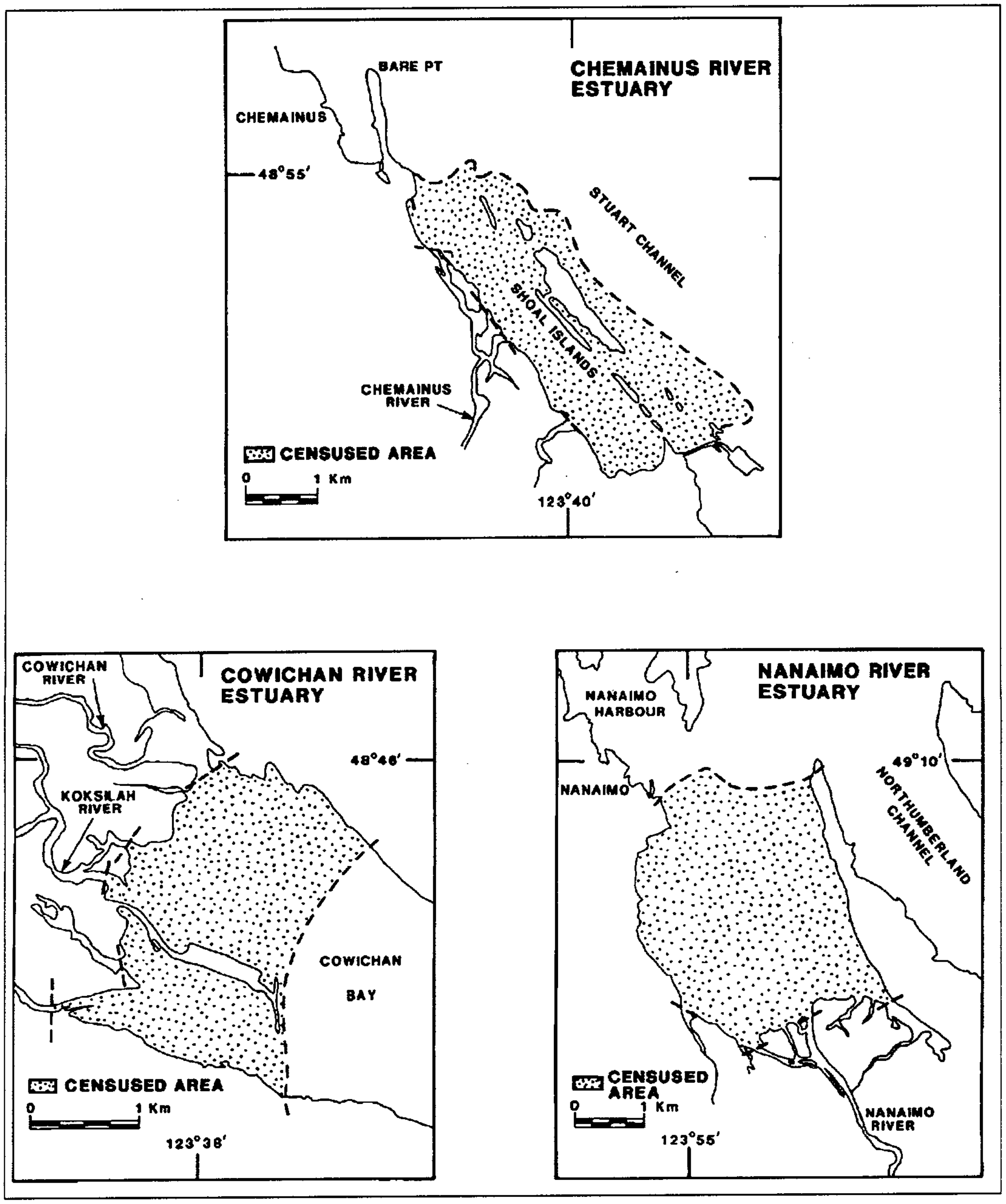
The Fraser estuary was censused independently by members of the Vancouver Natural History Society between March 1988 and February 1989 (Butler and Cannings 1989; Vermeer, Butler, and Morgan, this volume).

5. Results

5.1 Bird composition and densities

In all three estuaries, the highest waterbird densities occurred from October through April, the lowest from March through September (Fig. 3). Gulls and waterfowl were most numerous, fish-eating birds such as loons, grebes, cormorants, and alcids being far less abundant. The Nanaimo estuary had the greatest densities of all birds, followed by the Cowichan and Chemainus estuaries (Appendices 1, 2, and 3).

Figure 2
Chemainus, Cowichan, and Nanaimo river estuaries; shaded areas indicate sections censused in 1989



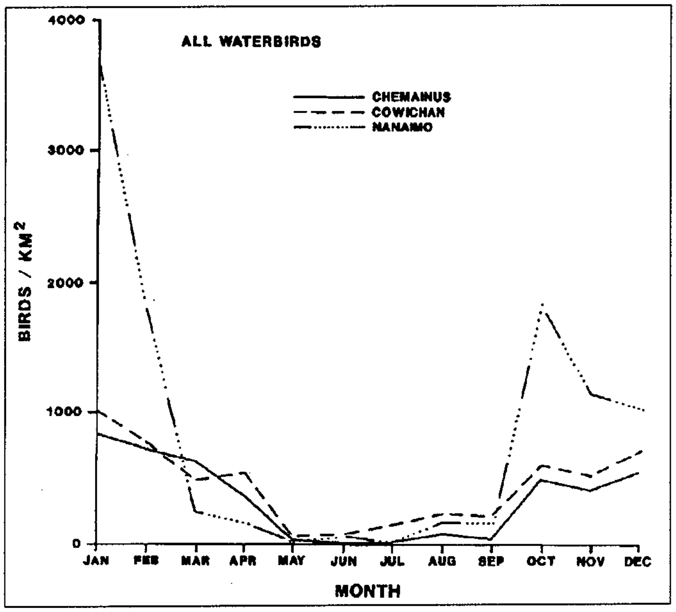
5.2 Fish-eating species

Of the piscivores, loons had the lowest densities (Fig. 4). Common Loons *Gavia immer* were seen in all three estuaries. Low numbers of Red-throated Loons *G. stellata* and Yellow-billed Loons *G. adamsii* occurred only in the Cowichan estuary. Grebes reached their highest densities in the Cowichan estuary from October through April (Fig. 4); Western Grebes contributed most to that density, but Horned Grebes *Podiceps auritus* and Red-necked Grebes *P. grisegena* attained higher densities in the Cowichan estuary than in the other two estuaries. Similarly, cormorants, primarily Double-crested Cormorants *Phalacrocorax auritus*, reached their highest densities in the Cowichan estuary. The Double-crested Cormorant was the most numerous cormorant in all estuaries, although low densities of Pelagic Cormorants *P. pelagicus* also occurred in all of them. Brandt's Cormorants *P. penicillatus* were seen only occasionally. Low densities of alcids were observed in all estuaries, Pigeon Guillemots *Cepphus columba* and Marbled Murrelets *Brachyramphus marmoratus* in all three estuaries, and a few Rhinoceros Auklets *Cerorhinca monocerata* in the Cowichan estuary.

5.3 Waterfowl

Dabbling and diving ducks dominated this group of birds, swans and geese occurring in much lower numbers. The highest densities of waterfowl were observed from October through April, particularly in the Chemainus and Cowichan estuaries (Fig. 5). Densities of swans, geese, and dabbling ducks were highest in the Cowichan estuary, whereas those of diving ducks were highest in the Chemainus and Cowichan estuaries (Figs. 5 and 6).

Figure 3
Seasonal changes in overall waterbird densities in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



Mute Swans *Cygnus olor* occurred only in the Cowichan estuary, whereas Trumpeter Swans *C. buccinator* were seen in all three estuaries. The Trumpeter Swan reached its highest density in the Cowichan estuary during February (Fig. 7). Canada Geese *Branta canadensis* were common in all three estuaries, whereas Lesser Snow Geese *Anser c. caerulescens* were seen only once, in the Nanaimo estuary.

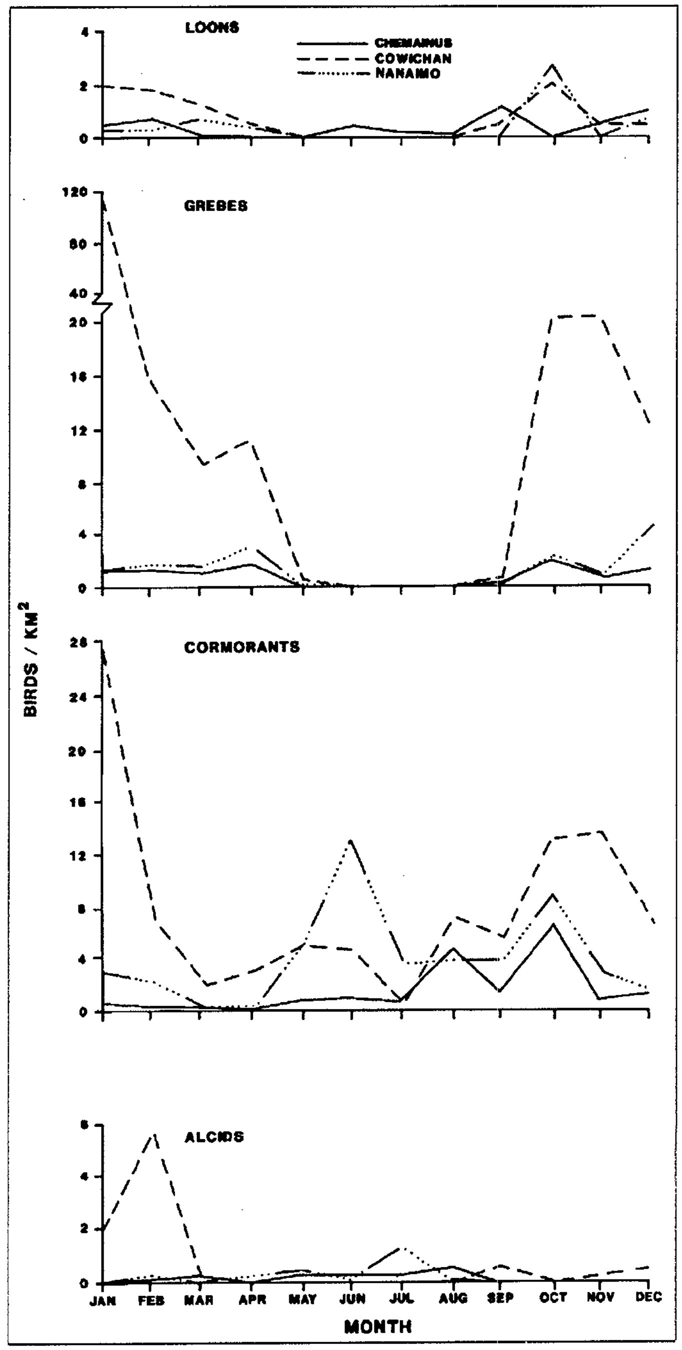
Mallards *Anas platyrhynchos*, American Wigeons *A. americana*, Northern Pintails *A. acuta*, and Green-winged Teals *A. crecca* were the most numerous dabbling duck species in all estuaries. There were few Mallards in the Nanaimo estuary, whereas Mallards reached their highest densities in the Cowichan estuary (Fig. 8). Other dabblers seen in small numbers were Eurasian Wigeons *A. penelope*, Blue-winged Teals *A. discors*, Gadwalls *A. strepera*, and Northern Shovelers *A. clypeata* (Appendices 1, 2, and 3).

Of the diving ducks, Greater Scaups *Aythya marila* and Surf *Melanitta perspicillata* and White-winged *M. fusca* scoters all attained their highest densities in the Chemainus estuary (Fig. 9). In contrast, Buffleheads *Bucephala albeola*, Barrow's Goldeneyes *B. islandica*, and Common Goldeneyes *B. clangula* were most numerous in the Cowichan estuary (Fig. 10). Common *Mergus merganser* and Red-breasted *M. serrator* mergansers were common in the Nanaimo and Cowichan estuaries and had low densities in the Chemainus estuary (Fig. 11). Other diving ducks seen infrequently were Black Scoters *M. nigra*, Hooded Mergansers *Lophodytes cucullatus*, Canvasbacks *Aythya valisineria*, Ring-necked Ducks *A. collaris*, and Harlequin Ducks *Histrionicus histrionicus* (Appendices 1, 2, and 3).

5.4 Gulls

Glaucous-winged Gull *Larus glaucescens* numbers in the Nanaimo estuary were so large (Fig. 12) that they

Figure 4
Seasonal changes in densities of loons, grebes, cormorants, and alcids in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



outnumbered all other birds, resulting in a disproportionate percentage of gulls occurring there (Table 1). Thayer's Gull *L. thayeri* was the second most numerous gull in the Nanaimo estuary in January and February. Mew Gulls *L. canus* were present mainly from October through April, whereas Ring-billed Gulls *L. delawarensis* were observed from June to September (Fig. 13). Mew and Ring-billed gulls had their highest densities in the Cowichan estuary. California Gulls *L. californicus* and Bonaparte's Gulls *L. philadelphia* visited the estuaries in spring (March–April) and again in late summer (mostly August) (Fig. 14). Both reached highest

Figure 5
Seasonal changes in densities of all waterfowl and swans and geese in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989

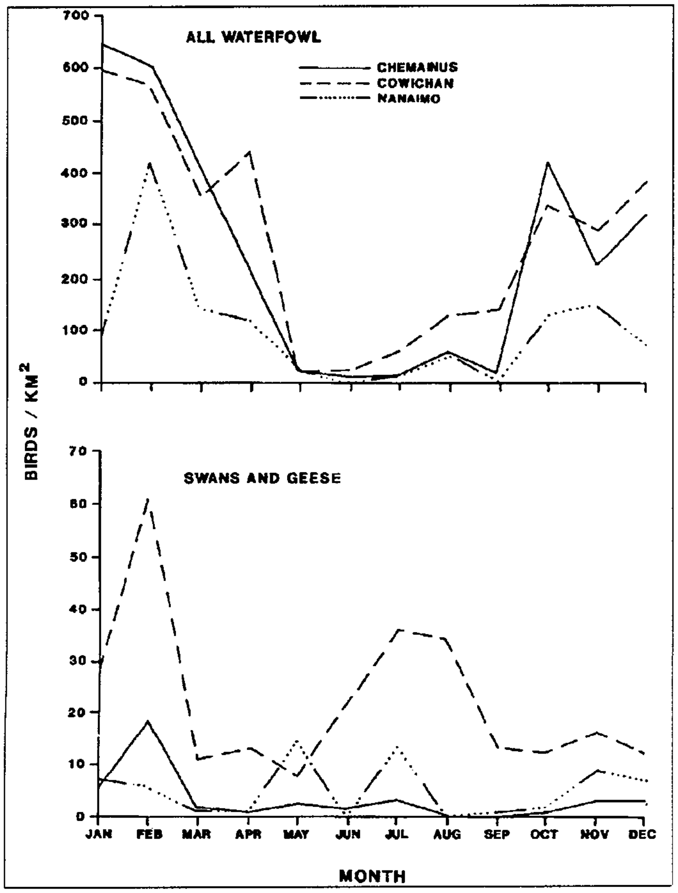
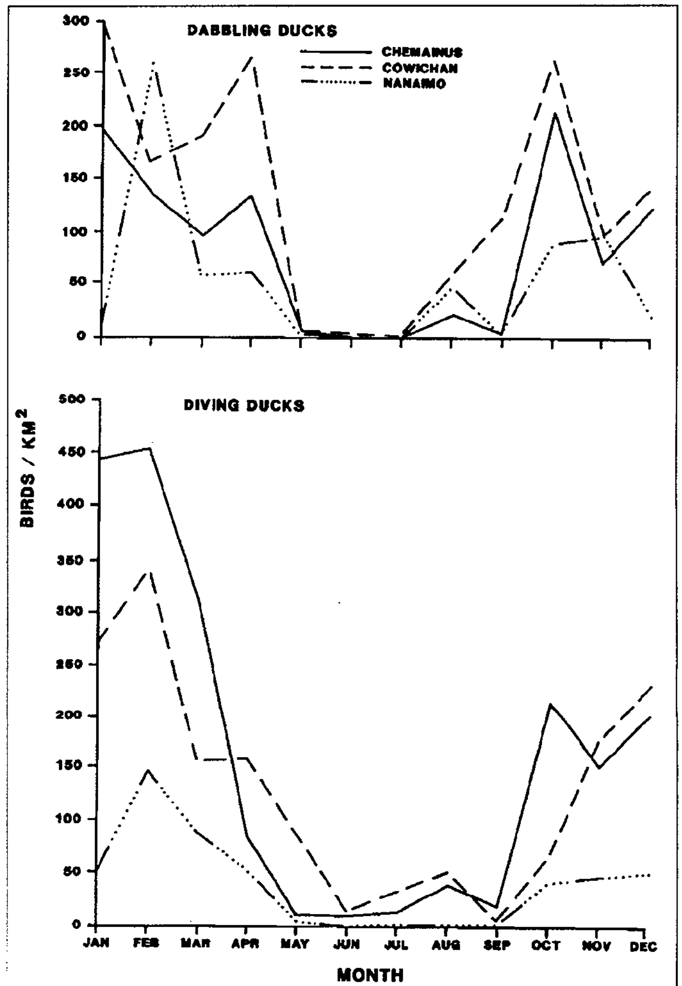


Figure 6
Seasonal changes in densities of dabbling and diving ducks in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



densities in the Chemainus estuary in spring and in the Cowichan estuary during August.

