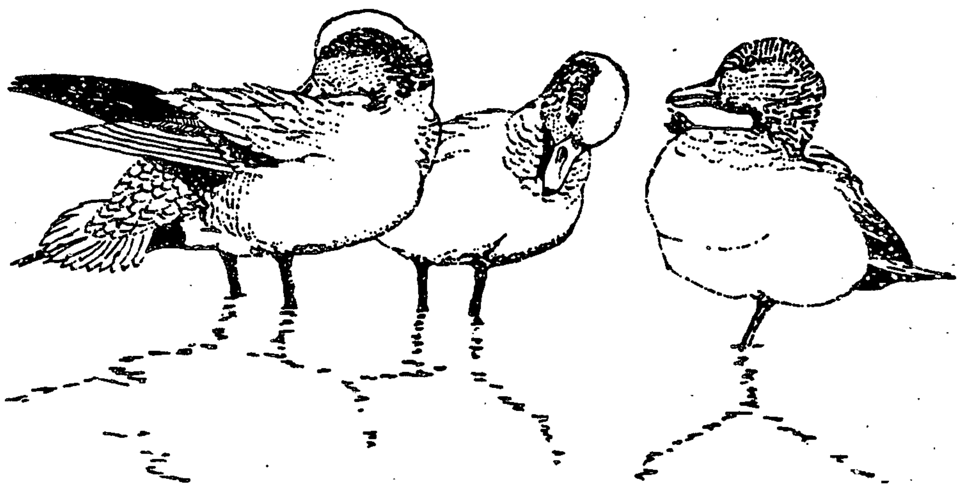
WINTER HABITAT FOR DABBLING DUCKS on Southeastern Vancouver Island British Columbia



JOAN EAMER

1985

Environment Canada
Canadian Wildlife Service

BC Ministry of Environment

Ducks Unlimited Canada

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Winter habitat for dabbling
ducks on southeastern
Vancouver Island, British
Columbia.

Cover sketch by Barry Leach.

February 8, 1986

To:

Director - British Columbia Wildlife Branch

Regional Director - Canadian Wildlife Service
Pacific and Yukon Region

Provincial Manager- Ducks Unlimited Canada

It is with great pleasure that we present you with copies of 'Winter Habitat for Dabbling Ducks on Southeastern Vancouver Island British Columbia'. This collection of three integrated papers was completed by Joan Eamer as an MSc. project at the University of British Columbia. The papers examine three levels of fall, winter and early spring habitat utilization by mallards and American wigeon on south-eastern Vancouver Island. The first paper examines the relative use of estuaries, sheltered beaches and adjacent agricultural habitats and assesses that use as a function of temporal and climatic variables. The second paper examines habitat use more closely, providing descriptions and analyses of specific habitat types utilized by ducks as feeding sites. The final paper reports the results of gullet analyses of mallard and American wigeon that were observed feeding on specific habitat types.

The thesis clearly demonstrates the importance of coastal and adjacent agricultural areas as habitat to dabbling ducks. It further serves to demonstrate the critical nature of those scarce habitats.

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Two significant ingredients leading to the success of this project were the support and cooperation of the sponsoring agencies. We look forward to participating in similar cooperative endeavours.

Yours sincerely,

Rodger Hunter
Coastal and Wetland Specialist
B.C. Ministry of Environment

Neil Dawe
Habitat Manager
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WINTER HABITAT FOR DABBLING DUCKS
ON SOUTHEASTERN VANCOUVER ISLAND, BRITISH COLUMBIA

by

Joan Eamer

B.Sc., University of Victoria, 1977

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(Department of Zoology)

We accept this thesis as conforming

to the required standard

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JUNE 1985

ABSTRACT

This study is an examination of the use of coastal estuaries and nearby farmland as habitat by dabbling ducks (mallard and American wigeon) during migrating and wintering periods. Its aim was to identify aspects of British Columbia coastal habitat of importance to dabblers through an analysis of the ducks' movements among habitat types and through a description of where and on what ducks feed. Data were collected in 1979 and 1980 along a 30 km stretch of coastline on southeastern Vancouver Island. Results are presented in 3 parts.

Part 1 examines the relative use of farm and coastal habitat through a series of censuses conducted weekly at 8 farm and 8 coastal sites. The strong negative correlation between counts at farm and coastal sites indicates that dabblers treat them as alternative habitats. The numbers of ducks on farms was positively correlated with the area of standing water on the fields. Farm habitat, apparently preferred during warm, wet weather, was not used when fields were dry or frozen.

Part 2 is a description of feeding location on fields, at estuaries and at a shallow, nonestuarine bay. It is based on observations at selected sites at high and low tide levels. Each duck in each observation period was classified as to location and activity. Both species fed primarily in shallow water, their feeding location shifting with the tides. Both marsh and marine sections of estuaries were used extensively for feeding. The shallow bay was used especially by American wigeon at low tide in fall and early winter. The high marsh areas at estuaries were particularly attractive to mallards when flooded by exceptionally high

tides. Feeding intensities were consistently high at farm sites for both species.

In Part 3, 23 mallards and 40 American wigeon were shot while feeding in estuarine locations commonly used for feeding. Analysis of gullet contents revealed that both species ate a wide variety of items. Main foods were, for mallards, seeds, invertebrates and green algae and, for American wigeon, green algae, roots, seeds and green vegetation. Algae and marine invertebrates are not usually considered to be important dabbler foods in estuaries.

Major conclusions and recommendations are:

1) Both farm and coastal sites are important to dabblers, with fields being favoured as feeding locations under good flood conditions and coastal habitat being vital during dry or freezing periods. As dabblers move among sites, assessment and management of wintering dabbler habitat should be by wetland complexes rather than by individual estuaries.

2) Dabblers feed in or near shallow water. Fields that do not flood are not worth maintaining as dabbler habitat. Assessment of estuarine marshes should consider the availability of food at all points of the tidal cycle.

3) As both species feed on a wide variety of items, factors affecting shallow water flooding and thus food availability are more important than plant species composition.

4) Marine deltas and beaches are important as refuges from disturbance and as feeding grounds. They form an integral part of dabbler coastal habitat.

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ACKNOWLEDGEMENTS

Funding for this study was provided by the British Columbia Ministry of Environment, Ducks Unlimited (Canada) and the Natural Sciences and Engineering Research Council of Canada. Invaluable advice and assistance were provided by E.J. Osmond-Jones, Neil and Karen Dawe of the Canadian Wildlife Service, Rodger Hunter of the B.C. Ministry of Environment and Ken Summers of Ducks Unlimited (Canada).

INTRODUCTION

Relatively little research has been carried out on North American duck wintering habitat. Studies related to breeding, dominating the literature until the 1970s, were motivated by concern over agricultural drainage in prairie nesting grounds and by the well-established link between duck productivity and population levels. The realization that wintering habitat is being eroded at an alarming rate (Ladd et al. 1974) and the recognition that factors affecting adult survival are poorly understood (Anderson and Burnham 1976) have broadened the scope of waterfowl research. Wintering habitat is now being studied within 2 frameworks: (1) waterfowl population biology and (2) land management.

Fluctuations in duck abundance have been related primarily to fluctuations in conditions on the breeding grounds (Anderson 1975) and longterm declines in populations have been attributed mainly to loss of breeding habitat (Bellrose and Low 1978). However, changes in wintering habitat may also affect population dynamics. Heitmeyer and Frederickson's (1981) study of mallards in the Mississippi flyway established a direct link between winter habitat and population fluctuations. They demonstrated that recruitment rates were affected more by wetland conditions (related to rainfall) on wintering grounds than by those on breeding grounds. Other evidence is indirect. The ducks' condition in winter and early spring is known to alter susceptibility to disease (Bellrose and Low 1978) and reproductive capability (Krapu 1981). On a longterm basis, declines of North American populations of several species, notably canvasback (*Aythya valisineria*) and black duck (*Anas rubripos*), have been attributed to increased natural mortality and decreased breeding success resulting from degradation of wintering habitat (Canadian Wildlife Service 1980).

The concerns of land managers relate more to the distribution and local abundance of waterfowl than to population dynamics. Whether degradation or loss of habitat in a region kills ducks or merely displaces them, the ducks are lost to that region. There are many documented cases of changes in waterfowl distribution patterns related to alterations in wintering grounds (Greenwalt 1976).

Coastal habitat is rapidly being lost. Ladd et al. (1974) estimated that, by 1970, 73% of U.S. estuaries had been moderately to severely degraded through filling, dredging, draining or use as garbage dumps. They predicted annual losses of 0.5 to 1.0% of remaining wetlands. In Canada, rates of loss of coastal habitat are comparable (Canadian Wildlife Service 1980). Since waterfowl are a resource highly valued by North Americans (Hammack and Brown 1974, Canadian Wildlife Service 1980), research which assists in making habitat management decisions is badly needed.

Waterfowl habitat management consists of (1) protection of habitat, (2) resolution of land-use conflicts resulting from industrial, residential or agricultural development and (3) habitat enhancement. Decision-making in all 3 areas requires an understanding of the ducks' distribution and habits. Midwinter censuses, conducted annually over U.S. wintering grounds, give only a general picture of the distribution of species (Bellrose 1976). Studies of specific areas provide information on local distribution and habitat requirements (Hartman 1963, Owen and Williams 1976, White and James 1978), important waterfowl foods (Yocom 1951, Landers et al. 1976, Hughes and Young 1982), the role of agricultural lands (Hirst and Easthope 1981, Baldassarre and Bolen 1984) and the effect of enhancement techniques such as water control and burning (Chabrek et al. 1975). A few studies have examined biomass relationships between waterfowl and their food supplies (Sincock 1965, Burton and Hudson 1978).

An estimated 80,000 dabbling ducks overwinter along the British Columbia coast, far more than anywhere else in Canada (Canadian Wildlife Service 1980). Many more pass through the region during the protracted, variable migration periods (Summers and Campbell 1978). The Fraser Delta supports large numbers of mallard (Anas platyrhyncos platyrhyncos), American wigeon (A. americana), pintail (A. acuta acuta) and American green-winged teal (A. crecca Carolinensis). In the smaller estuaries that dot the B.C. coast, mallard and American wigeon are most abundant.

B.C. estuaries, and in particular those of Vancouver Island, are under considerable pressure for development from industry, housing and logging interests (Hunter et al. 1980). Habitat losses are already substantial, with only 30% of the Fraser Delta remaining suitable for waterfowl (Canadian Wildlife Service 1980).

Despite the importance of the area to waterfowl and the recognized threats to habitat, our knowledge of dabbler distribution and habits on the B.C. coast is sketchy. Distribution data are limited to sporadic aerial censuses of sections of the coast (Summers and Campbell 1978 and Hunter et al. 1980). Most of the habitat use research is specific to the Fraser River Delta (Burgess 1970, Vermeer and Levings 1977, Hirst and Easthope 1981), which, in its size and degree of freshwater input, differs greatly from other estuaries in B.C. (Hunter et al. 1980). Several conclusions from research in the Fraser Delta are consistent with conclusions from studies of other large estuaries with extensive brackish to freshwater marshes. Main conclusions are:

(1) Dabblers feed in marshes and on nearby agricultural land (Burgess 1970, Thomas 1976, Hirst and Easthope 1981).

(2) Bays and mudflats are used mainly for resting (Benson 1961, Burgess 1970, Tamisier 1976, Vermeer and Levings 1977).

(3) Water levels play an important role in habitat choice (Burgess 1970, Chabrek et al. 1975, Thomas 1976, Hirst and Easthope, 1981).

(4) Mallards eat mainly marsh plant seeds and waste grain (Yocom 1951, Burgess 1970, Hughes and Young 1982).

(5) American wigeon eat mainly green leaves and stems of aquatic, marsh and cultivated plants (Yocom 1951, Burgess 1970, Bellrose 1976 p. 206).

Burgess (1970) also concluded that fluctuations in numbers were related to migration patterns and the fields and marshes were favoured as feeding grounds at different times of the year. Hirst and Easthope (1981) disagreed with the latter point, concluding that fields were used as an extension of marsh habitat.

The few studies of other B.C. coastal sites indicate that marine and salt marsh habitat may also be important to both species for feeding (Munro 1943 and 1949, Hatler 1973, Dawe 1980 and Dawe and Lang 1980). These findings are consistent with those of Lynch (1939) and Yocom and Keller (1961) for American wigeon and of Olney (1964) and Cronan and Halla (1968) for mallard.

This study is concerned with dabbler wintering habitat within the framework of coastal land management. The objective was to assist managers in identifying valuable coastal habitat by studying distribution and habitat requirements of dabblers along a section of the coast of Vancouver Island, British Columbia.

The study was initiated in conjunction with a program of aerial censuses of the Vancouver Island coastline and vegetation mapping of its estuaries, undertaken by the B.C. Ministry of Environment (Hunter et al. 1980). In order to interpret census data and marsh vegetation descriptions in terms of dabbler habitat values, one must know something about the movements and feeding habits of the ducks. An important objective of this study was to determine if the conclusions drawn from Fraser Delta studies may be applied to other B.C. estuaries. The thesis is presented in 3 parts, outlined below.

Coastal British Columbia can be regarded, from a dabbling duck's point of view, as a large area of mainly unsuitable habitat comprised of dense forests, mountains, steep, rocky shoreline and towns, interspersed with islands of suitable habitat (hereafter referred to as "sites"). Three types of sites are considered in this study: estuaries, non-estuarine shallow bays and farmland.

Part 1 of the thesis is an investigation of the fluctuations in dabbler numbers at coastal sites. I proposed movement between coastal and farm sites as an explanation for these fluctuations and I examined factors governing that movement. This section is based on a series of censuses at 16 sites.

Research and conservation efforts have focused on the marsh sections of estuaries, where plants, such as sedges, rushes and grasses grow. Dabblers also frequent the marine foreshore areas of estuaries, however, as well as marine flats in shallow, non-estuarine bays. Nearby agricultural lands are also potential feeding grounds for dabbling ducks.

Part 2 of the study is a description of where and when feeding occurs. I examined the relationship between water levels and choice of feeding location and assessed the value of fields, estuarine marshes, marine deltas and non-estuarine shallow bays as dabbler feeding habitat. This section is based on observations of the ducks' behaviour and location at several coastal and farm sites. I stress the relationship of time of feeding to the tidal cycle.

Potential food items are very patchily distributed in estuaries in the winter. Seeds fall off plants and are washed about with the rising and falling tides. Channels and flats of various elevations and salinities ensure a diversity of vegetation and invertebrate life. The ducks are presented with a different selection of potential food items in each part of the estuary.

The aim of Part 3 was to identify major food items selected by ducks in the important feeding locations. Analyses of gullet contents of ducks collected at estuarine sites form this section of the study.

To summarize, this is a study of habitat selection which examines 3 levels at which the ducks must make choices: (1) site, (2) feeding location and (3) food item. It is essential to keep this hierarchy in mind. Each level of selection can only be interpreted in relation to the levels above it. It is, for example, of little use to collect a sample of wigeon feeding in one part of an estuarine marsh if one has no idea how many wigeon feed in that part of the marsh and how frequently wigeon are at the estuary at all.

STUDY AREA

The study area is situated in the Nanaimo Lowland of southeastern Vancouver Island (Holland 1976), a hilly region largely covered in coniferous forests, lying between the mountains and the sea. The coastline is mainly steep and rocky, interspersed with shallow bays and estuarine wetlands. Agricultural land use consists of small-scale cattle production with some sheep farming and market gardening. Pastures are often poorly drained and subject to flooding in the winter.

Winters are wet and mild with periods of frost most often occurring in December and January. Longterm climatic data, taken from Environment Canada's climate station on the Big Qualicum River (10 km northwest of Little Qualicum River estuary, at 8 m elevation) provide the following average values (Air Management Branch, B.C. Ministry of Environment): 1275 mm rainfall annually and 47 cm snowfall; year-round average temperature of 9.2°C with maximum and minimum daily temperatures in January, the coldest month, of 4.9 and -0.4°C respectively. The winter of 1980-81 was exceptionally mild and about average in precipitation, with a total of 1027 mm from October to March compared to the longterm mean of 1045 mm for these months.

The tidal cycle is mixed, semidiurnal: there are 2 complete tidal oscillations in a tidal day, with inequalities both in heights of highs and lows and in time periods between them. Tidal range is about 2 to 4 m (Fisheries and Oceans Scientific Information and Publications Branch 1981).

PART 1: SELECTION OF SITE

INTRODUCTION

Ducks move about a great deal in winter. Any understanding of their ecology must begin with an understanding of their movements -- where do they go and under what influences? Direct study of the ducks' home ranges would be ideal but expensive and difficult, due to the problems involved with capturing and tracking migratory ducks in mountainous terrain. Information about movements, however, can be inferred from duck counts taken at different sites under different conditions. This is the approach taken here.

Previous studies have shown that the numbers of dabbling ducks in migrating and wintering periods at any 1 site along the British Columbia coast fluctuate considerably. Fluctuations have been described on 2 scales: seasonal and day-to-day.

Burgess (1970) detected a seasonal pattern in 2 years of aerial counts of dabbling ducks in the Fraser Delta and adjacent uplands. Peak numbers of the 4 most abundant species (mallard, American wigeon, pintail and American green-winged teal) occurred in November and December, followed by a sharp drop in January. Numbers increased again in late winter, reaching a lesser peak in April. He attributed these fluctuations to migration. He postulated 3 seasonal components of the winter duck population: a fall migrating component (late August through December), a wintering component (January) and a spring migrating component (end of January to early May). He assumed that low counts in the short wintering period occurred because most of the ducks had migrated south.

