Populations, biomass and food habits of ducks on the Fraser Delta intertidal area, British Columbia

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Introduction

The Fraser Delta intertidal region consists chiefly of three extensive tidal flats (Figure 1): Sturgeon and Roberts Banks, together also referred to as the Fraser Delta foreshore, and Boundary Bay. These areas constitute the largest wintering grounds for ducks along the British Columbia coast, and the Canadian Wildlife Service have made aerial surveys of ducks there for a decade. Food studies on dabbling ducks have been conducted in estuarine marshes of Sturgeon and Roberts Banks by Burgess (1970), but in 1974, the first author initiated the first comprehensive food study of diving ducks on the tidal flats. An attempt is made here to present the population and food data as a stepping stone for further ornithological investigations as well as for environmental assessment.

Methods

Populations

The survey data presented here span a ten-year period from 1966 to 1975, on five game species, Mallard *Anas platyrhynchos*, Pintail *A. acuta*, Green-winged Teal *A. crecca carolinensis*, American Wigeon *A. americana*, and Greater Scaup *Aythya marila*. The surveys were carried out by many different observers, at different times of day, at various tidal levels and in fluctuating weather conditions. This did not enhance uniform and systematic collection of data. Counts of ducks, therefore, tend to be usually much lower than the numbers actually present. Emphasis will therefore be placed on maximum counts. Besides the annual winter surveys, Sturgeon and Roberts Banks and Boundary Bay were censused during the summer of 1974.

During the aerial surveys a single strip along the shoreline of Sturgeon and Roberts Banks was usually flown. All birds in the area approximately two-thirds of a mile seaward of the water's edge were counted. Boundary Bay was flown usually twice, once along the shoreline and once farther out over the Bay. In the summer of 1974, the same procedure was followed for Sturgeon and Roberts Banks, but Boundary Bay was surveyed extensively over two-thirds of its surface. In addition, ground counts of ducks were made along Iona Jetty on Sturgeon Banks and frequent observations were made from a boat.

Food habits

Diving ducks were collected from January to March and from May to August, 1974, and in March 1976, for food analyses. The ducks were frozen as soon as possible after collection. The stomachs and esophagi of the birds were dissected at a later date and the food contents stored in glass jars with 10% formaldehyde. Food items were identified to the lowest taxon possible. The total weight of food from each bird was obtained by weighing stomach and esophagus contents on a Mettler H-5 macrobalance. An estimate of the volume of each food item was then used to obtain wet weights of each taxon.

Description of intertidal area

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

Marshes

The Sturgeon and Roberts Banks sea dyke marshes cover approximately 1,500 hectares. The fresh water discharged by the various arms of the Fraser River, which run through Sturgeon and Roberts Banks, has a marked influence on the Banks. Incoming tides back up the fresh water into the marshes. Therefore, they are predominantly fresh water marshes although brackish conditions do occur. Three vegetation types dominate: from the outside (2 m above chart datum) to the more elevated inside of the marsh (7 m tide level) they are bulrush *Scirpus* sp., sedge *Carex lyngbyei* and cattail *Typha latifolia*. The bulrush community is completely submerged at high tides. Burgess

(1970) found that *Scirpus americanus, Carex lyngbyei, Eleocharis macrostachya, Scirpus paludosus* and *Scirpus validus* composed 93% of all plants of the marsh. The first two species constituted 70% of all plants.

A 230 hectare eelgrass bed *Zostera marina* is situated adjacent to the Roberts Bank facility and the Tsawwassen ferry causeways on Roberts Bank. Sea lettuce *Ulva* sp. is commonly associated with it.

The Boundary Bay sea dyke marsh constitutes a narrow strip along the dyke. Its width varies from approximately 650 m in the west to a few metres in the east. This marsh is predominantly a salt water marsh since the Fraser River influence is considerably reduced compared to that on