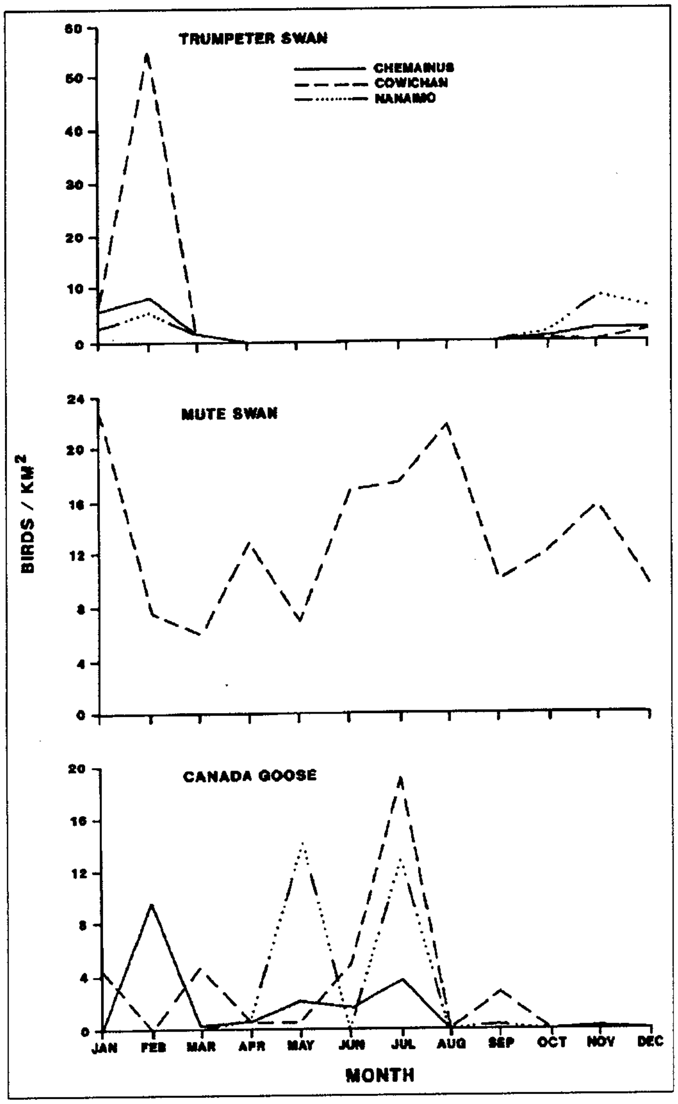
6. Discussion

6.1 Nanaimo estuary

Differences in compositions of bird populations between estuaries likely relate to differences in food sources and their availability and to the presence of loafing platforms. The relatively low densities of swans, diving ducks (except mergansers), and Mallards in the Nanaimo estuary (Figs. 4, 5, and 6) may be due to extensive log storage. Sibert and Harpham (1979) observed extensive habitat disruption of the Nanaimo estuary as a result of log storage and booming activities. They observed conspicuous grooves up to 15 cm deep in sediment parallel to the logs, with pits up to 0.5 m in depth and several metres in extent. Local accumulations of bark and other debris occurred in all pits and depressions. They also observed that tugs engaged in booming activities scoured the sediment. Persistent effects of scouring were visible in aerial photographs as striations and as channels criss-crossing the estuary. The disruption of the benthic fauna by these activities may affect the availability of mussels and bivalves on which Surf and White-winged scoters, Barrow's Goldeneyes, and Greater Scaups feed (Vermeer and Levings 1977; Vermeer 1981, 1982; Vermeer and Bourne 1984). Log storage may not seriously affect fish populations, as piscivores, such as Common and Red-breasted mergansers, had relatively high densities in the Nanaimo estuary (Fig. 11). Log storage may also have a limited effect upon Canada Geese, American Wigeons, Northern Pintails, and Green-winged Teals, which forage extensively on alternative foods in nearby pasture and farmlands, at river mouths, and in freshwater marshes. Those species had similar densities in the three estuaries. Mallards may have been scarce in the Nanaimo estuary because of a lack of available eelgrass (*Zostera* spp.) and because of a limited supply of agricultural foods. Mallards are known to feed extensively on eelgrass in the Fraser estuary and on corn, potatoes, and cabbage in nearby agricultural fields (Baldwin and Lovvorn 1992).

Brant *Branta bernicla* rely heavily on eelgrass as well as on *Ulva* spp. for their food in British Columbia's coastal waters (Vermeer et al. 1991). Prior to 1948, Brant were numerous in the Nanaimo estuary; since then, their numbers have declined significantly. Prior to the onset of log storage (1948), about two-thirds of the estuary was covered by eelgrass; in the 1970s, only a fraction (10%) of the eelgrass remained, restricted mostly to the estuary mouth. Small numbers of Brant were still seen occasionally foraging on eelgrass beds in the 1970s

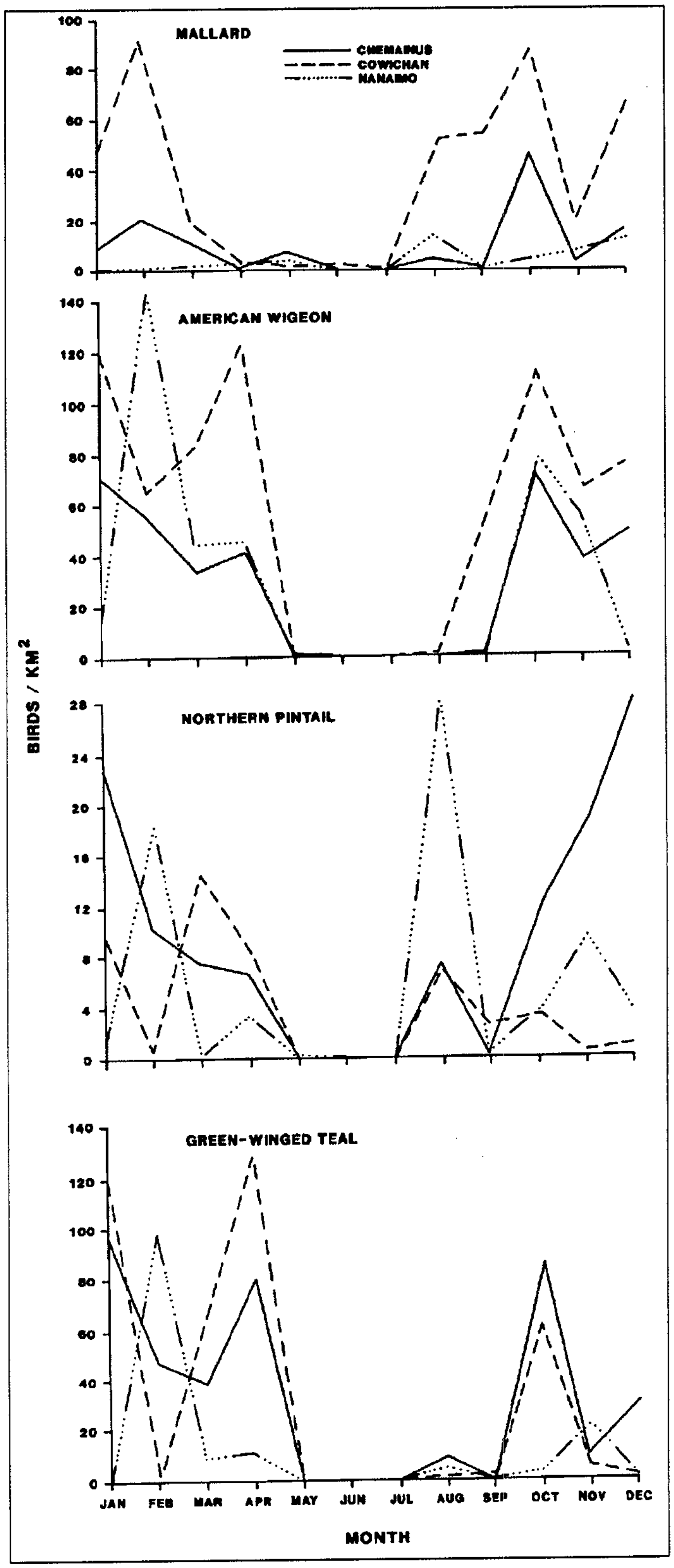
Figure 7
Seasonal changes in densities of Trumpeter and Mute swans and Canada Geese in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



(Trethewey 1974). This species was not seen during our study; however, it may have been missed because of the infrequent surveys.

Glaucous-winged Gulls had high densities in the Nanaimo estuary from September through February (Fig. 12). We estimated that there were 14 000 of this species in October and 25 000 in January (Appendix 3). These numbers greatly exceed those reported from any other Vancouver Island estuary. During February, 3260 Thayer's Gulls were also observed in the Nanaimo estuary (Appendix 3). Both species were seen mostly on booms, but they also occurred in large flocks on beaches near the mouth of the Nanaimo River. Compared with the large number of loafing gulls, relatively few were observed foraging. The Nanaimo estuary may therefore represent only an important resting place for Glaucous-winged and Thayer's gulls using the nearby Nanaimo garbage dump. On the Fraser estuary, Glaucous-winged Gulls were also most numerous nearest to the Greater Vancouver landfill (Vermeer, Butler, and Morgan, this volume).

Figure 8
Seasonal changes in densities of Mallards, American Wigeons, Northern Pintails, and Green-winged Teals in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



6.2 Cowichan estuary

Western Grebes, Double-crested Cormorants, and Common Mergansers contributed the most to the elevated densities of fish eaters observed in the Cowichan estuary, probably owing to the availability of fish. The Cowichan

Figure 9
Seasonal changes in densities of Greater Scaup and Surf and White-winged scoters in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989

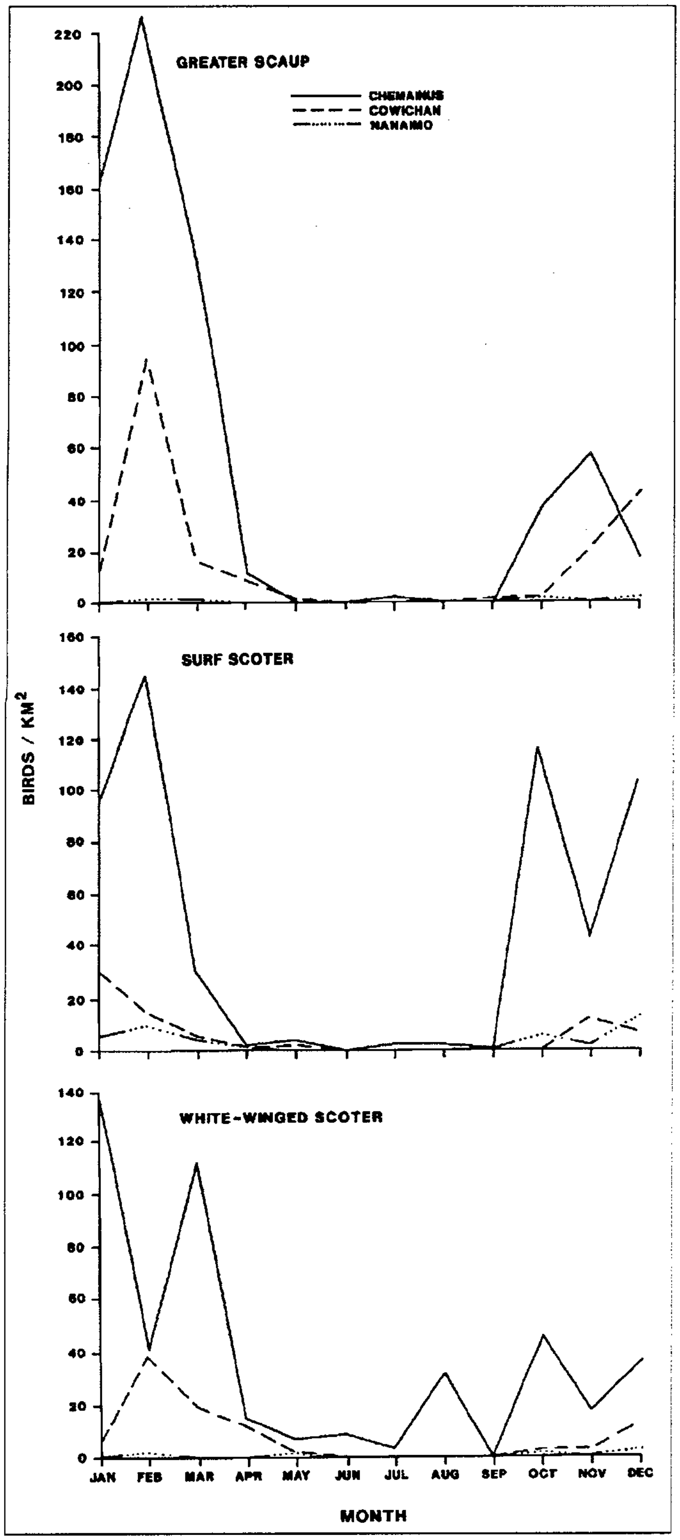
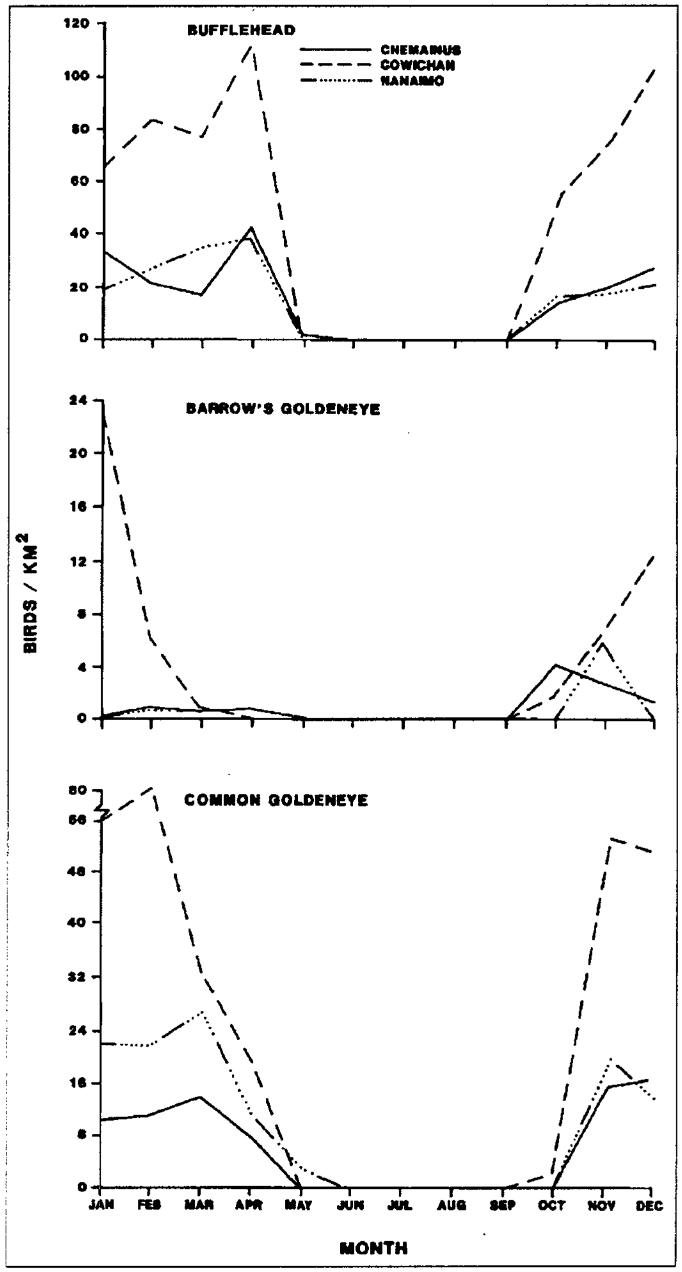


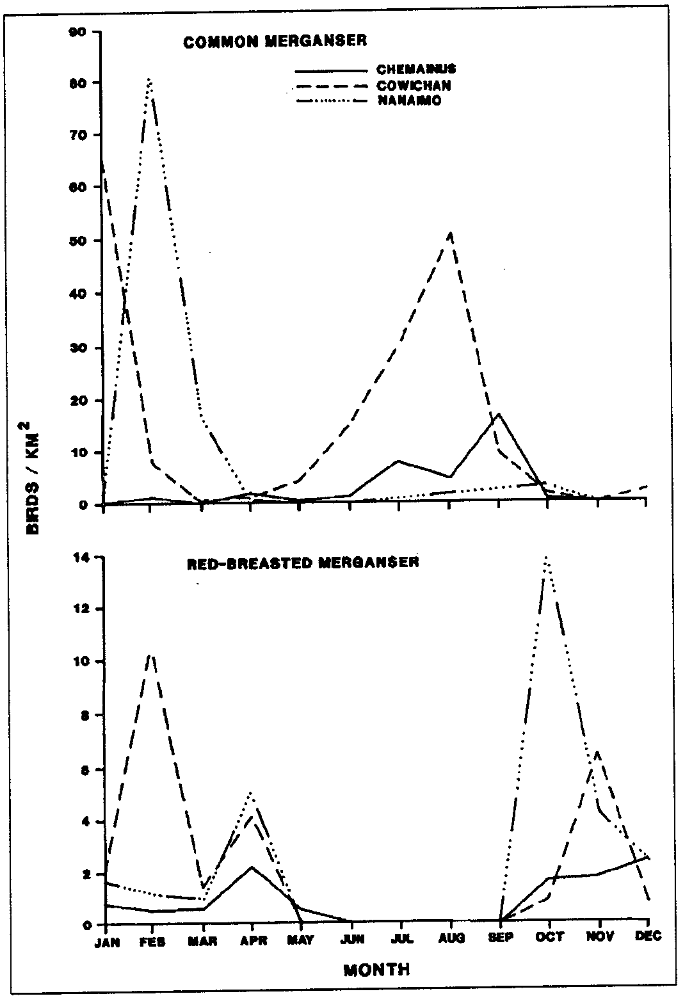
Figure 10
Seasonal changes in densities of Buffleheads and Barrow's and Common goldeneyes in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



estuary supports large numbers of salmon, Pacific herring *Clupea pallasi*, threespine stickleback *Gasterosteus aculeatus*, shiner perch *Cymatogaster aggregata*, and prickly sculpin *Cottus asper* (Bell and Kallman 1976a). Double-crested Cormorants may be attracted by the presence of herring (Vermeer, "The Gorge estuary," this volume), Western Grebes congregate at river mouths when juvenile salmon enter estuaries (Vermeer 1992), and Common Mergansers feed extensively upon sticklebacks and salmonids (Munro and Clemens 1932).