Similar patterns of seasonal fluctuations in dabbler numbers were reported from a 10-year study of the Fraser Delta (Vermeer and Levings 1977) and from a 5-year study on the Little Qualicum River estuary (Dawe 1980) and the Nanoose Creek estuary (Dawe and Lang 1980). In all of these, peak dabbler numbers occurred in November and December, followed by a sharp decline. Numbers at Nanoose and Little Qualicum appeared to remain low until the end of the spring migration period. Data were insufficient in the Fraser Delta study to detect any spring increase.

Agencies of the provincial and federal governments have conducted aerial surveys of the Vancouver Island coastline at infrequent intervals since the mid 1960s. One of the highest counts of dabbling ducks occurred during January of 1971 (Terrestrial Studies Branch, B.C. Ministry of Environment, unpublished data). Dawe (1976) and Dawe and Lang (1980) also reported abnormally high counts of mallard and American wigeon at Little Qualicum River estuary and Nanoose Creek estuary in January of 1979. Both of these months had long periods of freezing weather. Dawe suggested that during the freezing periods agricultural lands are unavailable and inland ducks are driven to the coast. This contradicts studies in the Fraser Delta, where low coastal numbers in January have been attributed to the high incidence of freezing temperatures during that month (Burgess 1970 and Leach 1972).

There are few studies with sufficient data to distinguish day-to-day fluctuations from seasonal ones. Dawe's (1980) report on the Little Qualicum River estuary provides the most extensive set of dabbling duck counts -- once a week for 5 years. However, his reduction of the data to monthly averages to display a seasonal trend masks wide day-to-day fluctuations, as may be seen in Table I.

Fluctuations in census data would result if the ducks displayed a daily rhythmicity of movement and if the time of day of the counts varied. Daily patterns in movements of waterfowl have been described by many authors (eg., Swanson and Sargeant 1972 and Campbell 1978). Local studies are contradictory. Hatler (1973) in 8 days of morning and afternoon aerial dabbler censuses on tidal flats found consistently higher numbers in the morning. Munro (1943) and Burgess (1971) described regular daily farm-coast flights for dabblers. Hirst and Easthope (1981), however, found no significant difference between morning and afternoon censuses for mallards and American wigeon in fields on the Fraser Delta.

A preliminary census study was conducted from February to April, 1980 at Little Qualicum River and Nanoose Creek estuaries (Appendix 1). Wide day-to-day fluctuations in dabbler numbers occur in the study area. Time of day does not appear to be a major factor. Numbers of mallards and American wigeon at one estuary and at a nearby farm were negatively correlated -- when fewer ducks were in the estuary, more ducks were inland. High counts on the farm occurred when large areas of the fields were flooded.

This preliminary work suggested that coastal and inland agricultural sites may be alternative habitat types, and that duck movements among sites may be regulated partly by the degree to which inland sites are flooded. This is contradictory to the conclusions of Hirst and Easthope

Table I. Counts of American wigeon at Little Qualicum R. estuary 1975-76 (N.K. Dawe, unpublished data).

	weekly counts				average
October		638	22	86	249
November	68	27	7	0	97
December	117	0	124	75	79
January	2	29	0	1	8
February	19	0	1	0	5
March	9	24	1	4	10

(1981) in a study of the Fraser River estuary and nearby farmlands. They found a positive correlation between dabbling duck numbers on coastal and farm sites and concluded that ducks treat agricultural lands as an extension of coastal habitat, with fluctuations in numbers being related primarily to migration patterns.

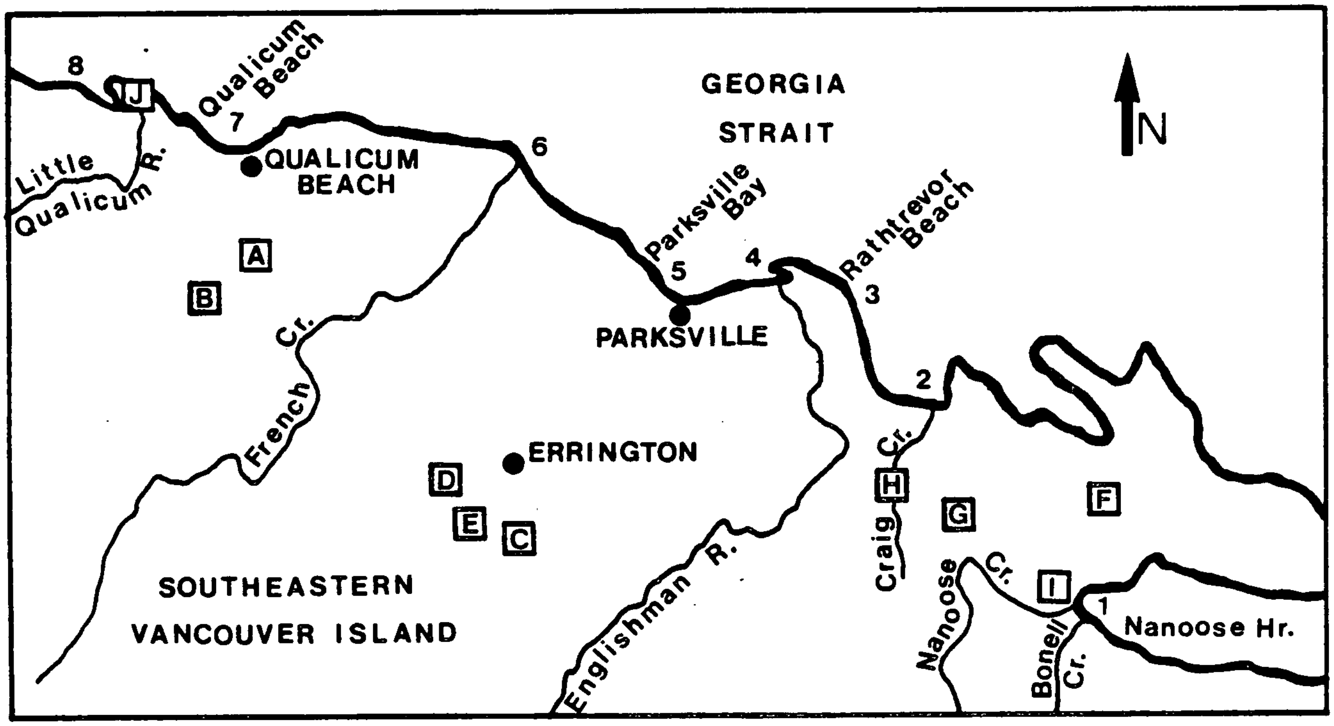
The purpose of this part of the study, carried out from October, 1980 through April, 1981, was to clarify the relationship between coastal and farm sites for southeastern Vancouver Island. I asked three questions: (1) Can movement between the 2 types of habitat account for some of the day-to-day and seasonal fluctuations in dabbling duck numbers at coastal sites? (2) If so, is the amount of standing water on the fields an important factor? (3) What happens in freezing weather: do ducks leave the area or move from the fields to the coast?

STUDY AREA

The study area consisted of 8 sites located along a 30 km section of coastline, from Nanoose Harbour to the mouth of the Little Qualicum River, and 8 nearby agricultural sites (Fig. 1). The coastal sites were of 2 types: estuaries, and non-estuarine shallow bays. Each estuarine site included the intertidal marsh at the mouth of the river or creek, surrounding beaches and deep water areas seaward to the limit of visibility with a 20-power spotting scope. Bay sites, which contained little or no vascular plant growth, consisted of beach and deep water areas. The farm sites were blocks of pastureland ranging in size from 19 to 138 hectares. Vegetation varied within and among sites from heavily-grazed pastures of mixed grasses and forbs to fields of tall, coarse canary grass (*Phalaris arundinacea*) interspersed with clumps of sedge (*Juncus effusus*).

Two of the estuaries, Little Qualicum River and Nanoose Creek, form the Qualicum National Wildlife Area, managed by the Canadian Wildlife Service (see Dawe 1976 and 1980, Dawe and Lang 1980 and Dawe and White 1982 for descriptions of vegetation). Small mowed fields are maintained adjacent to each estuary, primarily as habitat for dabbling ducks. These fields were treated as 2 additional farm sites.

Fig. 1. Study area. Scale: 1:150,000. Numbers indicate coastal sites: 1, 2, 4, 6 and 8 are estuaries; 3, 5 and 7 are bays. Letters indicate farm sites (lot numbers from map sheets 92F/7, 1976 and 92F/8, 1977, Surveys and Mapping Branch, Department of Energy, Mines and Resources, Ottawa): A=lot 8; B=lots 18 and 37; C=lot 46; D=lot 24; E=lots 100 and 25; F=lot 62; G=lot 169; H=lot 44; I=meadows at Nanoose Unit, Little Qualicum National Wildlife Area; J=meadows at Marshall-Stevenson Unit, Little Qualicum National Wildlife Area.



GEORGIA
STRAIT
N
8
J
Qualicum Beach
7
QUALICUM
BEACH
Little Qualicum R.
6
A
B
French Cr.
Parksville Bay
5
4
PARKSVILLE
Rathtrevor Beach
3
2
ERRINGTON
D
E
C
Craig Cr.
H
G
F
Englishman R.
SOUTHEASTERN
VANCOUVER ISLAND
Nanoose Cr.
I
1
Nanoose Hr.
Bonell Cr.

FIELD METHODS

Censuses were conducted once a week from October 6, 1980 to April 28, 1981. Additional censuses were carried out on freezing days, defined as days that followed a night of frost and for which freezing temperatures were forecast for at least most of the day. Five freezing days occurred during the study period.

Each census consisted of counts of mallards and American wigeon at all farm and coastal sites. Prior to the study period, a census route was established at each site. Observations were made on foot and from vehicles, using binoculars and spotting scopes, at predetermined points along the routes. Three observation towers were constructed at sites where there were no natural vantage points. Ducks were counted individually whenever possible. When many ducks were disturbed and took flight, numbers were estimated. Data were recorded on cassette tapes. Several routes were altered in the early weeks of the study in order to minimize disturbance to the ducks. Coastal and farm sites were censused concurrently by 2 observers, from approximately 0900 to 1600 hours. Due to a tape recorder malfunction, most of the coastal census for April 21 was lost. Thirty-one complete censuses were obtained. Appendix 2 contains census results for each site.

At each farm site, the area of flooded land was estimated for each census day. Detailed maps of the sites were drawn from aerial photographs. Each census day, boundaries of all flooded areas were sketched on tracing paper placed over the maps. When standing water was very broken up, the proportion (out of 10) of each field that was covered in water was estimated. Gauges (2 m strips of wood painted in alternating 10cm black and white stripes) were installed at low elevation points at the farm sites to assist in comparing water levels. On freezing days, the areas of unfrozen standing water were estimated. When the flooded area was too small and scattered to measure accurately, it was recorded as 0 or 0.1 ha, whichever seemed closest.

This method was not suitable for sites I and J (Figure 1), the 2 fields included in the National Wildlife Area, due to their smaller size. Dimensions of puddles were estimated in metres and the flooded areas recorded to the nearest 10 m^2, resulting in a greater degree of precision for these sites. Data from these sites are not included in the statistical analyses, but are plotted on Fig. 3 for comparison.

Sources of Error

This study is not concerned with the estimation of numbers of ducks in the region but rather with the relationship between numbers on farms and on the coast. As such, errors made in duck counts and in flooded-area estimates should not affect the conclusions if the errors are either randomly distributed or consistent.

Observer error was made as consistent as possible by following standardized procedures and by assigning 1 observer to coastal sites and 1 to farm sites. All flooded-area estimates were made by the same observer. Visibility varied greatly with weather conditions at all sites; in fog and heavy rain, duck numbers were probably underestimated. However, as both farm and coastal sites were affected in the same manner, errors related to weather conditions should not bias the results.

Two sources of bias error were considered. Visibility, particularly at the farm sites, was affected by the height of vegetation. This could have contributed to lower counts at the farm sites in the latter part of the census period, when grass was taller. Ducks were also harder to spot on the fields when there was little or no standing water. This could have contributed to lower counts at farm sites at times of low flooding.

An attempt was made to assess the extent of this problem by walking through the farm sites after censusing in the spring and at other times of low flooding. As few uncounted ducks were flushed out, I feel that bias error was not significant.

STATISTICAL METHODS AND RESULTS

For each census, counts of mallards and American wigeon were totalled for farm and for coastal sites. Results for all 32 censuses are shown in Fig. 2.

In order to test the hypothesis that fluctuations in duck numbers on the coast are due, in part, to movement between the coast and farmland, linear correlation analyses were performed (Table II). Partial correlation coefficients between coastal and farm counts, partialled on date, were calculated. These analyses assess the linear relationship between numbers of ducks on the coast and at farms, taking into account variation due to an overall linear decline in numbers during the study period.

As may be seen in Fig. 2, there were serious departures from linearity at both ends of the study period. Coastal numbers increased for both species through October, while farm numbers levelled off to near-zero in October and April. Accordingly, the analyses were performed on the 24 censuses from November to March.

It is clear from Fig. 2 that the extremely high coastal and low farm counts from the 5 censuses on freezing days contribute greatly to these significant negative correlations. To test if the relationship held for nonfreezing days, the correlation analyses were performed omitting these 5 censuses. For all data sets, duck numbers at coastal sites are significantly negatively correlated with numbers at farm sites.

The area of each flooded patch sketched on the maps of the farm sites were calculated on a microcomputer programmed to operate as a digitizer. When an estimate was in the form of the proportion of a field

Fig. 2. Census totals for coastal and farm sites and flooded areas at farm sites. Shaded strips designate freezing periods.

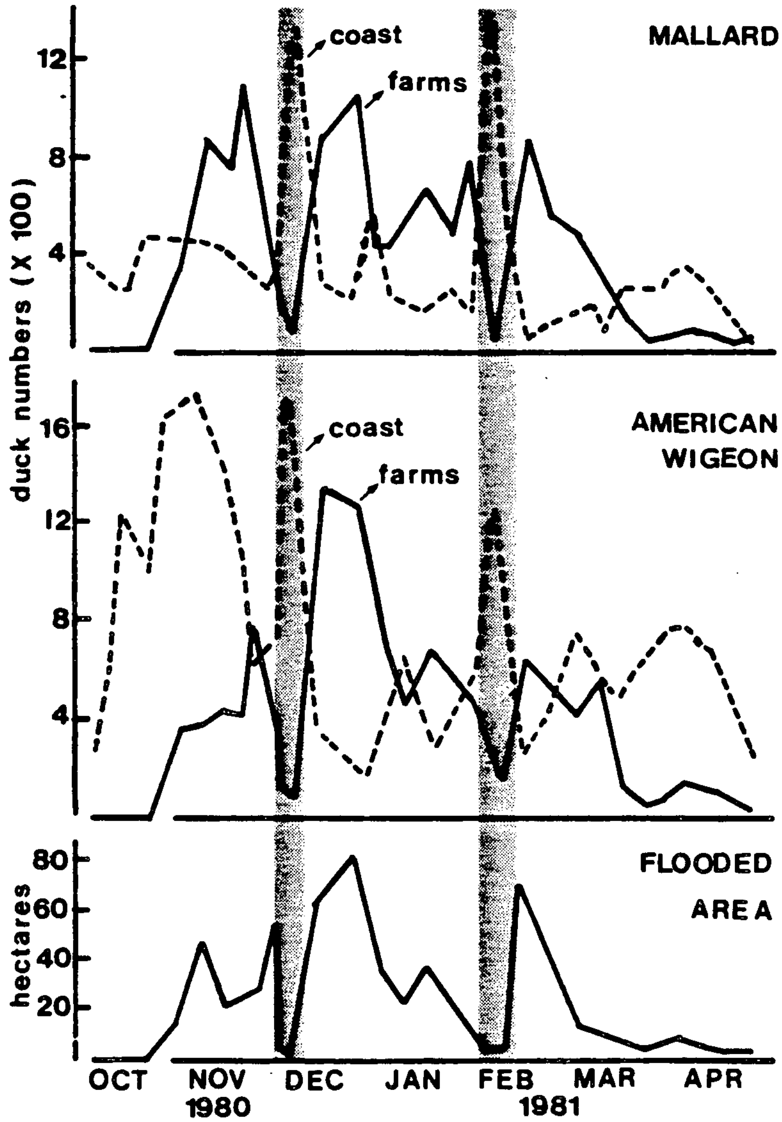

MALLARD
coast
farms
12
8
4
duck numbers (X 100)
AMERICAN
WIGEON
coast
farms
16
12
8
4
FLOODED
AREA
hectares
80
60
40
20
OCT
NOV
1980
DEC
JAN
FEB
1981
MAR
APR

Table II. Partial correlation analyses between farm and coastal numbers, partialled on date.

Data set	N	Partial correlation coefficient between farm and coastal numbers[a]
MALLARD		
all census days	24	-.68**
nonfreezing days	19	-.64**
freezing days	5	-.99**
AMERICAN WIGEON		
all census days	24	-.83**
nonfreezing days	19	-.84**
freezing days	5	-.91**

[a] Significance is assessed with a one-tailed t-test with N-3 df.