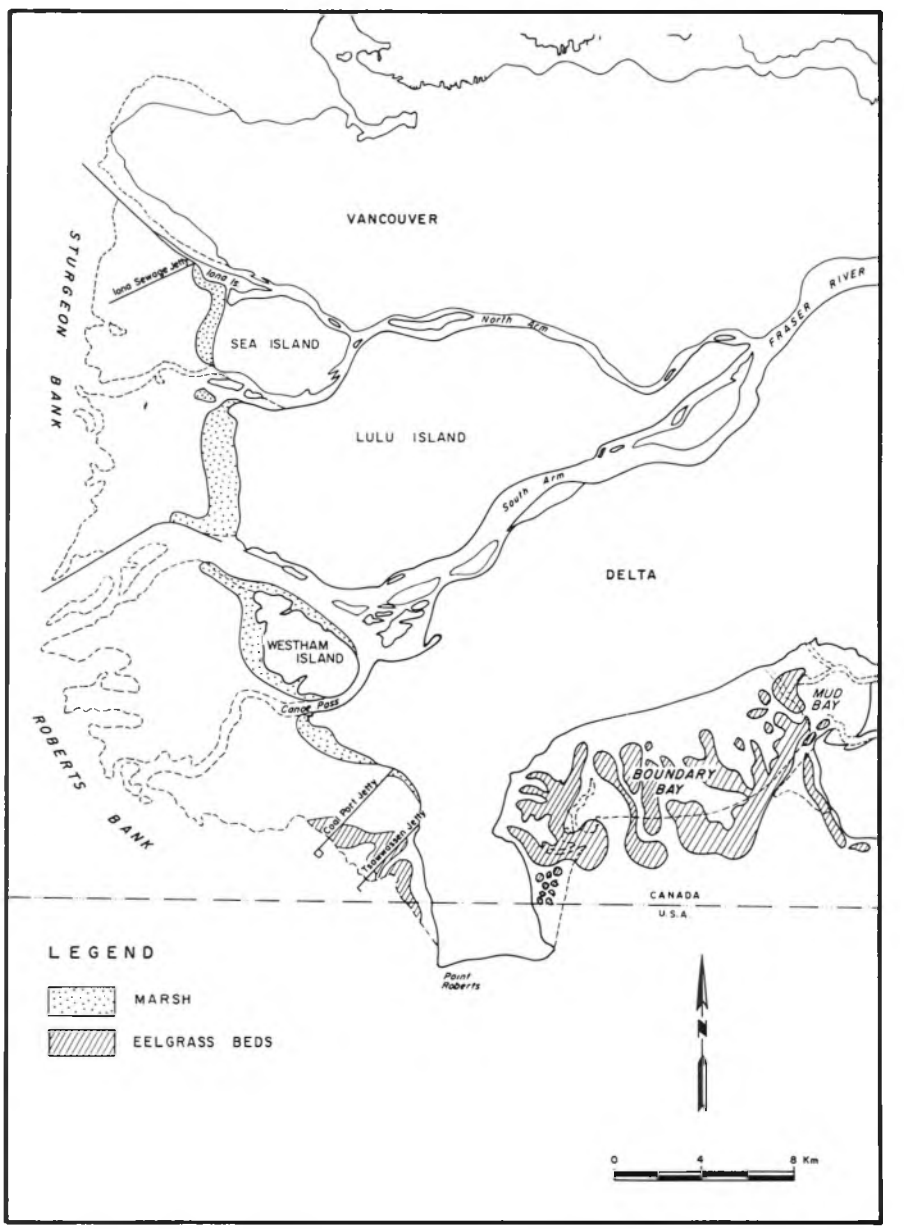

Figure 1. Fraser Delta intertidal region.

Sturgeon and Roberts Banks. Fresh water input from the Serpentine and Nicomeckl Rivers in the east does not appear to affect the halophytic nature of the marsh much, which is characterized by a lack of tall emergent vegetation. The upper portion of it is dominated by woody glasswort *Salicornia virginica*, quack grass *Agrophyron repens*, fescue grass *Festuca rubra* and foxtail *Hordeum jubatum*, while the lower part contains saltbush *Atripex patula*, tufted hairgrass *Deschampsia caespitosa*, desert saltgrass *Distichlis stricta*, seaside plantain *Plantago maritima* and woody glasswort. In late fall and early winter large quantities of organic debris consisting mostly of eelgrass *Zostera* sp., red algae *Jania* sp. and sea lettuce are transported into the marsh via tidal creeks (Kellerhals & Murray 1969).

Eelgrass beds cover approximately 1,200 hectares of Boundary Bay (Figure 1). There are three species. *Zostera marina* and *Z. latifolia* are found in the lower intertidal and subtidal region and in and near tide channels. *Z. nana* is found in more exposed inter-tidal regions.

Macrobenthic invertebrates

Levings & Coustalin (1975) conducted a quantitative investigation of the biomass of the macrobenthos in the sediment surface of Sturgeon and Roberts Banks and found the highest biomass in the muds adjacent to the sea dyke marsh and in the eelgrass beds. Polychaetes *Manayunkia aestuarina*, and amphipods *Corophium salmonis* and *Tanais* spp. are major contributors to the biomass there. In the lower intertidal areas, the bivalves *Macoma* spp., dominate the biomass, except in eelgrass beds on southern Roberts Bank. There crustaceans and polychaetes are most abundant. On Sturgeon Bank mobile epifauna (e.g. shrimp, *Crangon fransciscorum*) dominates the biomass in plankton tows at high tide in July. Attached benthic epifauna are uncommon on the tidal flats, probably because of the scarcity of a stable substrate. Where pilings, causeways and jetties are present, and temperature and salinity conditions permit, epifauna such as barnacles *Balanus glandula* and mussels *Mytilus edulis* are found.

The macrobenthos of the intertidal mud and sand flats of Boundary and Mud Bay has been investigated by Kellerhals & Murray (1969), Patching (1972) and O'Connell (1975). Of the epifauna, the gastropod *Batillaria zonalis* is the most common snail in the upper and middle intertidal zones. In the lower intertidal, another snail, the lean dogwhelk *Nassarius mendicus* is dominant. The yellow shore crab *Hemigrapsus oregonensis* is also common in the upper intertidal area and an amphipod *Anisogammarus* in the upper and middle intertidal. Pacific edible crab *Cancer magister*, rock crab *Cancer productus* and purple seastar *Pisaster ochraceus* are common on the low intertidal and subtidal sandflats.