Mute Swans were seen only in the Cowichan estuary, where they were introduced, and where there is abundant food. They nest nearby in the Cowichan valley. Two other species, the Canada Goose and Common Merganser (Figs. 7 and 11), were also observed in high densities in the Cowichan estuary in summer. Both nest nearby. High densities of Trumpeter Swans in Cowichan Bay during early winter may relate to an abundance of food in the brackish marshes and in nearby fields. Boyd (this volume) observed Trumpeter Swans foraging extensively in farm fields adjacent to the Fraser estuary. Why the three *Bucephala* species had high densities in the Cowichan estuary is unknown. All three feed upon a wide

Figure 11
Seasonal changes in densities of Common and Red-breasted mergansers in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



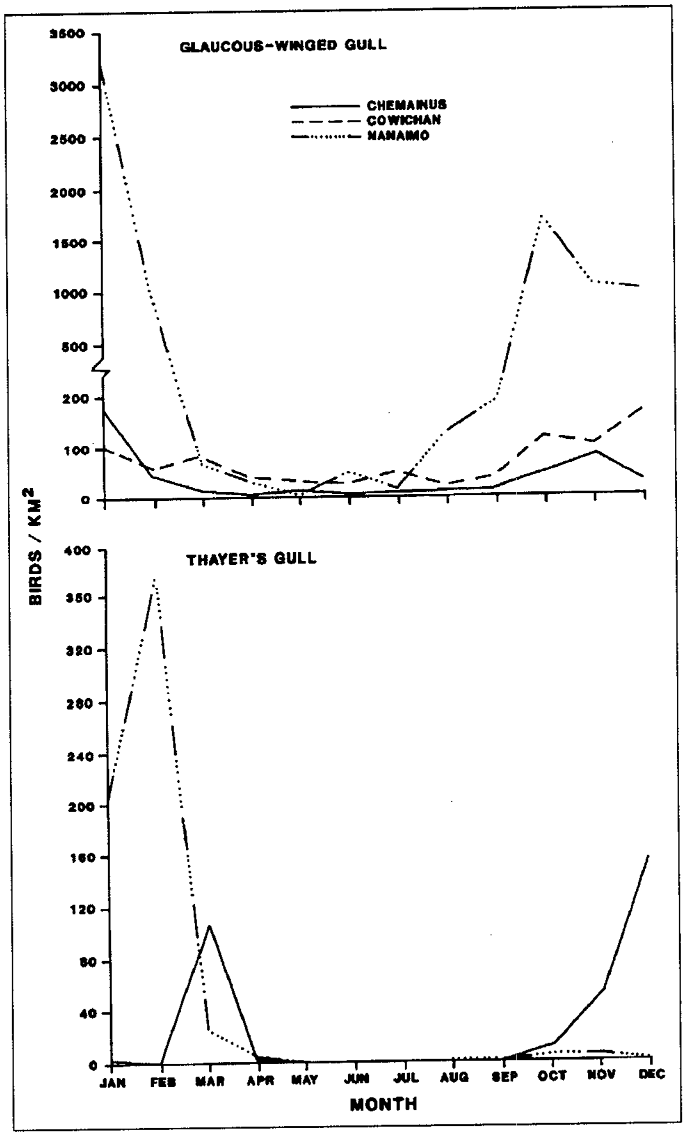
variety of snails at nearby Saltspring Island, and both Common and Barrow's goldeneyes were observed to feed extensively upon herring eggs in spring (Vermeer 1982). Similarly, it is unknown why there was a high density of Mew Gulls in the Cowichan estuary. Mew Gulls were observed to have mainly a diet of herring, and to a lesser extent crabs, at nearby Saltspring Island in fall (Vermeer et al. 1987). Herring and crabs are numerous in the Cowichan estuary (Bell and Kallman 1976a).

6.3 Chemainus estuary

The high densities of Greater Scaups and Surf and White-winged scoters in the Chemainus estuary (Fig. 9) may be related to the presence of numerous bivalves and snails (Bell and Kallman 1976a), on which those ducks feed (Vermeer and Levings 1977; Vermeer 1981; Vermeer and Bourne 1984).

Bonaparte's and Mew gulls were also observed to have higher densities in the Chemainus than in the other two estuaries. Bonaparte's Gulls may be attracted to euphausiids and amphipods, brought to the surface by tidal currents in nearby Stuart Channel, on which those gulls have been seen feeding in fast tidal currents in Active Pass (Vermeer et al. 1987).

Figure 12
Seasonal changes in densities of Glaucous-winged and Thayer's gulls in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



6.4 Comparison with the Fraser estuary

The densities of the combined waterbird populations in the Chemainus, Cowichan, and Nanaimo estuaries on Vancouver Island are compared with those of the Fraser estuary in Figure 15. The three Vancouver Island estuaries, as well as the Fraser estuary, represent a wide range of estuarine habitats.

Most of the piscivorous loons and grebes had slightly higher densities in the Fraser estuary, while the densities of cormorants (mostly Double-crested Cormorants) were similar between the two regions.

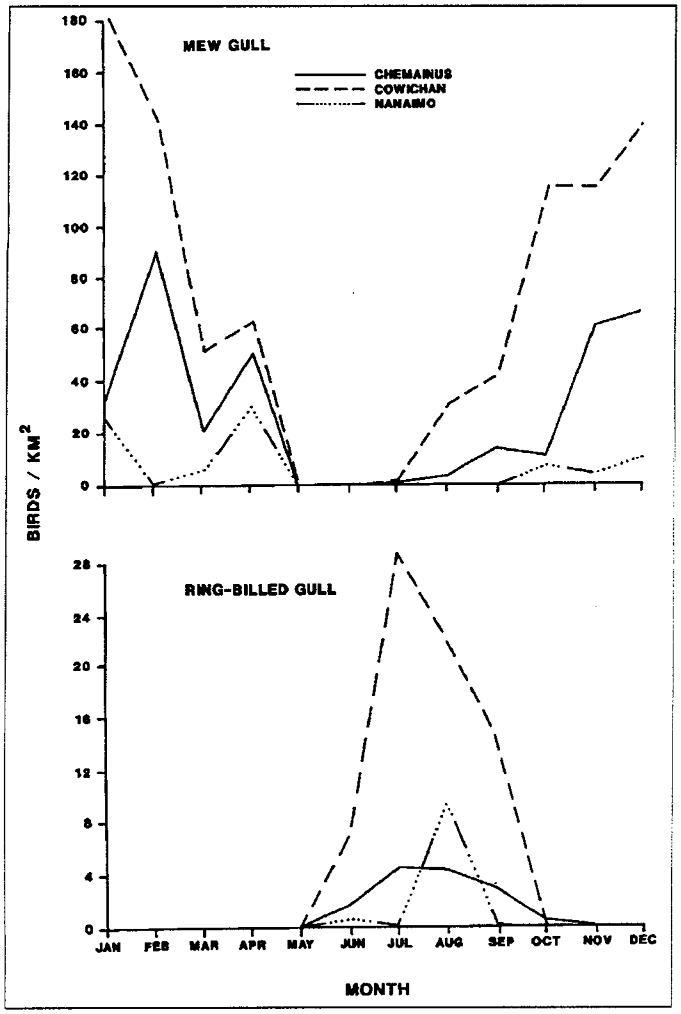
Swans had somewhat higher densities in the Vancouver Island estuaries than in the Fraser estuary, mainly as a result of high densities in the Cowichan estuary. Mute Swans were not observed in the Fraser estuary or in the Chemainus and Nanaimo estuaries.

Geese had much higher densities in the Fraser estuary than in the Vancouver Island estuaries, because of Brant and Lesser Snow Geese being numerous only in the Fraser estuary. Lesser Snow Geese are attracted to the

Table 1
Comparison of average proportions (percentages) of major bird groups in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989

	% of bird group		
Bird groups	Chemainus River estuary	Cowichan River estuary	Nanaimo River estuary
Loons	0.1	0.2	0.05
Grebes	0.3	3.9	0.1
Cormorants	0.4	1.8	0.5
Alcids	0.1	0.2	0.05
Swans	0.5	1.2	0.2
Geese	0.4	0.6	0.3
Dabbling ducks	22.6	29.4	6.2
Diving ducks	44.5	28.2	4.7
Gulls	31.1	34.5	87.9

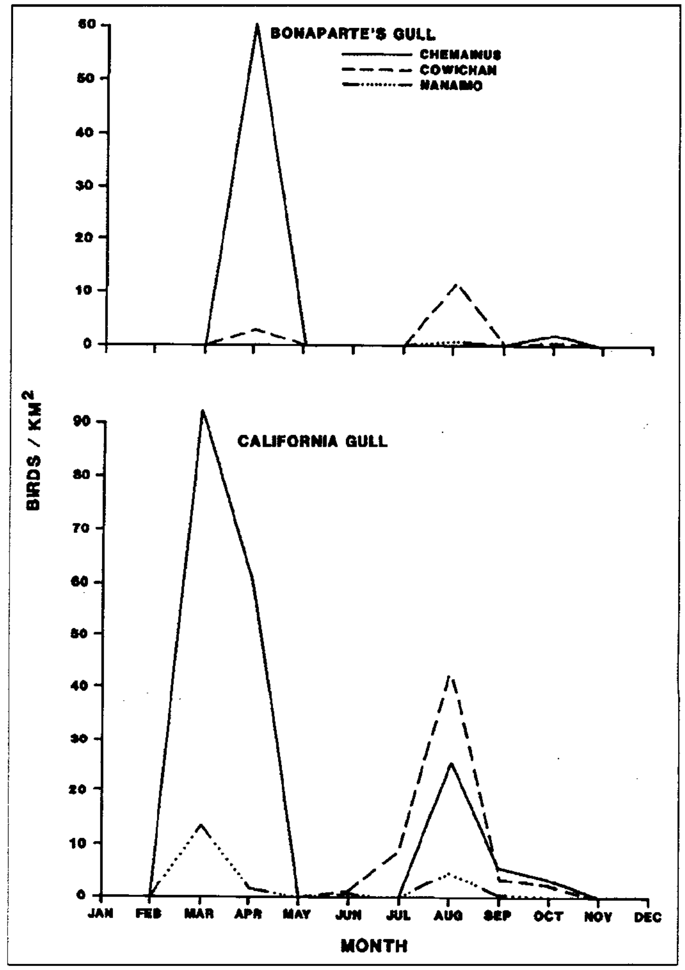
Figure 13
Seasonal changes in densities of Mew and Ring-billed gulls in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989



extensive brackish water marshes over Sturgeon Bank, where they feed upon sedges (*Carex* spp.) and bulrushes (Burton 1977; S. Boyd, pers. commun.). During high tide, Lesser Snow Geese feed on winter rye on nearby farmland (S. Boyd, pers. commun.). Brant are attracted to the extensive eelgrass beds in the Fraser River delta in spring.

We have combined all ducks in the Fraser estuary, as many birds could not be identified to a group (e.g., dabbling or diving ducks). As with geese, ducks had much higher densities in the Fraser estuary than in the

Figure 14
Seasonal changes in densities of Bonaparte's and California gulls in the Chemainus, Cowichan, and Nanaimo river estuaries in 1989

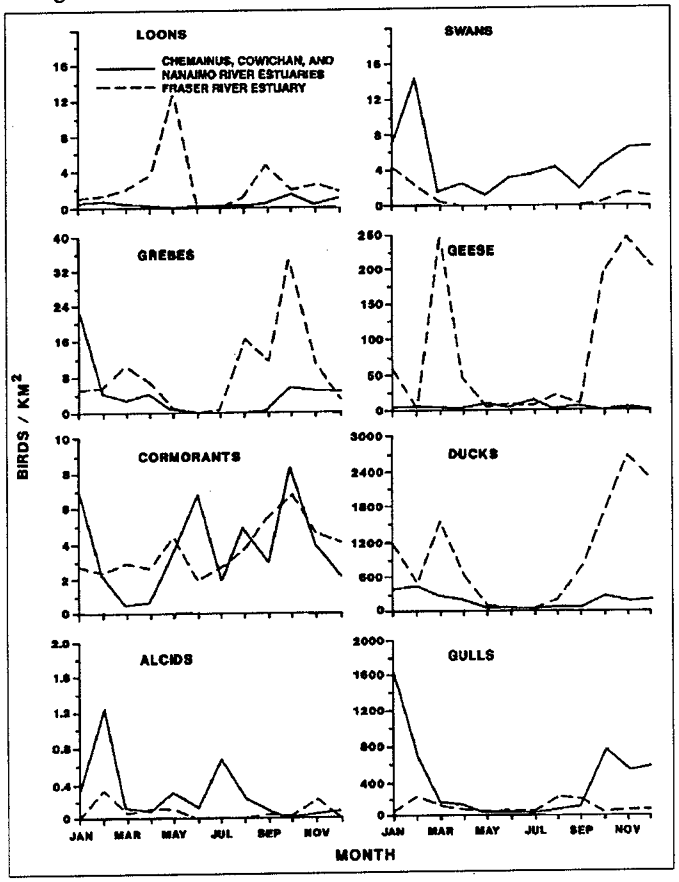


Vancouver Island estuaries, those high densities reflecting the presence of extensive eelgrass beds and their associated invertebrate community, as well as large tracts of nearby farmlands, which attract tens of thousands of dabbling ducks in fall and winter (Breault and Butler 1992; Vermeer, Butler, and Morgan, this volume). Shifts to upland habitats occur among ducks in Vancouver Island estuaries (Eamer 1985), but farmlands are less extensive there.

Gulls had much higher densities in the Vancouver Island estuaries than in the Fraser estuary from October through March, primarily because of the presence of many Glaucous-winged Gulls loafing on log booms in the Nanaimo estuary. The Glaucous-winged Gull was also the most numerous gull in the Fraser estuary. Higher gull densities in the Fraser estuary in August and September resulted from a far greater influx of California and Ring-billed gulls than occurred at the Vancouver Island estuaries (Vermeer, Butler, and Morgan, this volume).

The proportions of ducks (82.4%) and geese (7.3%) were much higher in the Fraser estuary, where there were fewer gulls (8.8%) than in the Vancouver Island estuaries (see Table 1).

Figure 15
Comparison of seasonal changes in densities of different waterbird groups in Chemainus, Cowichan, and Nanaimo river estuaries with that of the Fraser River estuary in the Strait of Georgia



7. Conclusions and recommendations

Comparisons between the three Vancouver Island estuaries and the Fraser estuary showed that each area supported different densities of each species. In contrast, seasonal changes in bird densities followed the same trends in all estuaries (i.e., densities were high from fall to spring and low in summer). There are many factors that may determine the size and composition of bird populations in estuaries. The availability, abundance, and type of food may have influenced the numbers and compositions of waterbird populations present. Feeding conditions on adjacent pasture, grass, and agricultural lands and in freshwater marshes may have determined how many geese, swans, and dabbling ducks were present. The presence of nearby garbage dumps likely influenced the numbers of gulls in the Fraser and Cowichan estuaries. The presence of nearby, undisturbed areas for nesting likely played a role in the utilization of estuaries by several species. Unless one has a thorough knowledge of the relative abundance and types of foods available in estuaries and in nearby freshwater and terrestrial habitats, the size and composition of waterbird populations in an uncensused estuary will be difficult to predict. We therefore recommend that all waterbird populations in the major British Columbia estuaries (i.e., those with more than 2 km² of intertidal area) be censused to determine their relative importance for migratory waterbirds.

We also suggest that (1) the feeding ecology of waterbirds, and the relative abundance of their prey, be thoroughly examined for the most important estuaries; and (2) the effect of log storage on birds and their prey be thoroughly investigated, as many British Columbia estuaries are extensively used by that industry.