**P<0.01

that was flooded, the field area was calculated and then multiplied by this proportion. For each census, flood areas were totalled for each farm site and then for all farm sites.

In Fig. 2 the total flooded areas are displayed for all censuses. Flooded areas for each site are listed in Appendix 3.

To test the hypothesis that movement by dabbling ducks between the coast and farms is related to the amount of standing water on fields, linear regression analyses were performed (Table III). In each test, the independent variables are date and total flooded area at the farm sites; the dependent variable is duck numbers on the coast. As in the preceding correlation analyses, only censuses from November through March are included since a linear model is used to adjust for the seasonal decline in overall numbers. Nonfreezing and freezing days were also examined separately. The tests of significance for the partial regression coefficients are one-tailed because I hypothesized that (a) large flooded areas should result in a movement of ducks to the farms, and (b) when the fields dry up, ducks should return to the coast. This would result in negative coefficients.

The overall regressions and the partial regression coefficients are significant for both species for all census days and for nonfreezing days. As the regressions for the freezing days are nonsignificant, further tests on these data sets are not warranted (Zar 1974). The coefficients of determination express the percentage of the variability in coastal numbers that may be explained by the date and by the flooded areas at the farm sites.

If the ducks choose farm habitat largely on the basis of amount of standing water, the mean number of ducks at each farm site should depend upon

Table III. Multiple regression analyses: coastal numbers as a function of date and flooded area at farm sites.

Data set	N	F(df=2 and N-3)	Coefficient of determination (R^2 x 100)	Partial regression coefficient for flooded area[a]
MALLARD				
all census days	24	6.38**	37.8	-8.25**
nonfreezing days	19	7.70**	49.1	-2.05**
freezing days	5	2.20[ns]	-	-
AMERICAN WIGEON				
all census days	24	22.21**	67.9	-13.30**
nonfreezing days	19	11.35**	58.7	-11.16**
freezing days	5	10.31[ns]	-	-

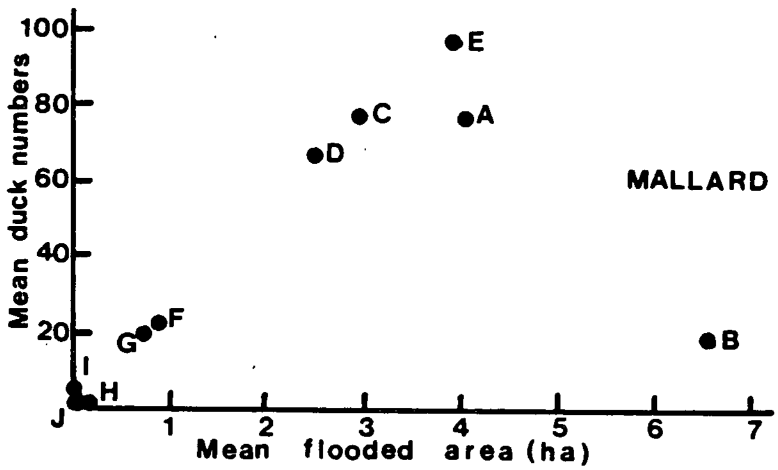
[a] Significance is assessed with a one-tailed t-test with N-3 df.

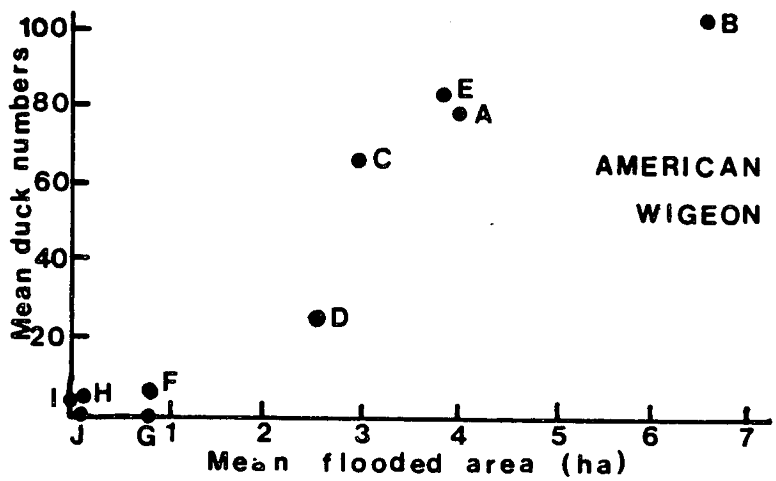
**$P<0.01$

[ns]not significant ($P>0.05$)

the mean flooded area at that site, with sites with higher flooded areas supporting more ducks. Duck numbers and flooded areas at each farm site were averaged over all 32 censuses. The results are displayed in Fig. 3. Linear regression analyses were performed on these data. For American wigeon, the resulting regression coefficient of 18.7 was significantly greater than zero in a one-tailed t-test with 8 df($P<0.01$). The coefficient of determination was 90.0%. For mallards, the regression coefficient of 6.6 was not significantly greater than zero ($P>0.05$). It is apparent from Fig. 3 that one data point, site B, greatly reduced the slope of the regression line. Exclusion of site B results in a significant ($P<0.01$) regression coefficient of 21.6 and a coefficient of determination of 92.3% for mallards.

Fig. 3. Mean duck numbers and mean flooded areas at farm sites. Letters refer to farm site locations (Fig. 1). All means are calculated from the same 32 censuses.


100
80
60
40
20
Mean duck numbers
E
C
A
D
MALLARD
F
G
B
I
H
J
1
2
3
4
5
6
7
Mean flooded area (ha)


100
80
60
40
20
Mean duck numbers
B
E
A
C
AMERICAN
WIGEON
D
F
I
H
J
G
1
2
3
4
5
6
7
Mean flooded area (ha)

DISCUSSION

Farm-Coast Movement and Degree of Flooding

The very strong negative correlations between total counts at farm and coastal sites (Table II) suggest that the 2 types of habitat are used alternatively. As there were frequent shifts in the relative use of coastal and farm sites throughout the study period, I concluded that the wide day-to-day fluctuations at any 1 site are due in part to this relationship. The extent of these fluctuations (Appendix 2) suggests that movement among farm sites and among coastal sites also must be common. This is discussed further in Part 2.

It is clear from Fig. 3 that the number of ducks inland is strongly tied to the area of flooding on the fields. This means that under conditions of high flooding, there is a movement of dabblers away from the coast (Table II). Flooding, resulting from the accumulation of rainwater in poorly drained fields and from overflow of low-gradient sections of creeks, follows a seasonal pattern that depends on the seasonal pattern of precipitation. It appears, then, that seasonal fluctuations in duck numbers at individual coastal sites are due in some measure to fluctuations in flooding of fields.

The extent of this dependency may be underestimated because of the relative amounts of farm and coastal habitat surveyed. The coastal census route probably included most dabbler habitat from Nanoose Bay to Little Qualicum River estuary. However, several farms in the vicinity were not censused but were frequented by dabbling ducks. This assessment is based on conversations with local residents, observations by the author and an aerial survey of the study area conducted on November 26, 1980.

When fields were attractive to ducks, then, a smaller proportion of the true number of ducks in the vicinity would have been counted than at times when coastal habitat was favoured. This is supported by the high total counts of both species on freezing days, when farm habitat was the least attractive (Fig. 2). This means that seasonal fluctuations in total counts may still reflect the coastal-farm relationship as well as migration and mortality. As the ducks' home ranges are completely unknown, it is not possible to separate these effects.

If the same inverse relationship between farm and coastal habitat occurs in the Fraser Delta area, it could affect the seasonal fluctuations that have been attributed to migration patterns (Burgess 1970, Leach 1972, Vermeer and Levings 1977). Studies in the Fraser Delta have included most of the coastal habitat and some adjacent agricultural lands. However, many farms in the Lower Fraser valley flood and are frequented by ducks but were not censused. The midwinter dropoff in numbers observed in these studies is during the season of extensive field flooding. Burgess (1970) reported that the highest number and proportion of ducks on farms coincided with the mid-winter decline in total duck counts.

Hirst and Easthope (1981) concluded that degree of flooding was the most important factor in choice of farm site for dabblers in the Fraser Delta area. However, they also concluded from a positive correlation between farm census totals and counts on adjacent coastal habitat that dabblers treat flooded fields as an extension of coastal habitat, with migration patterns accounting for fluctuations in numbers. I believe that this conclusion is not warranted, as flooding in the fields remained stable through most of their short study period (October to December). A similar positive relationship presumably would have resulted in the present study had flooded area on the fields remained stable. Hirst and Easthope's final conclusion, that eliminating or reducing field flooding would have little effect on migrating and wintering dabbling ducks, is not substantiated.

Studies in Britain and Louisiana indicate that changes in drainage patterns on coastal farm lands can affect wintering dabbling ducks. Owen and Williams (1976) found inland pastures to be the most important feeding habitat for European wigeon (Anas penelope) in Britain. Owen and Thomas (1979) conducted a study in England on the Ouse Washes (a large pasture area subject to extensive winter flooding). Before reserves were created, fluctuations in European wigeon numbers were tied closely to levels of flooding; the creation of permanent water bodies increased dabbler usage and reduced fluctuations in numbers. In coastal Louisiana, Tamisier (1976) concluded that wintering pintails and American green-winged teal fed mainly in flooded fields, while Chabrek et al. (1975) found that improving drainage of agricultural lands greatly reduced their use by all dabblers.

Selection among Farm Sites

The results of the site-by-site analysis depicted in Fig. 3 are somewhat surprising. The farm sites differed in many respects: size, proximity to roads and houses, hunting pressure, vegetation type, flooding regime (see Appendix 3) and the depth, number and shoreline length of the puddles. Presumably these factors greatly influence the types of food available and the degree of disturbance. Yet a linear relationship with mean flooded area accounted for 90.0% of the variability among mean American wigeon numbers at the farms and 92.3% of the variability among mean mallard numbers (excluding site B).

The presence of water appears to be both necessary and sufficient to make a field attractive to dabblers. Proximity to coastal habitat is not enough. Site I, adjacent to Nanoose Creek estuary, collected standing water in one small area only and received very little use. Site J, adjacent to Little Qualicum River estuary did not flood and was not used.

American wigeon apparently require a larger minimum flooded area. Sites F and G, with low mean flooded areas, received fairly regular use by mallards but only occasional use by American wigeon at times of highest flooding. Sites H and I, which rarely were flooded to any measurable degree, were used occasionally by mallards only.

Why site B should be so unpopular with mallards is difficult to say. It was close to a main road and was hunted, but so were several other sites. Its greater water depth is the most likely explanation. Studies have indicated that water depth is important in habitat selection for breeding mallards (Joyner 1980, Mack and Flake 1980) and for wintering mallards (Chabrek et al. 1975). Thomas (1976) found that mallards were unable to feed in water deeper than 40 cm. Part 2 of this study indicates that mallards rarely fed on land, while American wigeon frequently grazed on land near standing water.

Hunting Pressure

Movement between coastal and inland sites in the Fraser Delta area (Benson 1961, Burgess 1970, Leach 1972) and on southeastern Vancouver Island (Munro 1943) has been related to hunting pressure. Evening flights from the coast to fields for night feeding and morning flights to return to the coast to loaf offshore have been observed during the hunting season. This did not appear to occur in the study area, possibly because only a few of the sites (farm and coastal) were hunted. Regular morning and evening flights were not observed and residents of the farms that were censused did not believe that such flights occurred. Ducks of both species were observed on several occasions feeding and resting at night both at farm sites and at the Little Qualicum River estuary.

Tamisier (1976) concluded that hunting pressure may influence the distribution of ducks among sites in Louisiana. Hirst and Easthope (1981), however, reported that dabblers did not avoid fields subject to hunting disturbance in the Fraser Delta area. This would appear to be the case in this study also. Farm sites B and C were hunted occasionally and site D was hunted fairly frequently; hunting was not allowed at the other farms. Duck numbers at all sites were tied closely to flooded area, with the single exception of mallard numbers at site B (Fig. 3).

Freezing Weather

The most dramatic shifts between farm and coast use occurred during freezing weather. In both the December and February cold spells, large numbers of ducks occupied the coastal sites while few remained inland (Fig. 2). There was no indication that large numbers of ducks left the study area during or following freezing periods.

During freezing periods, when fewer ducks were on farms, more were found at the coast (Table II). The regressions between numbers at the coast and unfrozen flooded areas were not significant (Table III). Any true relationship with flooding, however, is likely to be non-linear; as more water freezes, less of the remaining water is shallow. As discussed above, water depth is probably important, particularly for mallards.

The ducks' behaviour when fields are frozen might be expected to depend upon the extent of the food resources that remain. It is possible, then, that dabblers would migrate south if coastal habitat were insufficient to meet their needs or if the cold spell continued for a longer period. In England, at the Ouse Washes, it has been reported that large numbers of wintering mallards and European wigeon remain in the area for freezing periods of a few days (Thomas 1976) but move to the coast during longer freezing spells (Owen and Thomas 1979). During the short periods of frost they feed on waste potatoes and leaves of winter wheat. This type of food resource is scarce in my study area but may be abundant in other parts of coastal British Columbia, notably the Fraser Delta.

The winter of 1980-81 contained fewer than average freezing days. To estimate the number of days with freezing in the fields, days with maximum temperatures of $\leq 3°C$ at the climate station on the Big Qualicum River were counted (Air Management Branch, B.C. Ministry of Environment). There were 8 such days during the study period compared to an annual average of 19 (SD=10.1) from 1964-1980.

Results from this study indicate that coastal habitat may be critically important when fields are frozen. However, this conclusion cannot be assumed to hold for other areas, since the use made of coastal sites during times of freezing in nearby fields may vary depending on agricultural practices and the relative amounts of farm and coastal habitat. No local dabbling duck studies containing farm and coastal census data have recorded the extent of freezing in the fields.

I recommend that researchers assessing dabbler habitat in coastal areas subject to frost apportion their sampling efforts to include freezing periods. A set of dabbler counts at a coastal site taken on freezing and nonfreezing days would yield two important types of information: (1) how many ducks use the site as part of their winter habitat (from high freezing counts) and (2) the importance of nearby farms as alternative sites (from the magnitude of the difference between freezing and nonfreezing counts).

PART 2: SELECTION OF FEEDING LOCATION

INTRODUCTION

Part 2 deals with selection of feeding location. I demonstrated in Part 1 that mallards and American wigeon on southeastern Vancouver Island move between coastal and farm habitat types, influenced by water conditions on the farms and by the presence or absence of freezing temperatures. But are both types of habitat used for feeding? Coastal habitat is very patchy, ranging from dense, high-marsh plant communities to unvegetated marine mudflats. Which of these patches are important for feeding? Tidally influenced habitat is continuously changing. How do the shifting water depths at coastal sites affect the ducks' feeding patterns?

To answer these questions, I attempted to systematically describe dabblers' activities and locations at coastal and farm sites. Most previous studies of ducks wintering in coastal areas of North America and Britain have based their conclusions regarding feeding location on counts of ducks in different habitat units, on crop or gizzard contents of collected ducks and on casual behavioural observations. The general conclusion has been that dabbling ducks feed primarily on vascular plants in tidal marshes and agricultural lands while most diving ducks feed on invertebrates in marine estuaries and bays (Yocom and Keller 1961, McMahan 1970, Kerwin and Webb 1972, Vermeer and Levings 1977, Hughes and Young 1982). Some authors (Lynch 1939, Munro 1943 and 1949, Olney 1964, Dawe 1980), however, have observed dabblers, including mallards and American wigeon, feeding on marine flats.

Tidal fluctuations are considered to affect feeding dabblers. Burgess (1970) concluded that dabblers feed more in tidal marshes at low receding tides. Munro (1949) also considered receding tides to be preferred by American wigeon feeding on marine flats.

In this study I examine feeding habitat preferences through a description of feeding locations. However, extrinsic factors such as predation and competition may also influence the animals' choice of location (Wiens 1976). As disturbance (related to predation) has been reported to affect distribution in dabblers (Hatler 1973, Tamisier 1976, Owen and Williams 1976) an assessment of the effect of disturbance on feeding location is included.

STUDY AREA

The study area consisted of 3 estuarine sites (Little Qualicum River, Englishman River and Nanoose Creek), 1 bay site (Rathtrevor Beach) and all farm sites censused in Part 1 (Fig. 1). Species composition of marsh vegetation and algae varies among the 3 estuaries (see Dawe 1976 and Dawe and Lang 1980 for species inventories of Nanoose and Little Qualicum, and Dawe and White 1982 for an analysis of the vegetation ecology of Little Qualicum). Certain features are common to the 3 estuaries, and to others in the region. They are outlined below.

In the marsh zone of the estuary, stream and tidal channels meander through vegetated flats and sometimes form small ponds. Channel and pond bottoms are sparsely vegetated, typical plants being *Ruppia maritima* and filamentous algae. The lower-elevation flats and lower channel edges are often sparsely vegetated in winter. Vegetation might include *Salicornia spp.*, *Glaux maritima*, *Distichlis spicata*, *Plantago spp.* as well as *Fucus spp.* and filamentous algae. Upper flats often support dense stands of vegetation in winter. Typically present would be plants of the grass (Graminae), sedge (Cyperaceae) and rush (Juncaceae) families and *Potentilla pacifica*. Dense, uniform stands of sedge (*Carex spp.*) occur along upper channel edges or as patches. In winter, the leaves and stems of most plants are dead; seeds and plant debris drift about the marsh with tidal fluctuations.