Of the infauna, the most abundant clam is the soft shelled clam *Mya arenaria*, which occurs in the upper intertidal and through the top portion of the middle intertidal zone. Butter clams *Saxidomus giganteus* are common in the middle intertidal gravel beds, while little-necked clams *Venerupis japonica* and *Protothaca staminea* occur in the lower intertidal zone on gravelly sediments. The heart cockle *Clinocardium nuttallii* is characteristic on muddy fine sand and in eelgrass beds in the low intertidal and subtidal zones. Bentnose *Macoma nasuta* and sand clams *M. secta* occur on muddy sand and sand respectively of the low intertidal and subtidal zones. *Mytilus edulis* is sparse except on rocky outcrops. The imported Japanese oyster *Crassostrea gigas* is common in the abandoned oyster farms of Mud Bay. Of the shrimp, the ghost shrimp *Callianassa californiensis* is common in the upper and abundant in the middle intertidal, while the blue mud shrimp *Upogebia pugettensis* is found in the eelgrass beds of the lower intertidal zone. Of the polychaetes, the Pacific lugworm *Abarenicola pacifica* is abundant in the upper and middle intertidal. Other polychaetes such as *Spio* sp., are abundant in the upper to lower intertidal transition, while *Nephtys caeca* and *Glycinde picta* are common in the middle and lower intertidal. In the eelgrass beds, the most abundant polychaete is the bamboo worm *Praxillela affinis pacifica.*

Aquatic birds

A description of the waterfowl of the Fraser Delta tidal flats has been provided by Campbell *et al.* (1972) and by Leach (1972). The most common goose wintering on the marshes of Roberts and Sturgeon Banks is the Lesser Snow Goose *Anser caerulescens.* Aerial surveys of the Canadian Wildlife Service indicate a winter population from 8,000 to 11,000 birds from October to April. Approximately from 2,000 to 3,000 Black Brant *Branta bernicla nigricans* can be seen on Boundary Bay between March and April during their northward migration. The most numerous wintering ducks from September

to April are Mallard, Pintail, American Wigeon, Greater Scaup and Surf Scoters *Melanitta perspicillata.* Other aquatic birds than waterfowl wintering on, or visiting the flats by the thousands are Western Grebes *Aechmophorus occidentales*, Dunlin *Calidris alpina* and Western Sandpipers *C. mauri.*

Results and discussion

Populations

The number of monthly aerial surveys conducted by the Canadian Wildlife Service over the years, 1966–1975 were 4, 14, 12, 8, 8, 2, 3, and 2 for each month from September to April respectively. Figure 2 shows the average number of ducks counted per species on Sturgeon and Roberts Banks and Boundary Bay. Counts for September and October have been divided bi-monthly to show the arrival of migrating ducks on the flats. Counts for February to April have been lumped because relatively few surveys were made. Since non-identified and other duck species made up a small portion of the total population counted, they are omitted.

The data show a gradual build-up for ducks in the fall, peaking from late October to December, and then declining during January through to April. American Wigeon are the most numerous ducks in early fall. In the second half of October there is a large increase for this species as well as for Mallard, Pintail and Greater Scaup. Scaup decrease after October, while Mallard, Pintail and Wigeon remain numerous during November and December. In September, more ducks are observed to Sturgeon and Roberts Banks than in Boundary Bay but they are more numerous in Boundary Bay from the second half of October until December. Many more scaup are observed in Boundary Bay than on the foreshore, especially during the second half of October. Scoters constitute the largest group of other ducks on the Fraser Delta intertidal area, though counts have been infrequent and are not as thorough as those for the four dabbling species and scaup. But like the scaup, scoters appear to be much more numerous from September to April in Boundary Bay than on the Fraser Delta foreshore with average peaks in November/December of 1,714 and 214 respectively.

The maximal numbers of ducks for each species observed on Sturgeon and Roberts Banks and Boundary Bay over the months September to April 1966–1975 are shown in Figure 3. Unidentified and other ducks have also been included. Since the number of unidentified ducks vary considerably from one survey to another, they have been averaged. The maximal numbers may reflect optimal usage of the tidal flats by the duck population. It can be seen that hundreds of

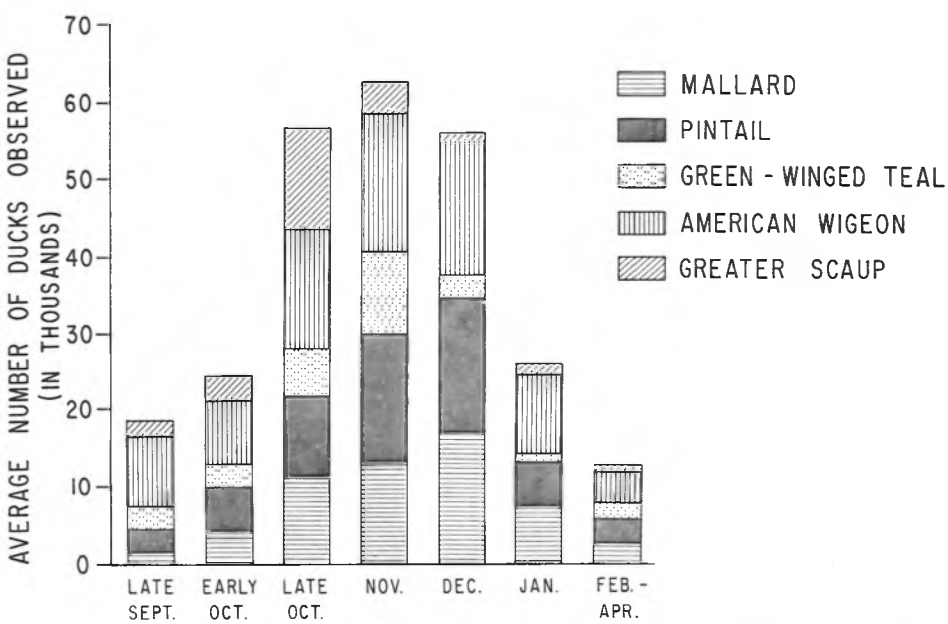

Figure 2. Average numbers of ducks on Sturgeon and Roberts Banks and Boundary Bay, September to April 1966–1975.

thousands of ducks utilize the flats from October through January. After January, the duck population declines to below 30,000 birds from February to April.