8. Acknowledgements

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Appendix 1
Number of waterbirds observed in the Chemainus River estuary from January through December 1989

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Common Loon	3	6	1			3	2	1	9	0	5	9
Western Grebe									2	7		
Horned Grebe	10	11	8	14						9	4	10
Red-necked Grebe			3						3	2		1
Double-crested Cormorant	1				7	8	3	38	5	24	3	3
Pelagic Cormorant	2	1	1				2	1	3	26	1	5
Trumpeter Swan	50	71	8							2	24	25
Canada Goose		80	2	4	17	14	30				1	
Mallard	70	169	96	15	60			36	10	375	30	125
American Wigeon	592	466	281	344	2				12	586	310	410
Eurasian Wigeon			2									
Northern Pintail	189	85	64	55				60		100	155	232
Green-winged Teal	790	394	328	661				75		710	80	240
Gadwall			5								3	
Northern Shoveler			11					5				
Greater Scaup	1345	1880	1102	98			2			294	475	140
Surf Scoter	795	1219	250	18	29		21	20		958	335	850
White-winged Scoter	1128	331	936	125	58	70	25	250		370	140	285
Black Scoter			3									3
Common Goldeneye	87	91	118	66						5	132	142
Barrow's Goldeneye	2	8	5	7						35	23	12
Bufflehead	283	178	143	351	1					118	150	228
Common Merganser		12		22	8	20	64	41	143	3		
Red-breasted Merganser	7	4	5	18	4					14	15	20
Hooded Merganser	6	1	8	3				4		5	6	2
Glaucous-winged Gull	1500	365	124	43	121	2	4	38	69	350	565	184
Herring Gull	2									9	6	70
Thayer's Gull	1		878	3						105	440	1300
California Gull			765	504			5	210	50	30		2
Mew Gull	280	737	174	415			2	35	125	101	510	560
Ring-billed Gull						14	37	35	25	4		
Bonaparte's Gull				510					3	18		
Caspian Tern						2						
Pigeon Guillemot			2		3	2	1	5				
Marbled Murrelet		1					1					
Total no. of birds	7143	6110	5323	3276	310	135	199	854	459	4260	3413	4858
No. of birds/km^2	865	740	644	397	38	16	24	103	56	516	413	588

Appendix 2
Number of waterbirds observed in the Cowichan River estuary from January through December 1989

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Common Loon	6	6	5	2					2	8	1	2
Red-throated Loon	2										1	
Yellow-billed Loon		1										
Western Grebe	450	50	2	15	2					60	83	30
Horned Grebe	8	8	33	27					2	20	8	14
Red-necked Grebe	4	7	3	3						5		3
Double-crested Cormorant	109	25	5	9	19	18	2	28	21	48	45	24
Brandt's Cormorant											1	
Pelagic Cormorant	3	2	3	3	1				1	3	7	1
Mute Swan	90	30	24	51	28	68	70	87	40	49	63	39
Trumpeter Swan	25	216										10
Canada Goose			19	2	2	20	75		12			
Mallard	184	365	77	15	10	10	1	202	211	348	78	260
American Wigeon	481	260	335	502				1	237	440	266	302
Eurasian Wigeon	2	1	1	1							2	
Northern Pintail	39	2	58	34				28	10	14	1	3
Green-winged Teal	473	7	265	515				1	8	241	25	5
Blue-winged Teal					6							
Gadwall	5		16							14	5	4
Northern Shoveler								1				
Ring-necked Duck		1										
Canvasback		20										
Greater Scaup	62	382	68	38	6				1	4	85	172
Surf Scoter	124	60	25	4	5						43	24
White-winged Scoter	30	151	77	51	8					3	4	48
Common Goldeneye	222	320	128	77						10	212	203
Barrow's Goldeneye	95	25	4							7	25	49
Bufflehead	263	335	309	448	2					219	307	414
Common Merganser	263	31	1	6	19	61	127	204	36	8		10
Red-breasted Merganser	6	42	6	17						4	26	3
Hooded Merganser	24	6	11	1				3	2	11	5	1
American Coot	2			6								2
Glaucous-winged Gull	428	235	314	180	135	104	193	79	156	427	373	625
Herring Gull	1										19	2
Thayer's Gull		1									73	1
California Gull						2	32	172	13	10		
Mew Gull	724	565	209	255			9	124	174	468	467	565
Ring-billed Gull						28	115	88	58			
Bonaparte's Gull				14				49		2	1	
Common Tern									1			
Pigeon Guillemot									2			
Marbled Murrelet	7	23									1	2
Rhinoceros Auklet	1		1									
Total no. of birds	4133	3177	1999	2276	243	311	624	1067	987	2423	2227	2818
No. of birds/km^2	1036	796	501	570	61	78	156	267	247	607	558	706

Appendix 3
Number of waterbirds observed in the Nanaimo River estuary from January through December 1989

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Common Loon	2	2	5	3						23		6
Western Grebe			1									30
Horned Grebe	5	10	10	25						13	5	6
Red-necked Grebe	7	4	2	1						5		1
Double-crested Cormorant	12	14	2	1	43	109	28	28	27	36	18	7
Brandt's Cormorant	13	1										
Pelagic Cormorant		3		1	1	3	3	5	6	39	4	4
Trumpeter Swan	23	51	9							15	72	56
Canada Goose	40			4	124		112		2			
Lesser Snow Goose										3		
Mallard	10	12	21	22	25			119		25	64	90
American Wigeon	121	1 240	392	410						672	470	30
Eurasian Wigeon	1											
Northern Pintail	13	160		28				240		33	83	33
Green-winged Teal		850	85	95				49		25	181	
Gadwall				2							4	
Northern Shoveler		8			6							
Greater Scaup	5	23	22							10		2
Surf Scoter	54	86	35	9						42	8	100
White-winged Scoter	14	19			5					3		10
Common Goldeneye	191	189	230	100	30					2	171	120
Barrow's Goldeneye	2	8	5								50	2
Bufflehead	172	236	305	331						140	150	178
Harlequin Duck									1			
Common Merganser		700	150	4			16	22	24	25		
Red-breasted Merganser	15	10	9	43						119	36	20
Hooded Merganser		8						1			3	2
American Coot				3				3				
Glaucous-winged Gull	25 000	8 870	597	282	30	403	68	1 049	1 612	14 370	8 700	8 500
Thayer's Gull	1 800	3 260	222	5				1	1	53	44	7
California Gull			112	15		1		37	9	1		
Mew Gull	225	15	56	260				10	11	71	50	100
Ring-billed Gull						4		80	1			
Bonaparte's Gull								1				
Pigeon Guillemot		1		2	4	1	12					
Marbled Murrelet		1						1				
Total no. of birds	27 725	15 781	2 270	1 646	268	521	239	1 648	1 694	15 725	10 113	9 304
No. of birds/km^2	3 689	1 835	264	191	31	61	28	191	197	1 829	1 178	1 082

Waterbird populations in the Courtenay River estuary: a comparison with southern Vancouver Island estuaries

Kees Vermeer

1. Abstract

The waterbird population in the Courtenay River estuary was censused each month of 1989. Diving ducks constituted, on average, 45.2%, dabbling ducks 25.9%, gulls 23.5%, and loons, grebes, cormorants, alcids, swans, and geese the remaining 5.5% of the waterbird population. Waterbird densities in the Courtenay River estuary were compared with those of three other estuaries on southern Vancouver Island. Seasonal trends were similar for the two estuarine regions; diving and dabbling ducks and gulls were also the major bird groups in the southern estuaries. There were also major differences. The Courtenay River estuary had higher densities of Trumpeter Swans *Cygnus buccinator* in winter. Mute Swans *C. olor* were observed only in the southern estuaries. Scoter densities were higher in the Courtenay River estuary, with the Black Scoter *Melanitta nigra* being prominent there but not in the south. Oldsquaws *Clangula hyemalis* were observed only in the Courtenay River estuary. Harlequin Ducks *Histrionicus histrionicus* and Bonaparte's Gulls *Larus philadelphia* were much more numerous in the Courtenay River estuary than to the south, whereas Green-winged Teals *Anas crecca* were more abundant in the southern estuaries.

The Courtenay River estuary has suffered much from development and pollution. It is recommended that the status of the environmental knowledge for the Courtenay River estuary be updated.

2. Résumé

En 1989, on a recensé tous les mois la population d'oiseaux aquatiques dans l'estuaire de la rivière Courtenay. La population était constituée, en moyenne, de canards plongeurs (45,2 %), de canards de surface (25,9 %), de goélands et de mouettes (23,5 %) et de huarts, de grèbes, de Cormorans, d'alcidés, de cygnes et d'oies et bernaches (5,5 %). On a comparé la densité de la population d'oiseaux aquatiques de l'estuaire de la rivière Courtenay avec celle de trois autres estuaires du sud de l'île de Vancouver. Les tendances saisonnières étaient semblables pour les deux régions estuariennes; les canards plongeurs et les canards de surface, de même que les goélands et les mouettes, composaient aussi la majeure partie des populations d'oiseaux des estuaires du sud. Il y avait cependant de grandes différences. Durant l'hiver, la densité des Cygnes trompettes *Cygnus buccinator* était plus élevée dans l'estuaire de la rivière Courtenay. Le Cygne tuberculé *C. olor* n'a été observé que dans les estuaires du sud. La densité des Macreuses était plus élevée dans l'estuaire de la rivière Courtenay que dans les estuaires du sud; la Macreuse à bec jaune *Melanitta nigra* prédominait dans la population de Courtenay mais non dans les autres. Le Canard kakawi *Clangula hyemalis* n'a été observé que dans l'estuaire de la rivière Courtenay. Les populations de Canards arlequins *Histrionicus histrionicus* et de Mouettes de Bonaparte *Larus philadelphia* étaient beaucoup plus importantes dans l'estuaire de la rivière Courtenay que dans le sud, alors que la Sarcelle à ailes vertes *Anas crecca* était plus abondante dans les estuaires du sud.

L'estuaire de la rivière Courtenay a subi les effets d'une pollution et d'une mise en valeur importantes. On recommande que les données environnementales sur l'estuaire de la rivière Courtenay soient mises à jour.

3. Introduction

The Courtenay River estuary (hereafter the Courtenay estuary) is one of the largest on Vancouver Island, supporting on average 6000 waterbirds in December (R.W. McKelvey, unpubl. data, in Morris et al. 1979). The most abundant birds between December 1974 and April 1975 were scoters, goldeneyes, Buffleheads *Bucephala albeola*, Mallards *Anas platyrhynchos*, American Wigeons *A. americana*, Northern Pintails *A. acuta*, Glaucous-winged Gulls *Larus glaucescens*, Mew Gulls *L. canus*, Herring Gulls *L. argentatus*, and Dunlins *Calidris alpina*. However, year-round censuses of waterbirds using the Courtenay estuary have not been made.

The objectives of this study were to determine the use of the Courtenay estuary by waterbirds other than shorebirds (i.e., sandpipers, plovers, etc.) throughout the course of one year and to compare waterbird densities with those in the Chemainus, Cowichan, and Nanaimo river estuaries (hereafter the Chemainus, Cowichan, and Nanaimo estuaries), located farther south on the east coast of Vancouver Island.

4. Study area and methods

The geology, soils, climate, oceanography, aquatic vegetation, invertebrate biology, fisheries, wildlife, water quality, pollution, and the effects of development in the Courtenay estuary have been reviewed by Morris et al. (1979).

The waterbird population (excluding shorebirds, such as sandpipers, plovers, etc.) of the Courtenay estuary was censused one day each month from January through December 1989 by two observers in a small boat at mid- to high tides. Censuses of the Chemainus (8.26 km^2), Cowichan (3.99 km^2), and Nanaimo (8.60 km^2) estuaries were made a day earlier than those of the Courtenay estuary. The censused area in the Courtenay estuary (Fig. 1) was calculated by use of a planimeter and hydrographic chart to be 9.25 km^2. Censused areas of the Chemainus, Cowichan, and Nanaimo estuaries are shown in Vermeer, Bentley, and Morgan (this volume).

5. Results

5.1 Seasonal composition

The highest numbers of waterbirds in the Courtenay estuary (>5000 birds) were observed from October through February, whereas the lowest numbers were seen in June and July (<1300 birds, Table 1). Diving and dabbling ducks and gulls made up the large majority of birds (Fig. 2). Over a 12-month period, diving ducks constituted, on average, 45.2%, dabblers 25.9%, and gulls 23.5% of the entire waterbird population. Loons, grebes, cormorants, alcids, swans, and geese made up the remaining 5.5% of the population.

Of the diving ducks, Surf Scoters *Melanitta perspicillata*, White-winged Scoters *M. fusca*, and Black Scoters *M. nigra* made up 65% of the total, Greater Scaups *Aythya marila* 15%, and Common Goldeneyes *Bucephala clangula* and Buffleheads 10%. Among the dabblers, Mallards and American Wigeons accounted for 93% of the total. Glaucous-winged, Bonaparte's *Larus philadelphia*, and Mew gulls made up 55%, 22%, and 12%, respectively, of the gull population. Glaucous-winged and Mew gulls were present in every month, Thayer's Gulls *L. thayeri* from October through April, Bonaparte's Gulls from April through November, and Ring-billed Gulls *L. delawarensis* mainly from June through October. California Gulls *L. californicus* visited the estuary from March through May and again from July through October (Table 1).

Diving ducks were more numerous than dabblers in every month except March, when most diving ducks temporarily abandoned the estuary (Fig. 2). Diving ducks whose numbers declined rapidly in March were Greater Scaups, Surf and White-winged scoters, and Oldsquaws *Clangula hyemalis* (Table 1). The populations of those species increased again in April before declining in summer.

5.2 Interestuarine comparison

Fish-eating birds (loons, grebes, cormorants, and alcids), swans, and geese occurred in low proportions in all four estuaries (Table 2). Dabbling and diving duck proportions were high in the Chemainus, Cowichan, and Courtenay estuaries, but not in the Nanaimo estuary. Although gulls constituted a major portion of waterbirds in all estuaries, the Nanaimo estuary supported a disproportionately high number of them.

No major differences were observed in the densities of loons, grebes, cormorants, alcids, and gulls in the Courtenay estuary compared with the same bird groups in the Chemainus, Cowichan, and Nanaimo estuaries combined, except that gulls were much more numerous in the southern estuaries in winter (Fig. 3). That was a result of the presence of large numbers of Glaucous-winged Gulls loafing on booms in the Nanaimo estuary (Vermeer, Bentley, and Morgan, this volume). Gull densities in the Courtenay estuary were similar to those in the Chemainus and Cowichan estuaries.

Densities of swans were similar in the two estuarine regions, except for January and February, when they were higher in the Courtenay estuary (Fig. 4). Trumpeter Swans *Cygnus buccinator* were observed at both Courtenay and the southern estuaries, whereas Mute Swans *C. olor* occurred only in the Cowichan estuary. Trumpeter Swans were present only from October through February in both estuarine regions. In January and February, Trumpeter Swans were more numerous at Courtenay than in the southern estuaries.

Densities of geese (mostly Canada Geese *Branta canadensis*) were similar for the two estuarine regions, except at Courtenay during April, when migrating Brant *Branta bernicla* arrived (Fig. 4). Densities of dabbling ducks (mostly Mallards and American Wigeons) were also similar for the two regions, except during November and

Figure 1
The Courtenay River estuary, showing the areas that were studied throughout 1989

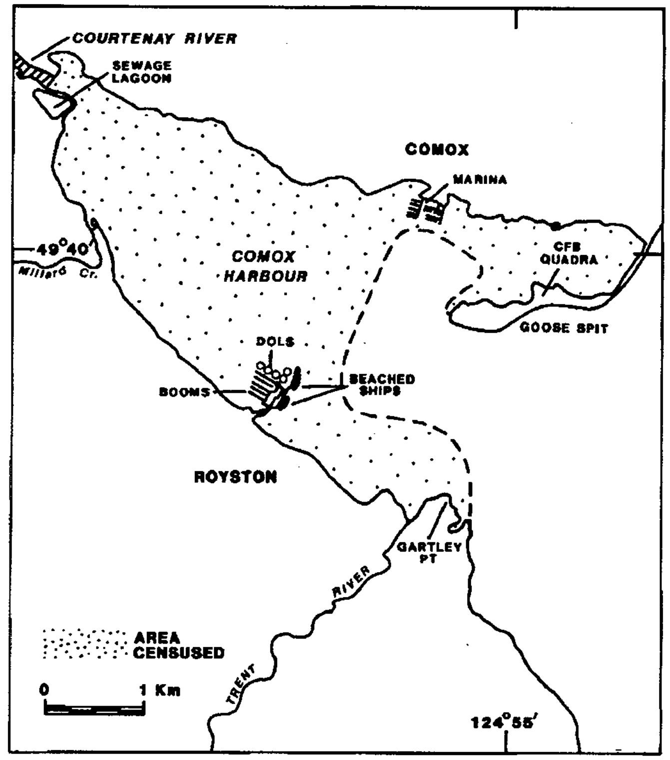


Table 1
Number of waterbirds observed (for a total of 47 species) in the Courtenay River estuary from January through December 1989

Species	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Common Loon	10	16	5	23	2	1		7	11	37	33	21
Pacific Loon	1				28					1		62
Red-throated Loon	3	2								4	29	9
Western Grebe	35			1					6	124	321	500
Horned Grebe	13	25	37	77	1			2	1	26	36	20
Red-necked Grebe	8	23	1	21	1			7		22	5	12
Eared Grebe										2		
Double-crested Cormorant	4		21	3	2				8	16	22	12
Brandt's Cormorant	5										2	
Pelagic Cormorant	2	1							7	18	24	10
Trumpeter Swan	133	350	6							1		32
Canada Goose	119	70		3	18	3	17		51		21	25
Brant				250								
Mallard	462	997	246	149	137	138	78	297	299	537	1495	1517
American Wigeon	904	1135	1070	317	22			8	222	1013	1691	695
Eurasian Wigeon	1		2							3	4	3
Northern Pintail	110	31	80	132	4			25	57	138	85	61
Green-winged Teal	10		10	5				3	2	82		12
Gadwall				3								
Northern Shoveler				4				5				
Canvasback	3	10	4								6	5
Greater Scaup	465	388	88	244	45		2	1		820	904	834
Surf Scoter	526	569	12	205	275	130	125	71	570	1890	867	1313
White-winged Scoter	390	306	28	1198	683	102	16	730	1722	1570	760	1540
Black Scoter	134	103		10	10			1		106	160	115
Common Goldeneye	170	206	54	111	3			1		62	474	303
Barrow's Goldeneye	8		1							2	18	5
Bufflehead	202	196	208	211						215	284	203
Harlequin Duck	5	13		46	73				7	13	28	17
Oldsquaw	53	46		70	10					42	70	84
Ruddy Duck		1										
Common Merganser	175	68	28	27	77	59	104				57	50
Red-breasted Merganser	102	28	42	23						184	18	33
Hooded Merganser										3		
American Coot												2
Glaucous-winged Gull	1165	1430	717	420	427	112	303	389	231	550	769	620
Herring Gull	1									2	1	2
Thayer's Gull		75	13	1						1	6	1
California Gull			9	300	285		22	38	29	15		
Mew Gull	50	220	350	189	3	19	34	184	81	245	87	80
Ring-billed Gull				7		36	202	249	75	28		
Bonaparte's Gull				356	192	629	260	830	589	17	5	
Caspian Tern							1					
Common Tern								1	30			
Common Murre	4											10
Pigeon Guillemot	2	1	1	9				1				
Marbled Murrelet	2	1		2		11	75	1	2		10	6
Total no. of birds	5277	6311	3033	4417	2298	1240	1239	3022	4140	7789	8292	8214
No. of birds/km^2	570	682	328	478	248	134	134	327	448	842	896	888

December, when they were higher at Courtenay. Diving duck (mostly scoters) densities were much higher at Courtenay than at the southern estuaries from September through December.

Besides major bird groups, some individual species had higher densities at Courtenay than at the southern estuaries (Fig. 5). Oldsquaws were seen only at Courtenay, and Black Scoters, Harlequin Ducks, and Bonaparte's Gulls were far more numerous there than in the three southern estuaries. Green-winged Teals *Anas crecca*, on the other hand, were observed to have much higher densities in the southern estuaries.

6. Discussion

6.1 Seasonal composition and estuarine comparison

The broad seasonal trends of waterbirds in the Courtenay estuary and the three southern estuaries were similar: high numbers occurred in winter, whereas few were present in summer. The overall proportions of waterbirds in the Courtenay estuary were similar to those in the Chemainus and Cowichan estuaries, with a few exceptions. The Nanaimo estuary differed from the other three estuaries in that it had disproportionately more Glaucous-winged Gulls and a reduced proportion of ducks.