The delta fans out into shifting, sometimes indistinct channels seaward of the marsh zone. These channels often support heavy growths of filamentous algae in the spring. Substrate type and amount of algal growth on the beach vary widely from site to site. Drift seaweed and eelgrass (Zostera marina) wash up and down the beach with the tide, accumulating in banks at high tide mark. The amount of drift seaweed varies from day to day.

The bay site, Rathtrevor Beach, is a shallow, sandy beach in Craig Bay. The farm sites are described in Part 1 and mean flooded areas are listed in Appendix 3. Area measurements at coastal sites would be misleading, as surveys were linear, following coastlines, streams and channels. Table IV presents approximate lengths of the main features surveyed. Measurements are of straight lines drawn along sections of the shorelines on a 1:50,000 map. The numerous smaller channels surveyed are not included.

Table IV. Lengths of major features surveyed for activity-location observations at coastal sites.

Site	Length of coastline surveyed (km)	Distance surveyed along main stream(s) or tidal channel(s)(km)
Little Qualicum R.	1.5	Lower river and channels 1.2
Englishman R.	1.3	East channels 0.8
		Lower river and west channels 1.1
Nanoose Cr.	0.9	Nanoose Cr. 0.4
		Bonell Cr. 0.4
Rathtrevor Beach	2.1	0

FIELD METHODS

Coastal Sites

Observations at coastal sites were made from October, 1980 to April, 1981 at times chosen to correspond to "low" and "high" tides (defined in Table V). A schedule of observation periods was drawn up using tide tables and the periods were randomly distributed among the 4 sites.

As river flow and weather factors such as wind velocity affected water levels, tide tables were used only as rough guides. Gauges were installed at the 3 estuarine sites to aid in standardizing water levels at which observations were made. The gauges consisted of strips of wood 3 m long, painted in alternating 20 cm black and white stripes. During preliminary studies, specific gauge readings were established as corresponding to about the middle of "high" and "low" tidal ranges. Observations were started when I estimated that the water would reach this level on the gauge during the observation period.

Methods were established during preliminary studies. The route followed at each site was chosen as a compromise between maximum coverage and minimum disturbance. Parts of Englishman River estuary were surveyed by vehicle, as this appeared to disturb the ducks less than did people on foot.

From set vantage points along the census route ducks were scanned (Altmann 1974) for activity and location (Table VI). Each duck was observed for about 2 seconds through 8 X 10 binoculars or a 20X scope. Data were recorded on cassette tapes. Adjustments frequently had to be made for movement. If, for example, activities were recorded for 10

Table V. Tidal range definitions.

Tidal range	Approximate tidal height (m)[a]	Marsh water levels	Marine water levels
Very high	Above 4.4	Upper flats shallow. Other zones deep.	Little shallow water at tideline. Beach and delta zones deep. No tidepools.
High	3.9-4.4	Upper flats dry. Lower flats and sedge stands shallow.	Similar to "very high".
Mid	3.0-3.8	Transition between "high" and "low".	
Low	2.0-2.9	Very low elevation zones only shallow. Other marsh zones dry.	Wide band of shallow water at tideline. Gravel bars exposed. Delta zone shallow. Some tidepools
Very low	Below 2.0	All vegetated zones dry.	Similar to "low", more tidepools.

[a] From tide tables (Fisheries and Oceans Scientific Information and Publications Branch 1981).

Table VI. Activity-location classifications

Classification	Description
ACTIVITY	
Feed	Any behaviour connected with feeding, including up-ending, swimming with head under water and pecking.
Move	Any movement not obviously associated with feeding, including social interactions.
Rest	Any position not moving.
LOCATION	
Land	No visible water; marsh, delta or marine zones. Distance from water estimated (within 1 m, 1 m to 5 m, or more than 5 m).
Shallow water	Water less than about 30 cm deep.
- Marsh	Stream and tidal channels and surrounding flats supporting well-established, tidally-influenced marsh vegetation.
- Delta	The seaward extension of stream channels, beyond the marsh zone to as far as the channels remain distinct.
- Marine	Beach areas seaward of the marsh zone, unvegetated or with growths of algae or eelgrass.
Deep water	Water deeper than about 30 cm; marsh, delta or marine zones

mallards in 1 location then the ducks moved to another location yet to be censused, an adjustment was required. I surveyed the second location and later subtracted 10 mallards in proportion to the activities of all mallards in that location. If movement was too extensive to keep track of, the observation was abandoned.

Farm Sites

During the census study (Part 1), activity-location observations were recorded at farm sites whenever at least 5 ducks of 1 species were present. The same classification system was used (Table VI), except location was recorded only as "land", or "water".

Disturbance

During farm and coastal observations, any disturbance causing at least 5 ducks to fly up was recorded. Apparent cause, number of each species of duck and where they went ("marsh", "bay" or "left site") were noted.

"Very High Tide" Observations

During the early winter I observed that, at tides in the upper range of "high" and in the "very high" range (Table V), generally occurring in early mornings, there was an influx of ducks at the 3 estuaries and feeding was more intense. Accordingly, an additional set of observations was added, from January to April, 1981, at Little Qualicum River estuary.

Part of the marsh, including upper flats, sedge stands and channels, was surveyed from an observation tower. Activity-location scans were made at 0.1 m intervals in water level, as the tide receded. Observations started at the highest water level for which there was sufficient light and continued until the reference gauge level for "high tide" (called gauge level 1) was reached. At gauge level 8, most of the high marsh area was flooded, while by gauge level 1, most of it was dry.

Activity and location were recorded (Table V) for each duck at each gauge level. In addition, all movements out of the marsh were noted. The number of ducks in each group that flew up, whether they went to the bay or left the site, direction of flight and any apparent disturbance were recorded.

Starting times of observations ranged from 0620 to 1055 hours, with observation periods lasting from 70 to 140 minutes. As a control, on 7 occasions when tides were below the "high" range, half-hour observations of the upper marsh were carried out starting at 0900 hours.

Sources of Error

Inevitably, parts of most sites were surveyed inadequately -- ducks could have been missed or were disturbed before the observer could record activity and location. If 20% of the total for a species in an observation period was unclassified, the data were discarded for that species.

Deep channels and upper flats with dense, high vegetation were more difficult to survey than were open areas. This introduced some degree of bias error to all estuarine observations. To assess this error, after several observation periods I walked through upper flats and along deep channels to flush out any uncounted ducks. When few had originally been observed, few if any extras were spotted. However, when ducks were abundant in the area, particularly at Englishman River, many uncounted ducks were often flushed out. Thus the results probably underestimate the use made of these zones but conclusions regarding the timing of this use should not be affected.

STATISTICAL METHODS AND RESULTS

Data are in the form of proportions: number of ducks in a certain class/number of ducks at the site. This enables one to compare across sites, tides and species when absolute numbers are very different. Proportions were calculated only when there were at least 5 ducks of the species at a site and at least 80% of the ducks were classified as to activity and location. When not all ducks were classified, the total of classified ducks (not of ducks present) was used to calculate proportions. Whenever a mean number of ducks or mean proportion of ducks is presented, its standard error (se) and sample size (N) are given as a measure of the accuracy of the sample mean. Sample sizes vary considerably, as many observations were discarded because of excessive disturbance.

In all statistical tests, data were checked for homoscedasticity using F tests and transformations were applied where appropriate. Unless noted otherwise, variances were equal ($P>0.01$). Normality of distributions was assessed graphically. There was a tendency for distributions involving proportions to be skewed to the right, particularly when means were close to 0. The skewness was not excessive, except where noted.

Duck Counts in Relation to Tide

If the ducks' movements among sites are correlated with tide level, mean numbers of ducks at "high" and "low" tides at each site should differ. To test this, two-tailed t-tests were performed for each coastal site and each species (Table VII). In 2 cases, as indicated, logarithmic transformations were used to correct for unequal variances. At Rathtrevor

Table VII. Duck counts at coastal sites, "high" and "low" tides.

Species/Site	"High" tide Mean ± se(N)	"Low" tide Mean ± se(N)	t-tests for difference between "high" and "low" tide numbers (t-statistic)
MALLARD			
Little Qualicum R.	140±43(19)	129±22(23)	0.46 [ns,a]
Englishman R.	106±14(21)	80±11(17)	1.29 [ns]
Nanoose Cr.	7±3(17)	17±4(22)	1.29 [ns,a]
Rathtrevor Beach	4±2(18)	42±12(21)	2.86 **
AMERICAN WIGEON			
Little Qualicum R.	150±33(19)	155±24(23)	0.11 [ns]
Englishman R.	244±28(21)	197±38(17)	1.02 [ns]
Nanoose Cr.	136±21(7)	162±25(22)	0.76 [ns]
Rathtrevor Beach	26±20(18)	255±53(21)	3.82 **

[a] Logarithmic transformation used.

** P<0.01

[ns] not significant (P>0.05)

Beach, for both species, variances were unequal and "high" tide sample distributions were highly skewed, with and without transformation. However, the conclusions are probably valid, as the sample means differ by a factor of 10 for both species. Dabblers were rarely present at "high" tide: in 18 observation periods, there were 15 zero-counts for mallard and 14 for American wigeon.

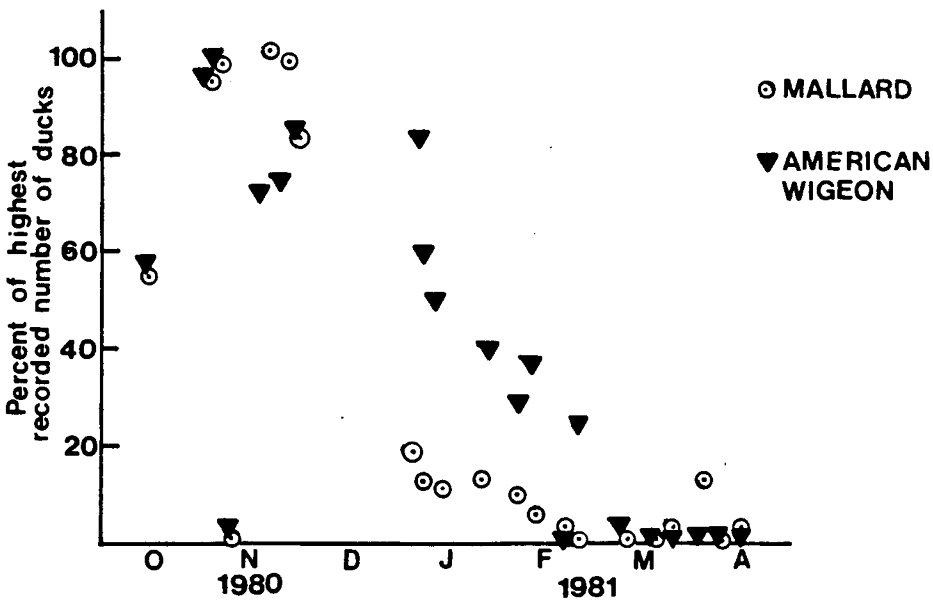
Duck Counts in Relation to Season

Numbers of ducks at each coastal site and tide level were plotted against date to check for seasonal trends. All exhibited wide day-to-day fluctuations. At the 3 estuarine sites, seasonal changes corresponded to the pattern of seasonal variation for coastal sites in the census data (Fig. 2). However, at the 1 bay site, the seasonal trend was markedly different (Fig. 4). Low tide observations only are plotted. Peak numbers, occurring in November, were 143 for mallard and 676 for American wigeon. The latter was the highest number of American wigeon recorded at a coastal site.

Activity-Location Data

In this section, the activities and locations of mallards and American wigeon at 4 coastal sites and 7 farm sites are described. A total of 158 observation periods at coastal sites provided 9411 classified counts of mallards and 26,032 counts of American wigeon. Eighty-one observation periods on farm sites provided 4833 classified counts of mallards and 5157 counts of American wigeon.

Fig. 4. Seasonal trend in duck numbers at Rathtrevor Beach.



100
80
60
40
20
Percent of highest recorded number of ducks
O
N
D
J
F
M
A
1980
1981
MALLARD
AMERICAN WIGEON

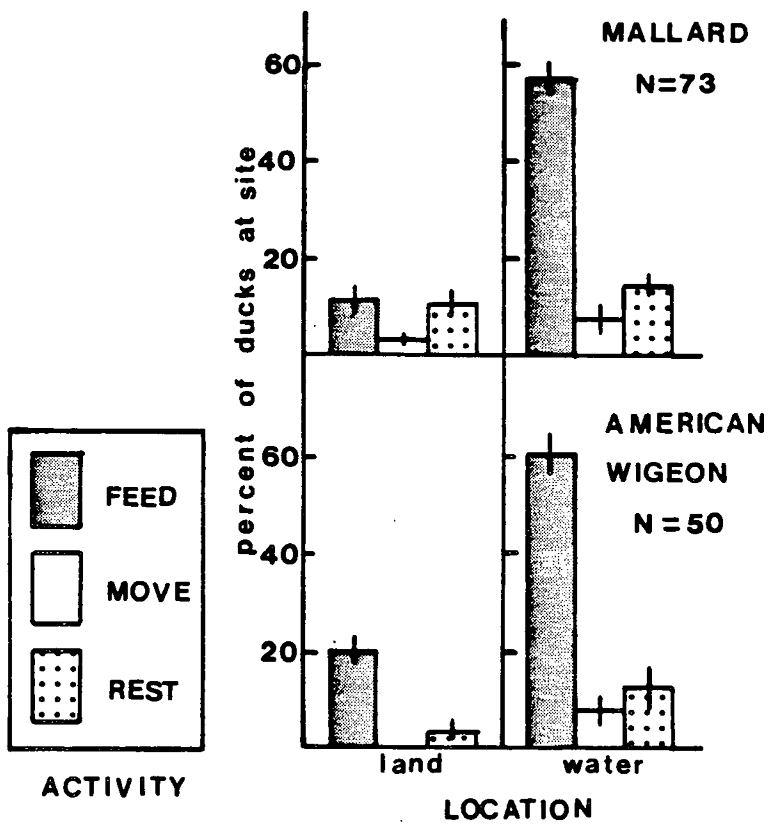
Activity-location data for all farm sites (combined) and each coastal site are presented in Figs. 5 to 9. The bars forming each row of each figure represent a full breakdown of activity and location, in terms of mean percentages, for the stated site and tide level. Means of less than 1% were not graphed.

Tables VIII and IX present additional information obtained from the activity-location observations. In Table IX, only "low" tide observations are presented, as the deltas were mainly under deep water at "high" tide.

Farm Sites

The null hypothesis: feeding intensity (percentage of ducks present that are feeding) is the same at all farm sites, was tested using data from farm sites with at least 5 observation periods. The data sets were: 73 observation periods at 7 sites for mallards, and 50 observation periods at 4 sites for American wigeon. Variances were unequal and sample sizes were very different, ranging from 6 to 16 for mallards and from 5 to 15 for American wigeon. Consequently, a nonparametric test (Kruskal-Wallis single factor analysis of variance by ranks) was applied to each data set. The resulting test statistics: $H = 9.94$ for mallards and $H = 4.30$ for American wigeon, are nonsignificant ($P>0.05$) when compared with the chi-square distribution. For both species, then, feeding intensity did not differ among farm sites. Mean feeding intensities thus calculated for all farm sites combined: 66% for mallards (se=3.2, N=73) and 79% for American wigeon (se=3.1, N=60).

Fig. 5. Activity-location data for mallard and American wigeon at farm sites. Bars are means; vertical lines are standard errors.



MALLARD
N=73
AMERICAN
WIGEON
N=50
percent of ducks at site
60
40
20
FEED
MOVE
REST
ACTIVITY
land
water
LOCATION

Fig. 6. Activity-location data for mallard at coastal sites during "high" tides. Bars are means; vertical lines are standard errors. Sites: Qual=Little Qualicum R. estuary; Eng=Englishman R. estuary; Nan=Nanoose Cr. estuary.