During the summer, Surf Scoters are the most numerous ducks present on the tidal flats, making up the vast majority of all scoters. Most depart from Boundary Bay in late May. Their numbers are low during June but by the end of July and at the beginning of August increase to nearly 10,000 birds. By late September their population appears to decline again (Table 1). It is estimated from the boat observations that 90% of the Surf Scoters are males. Approximately 500 White-winged Scoters *Melanitta fusca deglandi* also spend the summer in Boundary Bay but none was observed along Sturgeon and Roberts Banks. Very few Black Scoters *Melanitta nigra americana* were seen in Boundary Bay and at the Iona Jetty. Like the Surf Scoters, about 80 to 90% of the White-winged Scoters present in Boundary Bay during the summer are males. Greater Scaup are also more numerous in Boundary Bay than on Sturgeon and Roberts Banks. Except for a small flock of 60 birds at the mouth of Canoe Passage, all Scaup recorded for the foreshore were observed at Iona Jetty. Oldsquaws or Long-tailed Ducks *Clangula hyemalis* were only seen at Boundary Bay (Table 2). Less than 500 dabbling

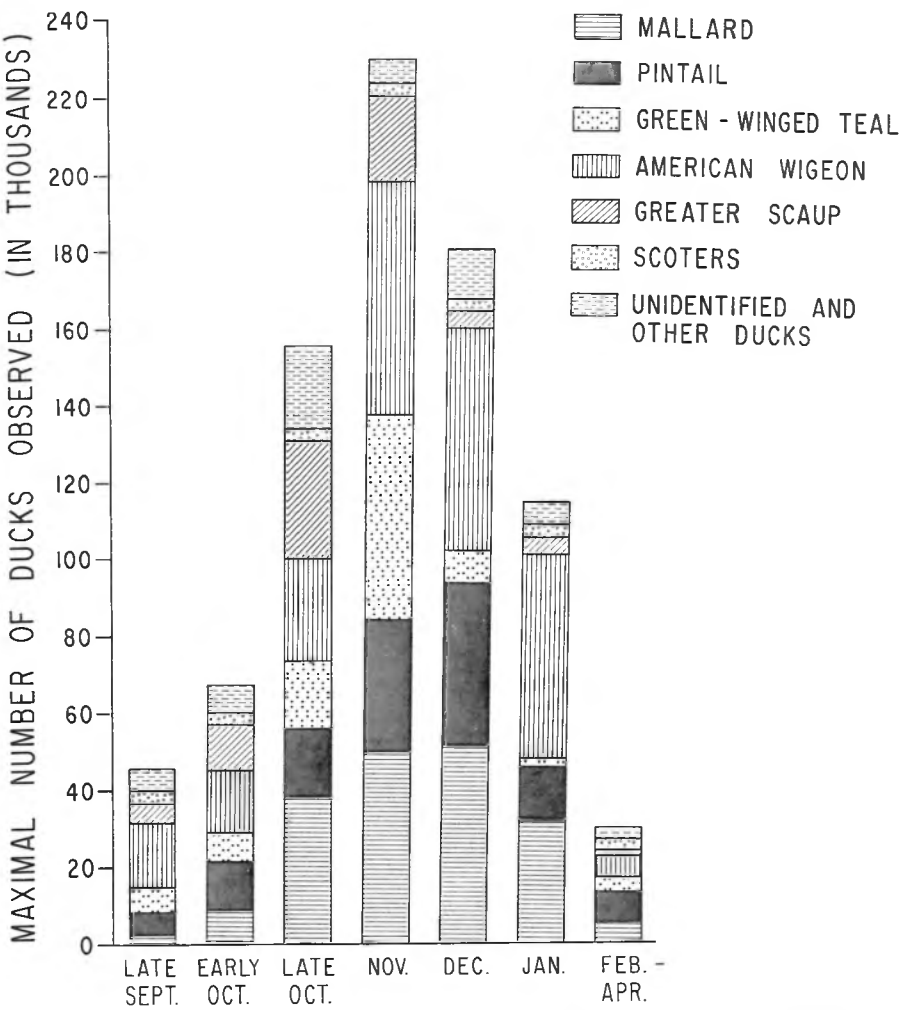

Figure 3. Maximal numbers of ducks per month, on Sturgeon and Roberts Banks and Boundary Bay, September to April 1966–1975.

ducks were observed on the tidal flats from May to July, 1974, the largest group being 400 Gadwall *Anas strepera* at Iona Jetty. Mallard and Pintail started to reappear from late July. Approximate counts ranged from 1,500 to 2,500 to 5,500 on 25th July, 16th August and 22nd August respectively.