Differences in waterbird species densities between estuaries likely relate to differences in food sources or their availabilities. There are extensive beds of eelgrass *Zostera marina* in the low intertidal zone of the Courtenay estuary (Morris et al. 1979). Eelgrass is important food for Brant, which likely explains their presence only in the Courtenay estuary.

Trumpeter Swans feed extensively upon emerged vegetation in the Courtenay estuary, particularly near Millard Creek. McKelvey (1981) determined that the rhizomes of three-square bulrush *Scirpus americanus* were the predominant food of the wintering swans in the Courtenay estuary, although the swans also fed upon grasses and sedges.

Figure 2
Seasonal changes in numbers and percentages of the major waterbird groups in the Courtenay River estuary, 1989

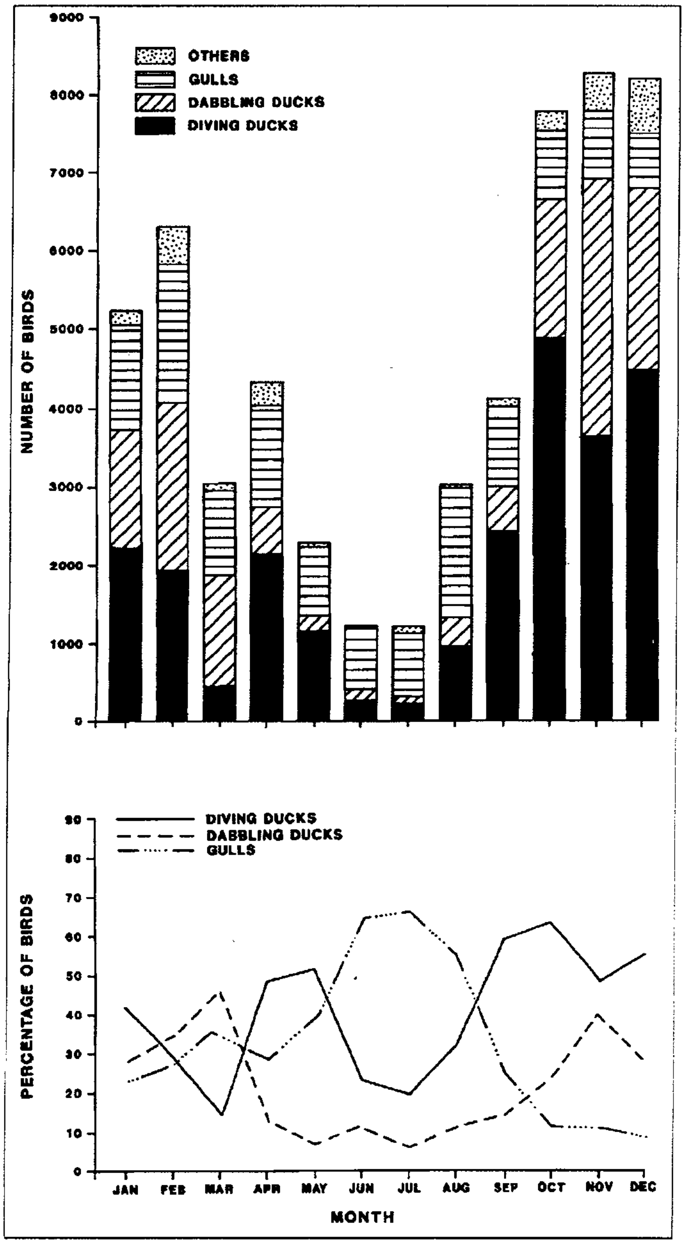


Figure 3
Comparison of densities of loons, grebes, cormorants, alcids, and gulls between the Courtenay and the Chemainus, Cowichan, and Nanaimo river estuaries

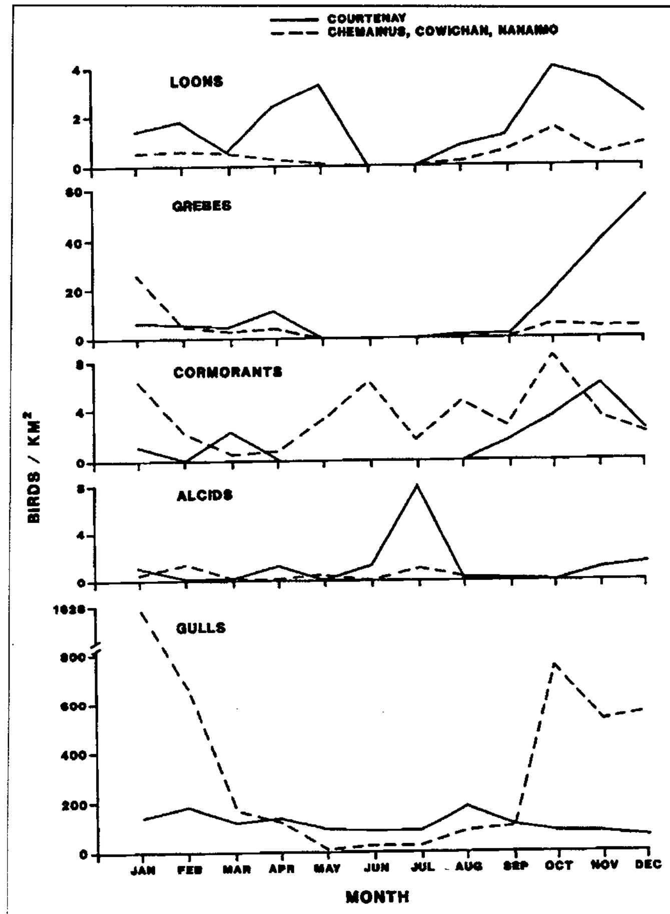


Table 2
Comparisons of average proportions (percentages) of major bird groups in the Chemainus, Courtenay, Cowichan, and Nanaimo river estuaries in 1989

Bird groups	Chemainus River estuary	Cowichan River estuary	Nanaimo River estuary	Courtenay River estuary
Loons	0.1	0.2	0.05	0.4
Grebes	0.3	3.9	0.1	2.4
Cormorants	0.4	1.8	0.5	0.3
Alcids	0.1	0.2	0.05	0.3
Swans	0.5	1.2	0.2	0.9
Geese	0.4	0.6	0.3	1.1
Dabbling ducks	22.6	29.4	6.2	25.9
Diving ducks	44.5	28.2	4.7	45.2
Gulls	31.1	34.5	87.9	23.5

The Courtenay estuary supports an abundance of blue mussels *Mytilus edulis* and clams (Morris et al. 1979). Blue mussels are important foods of Black and Surf scoters, whereas both clams and mussels are consumed in large quantities by White-winged Scoters in British Columbia coastal waters (Vermeer 1981; Vermeer and Bourne 1984). The high density of scoters in the Courtenay estuary may relate to the abundance of those molluscs.

The presence of substantial numbers of Oldsquaws and Harlequin Ducks in the Courtenay estuary may relate to nearby spawning grounds of Pacific herring *Clupea pallasi* along Baynes Sound and Denman Island (Morris et al. 1979). Those ducks, as well as Surf and White-winged scoters, Greater Scaups, and Common Goldeneyes, switch to feeding upon herring spawn when it is available (Vermeer 1981). This may explain their sudden decline in the Courtenay estuary in March, as they possibly had departed for the herring spawning grounds. After the end of spawning in March, these bird species likely returned to the Courtenay estuary.

Mostly juvenile Bonaparte's Gulls used the Courtenay estuary in early summer, whereas both adults and juveniles were found there in late summer and early fall. This species may have been attracted to the area because of the presence of juvenile herring, on which they feed (Vermeer et al. 1987). Marbled Murrelets *Brachyramphus marmoratus*, which peaked in number in

Figure 4
Comparison of densities of the major waterfowl groups between the Courtenay and the Chemainus, Cowichan, and Nanaimo river estuaries

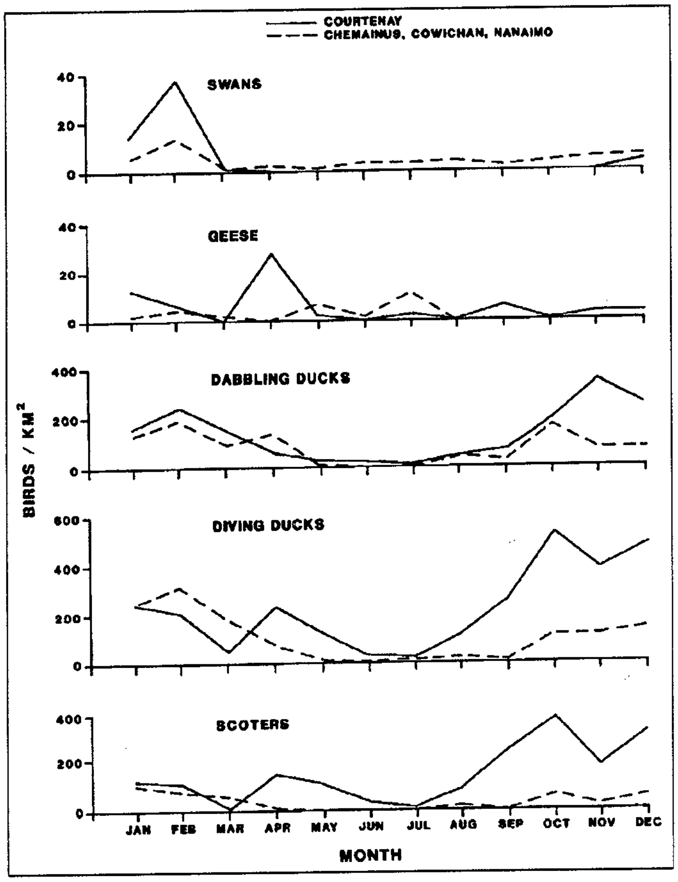
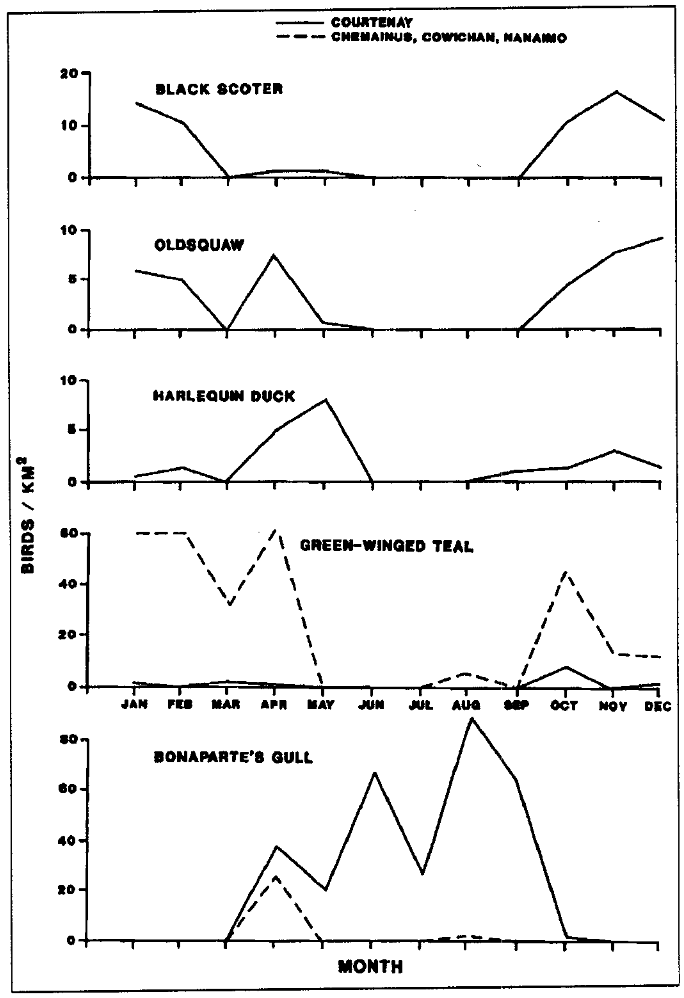


Figure 5
Comparison of densities of four duck species and Bonaparte's Gull between the Courtenay and the Chemainus, Cowichan, and Nanaimo river estuaries



the estuary in July, may also have been attracted to the same food source (see Vermeer and Thompson 1992).

Green-winged Teals were far more numerous in the southern estuaries than in the Courtenay estuary. This species is frequently seen in and near brackish and freshwater marshes, which are more extensive in the three southern estuaries than in the Courtenay estuary (Campbell Prentice and Boyd 1988).

6.2 The need for monitoring the estuary

The Courtenay estuary has suffered much from development and pollution (Burns 1976; Morris et al. 1979). However, the estuary still constitutes a major feeding and resting habitat for a variety of waterbirds. The waterbird population visiting the estuary in this study was similar in composition and magnitude to that observed in the winter of 1974–75 (R.W. McKelvey, unpubl. data, in Morris et al. 1979). The exception was that Herring Gulls, which had been reported to be common by R.W. McKelvey, were seen only in small numbers in the present study. It is likely that those gulls reported by McKelvey were Thayer's Gulls; Herring Gulls are uncommon throughout all of the Strait of Georgia, including its major estuaries. If environmental perturbations continue, the fauna in the Courtenay estuary could be seriously affected and may ultimately decline as a result. For that reason, it is important to frequently monitor the different biota and the amount of development to determine interactions, so that measures can be taken to halt further degradation.

7. Acknowledgements

M. Bentley assisted with the census of birds in the Courtenay estuary. R.W. Butler, R.W. Elner, K.H. Morgan, and N.A.M. Verbeek read the manuscript and made pertinent comments. S. Bucknell typed the manuscript.

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Habitat use by waterbirds in the Cowichan River estuary

Kees Vermeer, Ken H. Morgan, G.E. John Smith, and Allen N. Wisely

1. Abstract

Use of habitats (subtidal zone, intertidal zone, river mouths, fields, and log booms and pilings) by waterbirds was investigated in the Cowichan River estuary, Vancouver Island, British Columbia. Habitat was the main factor that correlated significantly with the distribution of waterbirds. Most fish-eating birds other than Double-crested Cormorants *Phalacrocorax auritus* occurred over subtidal areas. Dabbling ducks were found mostly in river mouths, whereas diving ducks were most numerous in intertidal areas. Barrow's Goldeneyes *Bucephala islandica* and Hooded Mergansers *Lophodytes cucullatus* had significantly higher densities on booms and pilings than in any other habitats; Mute Swans *Cygnus olor*, American Wigeons *Anas americana*, and Buffleheads *Bucephala albeola* switched from river mouths in January to intertidal areas in April; and Canada Geese *Branta canadensis* moved from fields in January to river mouths in April. Species densities were also correlated with tidal level. Surf Scoters *Melanitta perspicillata* and White-winged Scoters *M. fusca* had high densities in subtidal areas during low tide. Mute Swans, American Wigeons, and Glaucous-winged Gulls *Larus glaucescens* were most numerous in river mouths, and Mew Gulls *L. canus* were abundant at river mouths and on booms and pilings during high tide.

2. Résumé

On a étudié l'utilisation des habitats (zones infratidale et intertidale, embouchures de la rivière, champs, estacades et pieux) par les oiseaux aquatiques dans l'estuaire de la rivière Cowichan, sur l'île de Vancouver, en Colombie-Britannique. L'habitat est le principal facteur présentant une corrélation significative avec la répartition des oiseaux aquatiques. Mis à part le Cormoran à aigrettes *Phalacrocorax auritus*, la plupart des oiseaux piscivores se trouvaient dans la zone infratidale. Les canards de surface ont été observés surtout à l'embouchure des rivières; les canards plongeurs étaient en plus grand nombre dans la zone intertidale. Les populations de Garrots de Barrow *Bucephala islandica* et de Becs-scies couronnés *Lophodytes cucullatus* étaient beaucoup plus denses sur les estacades et les pieux que partout ailleurs. Les populations de Cygnes tuberculés *Cygnus olor*, de Canards siffleurs d'Amérique *Anas americana* et de Petits Garrots *Bucephala albeola*, qui se trouvaient à l'embouchure des rivières en janvier, se sont déplacées vers la zone intertidale en avril. Les populations de Bernaches du Canada *Branta canadensis*, qui étaient dans les champs en janvier, se sont retrouvées dans l'embouchure des rivières en avril. La densité des espèces est également en corrélation avec la marée. À marée basse, la densité des populations de Macreuses à front blanc *Melanitta perspicillata* et de Macreuses à ailes blanches *M. fusca* était élevée dans la zone infratidale. À marée haute, le Cygne tuberculé, le Canard siffleur d'Amérique et le Goéland à ailes grises *Larus glaucescens* étaient surtout nombreux dans les embouchures et le Goéland cendré *L. canus* était abondant dans les embouchures, sur les estacades et sur les pieux.