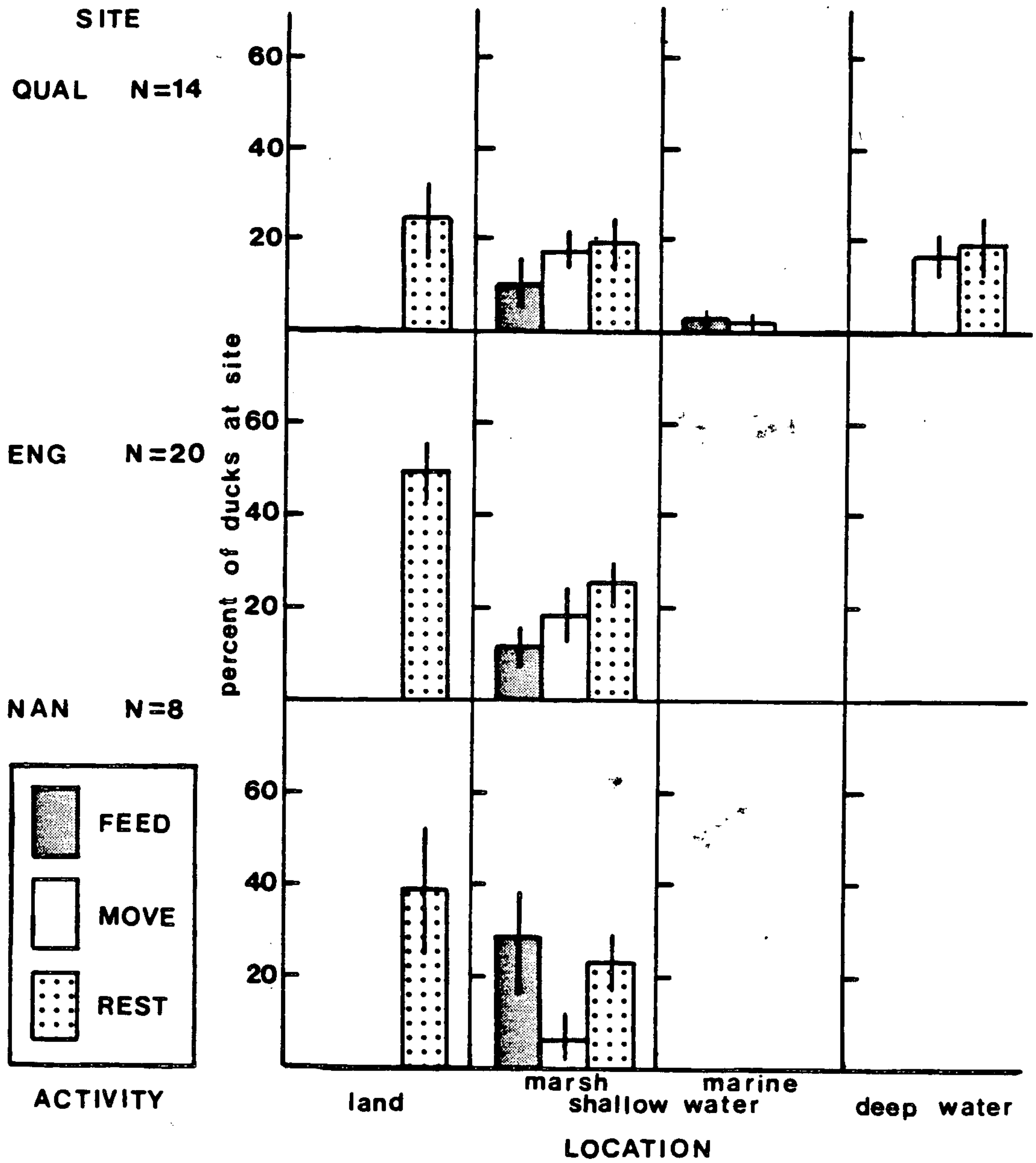

SITE
QUAL N=14
ENG N=20
NAN N=8
FEED
MOVE
REST
ACTIVITY
percent of ducks at site
60
40
20
land
marsh
shallow water
marine
deep water
LOCATION

Fig. 7. Activity-location data for mallard at coastal sites during "low" tides. Bars are means; vertical lines are standard errors. Sites: Qual=Little Qualicum R. estuary; Eng=Englishman R. estuary; Nan=Nanoose Cr. estuary; Rath=Rathtrevor Beach.

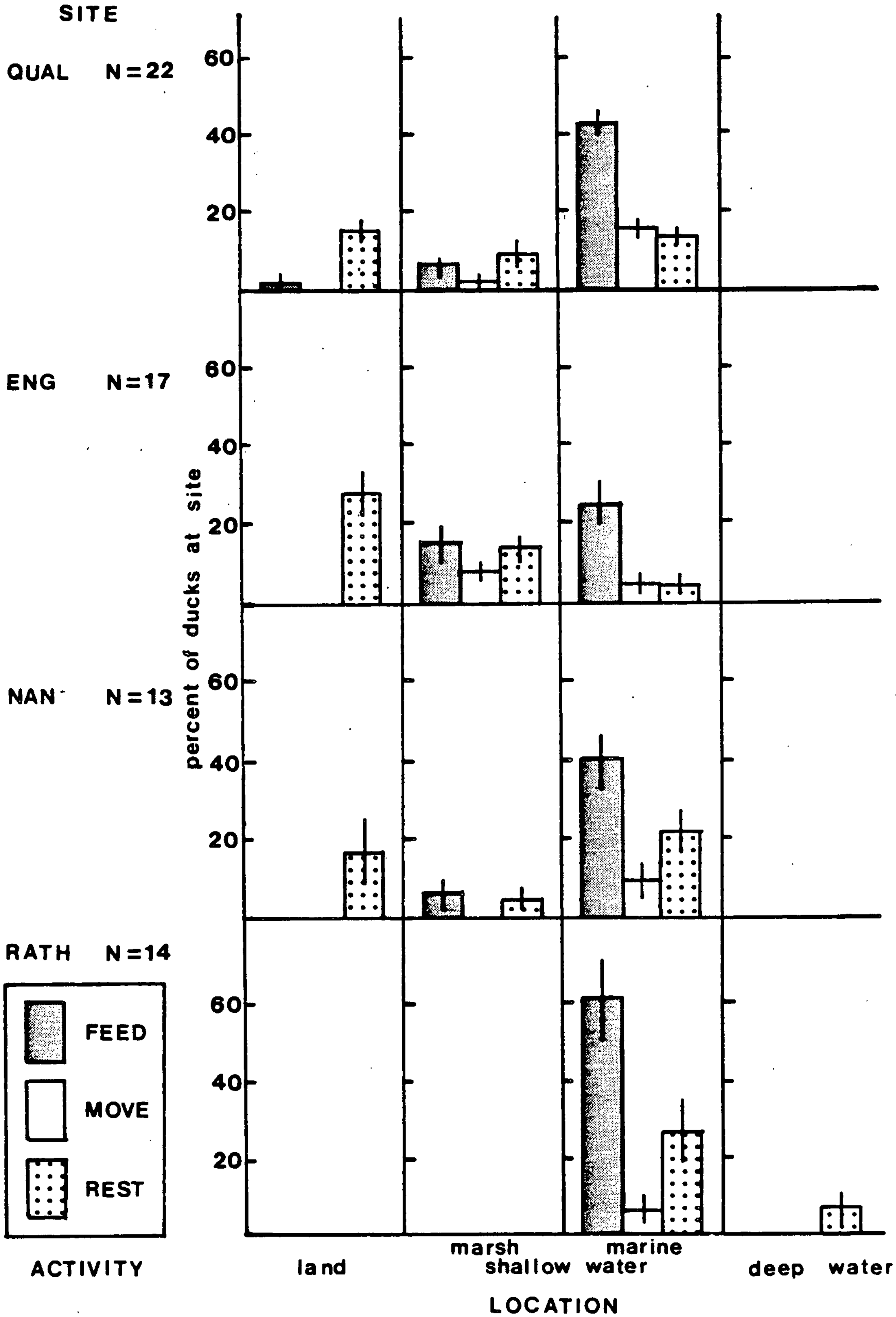
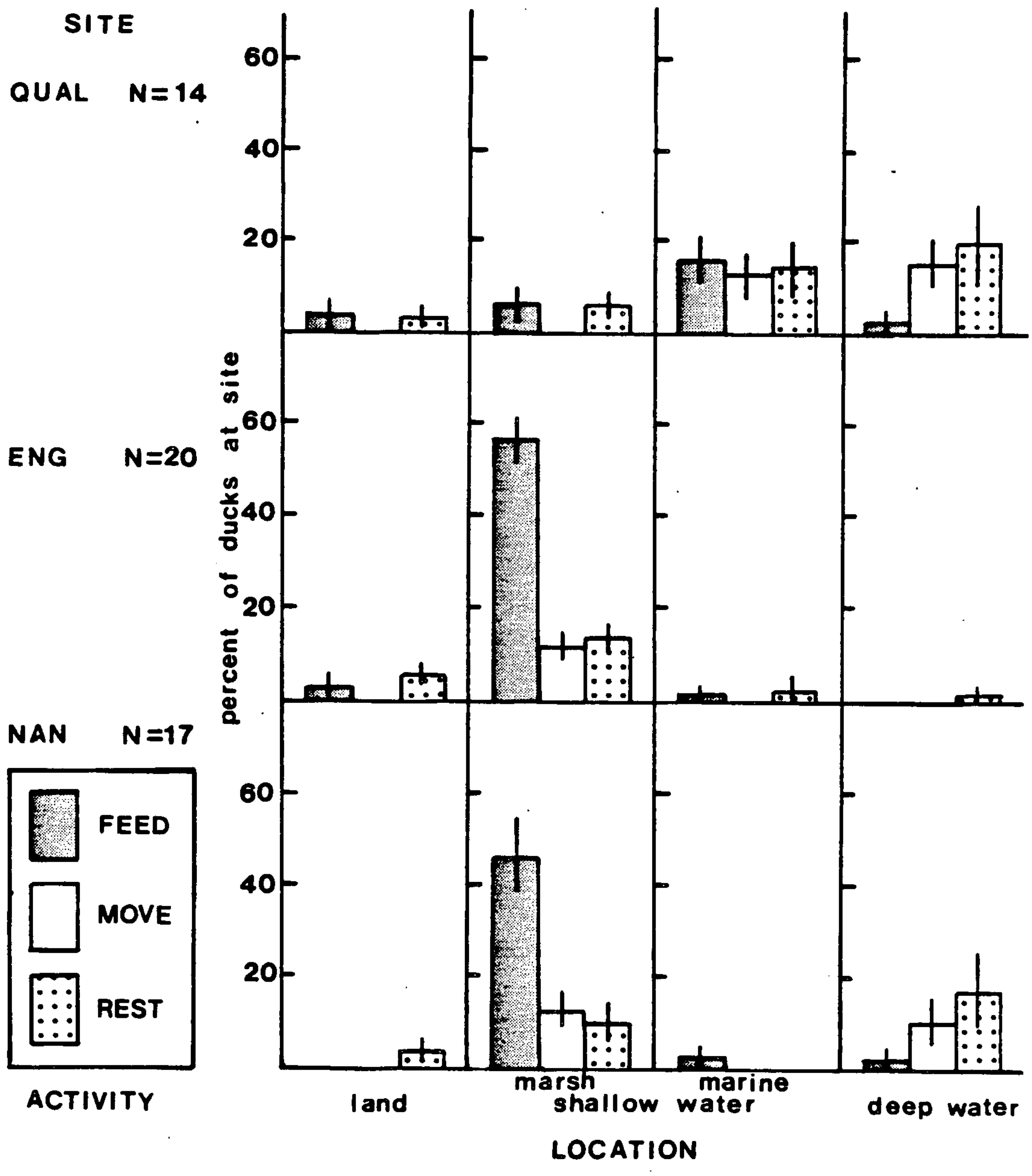
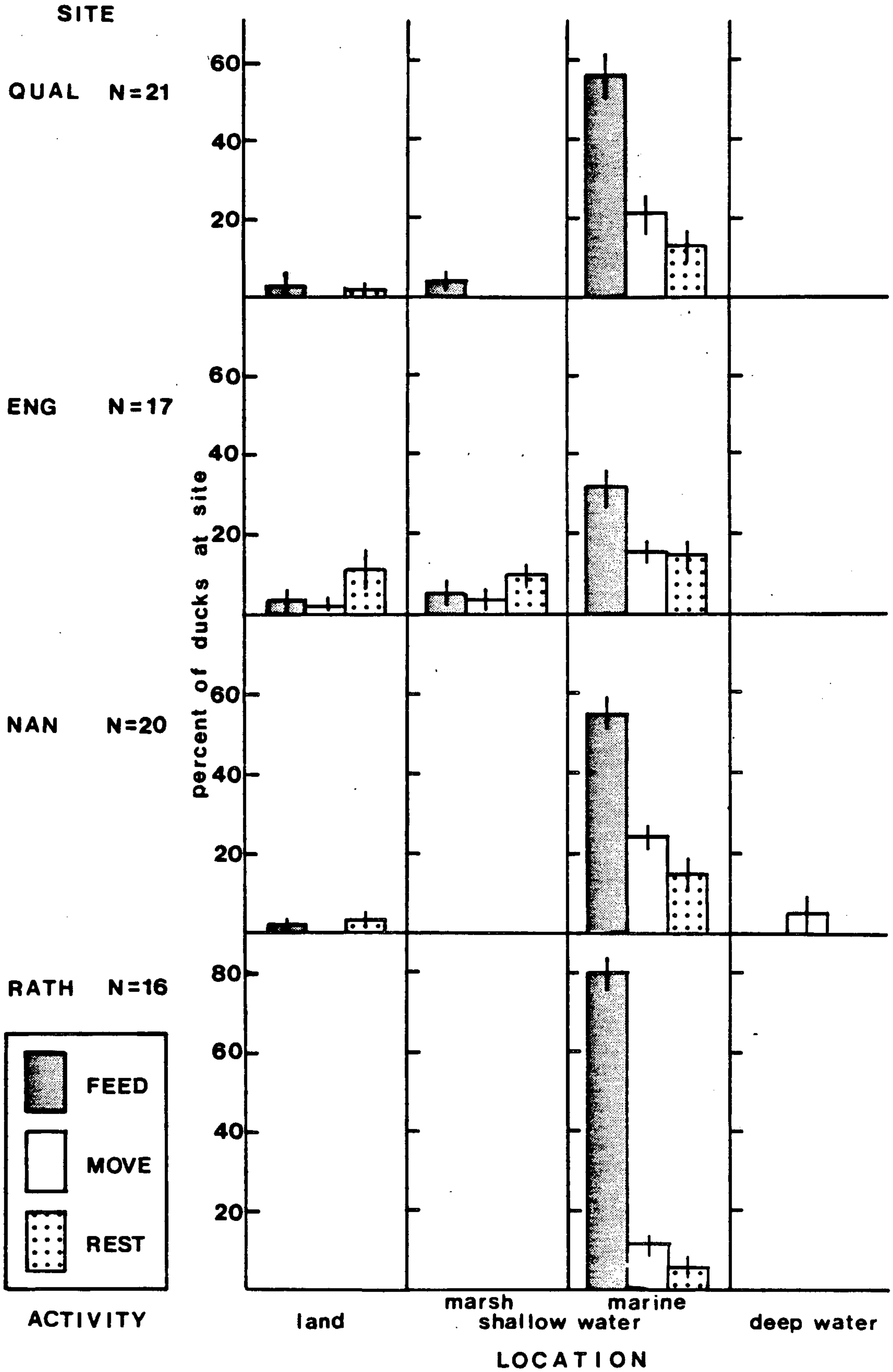

SITE
QUAL N=22
ENG N=17
NAN N=13
RATH N=14
60
40
20
percent of ducks at site
FEED
MOVE
REST
ACTIVITY
land
marsh
shallow
marine
water
deep water
LOCATION

Fig. 8. Activity-location data for American wigeon at coastal sites during "high" tides. Bars are means; vertical lines are standard errors. Sites: Qual=Little Qualicum R. estuary; Eng=Englishman R. estuary; Nan=Nanoose Cr. estuary.



SITE
QUAL N=14
ENG N=20
NAN N=17
FEED
MOVE
REST
ACTIVITY
percent of ducks at site
60
40
20
land
marsh
shallow water
marine
water
deep water
LOCATION

Fig. 9. Activity-location data for American wigeon at coastal sites during "low" tides. Bars are means; vertical lines are standard errors. Sites: Qual=Little Qualicum R. estuary; Eng=Englishman R. estuary; Nan=Nanoose Cr. estuary; Rath=Rathtrevor Beach.



SITE
QUAL N=21
ENG N=17
NAN N=20
RATH N=16
FEED
MOVE
REST
ACTIVITY
percent of ducks at site
60
40
20
80
land
marsh
shallow water
marine
deep water
LOCATION

TABLE VIII. Ducks on land: distance from water.

Species/site	Total number of ducks recorded on land	Percent within 1 m of water	Percent from 1 m to 5 m from water	Percent greater than 5 m from water
MALLARD				
Coastal sites	2568	81	17	5
Farm sites	1119	74	26	1
AMERICAN WIGEON				
Coastal sites	1737	79	14	7
Farm sites	1195	87	8	5

TABLE IX. Use of delta areas for feeding at "low" tide.

Species/site	(Number of ducks feeding in delta zone / Number of ducks feeding in delta and marine zones) x 100 Mean ± se(N)
MALLARD	
Little Qualicum R.	63 ± 7(18)
Englishman R.	37 ± 12(8)
Nanoose Cr.	39 ± 12(10)
AMERICAN WIGEON	
Little Qualicum R.	51 ± 8(21)
Englishman R.	50 ± 11(16)
Nanoose Cr.	40 ± 9(20)

Farm observations were examined for dependence of feeding intensity on time of day. The 70 observation periods for mallards and 69 observation periods for American wigeon ranged from 0915 to 1700 hours. As any relationship might be expected to be nonlinear, the data were examined as scatter plots of feeding intensity as a function of time. No nonlinear relationships were apparent for either species. Linear regression analyses resulted in the following regression coefficients: b = 0.003 for mallards and b = 0.047 for American wigeon, both nonsignificant in two-tailed t-tests.

"High" and "Low" Tides

Table X indicates that the relationship between feeding intensity and tide level varied among the coastal sites. For the 1 instance in which the variances were unequal, the t-statistic was well above the P=0.01 level and I feel that the conclusion is valid.