Biomass

The biomass of ducks present in the Fraser Delta intertidal area from the second half of September to April has been calculated from the maximal populations shown in Figure 3 and multiplied with the average body weight of ducks (Table 2). Average body weights are derived from Kortright (1953) except for scoters which have been obtained from 69 birds weighed (this study). The total duck biomass fluctuates from September to April, reaching highest values from late October to December with a peak of 9·0 kilogram per hectare in November. Mallard and American Wigeon account for more than half the duck biomass on the tidal flats from September to April.

The Greater Scaup of all the ducks may be most suitable for the study of trophic and biomass relationships as this duck is most restricted to the intertidal area for feeding purposes. Large numbers of dabbling ducks undoubtedly use the tidal flats for loafing (especially in Boundary Bay) but feed inland.

Table 1. Aerial counts of diving ducks along Sturgeon and Roberts Banks and Boundary Bay, May to September, 1974.

Time of count	No. ducks observed along Sturgeon and Roberts Banks			No. ducks observed in Boundary Bay		
	Scoters	Greater* Scaup	Oldsquaw	Scoters	Greater Scaup	Oldsquaw
May	0	246	0	2695	—	—
June	0	375	0	1000†	639	194
July	120	209	0	3155	250	379
August	160	20	0	9825	140	190
Begin. September	54	0	0	8589	610	28
Late September	212	0	0	2806	1750	12

* Ground count on Iona Jetty.
† Estimated.

Table 2. Biomass of ducks on the Fraser Delta tidal flats September to April.

	Biomass in hundreds of kilograms							
Months	Mallard	Pintail	American Wigeon	Green-winged Teal	Greater Scaup	Scoters*	Unidenti-fied and other ducks	Total biomass per month
Late September	26	54	119	25	59	33	34	350
Early October	97	119	123	26	106	33	56	560
Late October	438	160	198	62	298	33	184	1373
November	572	310	448	187	216	33	31	1797
December	592	377	421	30	46	33	99	1598
January	372	125	396	4	42	33	42	1014
February	29	47	32	9	15	33	24	189
March	61	75	42	12	14	33	27	264
April	48	25	42	12	13	33	55	228
Mean biomass† per species/per month	246	145	208	40	75	33	54	801

* Since Surf Scoters made up vast majority of scoters, the estimated numbers of this species (about 3,000 birds from September to April) have been multiplied with their mean body weight (1,100 grams) to arrive at approximate biomass of scoters.
† Early and late October figures averaged before calculation of mean.

Food habits

Some information on the food habits of the dabbling ducks on the Fraser Delta foreshore has been collected by Burgess (1970). Mallard, Pintail, American Wigeon and Green-winged Teal feed mainly on plant foods on the Sturgeon and Roberts Banks. Analyses of the stomach contents revealed that *Carex lyngbyei, Scirpus validus* and *Scirpus americanus* are the most important tidal marsh food items. During the present study, esophagi and stomachs of 10 American Wigeon, 5 Gadwall and 2 Green-winged Teal, collected during January and March on the flats beyond the marshes near the Iona Jetty were also analysed for food contents. These indicated that American Wigeon and Gadwall also feed to a considerable extent on algae *Ulva* sp., *Enteromorpha* sp., and *Lola lubrica*, besides vascular plants on the tidal flats. T. E. Barnard (pers. com.) examined gizzards of 16 Mallard, 11 Pintail, 10 American Wigeon and 8 Green-winged Teal from the Boundary Bay flats in 1970. Provisional results showed that vascular plant seeds dominated in the stomachs of all ducks, indicating dabblers did not primarily feed on the intertidal flats. Snails were present in four Pintail gizzards.

Since very little appeared to be known about the diet of diving ducks on the Fraser Delta, which are more marine-oriented, the present study concentrated on the food habits of Surf Scoters, Black Scoters, White-winged Scoters, Greater Scaup, Oldsquaws and Common Goldeneyes *Bucephala clanqula*.

Animal matter occurred most frequently in the scoters, Oldsquaws and Common Goldeneyes, while plant food appeared to be as important as animal prey for Scaup (Table 3). Of the animal prey, bivalves were most numerous in scoters and Oldsquaws, crustaceans in Common Goldeneyes and bivalves and snails in Greater Scaup. Of the plant food in scaup, vascular plants occurred more frequently than algae. Of all ducks, White-winged Scoters fed most frequently on snails. The data on numerical abundance coincided with the wet weight of prey organisms for the six diving ducks, except for Scaup (Table 3). Algae dominated all the other food items combined for Greater Scaup on a wet weight basis. Since the wet weight of prey organisms obviously shows better the quantitative intake of the food of ducks, presentation of food items will be henceforth on that basis.

Of the four duck species in which bivalves constituted the most important food, Black and Surf Scoters ate mainly mussels *Mytilus edulis*; White-winged Scoters heart cockles and little necked-clams and Oldsquaws sand clams (Table 4). Bivalves also constituted the principal food of Surf, Black and White-winged Scoters on the New England coast. There Stott & Olson (1973) found that the scoters mainly fed on short razor clams

Table 3. Percentage frequency and wet weight of food items in six diving duck species collected on the Fraser Delta tidal flats in the winter and summer of 1974 and in March, 1976.