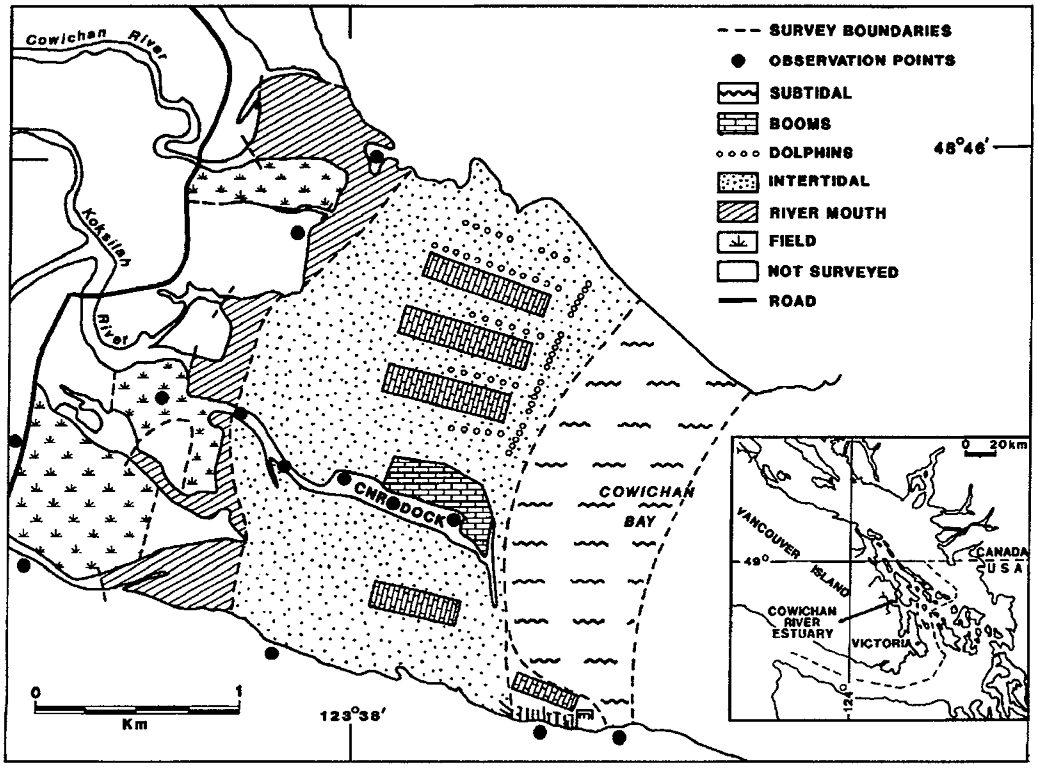
3. Introduction

Many Vancouver Island estuaries have been considerably reduced in size by human development. Campbell Prentice and Boyd (1988) reported that extensive human development, including log handling and storage, pulp mills, and marinas, had led to more than a 30% decline in area of estuarine habitats along the east coast of Vancouver Island over the last 100 years. Because of the threats to Vancouver Island estuaries, the Canadian Wildlife Service initiated a year-long census to determine the size and composition of waterbird populations in five estuaries on the east coast of Vancouver Island (Courtenay, Chemainus, Cowichan, Gorge, and Nanaimo estuaries). In this paper, we describe the influence of tide level and season on habitat use by waterbirds in the Cowichan River estuary. The influence of tide level on habitat use is well documented for both short- and long-legged wading birds (e.g., Burger et al. 1977; Connors et al. 1981; Black and Collopy 1982; Fleischer 1983; Powell 1987) but to a much lesser extent for waterbirds such as gulls and waterfowl (e.g., Tangren 1982; Morgan et al. 1987; Vermeer et al. 1991).

4. Study area

The geology, soils, climate, aquatic vegetation, invertebrate biology, and fisheries of the Cowichan River

Figure 1
Location of habitats in the Cowichan River estuary, Vancouver Island, British Columbia. "Dolphins" is a cartographer's name for pilings.



estuary have been reviewed by Bell and Kallman (1976). The waterbird population of the estuary has been censused throughout one year (Vermeer, Bentley, and Morgan, this volume).

5. Methods

5.1 Data collection

Five habitat types within the Cowichan River estuary (offshore subtidal zone, intertidal zone, river mouths, grassy fields, and log storage booms and pilings) were delineated on hydrographic charts. Each habitat type was censused by one observer twice a day (morning and afternoon) between 13 and 30 January 1990 and between 15 and 29 April 1990 (Fig. 1). Waterbirds other than shorebirds (i.e., sandpipers, plovers, etc.) were counted from the shore through binoculars and a spotting telescope. The surface area of each habitat type was calculated with a planimeter on a hydrographic chart. The subtidal, intertidal, river mouth, and field areas surveyed were 1.18, 3.24, 0.82, and 0.66 km^2, respectively. The area covered by booms and pilings could only be estimated, as the configuration of the booms changed throughout the study. During January, booms and pilings covered approximately 0.5 km^2, whereas in April their area had declined to approximately 0.25 km^2.

The feeding activity of Mute Swans *Cygnus olor*, American Wigeons *Anas americana*, Glaucous-winged Gulls *Larus glaucescens*, and Mew Gulls *L. canus* was examined on 10 and 29 April 1993, as the choice of habitat had been observed to be influenced by the tide level in 1990. Counts were made at 10-minute intervals, determining the frequency of feeding activity of those species.

5.2 Data analysis

We considered several factors that could influence the density of waterbirds in the estuary. These included habitat (five types), tide height (divided into four categories), and time of day (morning or afternoon). To test for the effect of each of the factors, we performed a separate statistical analysis for each of the species in each of the two months of observation. A three-way analysis of variance, including second-order interactions, was performed for each of 59 bird groups and species by month combinations (32 in January and 27 in April). To account for the increasing type I error with so many separate analyses, we used Bonferroni's techniques and adjusted the p-value by a factor of 59 for specific factors when using the statistical tables. Thus, for a specific factor or interaction to be significant at $p = 0.05$, we must require that the corresponding F-value be significant at $p = 0.05/59 = 0.0008$. The differences for each of the 59 bird groups were very significant for habitat, most below $p = 0.0001$. We did not tabulate the results of the analyses of variance.

Because there were significant differences in habitat for each bird group and species by month combination, we performed Tukey's multiple-range test for differences in habitat (see Tables 1, 2, and 3) by including other factors in the error terms and have shown differences that are significant at $p = 0.05$.

Table 1
Mean densities of major waterbird groups in different habitats of the Cowichan River estuary, 13–30 January and 15–29 April 1990

		Mean no. of birds/km² ± SD				
Bird groups	Month	Subtidal zone	Intertidal zone	River mouths	Fields	Booms and pilings
Loons	Jan.	4.2 ± 3.6^{a}	0.5 ± 0.5^{b}	$0.05\pm0.2^{b,c}$	0^{c}	$0.4\pm1.0^{b,c}$
	Apr.	0.6 ± 0.7^{a}	0.1 ± 0.3^{b}	0^{b}	0^{b}	0^{b}
Grebes	Jan.	192.5 ± 60.1^{a}	5.1 ± 3.0^{b}	0.6 ± 1.1^{d}	0^{d}	3.5 ± 3.9^{c}
	Apr.	54.8 ± 26.0^{a}	6.8 ± 6.0^{b}	0^{c}	0^{c}	0^{c}
Cormorants	Jan.	2.9 ± 2.0^{b}	0.9 ± 1.2^{c}	0.1 ± 0.6^{d}	0^{d}	33.0 ± 16.4^{a}
	Apr.	2.9 ± 5.1^{b}	$0.6\pm0.9^{b,c}$	$0.6\pm1.4^{b,c}$	0^{c}	70.5 ± 44.7^{a}
Dabbling ducks	Jan.	0^{c}	28.3 ± 41.7^{b}	360.4 ± 323.9^{a}	122.6 ± 138.1^{a}	6.5 ± 17.0^{c}
	Apr.	0.7 ± 3.6^{b}	166.1 ± 77.8^{a}	203.1 ± 161.6^{a}	0.1 ± 0.4^{b}	0.3 ± 1.6^{b}
Diving ducks	Jan.	13.0 ± 13.7^{c}	87.6 ± 26.4^{a}	141.3 ± 62.3^{a}	1.5 ± 6.5^{d}	52.0 ± 21.0^{b}
	Apr.	9.3 ± 27.5^{c}	65.9 ± 16.1^{a}	34.6 ± 18.1^{b}	0^{d}	3.3 ± 5.4^{c}
Gulls	Jan.	21.5 ± 22.8^{b}	55.0 ± 92.6^{b}	382.9 ± 241.1^{a}	120.0 ± 168.8^{b}	237.3 ± 282.2^{a}
	Apr.	3.3 ± 8.0^{b}	102.4 ± 37.8^{a}	179.3 ± 225.9^{a}	0^{b}	98.8 ± 100.0^{a}
All waterbirds	Jan.	$248.1\pm73.0^{b,c}$	187.8 ± 138.5^{c}	949.8 ± 533.7^{a}	$275.8\pm225.2^{b,c}$	332.0 ± 291.4^{b}
	Apr.	72.3 ± 46.7^{c}	350.1 ± 102.3^{a}	455.1 ± 329.1^{a}	11.2 ± 14.7^{d}	173.1 ± 98.6^{b}

Note: Number of observations: 26 in January, 24 in April. The superscripts denote significant differences. If two means do not have a common letter in their superscripts, they are significantly different at $p = 0.05$. The highest density for each bird group/month combination is underlined. More than one density may be underlined if the means are not significantly different.

Table 2
Mean densities of the most common fish-eating species (loons, grebes, cormorants, alcids) and gulls in different habitats of the Cowichan River estuary, 13–30 January and 15–29 April 1990

		Mean no. of birds/km² ± SD				
Species	Month	Subtidal zone	Intertidal zone	River mouths	Fields	Booms and pilings
Loons						
Common Loon	Jan.	1.5 ± 1.3^{a}	0.3 ± 0.3^{b}	0^{b}	0^{b}	0.4 ± 1.0^{b}
	Apr.	0.6 ± 0.7^{a}	0.1 ± 0.3^{b}	0^{b}	0^{b}	0^{b}
Red-throated Loon	Jan.	2.8 ± 3.0^{a}	0.2 ± 0.5^{b}	0.05 ± 0.2^{b}	0^{b}	0^{b}
Grebes						
Western Grebe	Jan.	188.8 ± 60.6^{a}	1.3 ± 2.2^{b}	0^{c}	0^{c}	0^{c}
	Apr.	46.7 ± 20.6^{a}	2.2 ± 3.0^{b}	0^{c}	0^{c}	0^{c}
Red-necked Grebe	Jan.	2.2 ± 1.6^{a}	0.01 ± 0.07^{b}	0^{b}	0^{b}	0.2 ± 0.8^{b}
	Apr.	1.3 ± 1.2^{a}	0.08 ± 0.2^{b}	0^{b}	0^{b}	0^{b}
Horned Grebe	Jan.	$1.5\pm1.7^{a,b}$	3.8 ± 2.1^{a}	$0.6\pm1.2^{b,c}$	0^{c}	0^{c}
	Apr.	6.8 ± 12.4^{a}	4.5 ± 4.0^{a}	0^{b}	0^{b}	0^{b}
Cormorants						
Double-crested Cormorant	Jan.	2.3 ± 1.6^{b}	0.8 ± 1.2^{c}	0^{d}	0d	30.9 ± 16.0^{a}
	Apr.	2.9 ± 5.1^{b}	0.6 ± 0.9^{c}	0.6 ± 1.4^{c}	0^{c}	70.5 ± 44.8^{a}
Alcids						
Marbled Murrelet	Jan.	11.5 ± 9.4^{a}	0^{b}	0^{b}	0^{b}	0^{b}
Gulls						
Glaucous-winged Gull	Jan.	3.2 ± 4.2^{c}	28.7 ± 44.3^{b}	122.6 ± 120.2^{a}	47.1 ± 54.2^{b}	206.8 ± 221.0^{a}
	Apr.	1.5 ± 4.3^{b}	60.1 ± 38.6^{a}	145.9 ± 166.0^{a}	0^{b}	47.3 ± 32.3^{a}
Mew Gull	Jan.	18.6 ± 20.4^{b}	26.2 ± 52.7^{b}	259.8 ± 182.0^{a}	72.0 ± 127.9^{b}	30.5 ± 81.3^{b}
	Apr.	1.2 ± 3.8^{b}	40.0 ± 18.5^{a}	32.1 ± 74.1^{a}	0^{b}	49.7 ± 73.6^{a}

Note: Number of observations: 26 in January, 24 in April. The superscripts denote significant differences. If two means do not have a common letter in their superscripts, they are significantly different at $p = 0.05$. The highest density for each species/month combination is underlined. More than one density may be underlined if the means are not significantly different.

6. Results

There were no significant differences in the numbers of species in the estuary between mornings and afternoons. Habitat was the main factor that correlated significantly with the distribution of all major bird groups (Table 1) and all waterbird species in the estuary (Tables 2 and 3). The highest overall waterbird densities were observed in river mouths in January and in both river mouths and the intertidal zone in April (Table 1). Loon and grebe densities were highest in the subtidal zone, whereas cormorants were most abundant on booms and pilings. Dabbling ducks had their highest densities in river mouths and nearby fields in January and in river mouths and the intertidal zone in April (Table 1). Diving ducks were most numerous in river mouths and the intertidal zone in January, but in April they were concentrated primarily in the intertidal zone (Table 1). Gulls were found mostly in river mouths and on booms and pilings in January, whereas in April they were also abundant in the intertidal zone (Table 1).

Table 3
Mean densities of the most common waterfowl species in different habitats of the Cowichan River estuary, 13–30 January and 15–29 April 1990

Species	Month	Subtidal zone	Intertidal zone	River mouths	Fields	Booms and pilings
		Mean no. of birds/km^2 ± SD				
Swans						
Mute Swan	Jan.	2.1±4.5^{b,c}	4.9±4.8^{b}	31.0±22.4^{a}	0^{c}	1.0±2.6^{c}
	Apr.	0.04±0.2^{c}	7.9±2.9^{a}	2.9±5.7^{b}	0.4±1.9^{c}	0^{c}
Trumpeter Swan	Jan.	0^{b}	0^{b}	0.6±2.0^{b}	6.0±5.6^{a}	0^{b}
Geese						
Canada Goose	Jan.	0^{b}	0^{b}	1.1±2.9^{b}	18.5±22.3^{a}	0^{b}
	Apr.	0^{d}	0.4±1.0^{c}	30.7±12.9^{a}	10.8±14.9^{b}	0^{d}
Dabbling ducks						
Mallard	Jan.	0^{c}	8.5±16.0^{b}	66.0±6.39^{a}	72.7±63.2^{a}	0^{c}
	Apr.	0^{b}	17.3±10.4^{a}	38.0±33.2^{a}	0.06±0.3^{b}	0^{b}
American Wigeon	Jan.	0^{c,d}	15.0±24.5^{b,c}	138.1±152.7^{a}	51.9±102.1^{b}	4.3±15.7^{c,d}
	Apr.	0.7±3.5^{c}	92.9±37.3^{a}	46.2±68.4^{b}	0^{c}	0.3±1.6^{c}
Northern Pintail	Jan.	0^{b}	1.9±3.0^{b}	65.5±80.0^{a}	2.5±6.3^{b}	0^{b}
	Apr.	0^{b}	7.9±6.0^{a}	7.9±9.0^{a}	0^{b}	0^{b}
Green-winged Teal	Jan.	0^{b}	2.9±7.1^{b}	117.3±116.9^{a}	2.5±11.9^{b}	0^{b}
	Apr.	0^{c}	46.9±37.9^{b}	110.5±75.9^{a}	0^{c}	0^{c}
Diving ducks						
Greater Scaup	Jan.	0.8±3.4^{b}	29.2±15.8^{a}	37.6±37.9^{a}	0^{b}	0^{b}
	Apr.	0^{b}	1.6±1.0^{a}	0.3±0.7^{b}	0^{b}	0^{b}
Surf Scoter	Jan.	0.07±0.3^{b}	5.6±2.3^{a}	0.1±0.5^{b}	0^{b}	0.5±1.7^{b}
	Apr.	1.9±3.8^{a}	1.7±1.8^{a}	0^{b}	0^{b}	0^{b}
White-winged Scoter	Jan.	0.1±0.4^{b}	6.4±3.2^{a}	0.3±0.8^{b}	0^{b}	0.5±1.9^{b}
	Apr.	0.7±1.5^{b}	2.6±2.5^{a}	0^{b}	0^{b}	0^{b}
Common Goldeneye	Jan.	1.1±1.7^{b}	17.8±5.1^{a}	17.6±11.8^{a}	0.8±3.6^{b}	12.5±7.3^{a}
	Apr.	1.7±4.8^{b,c}	8.2±3.8^{a}	1.5±2.4^{b}	0^{c}	0^{c}
Barrow's Goldeneye	Jan.	0^{c}	0.8±1.2^{b,c}	4.2±6.0^{b}	0^{c}	24.0±15.7^{a}
Bufflehead	Jan.	1.0±1.2^{d}	27.4±11.4^{b}	75.9±37.7^{a}	0^{c}	8.1±6.1^{c}
	Apr.	4.6±22.5^{c}	47.3±13.2^{a}	20.0±15.0^{b}	0^{c}	0^{c}
Common Merganser	Jan.	2.1±3.5^{a}	4.4±6.6^{a}	2.1±2.2^{a}	0.1±0.6^{b}	0.9±1.6^{a,b}
	Apr.	0.1±0.4^{c}	3.0±2.8^{b}	12.8±9.8^{a}	0^{c}	3.3±5.4^{b}
Red-breasted Merganser	Jan.	6.8±9.9^{a}	0.5±1.2^{b}	0.1±0.5^{b}	0^{b}	0^{b}
	Apr.	0.4±0.9^{b}	1.0±1.7^{a}	0.05±0.2^{b}	0^{b}	0^{b}
Hooded Merganser	Jan.	0^{c}	1.0±0.6^{b}	1.6±1.8^{c}	0^{b}	5.5±5.5^{a}

Note: Number of observations: 26 in January, 24 in April. The superscripts denote significant differences. If two means do not have a common letter in their superscripts, they are significantly different at $p = 0.05$. The highest density for each species/month combination is underlined. More than one density may be underlined if the means are not significantly different.

Of the piscivores, Common *Gavia immer* and Red-throated *G. stellata* loons, Western *Aechmophorus occidentalis* and Red-necked *Podiceps grisegena* grebes, and Marbled Murrelets *Brachyramphus marmoratus* had their highest densities in the subtidal zone, whereas Horned Grebes *P. auritus* were numerous in both subtidal and intertidal habitats (Table 2).