Ebb and Flow Tides

"Low" tide data sets for each coastal site were examined for differences between feeding intensity along the tide line at ebb and flow tides. The statistic used was: number of ducks feeding in the shallow water marine zone/the number of ducks at the site. The data sets were divided into ebb and flow tide observations. When the midpoint between start and finish times fell within a half hour of low tide, the observation was disregarded. The null hypothesis of equal feeding intensities at ebb

TABLE X. Feeding intensity at coastal sites, "high" and "low" tides.

Species/Site	Percentage of ducks present that were feeding. Mean ± se(N) "High tide"	"Low" tide	t-tests for differences in feeding intensities at "High" and "low" tides
MALLARD			
Little Qualicum R.	12±4.2(14)	47±4.6(22)	5.25 **
Englishman R.	12±3.1(20)	38±5.2(17)	4.47 **
Nanoose Cr.	28±11(8)	46±8.4(13)	1.37 [ns]
Rathtrevor Beach	ducks rare	60±9.5(14)	-
AMERICAN WIGEON			
Little Qualicum R.	29±6.7(14)	63±3.0(21)	5.25 **
Englishman R.	61±4.8(20)	42±4.3(17)	2.82 **
Nanoose Cr.	49±6.5(17)	56±3.9(20)	1.00 [ns]
Rathtrevor Beach	ducks rare	81±3.6(16)	-

[a] Variances unequal

** $P<0.01$

[ns] not significant ($P>0.05$)

and flow tides was accepted in two-tailed t-tests for all data sets. Test statistics are listed in Table XI.

"Very High" Tide Data (Little Qualicum River Estuary)

Number of ducks present, expressed as a proportion of the peak number, and feeding intensity, are plotted against gauge height in Fig. 10. Feeding intensity was calculated when at least 5 ducks were present. The average number of mallards present ranged from 95 at gauge height 5 to 20 at gauge height 1. There were fewer American wigeon present, with average numbers ranging from 21 at gauge height 5 to 9 at gauge height 1. The greatest numbers recorded at 1 scan were 192 mallards and 43 American wigeon. During the 7 control observations, when water levels were below "high", 4 or fewer mallards and no American wigeon were recorded.

A total of 1498 mallards in 102 groups left the marsh during the 13 observation periods. Of these, 21% (in 15 groups) settled in the bay and the remainder left the site. Ninety-eight percent of mallards leaving the site flew west. Of the 228 American wigeon that left the marsh (in 38 groups), 47% (in 14 groups) settled in the bay and the rest left the site, all flying east.

Disturbance Data

As the observers were often the cause of the disturbance and as observation times were chosen to avoid periods of heavy disturbance, the data do not reflect the true frequency of man-related disturbances at the sites. However, they are of interest in terms of the behaviour of ducks

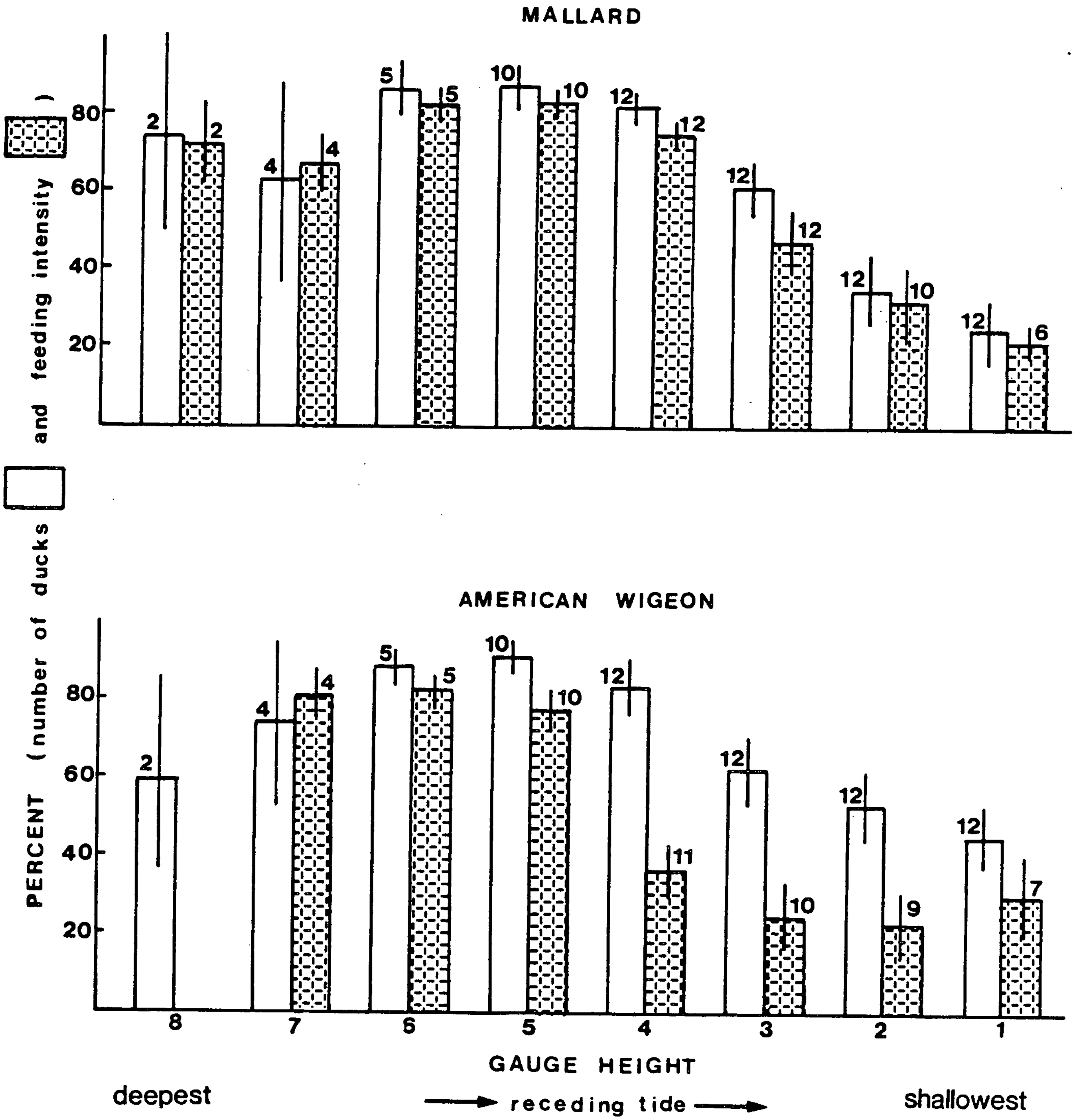
Table XI. Feeding intensity at ebb and flow tides.

Site	H_o: No difference between ebb and flow tide feeding intensities			
	Mallard		American wigeon	
	df	t-statistic	df	t-statistic
Little Qualicum R.	18	1.28[a,ns]	18	0.02[ns]
Englishman R.	15	1.28[ns]	15	0.08[a,ns]
Nanoose Cr.	sample too small		15	0.32[ns]
Rathtrevor Beach	9	0.30[a,ns]	11	0.44[ns]

[a] t-statistic calculated using arcsine transformation to correct for unequal variances.

[ns] not significant (P>0.05)

Fig. 10. "Very high tides" (Little Qualicum R. estuary): number of ducks and feeding intensity as a function of gauge height. Intervals between gauge heights are 0.1 m. Gauge height 1 corresponds to the reference "high" tide level. Number of ducks is expressed as a percentage of the highest number recorded for the observation period; feeding intensity is the percentage of ducks present that were feeding. Bars are means; vertical lines are standard errors; numbers are sample sizes.

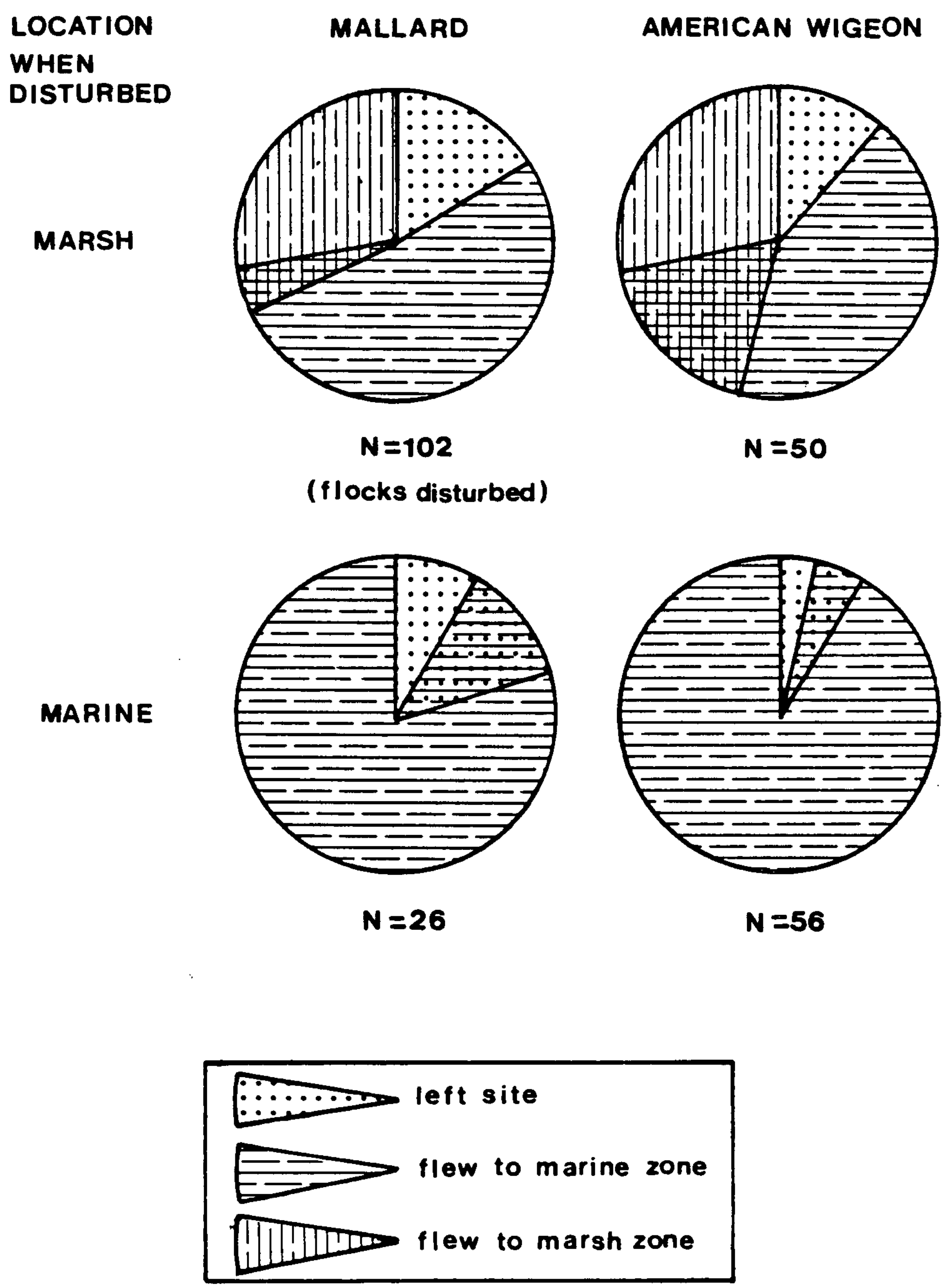


MALLARD
AMERICAN WIGEON
PERCENT (number of ducks and feeding intensity)
80
60
40
20
2
4
5
10
12
6
11
9
7
8
3
1
GAUGE HEIGHT
deepest
receding tide
shallowest

when disturbed. Causes of disturbances were, in order of decreasing frequency: people, vehicles, raptors, dogs, aircraft, gunshots and boats.

Fig. 11 presents a breakdown of where ducks disturbed at coastal sites went. At farm sites, 46 mallard and 31 American wigeon disturbances were recorded. For 70% of mallard disturbances and 48% of the American wigeon disturbances, most or all of the ducks left the site.

Fig. 11. Where ducks went when disturbed (coastal sites). Each sector represents the proportion of all recorded disturbances in the stated location, all sites combined. Numbers of ducks in flock (mean $\pm$ se) are indicated with arrows.


LOCATION
WHEN
DISTURBED
MALLARD
AMERICAN WIGEON
MARSH
N=102
(flocks disturbed)
N=50
MARINE
N=26
N=56
left site
flew to marine zone
flew to marsh zone

DISCUSSION

Farm and Coastal Habitat

Mallard and American wigeon fed regularly and extensively in both farm and coastal habitat. Burgess (1970) concluded that American wigeon used the tidal marshes and marine foreshore of the Fraser R. delta mainly for resting, while mallard fed extensively in the marshes only at certain times of the year. Other authors have reported wintering dabblers using coastal sites largely as resting grounds (Owen 1973, Tamisier 1976). There were no such patterns of differential use in this study. When dabblers were at the coastal sites, at "high" and "low" tides and throughout the study period, feeding occurred (Figs. 6 to 9).

The choice of feeding location within sites was clearly related to the distribution of shallow water. Both species displayed a stronger tendency to feed on land at farm sites than at coastal sites (Figs. 5 to 9), but they rarely moved more than 5 m from water (Table VIII) and did not frequent sites without water (Fig. 3). The few ducks recorded feeding in deep water appeared to be pecking at floating plant fragments.

The conclusion that shallow water is essential for most feeding is consistent with the observation that shallow water distribution is a major determinant of dabbler distribution (Thomas 1976, Wheeler and March 1979, Heitmeyer and Vohs 1984, Part 1 of this study). Dabbling ducks have 2 basic methods of feeding: filter-feeding and plucking (Goodman and Fisher 1962 pp. 19-37). The former method requires water, the latter does not. Even when water is not needed for feeding it may be needed for predator avoidance, as dabblers often respond to disturbances by flying to nearby open water (Tamisier 1976, Fig. 22 of this study).

On the basis of an apparent preference for farmland, given the right water conditions (Part 1) and the consistently high feeding intensities at all farms, it seems reasonable to conclude that for mallards and American wigeon flooded fields are prime feeding sites. Feeding intensity did not vary among farm sites and the number of ducks at each farm site was largely a function of the flooded area (Fig. 3). This indicates that, although the sites were very different, all fields covered in shallow water were equally desirable as feeding locations. Wheeler and March (1979) found that fields flooded by shallow water were selected at random by breeding mallards. In other studies, however, food type (Johnson and Montalbano 1984) or food density (Bossenmaier and Marshall 1958) were major factors in dabbler habitat selection.

Although they may provide excellent feeding grounds, farmlands can become unavailable for long periods when fields freeze over or dry up. Coastal sites provide more reliable habitat. They freeze less readily and, as water conditions are controlled mainly by tides, most parts of each site are covered in shallow water for 1 or 2 periods each day throughout the migrating and wintering period.

Feeding Locations at Coastal Sites

Both estuarine marshes and marine deltas and beaches were important feeding habitat for mallards and American wigeon. Tide level was all-important in selection of feeding location. At "high" and "very high" tides, ducks fed mainly in the marsh flats and channel edges that were covered in shallow water (Figs. 6 and 8). At "low" tide, ducks fed mainly along the beach tideline, in tidepools and in marine delta channels. "Mid" tide range was a transition period during which shallow water in estuaries covered some marsh and some marine habitat, making parts of each available for feeding.

Marine delta channels occupied only small portions of the 0.9-1.5 km of coastline surveyed at each of the 3 estuaries. The high proportion of marine-feeding ducks concentrated in the deltas (Table IX) indicates that these were preferred feeding locations. This may be related to the growth of filamentous algae, as discussed in Part 3.

Ducks feeding in the marine zones did not distinguish between ebb and flow tides (Table XI), indicating that the common hunters' belief that waterfowl feed only on receding tides is unfounded. Burton and Hudson (1978) also reached this conclusion for snow geese (*Anser caerulescens caerulescens*) in the Fraser Delta.

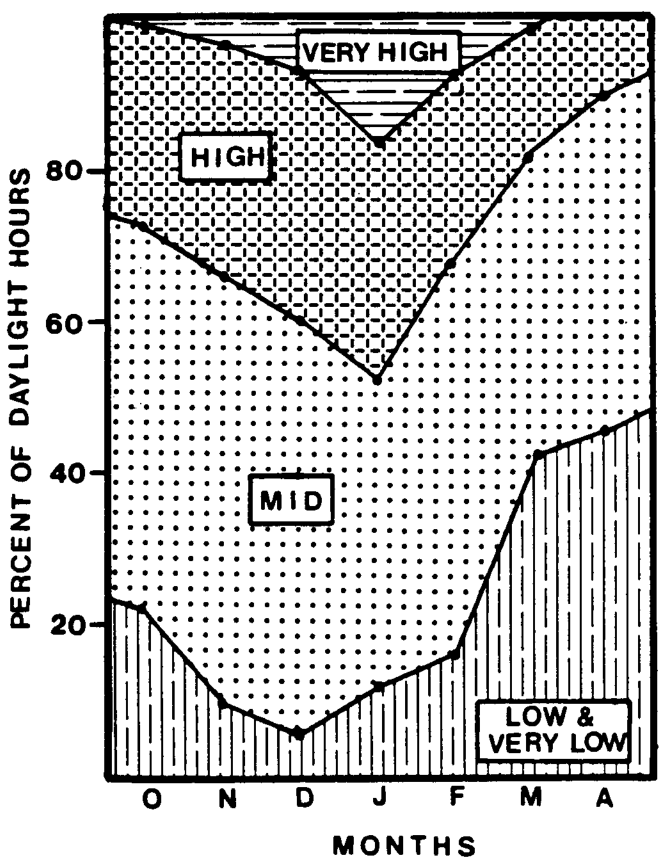
Although almost all feeding at coastal sites occurred in shallow water, land and deep water were used for other purposes. The dry banks of estuarine channels and ponds were used, especially by mallards, as resting locations (Figs. 6 to 9). Unflooded parts of the marine zone were little used. Deep water sections of coastal sites were important to both species as refuges following disturbances (Fig. 11) and at some sites as resting habitat at "high" tide (Figs. 6 and 8). Ducks also rested in shallow water alongside feeding and moving ducks.