Prey Items	Surf Scoter		Black Scoter		White-winged Scoter		Old-squaw		Common Golden-eye		Greater Scaup	
	% Freq.	% Wt.	% Freq.	% Wt.	% Freq.	% Wt.	% Freq.	% Wt.	% Freq.	% Wt.	% Freq.	% Wt.
Bivalves	83	79	100	60	90	43	94	58	60	16	44	10
Snails	17	3	15	Trace*	63	30	36	8	27	7	36	16
Crustaceans	26	4	31	4	30	25	49	33	93	61	10	Trace
Polychaetes	12	5	39	21	3	Trace	0	0	0	0	2	Trace
Vascular Plants	10	2	23	3	10	1	3	1	27	6	38	14
Algae	2	Trace	15	1	3	Trace	3	Trace	7	10	48	60
Digested Matter	—	7	—	11	—	1	—	Trace	—	0	—	Trace
Total number of birds analysed	58		13		30		33		15		50	
Total wet weight in grams	755		243		1046		277		125		393	

* Trace = <0·5%.

Table 4. Percentage wet weight of bivalves in three scoter species and Oldsquaws collected on the Fraser delta tidal flats in the winter and summer of 1974 and in March, 1976.

Bivalves	Percentage wet weight of bivalves			
	Surf Scoter	Black Scoter	White-winged Scoter	Oldsquaw
Mytilus edulis	76	65	2	Trace
Mya arenaria	11	20	6	Trace
Clinocardium nuttallii	Trace	Trace	50	2
Protothaca staminea	5	0	38	1
Macoma sp.	0	3	2	82
Kellia laperousii	0	0	0	3
Psephidia lordi	0	0	0	1
Venerupis sp.	0	0	0	Trace
Yoldia	Trace	0	0	0
Glycymeris subobsoleta	Trace	0	0	Trace
Unidentified bivalves	7	12	2	11
Total wet weight of bivalves in grams	577	144	452	161

Siliqua costata and arctic wedge clams *Mesodesina arctatum*. McGilvrey (1967) collected scoters four years before in the same area and found their diet to consist chiefly of *Yoldia* clams. MacKay (1891) reported that the food of the three scoters in New England consists of black mussels *Modiolus modiolus*, small sea clams *Spisula solidissima*, scallops *Pecten concentricus* and short razor clams. Black and White-winged Scoters on Danish and southern Swedish coasts appear to have principal diets of *Mytilus edulis* and *Macoma balthica* (Madsen 1954; Nilsson 1972). Cronan & Hall (1968) reported that White-winged Scoters chiefly fed on northern quahog *Mercenaria mercenaria* in Rhode Island waters. Grosz & Yocom (1972) found that rock clams and sand clams *Macoma iris* constituted their principal food on Humboldt Bay and on the open ocean of north-west California. From the above studies it appears that bivalves constitute the main diet of scoters in the marine habitat, but the species of bivalve prey varies from one location to the next and may change over the years for the same region. As in our study, bivalves constituted the principal diet of Oldsquaws in Danish and southern Swedish waters (Madsen 1954; Nilsson 1972), but Stott & Olson (1973) observed the northern periwinkle *Lacuna vincta* to be the dominant Oldsquaw prey in New England.

Of the White-winged Scoters and Greater Scaup eating snails *Batillaria zonalis* formed most of the snail weight (Table 5). Snails constituted a much less important part of the diet of White-winged Scoters in New England (Stott & Olson 1973) and California (Grosz & Yocom 1972) and in that of Greater Scaup in Connecticut (Cronan 1957) than in the Fraser Delta.

Table 5. Percentage wet weight of snails in White-winged Scoter and Greater Scaup collected on the Fraser delta tidal flats in the winter and summer of 1974 and in March, 1976.

Snails	Percentage wet weight of snails	
	White-winged Scoter	Greater Scaup
Batillaria zonalis	80	75
Nassarius obsoletus	9	Trace
Nassarius mendicus	2	0
Nucella lamellosa	0	1
Nucella sp.	4	0
Turbiniella escholtzii	Trace	4
Lacuna sp.	0	13
Littorina scutulata	0	1
Miterella sp.	0	Trace
Urosalpinx cinerea	0	Trace
Odostomia sp.	0	Trace
Unidentified snails	5	6
Total wet weight of snails in grams	312	63

Crustaceans constituted the principal food of Common Goldeneyes (Table 3). Most of the crustacean weight in this species consisted of crabs and shrimp (Table 6). Crabs also appeared to dominate the diet of Common Goldeneyes collected from Rhode Island and Great Britain (Cronan & Halla 1968; Olney & Mills 1963). Crustaceans, such as shrimp and crab are reported from Goldeneyes in Baltic waters (Madsen 1954).

But in southern Sweden, Goldeneyes fed mostly on *Mytilus edulis* in December and on *Nereis diversicolor* during March and April (Nilsson 1972). Gammarus and *Idotea* sp. were also encountered in Swedish Goldeneyes. Most animal food collected from goldeneyes in New England by Stott and Olson (1973) could not be identified. In the identified foods, however, crustaceans constituted an important portion of the diet. It appears then, that with the exception of the Swedish findings, crab and shrimp frequently make up the main diet of Common Goldeneyes in marine waters. Crustaceans also make up an important portion of the food of Oldsquaws and White-winged Scoters on the Fraser Delta tidal flats (Table 3). Shrimp, amphipods and isopods constituted the main crustacean food for Oldsquaws whereas White-winged Scoters ate mainly barnacles, crab and shrimp. Oldsquaws, of all the six species, contained the greatest variety of shrimp and amphipod species. Of the shrimp, *Crangon fransciscorum* appeared to be utilized by Oldsquaws at the Fraser Delta tidal flats (Table 6). After the northern lacuna periwinkle, sand shrimp *Crangon septemspinosus* made up most of the food of Oldsquaws in New England (Stott & Olson 1973). Crabs *Cancer magister* also constituted an important portion (15%) of the food of White-winged Scoters at Humboldt Bay, California (Grosz & Yocom 1972).