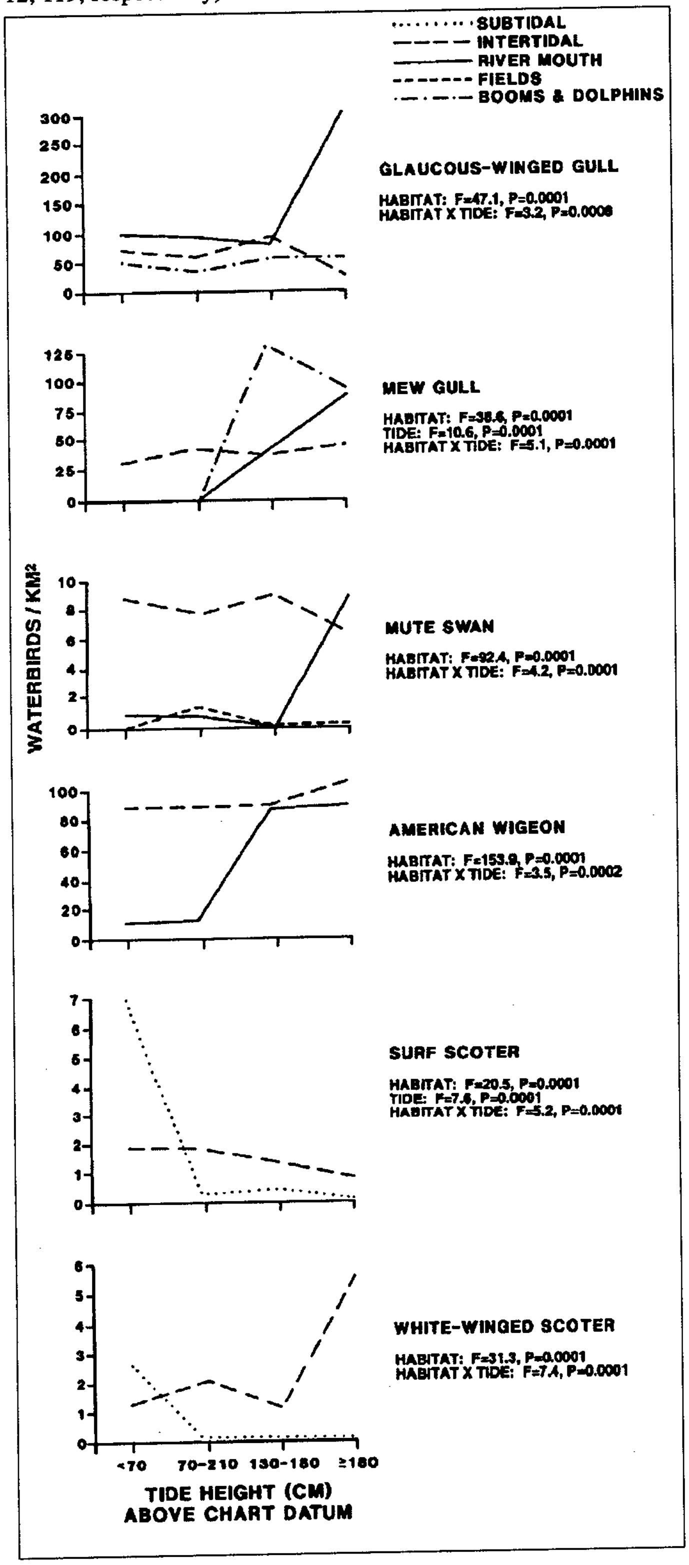
Glaucous-winged Gull densities were high on booms and pilings and in river mouths in January and additionally in the intertidal zone during April (Table 2). Mew Gulls were most dense at river mouths in January, whereas in April they were also abundant on booms and pilings and in the intertidal area.

Habitat densities of 16 waterfowl species are shown in Table 3. In January, Mute Swans were found mostly at river mouths, whereas Trumpeter Swans *C. buccinator* occurred mostly in fields. By April, Mute Swans had switched to the intertidal zone. Canada Geese were at their highest densities in fields in January but by April had switched mainly to river mouths. American Wigeons switched from primarily river mouths in January to predominantly intertidal areas in April. Mallard *Anas platyrhynchos* and Green-winged Teal *A. crecca* densities were high at river mouths during January and April. However, Mallards were also numerous in fields in January and in the intertidal zone during April.

Densities of many species of diving ducks were high in the intertidal zone in January or April; the exceptions were Barrow's Goldeneyes *Bucephala islandica* and Hooded Mergansers *Lophodytes cucullatus*. These two occurred in significantly higher densities on booms and pilings than in all other habitats (Table 3). Fields were seldom used by diving ducks. Greater Scaup *Aythya marila* and Common Goldeneye *Bucephala clangula* densities were high at river mouths and intertidal areas. Surf Scoters switched from primarily intertidal areas in January to subtidal and intertidal habitats in April. White-winged Scoters were most dense both months in intertidal areas. Buffleheads switched mostly from river mouths in January to the intertidal zone in April. Common Mergansers *Mergus merganser* were approximately equally distributed between the subtidal zone, the intertidal zone, and river mouths in January, but by April they were concentrated at river mouths. In contrast, Red-breasted Mergansers *M. serrator* moved from subtidal habitat in January to intertidal habitat in April.

For six species, the level of the tide was significantly correlated to habitat in April (Fig. 2). Mute

Figure 2
Significant correlations of waterbird species with habitat and tide in the Cowichan River estuary in April 1990 (degrees of freedom for habitat, tide, habitat × tide are 4, 119; 3, 119; and 12, 119, respectively)



Swan, American Wigeon, and Glaucous-winged and Mew gull densities increased in river mouths at high tide, whereas Mew Gulls moved also to booms and pilings during high tide. Surf and White-winged scoters were found mostly in the subtidal zone during low tide, whereas White-winged Scoters tended to move in intertidal areas at high tide.

The frequency of feeding activity of Glaucous-winged and Mew gulls is shown on 10 April 1993 and that of Mute Swans and American Wigeons on 24 April 1993 in Figure 3. Glaucous-winged and Mew gulls mostly loafed at river mouths (the former also loafed on booms and pilings) at high tide and fed extensively in the intertidal zone at low tide. On the other hand, Mute Swans and American Wigeons fed mostly at river mouths (and the latter also in fields) during high tide, whereas both species showed low to moderate feeding activity in the intertidal zone during low tide.

7. Discussion

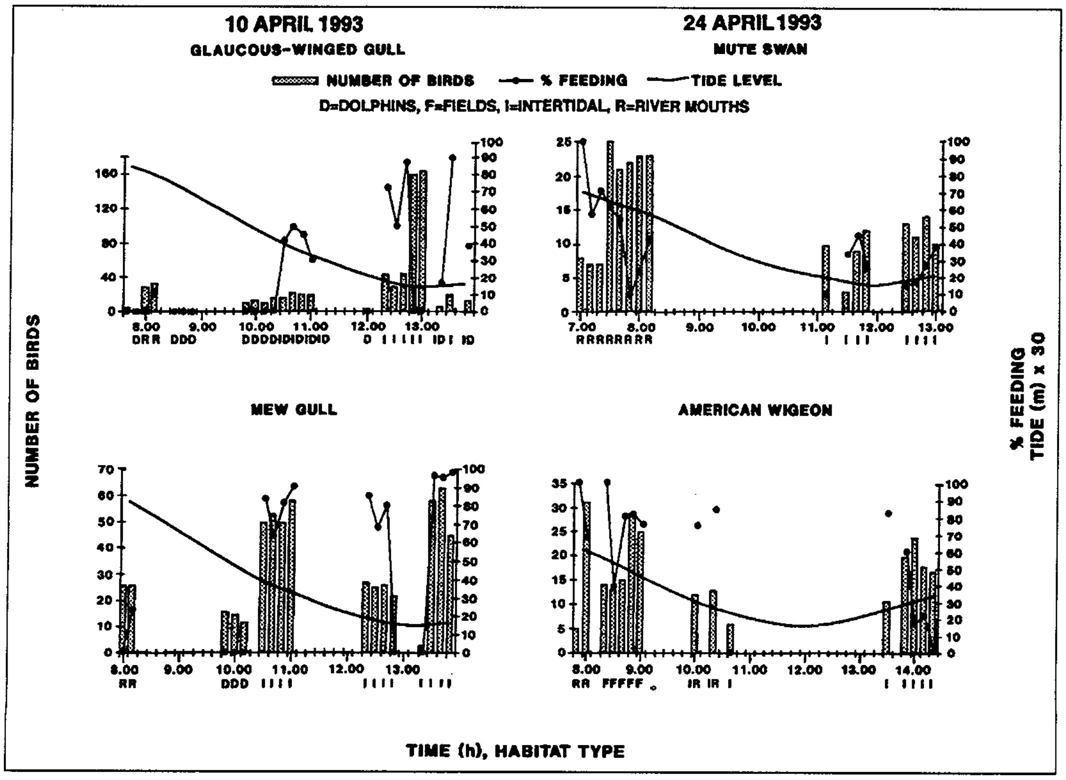
Selection of habitat by a species may reflect preference for a certain feeding area, loafing site, or both. Booms and pilings are normally selected because they provide a loafing site. However, Barrow's Goldeneyes were often seen diving among log booms, suggesting that those birds were utilizing the area beneath booms for feeding. Cormorants, gulls, and Barrow's Goldeneyes have previously been reported to use booms and pilings as loafing sites (e.g., Morgan et al. 1987; Vermeer 1989; Vermeer and Morgan 1992).

Most loons and grebes as well as Marbled Murrelets were seen over subtidal areas, likely because of the occurrence of fish there. Although Double-crested Cormorant density was observed to be highest on booms and pilings (found mainly in the intertidal zone), their next highest density was in the subtidal area (Table 1), suggesting a preference for foraging there.

Glaucous-winged and Mew gulls frequently rested on booms and pilings, as well as at river mouths, where they also rested or bathed. Both species were seen feeding actively in the intertidal zone. Their diets have been found to consist mainly of amphipods, barnacles, bivalves, crabs, and snails (Vermeer 1982a; Vermeer et al. 1987). Mute Swans were observed eating aquatic plants both in the intertidal area and at river mouths, whereas Trumpeter Swans fed mostly on vegetation in the fields. The majority of dabbling ducks were observed at river mouths; this was not unexpected, as most of these ducks forage in fresh-water habitats. Dabblers have also been observed to be the most numerous waterbirds in river mouths in other Vancouver Island estuaries (KV, unpubl. data). Mallards and American Wigeons were seen feeding in nearby fields, which has also been reported for other Vancouver Island estuaries (Eamer 1985). In the Fraser River estuary, Mallards and American Wigeons forage extensively on eelgrass and associated amphipods and snails in the intertidal zone in fall. They later shift to nearby farm-lands, where they eat wild seeds, grasses, corn, potatoes, cabbage, and insects (Baldwin and Lovvorn 1992). Diving duck densities, except those of Barrow's Goldeneyes and Hooded and Red-breasted mergansers, were high in the intertidal zone, where they are known to feed on a variety of invertebrates (Vermeer and Levings 1977; Vermeer 1981, 1982b; Vermeer and Bourne 1984).

The shift of marine birds to different habitats at low and high tides may reflect food accessibility. For example, Surf and White-winged scoters apparently

Figure 3
Feeding activity of Glaucous-winged and Mew gulls, Mute Swans, and American Wigeons at the Cowichan River estuary in relation to time of day, habitat, and tide level on 10 and 24 April 1993



concentrated in subtidal areas at low tide (Fig. 2). The switch may have been the result of marine invertebrate prey being more accessible in the subtidal zone at low tide (lower water column, hence less effort to feed on the bottom). White-winged Scoters were observed to increase in the intertidal area at high tide, but Surf Scoters were not (Fig. 2). This different reaction by the two species may be related to White-winged Scoters foraging primarily for clams (Vermeer and Bourne 1984) in the intertidal zone at high tide (at low tide, clams migrate deeper into the substrate; N. Bourne, pers. commun.). Surf Scoters, on the other hand, feed chiefly on blue mussels *Mytilus edulis* (Vermeer and Bourne 1984), which are either absent or scarce on the soft substrate of the Cowichan River estuarine intertidal zone. Another example of habitat shifts was that of Glaucous-winged and Mew gulls. Both species commonly fed landward of the water's edge during low tide. However, with rising tide, less of the intertidal area is accessible for foraging gulls. Consequently, gulls moved at high tide to river mouths, mostly to loaf and bathe.

8. Acknowledgements

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Estimated energy consumption by estuarine birds at different trophic levels

Robert W. Butler, Kees Vermeer, and
G.E. John Smith

1. Abstract

The waterbird community in six Strait of Georgia estuaries investigated for one year consisted of herbivores, benthivores, omnivores, and piscivores; the first two bird groups predominated in numbers and energy consumption. It was estimated that all waterbirds consumed 41.7 billion kilojoules of energy in the six estuaries in a year, of which 24.1 billion kilojoules were assimilated and 17.6 billion kilojoules were excreted. An estimated 48.4% of the 24.1 billion kilojoules of assimilated energy was necessary to maintain the herbivores; 41.7% was needed by benthivores, 6.5% by omnivores, and 3.4% by piscivores. Over 80% of the energy required by birds in a year was consumed between October and March.

2. Résumé

La communauté d'oiseaux aquatiques de six estuaires du détroit de Georgia, étudiée toute une année, est composée d'herbivores, de benthivores, d'omnivores et de piscivores. Les oiseaux des deux premiers groupes étaient les plus nombreux et les plus grands consommateurs d'énergie. On a estimé la consommation énergétique annuelle de tous les oiseaux aquatiques dans les six estuaires à 41,7 milliards de kilojoules; 24,1 milliards de kilojoules ont été assimilés et 17,6 milliards de kilojoules ont été excrétés. On estime que 48,4 % des 24,1 milliards de kilojoules assimilés sont nécessaires à la survie des herbivores, 41,7 % aux benthivores, 6,5 % aux omnivores et 3,4 % aux piscivores. Plus de 80 % de l'énergie nécessaire aux oiseaux dans une année est consommée entre octobre et mars.

3. Introduction

Food chain relationships are important in understanding the population dynamics and management of marine resources. Many lower trophic relationships have been described (see references in Healey 1979). However, the importance of birds in transferring food energy between trophic levels in estuaries has not been quantified (Simenstad 1983). Avian assemblages illustrate the most diverse spectrum of trophic level linkages in estuaries (O'Connor 1981; Simenstad 1983), and large nonbreeding populations might be important in estuary dynamics.

The purpose of this paper is to estimate the amount of energy consumed by waterbirds at four trophic levels in six estuaries in the Strait of Georgia.

4. Methods

Analysis of trophic organization of birds in estuaries requires information on the abundance, diet, and energy consumption of birds in estuaries. We used Krebs's (1972) definition of trophic levels as the functional classification of birds in a community according to feeding relationships. Our approach was to compare estimates of energy consumption by bird communities in six estuaries.

We estimated the amount of energy required for existence by birds (E_c) in each estuary from the equation:

$$E_c = N_m \times B \times D_m$$

where N_m is the number of birds present in month m, B is the energy required for existence per bird per day (kJ/d), and D_m is the number of days in month m. Each of these terms is described below.

4.1 Number of birds present each month (N)

We used the monthly population estimates of birds counted in the Fraser, Cowichan, Chemainus, Courtenay, Nanaimo, and Gorge estuaries shown in tables and appendices in the relevant papers in this volume. Details of methods of censusing birds in the six estuaries have been provided in each paper. We assumed that the numbers of birds seen on the single monthly censuses in each estuary approximated the average number of each species on all days of that month. For the Fraser River estuary, we assigned species in proportion to their abundance in the original data set reported by Butler and Cannings (1989).

4.2 Energy requirements (B) per month (D)

The energy requirement per day of each species was estimated from Kendeigh's (1970) equation

Table 1
Number of birds at four trophic levels in Strait of Georgia estuaries

Trophic level	No. of birds (000s)					
	Fraser	Cowichan	Chemainus	Courtenay	Nanaimo	Gorge
Herbivore	63.9	6.5	9.7	18.1	4.3	5.8
Benthivore	646.8	6.4	14.7	20.8	5.0	5.0
Omnivore	49.0	3.3	6.2	7.2	5.4	2.0
Piscivore	36.0	6.1	5.7	8.1	2.8	1.7
Total	795.7	22.3	36.3	54.2	17.5	14.5

Table 2
Estimated existence energy assimilated by waterbirds in a year at four trophic levels in Strait of Georgia estuaries

Tropic level	Estimated existence energy (kJ × 10^6)[a]							
	Fraser	Cowichan	Chemainus	Courtenay	Nanaimo	Gorge	Total	%
Herbivore	10 507	188	255	437	100	161	11 648	48.4
	(50)	(40)	(34)	(37)	(29)	(54)		
Benthivore	9 082	101	283	457	79	57	10 059	41.7
	(43)	(21)	(37)	(39)	(23)	(19)		
Omnivore	1 041	72	134	155	111	44	1 557	6.5
	(5)	(15)	(18)	(13)	(32)	(15)		
Piscivore	388	109	87	133	59	36	812	3.4
	(2)	(23)	(11)	(11)	(17)	(12)		
Total consumption	21 018	470	759	1 182	349	298	24 076	100.0

[a] Percentage of total assimilation at four trophic levels in each estuary appears in parentheses below each estimate.

$EE = 4.337\ W^{0.530}$, converted into kilojoules by a constant multiplier of 4.184. EE is the energy required for existence, and W is the body mass in grams. The mean body mass of each species was taken from Dunning (1984). We multiplied EE by the number of days per month (D) to estimate energy consumption for the entire month.

4.3 Trophic organization

Each species was assigned to one of four trophic levels based on its diet. Information on the diet of each species was taken from reviews by Vermeer and Ydenberg (1989), Verbeek and Butler (1989), Baldwin and Lovvorn (1992), and unpublished data (RWB and KV). The trophic levels used were herbivore, benthivore, piscivore, and omnivore. Herbivores ate predominantly plants that grew in estuaries and adjacent agricultural lands: they included swans, geese, and most dabbling ducks. Benthivores included most diving ducks, some of the gulls, and all shorebirds. Piscivores included all loons, grebes, cormorants, herons, and mergansers and some gulls. Omnivores were species that foraged at more than two levels and included some of the dabbling ducks and gulls. We eliminated the Glaucous-winged Gull *Larus glaucescens* from the Nanaimo River estuary census because it foraged mostly at a landfill rather than in the estuary. For species that foraged about equally at two trophic levels, we assigned the number of birds counted by the proportion of the diet that came from each trophic level.

5. Results

Benthivores were by far the most numerous group of birds in the Fraser River estuary; they were also the most numerous in the Chemainus and Courtenay river estuaries (Table 1). This group included large numbers of shorebirds in the Fraser River estuary and diving ducks in all estuaries. Herbivores were numerous in all estuaries, followed closely by large numbers of omnivores (Table 1). Piscivores were generally less numerous than omnivores (Table 1).