Each coastal habitat type, then, is available primarily at specific tide levels. An evaluation of the relative importance of these habitat types to dabblers should therefore take into account the amount of time each is available. As Fig. 12 illustrates, there are strong seasonal fluctuations in tidal ranges, with low tides occurring more frequently in the fall and spring and high tides occurring more frequently in mid-winter.

These fluctuations are less over 24-hour days than over daylight-hour days (Dawe and White 1982); specifically, frequent low tides occur at night during winter. Thus the relative use of marsh and marine habitats also depends upon the extent to which the ducks feed at night. It was not possible to carry out systematic observations at night, but on several nights during full moon periods, I observed (with the aid of a night scope) ducks resting and feeding in marine zones at "low" tide and in marsh zones at "high" tide at Little Qualicum River estuary. Night feeding among dabblers has been reported both on the breeding grounds (Swanson and Sargeant 1972) and on coastal winter habitat (Tamisier 1974, Baldassare and Bolen 1984). The following discussion is based on feeding during daylight hours. If night feeding is extensive, seasonal variations in coastal habitat availability should be less marked.

Marine deltas and beaches provided important feeding habitat, particularly in early fall and in spring. During these periods, low tides were common in the day (Fig. 12) and dabbler use of coastal sites was relatively high (Fig. 2). This pattern of use can be expected to occur most years as it was related to the seasonal pattern of water accumulation

Fig. 12. Percent of daylight hours at different tidal ranges. Tidal ranges defined in Table V. Adapted from submergence/emergence ratios calculated for plant communities at Little Qualicum R. estuary in 1978 by Dawe and White, 1982. Data points are monthly means.


VERY HIGH
HIGH
MID
LOW &
VERY LOW
PERCENT OF DAYLIGHT HOURS
80
60
40
20
O
N
D
J
F
M
A
MONTHS

in fields (Part 1). From late November to February, marine habitat was less available and many dabblers were often at farm sites for long periods.

Dabbler use of Rathtrevor Beach, which contains marine beach habitat but no delta channels, dropped off sharply in midwinter (Fig. 4). As discussed in Part 3, this may result from a preference for marine deltas in the spring.

Marine zones are considered to be unimportant as dabbler feeding grounds in the Fraser Delta (Burgess 1970, Vermeer and Levings 1977, Hirst and Easthope 1981). However, this conclusion has not been substantiated by any systematic observations of dabbler activity. It is based partly on assumptions about dabbler food habits that may be incorrect (Part 3).

Estuarine marshes provided important feeding habitat throughout the study period, but the relative importance of the different marsh zones varied. Lower marsh flats and lower parts of channel edges, flooded by shallow water through much of the "mid" and lower "high" tidal ranges, were available as feeding habitat for about half of most days from October to April. Sedge stands on upper channel edges and middle-elevation flats were available for feeding at "high" tide. This tidal range occurs least in the spring and most in midwinter. The high marsh flats were flooded only at "very high" tides which occur only sporadically, mainly in midwinter. Overall, a broader range of marsh habitat is available in fall and midwinter than in spring.

If vegetation mapping is used as a technique for dabbler habitat assessment in estuaries, consideration must be given to the timing of availability of food plants, not just to their abundance. The high marshes (at Little Qualicum, these are the Juncus high marsh and Deschampsia flats of Dawe and White 1982) are densely vegetated areas containing species that are commonly listed as dabbler food plants (Martin and Uhler 1939, Yocom 1951). However, they are available as feeding grounds relatively rarely. The lower marsh zones, on the other hand, while sparsely vegetated and with lower species diversity (Dawe and White 1982), are available for about half of most days.

Goss-Custard and Charman (1976) cautioned against the use of food abundance as a measure of habitat quality when foods are available only under certain conditions. Chabrek et al. (1975) found that the abundance of marsh plants bore no relationship to duck usage of Louisiana coastal marshes because water depth made much of the vegetation unavailable for much of the time. The best approach may be to catalogue available feeding habitat at various tidal ranges.

Variations among estuaries in patterns of use at "high" and "low" tides (Figs. 6 to 9) probably are linked to variations in the relative amounts of low, middle and high elevation marsh habitat and marine habitat. Other factors such as salinity levels, disturbance and vegetation and invertebrate composition would also have an effect. For example, that American wigeon made little use of the marsh at Little Qualicum R. estuary was probably due to a combination of factors, including (1) the relatively small area of low marsh habitat at the site (a result of site topography and channelling of the lower river) and (2) disturbance from a nearby road.

Variations among coastal sites in average numbers of each species (Table VII) probably also result from a combination of factors. American wigeon numbers did not differ greatly among sites. Mallard counts, however, were much higher at Little Qualicum River and Englishman River estuaries than at Nanoose Creek estuary and Rathtrevor Beach. Both of the former sites contain relatively large areas of high and middle elevation marsh flats and many channels with sedge stands on the banks. Both are mainly brackish marshes. Nanoose Creek is more open, with fewer channels and less high marsh and is more saline (N.K. Dawe, personal communication). Rathtrevor Beach contains no marsh habitat. Kerwin and Webb (1972) and Chabrek et al. (1975) concluded that mallards feed more in fresh and brackish coastal marshes than in salt marshes.

There are few data with which to compare these observations, as the few B.C. waterfowl censuses outside the Fraser Delta have combined dabbler species (Hatler 1973, Hay 1976). A larger scale study would be required to isolate the factors that make a site attractive to mallards. Both site characteristics and proximity to other coastal and inland feeding locations should be considered.

Disturbance

The overall effect of disturbance was to drive ducks either from the site or from the marshes to the marine (usually deep water) zones (Fig. 11). Thus when using duck abundance as a measure of habitat preference in estuaries, one should keep in mind that dabblers may underutilize marsh habitat as a result of disturbance. Hatler (1973), Tamisier (1976) and

Owen and Thomas (1979) concluded that disturbance may affect the distribution of dabblers.

Disturbances in the marshes more frequently affected mallards and those in marine zones more frequently affected American wigeon. This is to be expected from the 2 species' relative use of marsh and marine (Figs. 6 to 9).

Bay areas provided refuges from disturbance; at farm sites, with no comparable habitat, disturbed ducks left the site much more frequently. The levels of disturbance in bays as well as in feeding zones should be considered in coastal habitat evaluations.

Movement among Feeding Locations in Relation to Tide Level

Campbell (1978) suggested that, although daily routines in distribution and feeding intensity are the general rule for waterfowl, tidal routines may take over in estuaries where feeding is possible only at certain water levels. Numbers of ducks at coastal sites were not related to time of day (Appendix 1) and there was no evidence of daily routines in feeding activity. Part 1 indicated that water levels on fields affected dabbler movement between farm and coastal sites. Part 2 indicates that movements among coastal sites follow tidal routines.

Over the "low" to "high" tidal range, there was no net movement in or out of estuaries (Table VII). The shallow bay site, however, was favoured at "low" tides. At "very high" tides, the high marsh at Little Qualicum River estuary attracted large numbers of dabblers that regularly left the site as the tide receded (Fig. 10). Feeding intensities were especially high at these locations and tide levels (Table X and Fig. 10).

Perhaps it is energy-efficient for ducks to remain at the estuaries, which provide feeding habitat over most of the tidal range, alternately resting and feeding, while making forays to feeding grounds that become particularly attractive at certain water levels. These would include: (1) at "very high" tides, estuaries with extensive high marsh flats (mallard especially), (2) at "low" tides, large marine beaches (American wigeon especially) and (3) flooded fields (both species).

In the "very high" tide study, dabbler movement and feeding activity were examined in relation to small changes in water levels (Fig. 10). As the tide receded and less of the high marsh was available for feeding, the ducks stopped feeding and flew from the marsh, either settling in the bay or leaving the site. Mallards leaving the site flew west and American wigeon leaving the site flew east. This result was unexpected, since the 2 species were commonly found together in mixed flocks.

These observations suggest that each species has its own regular pattern of movement among sites. Since the departure of ducks from the site was precisely correlated with water level and not with time of day, it appears that tide level is the key controlling factor. When "very high" tides occurred in the early morning, unusually large numbers of ducks were already in the high marsh by first light. This suggests that regular, tide-related movements also occur at night.

PART 3: SELECTION OF FOOD ITEMS

INTRODUCTION

Part 2 indicated that most feeding occurs in shallow water and that both the estuarine marshes and the largely unvegetated marine zones provide important feeding habitat for mallards and American wigeon. Part 3 provides information on what the ducks are eating in major feeding locations of the coastal sites.

Bellrose (1976) summarized North American feeding studies of mallards (p. 242) and American wigeon (p. 206). He concluded that adult mallards are primarily grain and seed-eaters and that American wigeon feed mainly on the leaves and stems of aquatic plants and of cultivated grasses and forage crops. Burgess (1970) and Hughes and Young (1982) concluded that seeds, especially the achenes of Carex spp., are the mainstay of wintering mallards' diets in the Fraser and the Stikine River deltas, respectively. Burgess (1970) reported that American wigeon in the Fraser Delta eat mainly the leaves of cultivated grasses along with some seeds from tidal marshes.

STUDY AREA AND METHODS

Samples were collected from October, 1980 to April, 1981 at Little Qualicum River, Englishman River and Nanoose Cr. estuaries (Fig. 1), in marine and marsh zones. Part 2 contains site descriptions.

Ducks were shot after they had been observed feeding in shallow water within the marsh or marine zone for at least 10 minutes. From 1 to 4 ducks were shot at a time. The gullets (esophagi) were removed immediately and their contents stored in 10% formalin. Duck specimens (23 mallards and 40 American wigeon) were frozen and shipped to the B.C. Provincial Museum, Victoria, B.C.

The sampling date, location and tide level, along with main food items from gullet analyses for each duck or group of ducks shot, are presented in Table XII.

I attempted to obtain samples of the available food items at each collection site by removing several 0.1 m^2 quadrats of the substrate down to a depth of 10 cm. After washing and partly sorting these samples I abandoned the project when I realized how much work was involved in sampling a large enough area to estimate the relative abundance of potential food items. Ducks are far more efficient at removing small objects from a tangle of rotting organic material and mud than are humans. The habitat samples are described qualitatively.

The contents of each gullet were washed in a 50 um sieve and transferred to petri dishes where inorganic material was removed and food items were sorted under a dissecting microscope. Martin and Barkley

(1961), Prescott (1970), Hitchcock and Cronquist (1973), Waaland (1977) and Lehmkuhl (1979) were referred to for identification of food items. N.K. Dawe (CWS, Little Qualicum) assisted with many identifications. Sorted samples were stored in 80% ethanol. Volumes of each category and of the total organic contents of each gullet were measured to the nearest 0.05 ml by water displacement, using a 10 ml graduated cylinder.

Collecting locations were chosen to represent a broad spectrum of heavily-used feeding sites (Table XII). These ranged from the upper marshes at very high tides to the marine beach tideline and tidepools at low tides. The data, presented as frequency of occurrence of food items in various proportions in duck gullets, estimate the range of food items and their relative importance (by importance within each gullet and by frequency of occurrence).

Collecting locations were somewhat restricted both by the provisions of my permit and by practical considerations. In addition, samples are not independent as frequently more than 1 duck was shot at a time. I have not combined samples to calculate aggregate percents as is generally done with waterfowl food analyses (following Swanson et al. 1974). Such treatments of the data and subsequent conclusions regarding diets of waterfowl are only valid if the distribution of sampling effort reflects the distribution of the ducks' feeding effort.

Table XII. Summary of field notes for duck samples.

Date (1980-81)	No. of ducks	Tide level[a]	Site[b]	Location[c]	Main food item(s)
MALLARD MARINE ZONE SAMPLES					
Jan. 12	2	low	Qual	beach tideline	Zostera rhizomes
Jan. 14	1	low	Qual	beach tidepool	clams
Feb. 9	1	low	Qual	beach tidepool	clams
Mar. 12	1	low	Qual	delta channel	filamentous algae
Apr. 25	2	mid	Qual	delta tideline	mixed green algae
MALLARD MARSH ZONE SAMPLES					
Nov. 12	2	mid	Qual	channel edge	Carex achenes
Nov. 19	1	mid	Nan	lower flats	mixed seeds
Dec. 3	1	high	Qual	mid flats	Potentilla stems & roots
Jan. 6	2	high	Eng	mid flats	mixed seeds & invertebrates
Jan. 12	2	high	Eng	mid flats	mixed seeds & invertebrates
Mar. 12	1	mid	Qual	channel edge	snails, mixed seeds
Mar. 21	1	very high	Qual	upper flats	snails, mixed seeds & invertebrates
Mar. 21	4	very high	Qual	upper flats	snails, Potentilla stems & roots, mixed seeds & invertebrates
Apr. 10	2	mid	Nan	lower flats	snails, plant fragments, algae

[a] see Table V.

[b] Qual = Little Qualicum R. estuary; Nan = Nanoose Cr. estuary;

Eng = Englishman R. estuary; see Fig. 1.

[c] see Table VI.

Table XII (continued)

Date (1980-81)	No. of ducks	Tide level[a]	Site[b]	Location[c]	Main food item(s)
AMERICAN WIGEON MARINE ZONE SAMPLES					
Oct. 27	3	low	Qual	delta tideline	Ulva, Enteromorpha
Nov. 6	3	low	Qual	beach tidepool	Ulva, Enteromorpha
Nov. 24	2	low	Eng	delta tideline	Ulva, Enteromorpha, Zostera
Nov. 28	2	low	Eng	beach tideline	Ulva
Feb. 2	2	mid	Nan	beach tideline	Ulva, Enteromorpha
Feb. 14	2	low	Eng	delta channel	filamentous algae
Mar. 26	2	mid	Qual	beach tideline	mixed green algae
Mar. 30	1	low	Eng	delta channel	mixed green algae

[a] see Table V.

[b] Qual = Little Qualicum R. estuary; Nan = Nanoose Cr. estuary; Eng = Englishman R. estuary; see Fig. 1.

[c] see Table VI.

Table XII (continued)

Date (1980-81)	No. of ducks	Tide level[a]	Site[b]	Location[c]	Main food item(s)
AMERICAN WIGEON MARSH ZONE SAMPLES					
Oct. 31	1	mid	Qual	channel edge	*Agrostis* leaves
Dec. 5	4	mid	Eng	channel edge	*Carex* roots
Dec. 5	4	high	Eng	mid flats/ channel edge	*Carex* roots & filamentous algae
Dec. 10	4	very high	Nan	upper flats	*Agrostis* seeds
Jan. 22	2	mid	Nan	lower flats	filamentous algae
Feb. 16	2	mid	Nan	lower flats	filamentous algae
Mar. 27	1	high	Eng	lower flats	filamentous algae
Apr. 4	1	mid	Nan	lower flats	*Plantago* leaves
Apr. 8	2	high	Qual	mid flats	*Agrostis* seeds & leaves
Apr. 9	2	mid	Eng	channel edge	filamentous algae

[a] see Table V.

[b] Qual = Little Qualicum R. estuary; Nan = Nanoose Cr. estuary;
Eng = Englishman R. estuary; see Fig. 1.

[c] see Table VI.

RESULTS

Mean volume of organic gullet contents did not vary significantly among the 4 sample groups (by one-way ANOVA, $P<0.01$). The overall mean was 5.7 ml per gullet (sd=6.3).

Food items that made up $\geq$1% of organic gullet contents are listed in Tables XIII to XVI along with the frequency with which they appeared in various proportions in duck gullets. Major food items for each duck or group of ducks are summarized in Table XII.

All items found in large proportions in the gullets were present in the habitat samples. The bulk of habitat samples from marsh zones consisted of dead vegetation and root masses. Until new growth appeared in mid-February, green vegetation was limited to a few grass leaves. Seeds and invertebrates, relatively scarce in the habitat samples, were distributed throughout the dead vegetation, soil and detritus.

Filamentous algae in marine habitat samples were growing on rocks or shells in delta areas, whereas in marsh samples they grew on plants, especially *Salicornia*. Growth of filamentous algae was noticeably denser in the spring samples. *Enteromorpha* and *Ulva* occurred mainly in marine samples as drift fragments, mixed with pieces of brown and red algae and other organic debris. *Zostera marina* rhizomes appeared in habitat samples only once. Green *Zostera* leaves were never abundant.

Table XIII. Gullet contents of 7 mallards shot while feeding in marine zones.