The food habits of Surf Scoters and Greater Scaup collected from different locations of the tidal flats are compared in Table 7. The bivalves dominated in the Surf Scoter food from all three locations. Errant polychaetes constituted an important portion of the scoter diet at Roberts Bank. The food habits for Greater Scaup varied drastically from one location to the next. They fed predominantly on vascular plants on Sturgeon Bank, on algae on Roberts Bank and on snails in Boundary Bay. The average amount of food per scaup from Roberts Bank was at least five times greater than for birds from on Sturgeon Bank.

Seasonal changes in food habits of Surf

Table 6. Percentage wet weight of crustaceans in Common Goldeneyes (n = 15) Oldsquaws (n = 33) and White-winged Scoters (n = 30) collected on the Fraser delta tidal flats in the winter and summer of 1974 and in March, 1976.

Crustaceans	Percentage wet weight of crustaceans		
	Common Goldeneye	Oldsquaw	White-winged Scoter
Barnacles (*Balanus glandula*)	Trace	Trace	46
Crabs	48	12	34
Cancer productus	13	10	4
Telmessus cheiragonus	25	0	23
Hemigrapsus sp.	6	0	7
Pagurus sp.	1	0	0
Unidentified crabs	3	2	0
Shrimp	34	39	20
Upogebia pugettensis	34	0	20
Crangon fransciscorum	0	16	0
Cumacea	0	12	0
Pandalus sp.	0	9	0
Tanais sp.	0	1	0
Unidentified decapod (*Natantia*)	0	1	0
Amphipods	9	28	0
Anisogammarus confervicolus	9	0	0
Atylus sp.	0	23	0
Photis sp.	0	2	0
Ampelisca sp.	0	2	0
Corophium sp.	0	Trace	Trace
Gammarids	0	1	0
Isopods	4	21	Trace
Idotea sp.	0	21	0
Unidentified isopods	4	Trace	0
Ostracods	0	Trace	Trace
Unidentified crustaceans	5	0	0
Total wet weight of crustaceans in grams	77	92	262

Scoters, White-winged Scoters and Oldsquaws from Boundary Bay are compared in Table 8. Bivalves dominated in the diet of the Surf Scoter and Oldsquaw during the winter and summer. All three species fed more extensively on snails in the winter and crustaceans in the summer. Crustaceans dominated in the food of White-winged Scoters in the summer there (Table 8). Most of the crustaceans eaten by White-winged Scoters in the summer in Boundary Bay were barnacles, swallowed whole and therefore presenting very little food value. Whole barnacles should perhaps be classified as grit. If the barnacles are subtracted from the weight of food of the White-winged Scoters, the percentage weight of food at Boundary Bay in the summer would for bivalves, snails and crustaceans be 67, 15 and 18% respectively instead of 40, 9 and 51% (Table 8).

Of all six species, White-winged Scoters contained the least amount of grit exclusive of shell material (Table 9). This agrees with Grosz & Yocom (1972) who assumed that the large amount of shell material found in these ducks may act as a substitute for grit. In our study, Greater caup ate the greatest amount of grit and most was found in those scaup which fed on vascular plants and algae and the least in those which fed on snails (Table 10).

Feeding habitat

The feeding distribution of Oldsquaws, Surf and White-winged Scoters, and Greater Scaup during the summer of 1974 in Boundary Bay are shown in Figure 4. Several hundred Oldsquaws, usually in flocks from 5 to 50 birds, were seen along the outer subtidal and sandy part of the Bay and were

Table 7. Comparison of percentage wet weight of food items in Greater Scaup and Surf Scoter collected at three different locations on the Fraser Delta tidal flats during the winter.

	Percentage wet weight of food items					
	Great Scaup			Surf Scoter		
Food Items	Iona Island, Sturgeon Bank	Roberts Bank	Boundary Bay	Iona Island, Sturgeon Bank	Roberts Bank	Boundary Bay
Bivalves	21	5	6	98	48	72
Snails	1	2	93	0	2	15
Crustaceans	Trace	Trace	Trace	1	Trace	4
Polychaetes	0	0	Trace	0	23	0
Vascular plants	60	Trace	1	1	Trace	0
Algae	17	93	Trace	Trace	0	0
Digested matter	1	0	0	0	27	9
Total number of birds collected	24	12	6	17	10	8
Total wet weight of food in grams	89	238	57	383	173	98

Table 8. Comparison of percentage wet weight of food items in Surf Scoters, White-winged Scoters and Oldsquaws collected during the winter and summer at Boundary Bay.

	Percentage wet weight of food items					
Food items	Surf Scoter		White-winged Scoter		Oldsquaw	
	Winter	Summer	Winter	Summer	Winter	Summer
Bivalves	72	54	53	40	59	64
Snails	15	2	36	9	37	3
Crustaceans	4	26	9	51	4	33
Vascular Plants	0	14	1	Trace	0	0
Algae	0	Trace	0	Trace	0	Trace
Digested matter	9	4	2	0	0	0
Total number of birds collected	8	13	10	16	10	19
Total wet weight of food in grams	98	90	581	296	39	209

Table 9. Quantity of grit taken by six diving ducks.