An estimated 24.1 billion kilojoules of energy were assimilated by waterbirds in six estuaries throughout the year (Table 2). The greatest proportion of energy for existence metabolism was consumed by herbivores (48.4%), followed closely by benthivores (41.7%) (Table 2). Omnivores required 6.5% of the total energy, and piscivores needed 3.4% (Table 2). Herbivores consumed more energy because of the large body mass of ducks, geese, and swans compared with the more numerous and smaller body mass of the benthivorous shorebirds and ducks.

Relatively small amounts of energy were consumed by herbivores in the Nanaimo River estuary (Table 2), where log booms have destroyed large areas of eelgrass *Zostera marina* habitat. As a result, the other trophic groups were relatively larger than in other estuaries (Table 1). Omnivores were relatively less abundant and consumed relatively less energy in the Fraser River estuary than in other estuaries (Tables 1 and 2). Large numbers of omnivorous gulls forage in the Vancouver landfill on the Fraser River delta, but few use the estuary. Large numbers of piscivorous Western Grebes *Aechmophorus occidentalis*, Double-crested Cormorants *Phalacrocorax auritus*, and Common Mergansers *Mergus merganser* were counted in the Cowichan River estuary, perhaps because of the large runs of salmon and other fishes in the Cowichan River. This resulted in relatively more energy required by piscivores in the Cowichan River estuary than in other estuaries (Table 2).

Over 80% of the annual energy requirement of waterbirds in all estuaries occurred from early October to

Figure 1
Total estimated seasonal consumption (kJ × 10^6) by benthivores, herbivores, omnivores, and piscivores each month in six estuaries in the Strait of Georgia

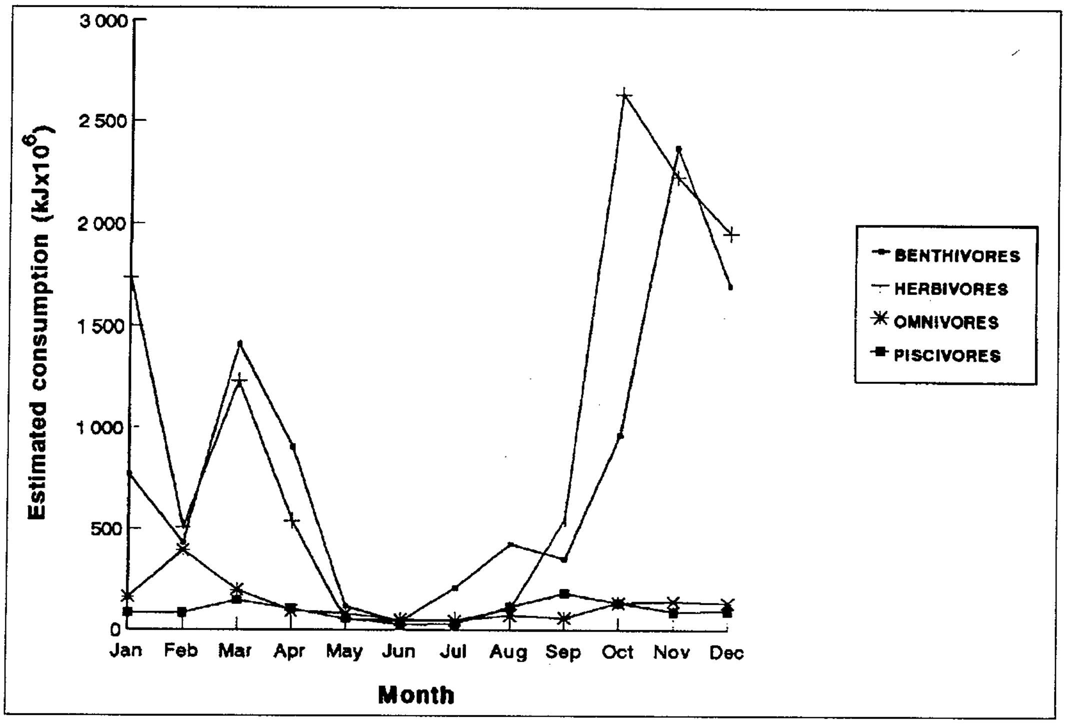
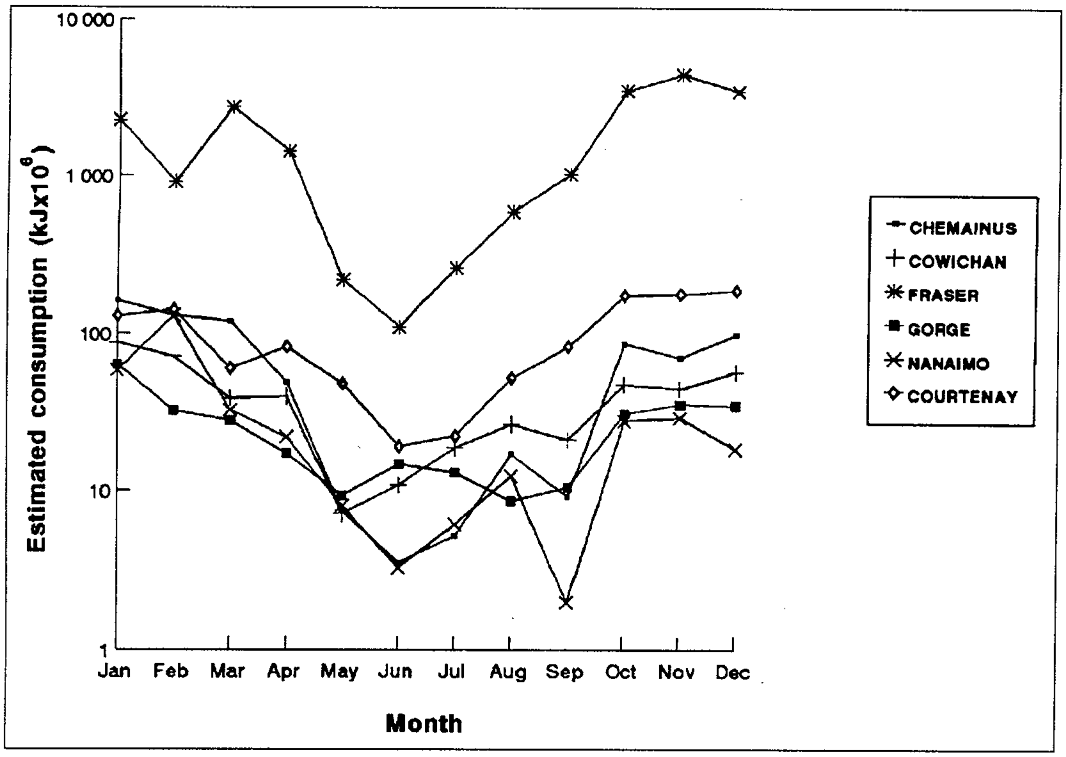


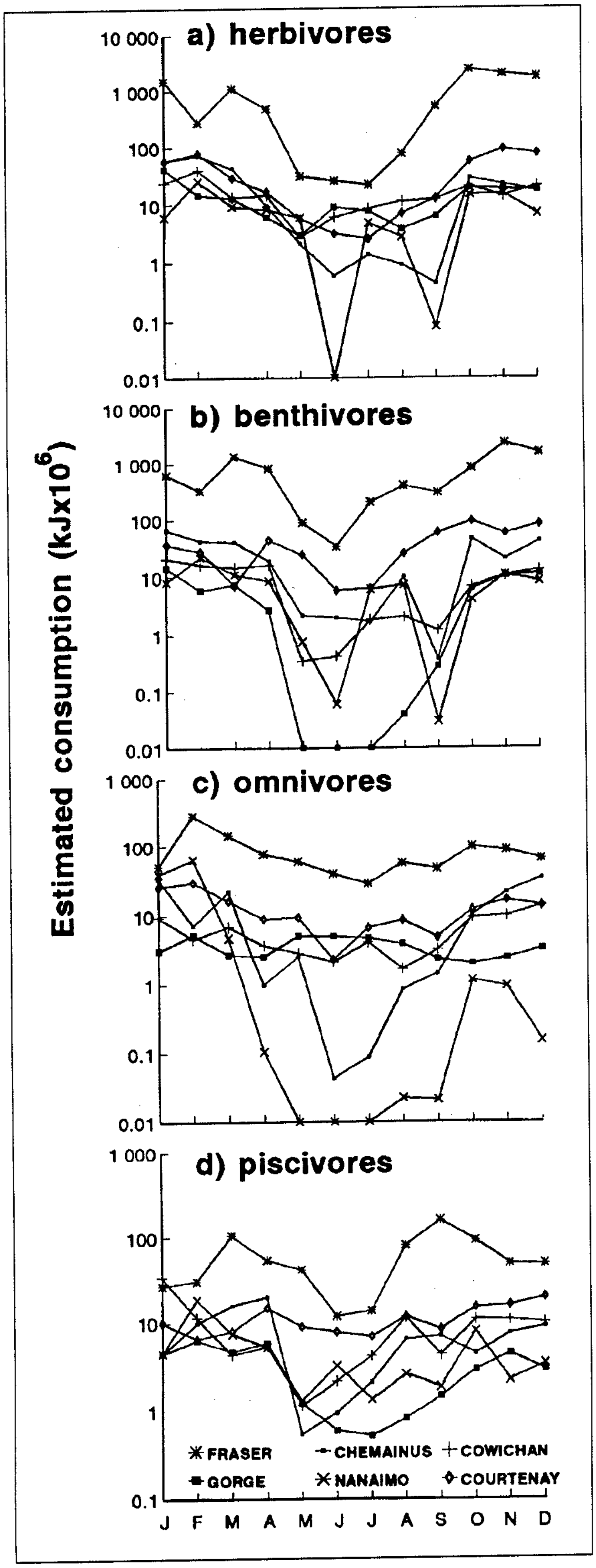
Figure 2
Total estimated consumption (kJ × 10^6) of all waterbirds each month in the Chemainus, Cowichan, Fraser, Gorge, Nanaimo, and Courtenay estuaries. Note the log scale on the y-axis.



the end of March. Herbivores and benthivores predominated throughout the year (Fig. 1). Annual energy consumption by waterbirds was similar in the six estuaries (Fig. 2) but differed among herbivores, benthivores, omnivores, and piscivores between estuaries (Fig. 3).

The predominant herbivores in the Strait of Georgia estuaries in autumn, winter, and spring were the Trumpeter Swan *Cygnus buccinator*, Lesser Snow Goose *Anser c. caerulescens*, and American Wigeon *Anas americana*. The most numerous benthivores were the

Figure 3
Estimated consumption (kJ × 10^6) by herbivores, benthivores, omnivores, and piscivores each month in six estuaries in the Strait of Georgia. Note the log scale on the y-axis.



Dunlin *Calidris alpina* in autumn and winter and the Western Sandpiper *C. mauri* in spring and summer. Piscivores were composed mostly of loons, grebes, and cormorants in autumn, winter, and spring and Great Blue Herons *Ardea herodias* in summer. Omnivores were mostly Glaucous-winged Gulls that gathered in large numbers in estuaries near landfills in autumn, winter, and spring (Butler et al. 1980).

The assimilation efficiency of herbivorous birds feeding on estuarine foods ranges from about 25 to 60%, compared with 20–40% for benthivores (Baldwin and Lovvorn 1992) and about 78% for piscivores (Castro et al. 1989). Most omnivores were gulls whose assimilation efficiency is likely similar to that of piscivores because they eat largely animal foods. We assumed an efficiency of 75% for omnivores. Therefore, an estimated 60, 70, 22, and 25% of the respective food energy consumed by herbivorous, benthivorous, piscivorous, and omnivorous birds was excreted as waste products. When these multipliers were applied to the data in Table 2, it was estimated that 41.7 billion kilojoules of food energy were consumed annually by birds, of which 24.1 billion kilojoules were used to fuel their existence and 17.6 billion kilojoules were excreted.

6. Discussion

Other researchers have used unquantified diagrams to describe the food web linkages of birds in estuaries (O'Connor 1981; Simenstad 1983; Butler and Campbell 1987). These diagrams showed that birds form the most diverse feeding assemblage of animals in estuaries. Our study is the first to our knowledge that estimates the energy consumption of birds in estuaries. We showed that birds transport over 17 billion kilojoules of energy each year via their feces between different trophic levels. About half of that energy was transferred by herbivores and benthivores. Most of the herbivorous birds were ducks, geese, and swans that grazed the marshes, eelgrass beds, and adjacent agricultural lands (Burton 1977; Eamer 1985; Baldwin and Lovvorn 1992; Boyd, this volume). The large number of benthivores consisted chiefly of diving ducks and shorebirds that ate marine invertebrates (Levings and Coustallin 1975; Vermeer and Levings 1977). Piscivores included loons, grebes, cormorants, and herons, which were less abundant than other groups and consumed about 3% of the total energy consumption of waterbirds (Table 2).

Birds play an important role in the dynamics of estuaries. For example, Lesser Snow Geese consume an estimated 30–40% of the rhizome biomass in the Fraser River estuary each year (W.S. Boyd, unpubl. data), and American Wigeons consume about 80% of the shoots of eelgrass in autumn (Baldwin and Lovvorn 1992). The ecological consequence of the removal of such large quantities of vegetation from estuaries whose principal energy pathway is through the breakdown of plant detrital material (Kikuchi 1980; Simenstad 1983) is potentially great. Increased erosion by geese and swans digging for rhizomes also lowers the elevation of mudflats, which hinders marsh plant succession (W.S. Boyd, unpubl. data).

7. Acknowledgements

Bob Elner reviewed this manuscript, Shelagh Bucknell compiled data, and Pam Whitehead prepared the figures.

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The international significance and the need for environmental knowledge of estuaries

Kees Vermeer and Robert W. Butler

Estuaries are among the most productive biomes of the world (Mann 1982). Efficient nutrient recycling and retention (Odum 1971) result in high primary (algae and marsh plants) and secondary (aquatic invertebrates) production. Much organic material, produced in estuaries and brought in by tides, is consumed by bacteria and aquatic invertebrates.

Estuaries typically exhibit a low diversity of planktonic and benthic species (Day et al. 1989; Constanza et al. 1993). However, species that can tolerate the fluctuating environment of estuaries often occur in high densities that attract fish, bird, and mammal predators. Birds are especially abundant in estuaries because of the many associated habitats — such as intertidal mudflats, shallow subtidal waters, eelgrass beds, and cultivated lands — that provide them with additional food and shelter needs. No species of bird is confined to estuaries in British Columbia for its entire life cycle, but, over the course of a year, British Columbia estuaries provide food and shelter for species from three continents (Butler and Campbell 1987).

The sheltered waters of the Strait of Georgia estuaries and adjacent flatlands are used for log storage, industrial docking facilities, sewage treatment plants, airports, military establishments, pulp and paper mills, marinas, and boat ramps, among other things. Direct and indirect discharges of industrial waste products, oil, and other forms of chemical pollution have contaminated waterfowl, herons, and shorebirds (Vermeer and Vermeer 1975; Vermeer and Peakall 1979; Elliott et al. 1989; Whitehead 1989). Many Vancouver Island marshes have been considerably reduced in size by diking for agricultural, industrial, and housing developments. Campbell Prentice and Boyd (1988) reported that estuarine habitats along the east coast of Vancouver Island had declined in area by 30% since European settlement because of human development. Over the last two decades, these losses have been slowed, and in some cases reversed, after the values of these habitats to fish and birds became better understood. For example, marsh restoration projects have begun on the Cowichan, Englishman, and Campbell river estuaries since 1981. Similarly, development initiatives in the vicinity of Boundary Bay on the Fraser River delta have been curtailed subject to studies to determine habitat requirements of migratory birds and other wildlife (Butler 1992).

The British Columbia Round Table on the Environment and Economy (1993) predicts that the human population around the Strait of Georgia will double over the next 25 years, thereby intensifying pressure on estuaries. Much attention has been paid to preserving estuaries in British Columbia in recent years. The British Columbia Nature Trust, Ducks Unlimited, British Columbia Ministry of Environment, Lands and Parks, and Canadian Wildlife Service, among others, have secured habitats in several estuaries. However, formal recognition of the international significance of some sites has been slow, partly because of inadequate information. The Alaksen National Wildlife Area on the Fraser River delta is the only site that has been designated a "Wetland of International Importance Especially as Waterfowl Habitat" under the Ramsar Convention of 1971.

Information in the present report allows us to review the potential status of other estuaries in the Strait of Georgia. Although the number of waterfowl using the Chemainus, Courtenay, Cowichan, and Nanaimo river estuaries individually does not meet the Ramsar criterion of 20 000 waterbirds annually, bird populations use this complex of wetlands interchangeably with the Fraser River estuary and estuaries in Puget Sound (Baldwin and Lovvorn 1992). Moreover, about 4% of the 15 000 Trumpeter Swans *Cygnus buccinator* in North America spend the winter in the Cowichan (216 swans) and the Courtenay (350 swans) river estuaries, thereby qualifying both as Ramsar sites based upon the criterion of a site holding 1% of a flyway population. Estimates of the size of populations of the waterfowl species, especially diving ducks, that winter mostly north of the United States are incomplete (Bartonek 1989). Future censuses might indicate that estuaries of the Strait of Georgia exceed the criteria of the Ramsar Convention for these species.

In consideration of the "wise use" of Ramsar sites (Boyd and Pirot 1989), it is important to increase environmental knowledge and to keep abreast of human development that might threaten wildlife and their habitats in estuaries. The status of environmental knowledge was summarized in a Special Estuary Series published by the Department of Fisheries and Environment Canada between 1974 and 1981 for seven Strait of Georgia estuaries (Campbell, Chemainus, Cowichan, Courtenay, Fraser, Nanaimo, and Squamish river estuaries) and for four other estuaries in British Columbia (Bella Coola, Kitimat, Skeena, and Somass river estuaries). These reports provide a basis for comparisons of environmental conditions in the future. However, their incompleteness begs for studies that will allow us to predict changes to ecological conditions in British Columbia estuaries.

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