	Surf Scoter	Black Scoter	White-winged Scoter	Old-squaw	Common Goldeneye	Greater Scaup
Quantity of grit in grams	54	21	8(120)*	21	12	197
Total number of birds	58	13	30	33	15	50
Quantity of grit per duck in grams	0·9	0·6	0·3(4)	0·7	0·8	3·9

* Barnacles in parentheses.

Table 10. Quantity of grit taken by Greater Scaup at three different feeding locations in the winter.

Feeding location	Iona Island, Sturgeon Bank	Roberts Bank	Boundary Bay
Quantity of grit in grams	140	56	1
Number of ducks	29	12	6
Quantity of grit per duck in grams	6	5	0·1
Predominant food eaten	Vascular Plants	Algae	Snails

rarely observed within the 3 fathom line below chart datum. The Oldsquaws apparently fed in the deepest waters. Their subtidal distribution may relate to their extensive feeding on sand clams *Macoma* sp. Surf Scoters concentrated mostly in the area between 0 and 3 fathoms below chart datum. They were the most common birds during the summer and fed along the outer edges of the eelgrass beds, usually at low tide, but the majority remained farther out in the Bay. In June and part of July, an estimated flock of 1,000 to 1,200 moulting Surf Scoters concentrated about one kilometre off the rocky shore of Ocean Park and White Rock. White-winged Scoters were observed to feed in the lower-intertidal zone, especially over the eelgrass beds. Their feeding distribution may relate to that of their main diet on heart cockles. Greater Scaup were observed in shallow waters, and along the channels left on the flats by the receding tides. They were most often encountered in areas where the substrate was silted over.

Olson & Stott (1973) observed that at the New England coast the scoter species selectively used areas with sandy substrates, while Oldsquaws were distributed over all habitat types. Scott-Brown (1976), who investigated the feeding distribution of Surf Scoters and Greater Scaup along Burrard Inlet, British Columbia, found that Surf Scoters preferred sandy substrates to rock and mud/sand bottoms, while Greater Scaup preferred mud/sand substrates, in sheltered regions.

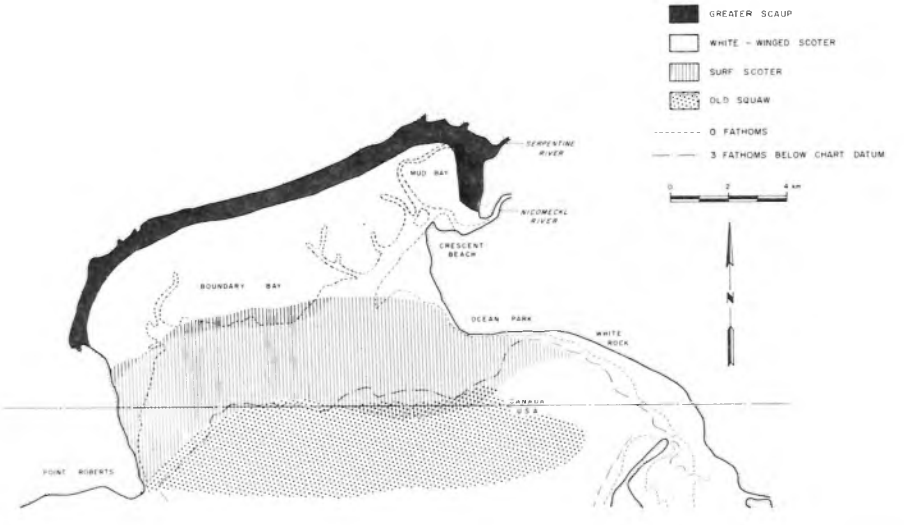

Figure 4. Comparison of the feeding habitat of Oldsquaws, Surf and White-winged Scoters and Greater Scaup in the summer of 1974, at Boundary Bay.

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Summary

Hundreds of thousands of ducks, mostly Mallard *Anas platyrhynchos* Pintail *A. acuta*, American Wigeon *A. americana*, Green-winged Teal *A. crecca carolinensis* and Greater Scaup *Aythya marila* visit the Fraser Delta intertidal area from October through January. Surf Scoters *Melanitta perspicillata* are most numerous in August and early September. Scaup and scoters appear to prefer Boundary Bay over Sturgeon and Roberts Bank. The total duck biomass on the tidal flats has a peak of 9 kilograms per hectare in November, Mallard and American Wigeon accounting for more than half.

Most dabbling ducks fed on marsh and other plants. Of six diving duck species invstigated, Black *M. nigra*, Surf and White-winged Scoters *M. fusca deglandi* and Oldsquaws *Clangula hyemalis* fed primarily on bivalves, Common Goldeneyes *Bucephala clangula* on crustaceans and Greater Scaup on algae. The food habits differ with respect to feeding location as well as time of season. Oldsquaws used mostly subtidal waters, Surf Scoters between 0 and 3 fathoms below chart datum, White-winged Scoters the lower intertidal zone, Greater Scaup a muddy substrate closest to the shoreline and sheltered in Boundary Bay.

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