Food item	Frequency of occurrence of food items. Categories are percent (by volume) of gullet contents. Data are numbers of ducks.			
	90-100%	50-90%	10-50%	1-10%
Green algae				
1. mainly *Ulva* and *Enteromorpha*	2	-	-	-
2. filamentous (*Microspora*)	1	-	-	-
Red algae	-	-	1	-
Zostera marina rhizomes	1	1	-	-
Vascular plant fragments	-	-	-	2
Polychaetes	-	-	1	-
Bivalves (*Mya arenaria* and *Macoma*)	1	1	-	-

Table XIV. Gullet contents of 16 mallards shot while feeding in marsh zones.

A. Type of food item	Frequency of occurrence of food items. Categories are percent (by volume) of gullet contents. Data are numbers of ducks.			
	90-100%	50-90%	10-50%	1-10%
Vegetation	-	2	5	6
Seeds and fruits	1	6	4	3
Invertebrates	2	5	4	4

B. Food item	50-100%	30-50%	10-30%	1-10%
Vegetation				
Green algae (Ulva and filamentous)	-	1	-	2
Salicornia shoots	-	-	1	-
Potentilla pacifica stems and roots	2	-	1	-
Carex shoots and bracts	-	-	1	2
Plant fragments	-	1	2	10
Seeds and fruits				
Chenopodiaceae seeds	-	1	1	3
Potentilla pacifica seeds	-	-	-	7
Rubus seeds	-	-	-	1
Leguminoseae seeds	-	-	-	1
Plantago seeds and fruit parts	-	-	1	1

Table XIV (continued)

B. Food item (continued)	Frequency of occurrence of food items. Categories are percent (by volume) of gullet contents. Data are numbers of ducks. 50-100%	30-50%	10-30%	1-10%
Compositae seeds	-	-	-	1
Triglochin maritimum seeds	-	1	1	3
Carex (mainly *lyngbyei*) achenes	2	-	4	6
Hordeum seeds	-	1	2	1
Invertebrates				
Gastropods (*Barleeia acuta*)	4	3	5	3
Arachnids	-	-	-	4
Isopods	-	-	-	2
Amphipods	-	-	1	1
Coleopteran larvae	-	-	-	2
Trichopteran larvae	-	-	4	4
Lepidopteran larvae	-	-	-	1
Dipteran larvae	-	-	1	9
Insect eggs and pupae	-	-	-	1

Table XV. Gullet contents of 17 American wigeon shot while feeding in marine zones.

Food item	Frequency of occurrence of food items. Categories are percent (by volume) of gullet contents. Data are numbers of ducks.			
	90-100%	50-90%	10-50%	1-10%
Green algae				
1. mainly *Ulva* and *Enteromorpha*	11	1	2	-
2. filamentous (mainly *Microspora*, *Cladophora* and *Monostroma*)	2	2	1	-
Zostera marina leaves	-	1	1	2
Vascular plant fragments	-	-	2	-

Table XVI. Gullet contents of 23 American wigeon shot while feeding in marsh zones.

Food item	Frequency of occurrence of food items. Categories are percent (by volume) of gullet contents. Data are numbers of ducks.			
	90-100%	50-90%	10-50%	1-10%
Green algae				
1. *Ulva*	-	-	2	1
2. filamentous (mainly *Cladophora* and *Monostroma*)	5	3	-	4
Brown algae	-	-	-	1
Zostera marina leaves	-	-	-	1
Salicornia shoots	-	-	1	-
Carex roots	6	1	1	1
Plantago martima leaves	-	1	-	-
Agrostis leaves	2	-	-	-
Agrostis seeds (in heads)	5	-	-	-
Triglochin seeds	-	-	-	1
Vascular plant fragments	-	-	2	-
Nematodes	-	-	-	1

DISCUSSION

The results indicate that both species select a wide variety of food types from the estuarine marshes and marine deltas and beaches of southeastern Vancouver Island. This conclusion is not consistent with the commonly-held view of mallards as seed-eaters and American wigeon as grass-eaters.

Green algae were found in the gullets of ducks of both species, often as the main constituent, throughout the sampling period, at all sites and in a variety of locations. Algae are clearly a major food source for American wigeon in the marine zones and in lower flats and marsh channels. As mallard foods were more variable and as only 7 mallards were collected from marine zones, it is not clear how important green algae are in mallards' diets. It is clear, however, that mallards do eat algae, sometimes in large quantities, in marine zones and lower marsh flats.

Both thalloid and filamentous algae were consumed. Ducks shot on marine beaches contained mainly Ulva and Enteromorpha, while samples from marsh zones contained mainly filamentous algae; delta samples contained both types. The concentration of feeding ducks in the delta channels (Table IX) suggests that filamentous algae are preferred over thalloid green algae when both are available.

The apparent seasonal shift from thalloid to filamentous algae in the American wigeon data (Table XII) is probably related to changes in availability. Filamentous algae were sparse in the winter, and increasingly abundant from mid-February on. Ulva and Enteromorpha appeared to be plentiful at all seasons. A preference for filamentous over thalloid species could account for the virtual abandonment of Rathtrevor Beach by dabblers in the spring (Fig. 4). With little fresh water input, the site produces almost no filamentous algae; nearby estuaries (Fig. 1) are possibly more attractive in the spring.

Several authors have observed American wigeon eating Ulva (Munro 1949, Dawe 1980, and Hatler 1973) and several have reported green algae in gullet or gizzard contents (Lynch 1939 and Vermeer and Levings 1977). However, algae has been regarded as a food eaten by American wigeon only occasionally or when preferred food sources fail. Only rarely has algae been mentioned in connection with mallards (Munro 1943 and Olney 1964).

American wigeon in this study were more opportunistic than is generally supposed. Part 2 indicated that they feed regularly and intensively in both marsh and marine areas. Yet, if their diet were mainly "the stems and leafy parts of aquatic plants...and upland grasses and clovers" (Bellrose 1976, p. 206), they would find little to suit them in the study area. Green Zostera marina leaves, a recognized marine food of American wigeon (Lynch 1939 and Yocom and Keller 1961), were not abundant in duck or habitat samples. Other green leaves were sparse in winter months, and occurred in only 3 of the gullet samples.

However, even when green leaves were abundant, in the late spring, gullet samples show that American wigeon also selected other food items. At high tides they pulled small Carex rootlets from the soft mud of channel edges and plucked intact seed heads from upper marsh areas. At mid tides they gleaned filamentous algae from the stems of Salicornia and ate green leaves and shoots. At low tides they plucked fragments of green algae from the tideline debris and ate the filamentous algae covering rocks and shells in delta areas.

In the marsh zones, mallards selected a variety of foods while American wigeon concentrated on 1 item at a time. In 18 of 23 marsh American wigeon, a single food item formed over 90% of gullet contents, compared with only 3 of the 16 mallard gullets from marsh zones. Mallards ate snails, roots and stem bases of *Potentilla pacifica*, *Carex* achenes and an assortment of seeds, insect larvae and fragments of vegetation. Seeds, while a major food item, do not dominate mallards' diets to the extent reported in other coastal studies (eg. Burgess 1970, Landers et al. 1976 and Hughes and Young 1982).

In marine zones, the small sample of mallards indicates that green algae, clams and eelgrass rhizomes may be important food items. The latter, however, are probably not abundant intertidally, while algae and clams are widespread (Dawe 1980 and Dawe and Lang 1980).

Marine invertebrates and insect larvae were frequently consumed in large quantities by mallards. Invertebrates constituted over half of the gullet contents of 9 of the 23 mallards studied. Snails (all *Barleeia acuta*, a small intertidal species) were found in all but 1 of the 16 mallards shot in a variety of marsh areas; insect larvae also occurred frequently, though in smaller proportions. With the exception of Munro (1943), Olney (1964) and Cronan and Halla (1968), studies of non-breeding mallards have concluded that invertebrates are consumed in small quantities only (eg. Burgess 1970, Bellrose 1976, p. 242, and Hughes and Young 1982).

Breeding mallards, however, may include large proportions of invertebrates in their diets (Swanson et al. 1979). All 7 ducks containing over 30% snails were shot in March and April, indicating that the ducks may have a greater preference for invertebrates in the spring.

Variations in sampling methods may have contributed to the marked differences between the results of this study and those of other coastal dabbler feeding studies. In some studies, the range of food items and the importance of algae and invertebrates could have been underestimated because of bias in methods of collecting and analysing samples.

Many studies were based on gizzard analyses. Due to differential rates of digestion of hard and soft items, use of gizzards results in a bias toward seeds; soft items such as invertebrates and algae are more rapidly digested (Swanson and Bartonek 1970). Swanson et al. (1979) concluded that this bias resulted in an underestimation of the importance of invertebrates to breeding dabblers.

Although authors of more recent duck studies are careful to reduce this bias and the bias resulting from unequal volumes of food in each duck (Swanson et al. 1974), the subject of bias in choice of collecting locations is rarely addressed. Collecting locations in duck food habit studies are generally not specified and their relationship to observed feeding locations is never discussed. If feeding locations within the study area are fairly homogeneous, this is not a problem. However, if the study area is patchy, samples must include foods selected from the various patches if conclusions drawn from the data are to be valid for the area as a whole.

As food passes rapidly through dabblers' gullets, ducks must be collected while feeding in a variety of locations. In this study no items were found in gullets that were not also available in the sampled habitat; therefore, a gullet sample probably represented the duck's feeding history over not much more than 10 minutes (the minimum time that ducks were observed feeding at each collecting location). Swanson and Bartonek (1970) found that almost all food items force-fed to blue-winged teals (*A. discors*) had passed through the gullets within 10 minutes.

Due to salinity and inundation-period gradients, coastal sites are always patchy. As high and mid-elevation marsh flats of estuaries generally provide more cover for observing and for hunting than do lower flats and marine zones, it is probable that a bias toward foods available in these areas has been introduced into the literature on dabbler feeding habits in coastal areas.

The apparent radical differences between the food habits of mallards and American wigeon in this study and those in the nearby Fraser Delta may be partly an artefact of sampling methods. The importance of the marine zone in the Fraser Delta has possibly been underestimated (Part 2). The few ducks collected in the marine zone indicate that American wigeon do eat green algae (Vermeer and Levings 1977) and mallards do eat marine invertebrates (Hirst and Easthope 1982). Samples from the only major food habits study of the Fraser (Burgess 1970) were mainly gizzard contents, collected in unspecified parts of the marshes and agricultural lands. Bias inherent in these methods would tend to underrepresent algae and invertebrates and to underestimate the range of food items in the ducks' diets.

CONCLUSIONS AND RECOMMENDATIONS

1. Dabblers move between coastal sites and flooded fields. No single site should be considered in isolation, but rather as part of a wetlands complex. If an estuary is to be protected as dabbler habitat, other elements of the wetlands complex should be considered for protection.

2. Fluctuations in dabbler numbers along the coastline are related to the degree of flooding on farmlands and to the presence or absence of freezing temperatures. Temperature and flood conditions on nearby fields should be recorded for each census and considered when interpreting the data.

3. Shallow, non-estuarine bays not previously considered important to dabblers may provide valuable feeding habitat at low tide in fall and early winter.

4. Coastal sites are vital during freezing weather when ducks are forced off frozen fields. Duck censuses should be scheduled to include freezing days, both to estimate the numbers of ducks in the region and to catalogue coastal sites that provide critical habitat.

5. Fields, when flooding conditions are good, are favoured over coastal sites, especially by mallards. Further elimination of flooded fields through drainage will reduce the preferred feeding habitat available to dabblers.

6. Mallards' and American wigeon's movements both within and among sites are partly dictated by water levels. Each species may have a regular pattern of movement among feeding sites, regulated by tides. When

assessing use of a coastal site, the ducks must be observed at all points of the tidal cycle.

7. At farm and coastal sites, almost all feeding occurs in or close to shallow water. Available feeding sites shift with weather conditions and with the tides. High marsh zones are popular feeding locations, especially for mallards, but are rarely available. High biomass of common duck food plants in this zone does not necessarily translate into good dabbler habitat. Fields which rarely flood receive little use and are not worth maintaining as dabbler feeding grounds.

8. Within shallow water zones, both duck species are opportunistic, feeding on a wide variety of food items. In assessing dabbler habitat, I recommend concentrating on factors affecting food availability: the slope of the land, the extent to which it floods (at inland sites) and the shallow water area, both marsh and marine, available over the tidal cycle at coastal sites. The species composition of marsh vegetation and the distribution of algae and invertebrates are probably of secondary importance.

9. Marine deltas and beaches are important as refuges from disturbance and as feeding areas, with green algae and marine invertebrates being major food items. These zones form an integral part of estuarine dabbler habitat.

10. Many of the conclusions drawn from Fraser Delta studies do not apply to other B.C. coastal areas such as those I studied. I question the validity of some of these conclusions for the Fraser system and recommend that they be reexamined.

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APPENDIX 1: PRELIMINARY STUDY, FEBRUARY TO APRIL, 1980

The preliminary study's objectives were: (1) to develop methods for the main study, (2) to assess the degree of day-to-day fluctuations in dabbler census data at coastal sites, (3) to test if time of day is a factor in these fluctuations, and (4) to see if dabbler numbers at a farm and a coastal site were correlated.

Counts of dabblers at Nanoose Creek and Little Qualicum River estuaries were conducted from February 4 to April 8, 1980. Censuses were done on foot, following set routes and using observation towers and natural vantage points. Counts started at either 0900, 1200 or 1500 hours. Duck counts are presented in Appendix 1, Table 1.

In order to test if duck abundance is affected by time of day, Kruskall-Wallis tests (non parametric analyses of variance) were performed for each species at each site, with data divided according to time of day. A nonparametric test was chosen because the data are highly skewed. The resulting test statistics (Zar 1974) are, for Little Qualicum: H=0.324 (mallard) and H=0.756 (American wigeon). None of these values are significant (P>0.05). Seasonal fluctuations in duck numbers should not affect these tests since the 3 types of censuses were spread evenly over the study period at each site. Duck abundance at each site, then, does not appear to be affected by time of day.

Twelve censuses at Little Qualicum River estuary were followed immediately by dabbling duck counts at a farm located 3km from the estuary. A log transformation was used to correct for heteroscedasticity, the variances being proportional to the means (Zar 1974). The correlation coefficients for both species were significantly negative in two-tailed tests ($P<0.01$).

Table 1. Census data, Little Qualicum River and Nanoose Creek estuaries, 1980.

Little Qualicum			Nanoose		
Date (1980)	Mallard	American wigeon	Date (1980)	Mallard	American wigeon
Feb. 4	157	399	Feb. 6	0	76
Feb. 9	10	4	Feb. 11	14	221
Feb. 15	38	36	Feb. 15	13	305
Feb. 18	27	0	Feb. 19	0	294
Feb. 21	47	10	Feb. 21	0	537
Feb. 22	3	8	Feb. 22	15	404
Feb. 25	25	6	Feb. 27	3	274
Feb. 26	4	2	Feb. 28	0	325
Mar. 1	9	0	Feb. 29	0	308
Mar. 4	45	9	Mar. 3	0	326
Mar. 5	33	7	Mar. 6	4	303
Mar. 8	34	61	Mar. 7	3	295
Mar. 10	62	63	Mar. 12	11	280
Mar. 12	52	50	Mar. 13	5	333
Mar. 15	24	74	Mar. 16	23	347
Mar. 19	109	143	Mar. 17	0	366
Mar. 21	134	129	Mar. 18	3	262
Mar. 22	135	76	Mar. 20	12	335
Mar. 22	135	76	Mar. 20	12	335
Mar. 24	137	192	Mar. 25	33	406
Mar. 25	75	137	Mar. 27	26	265
Mar. 28	239	175	Mar. 31	22	283
Mar. 30	213	149	Apr. 1	6	282
Apr. 5	89	108	Apr. 4	19	309
Apr. 8	119	267	Apr. 5	26	249
			Apr. 9	32	300

APPENDIX 2. CENSUS DATA FOR EACH SITE

Date (1980-81)	Mallard numbers at coastal sites[a]							
	1	2	3	4	5	6	7	8
Oct. 6	19	0	194	68	0	0	0	65
10	0	0	31	82	0	0	0	151
15	2	0	82	80	0	0	0	111
24	0	0	0	71	61	0	0	293
Nov. 4	26	0	128	150	0	5	0	126
11	4	0	125	122	0	0	0	168
18	49	0	142	115	12	0	0	82
20	0	0	121	127	0	0	0	69
25	0	0	0	156	4	0	0	106
Dec. 2(F)	22	0	92	121	0	0	0	153
4(F)	89	3	60	261	0	0	0	539
8(F)	29	24	181	490	11	21	0	607
16	24	0	31	164	7	0	0	39
30	2	0	12	133	8	0	0	75
Jan. 6	10	2	32	162	0	0	0	327
13	0	0	5	175	0	0	0	52
20	10	0	0	158	0	0	0	17
27	11	0	0	175	0	0	0	30
Feb. 3	12	0	8	126	0	0	0	27
10(F)	101	37	0	370	0	18	0	811
11(F)	35	0	11	214	0	20	0	272
17	0	0	0	22	0	0	0	0
24	11	0	0	87	0	0	0	0
Mar. 6	10	0	0	48	17	0	0	80
10	7	0	0	53	0	0	0	28
17	16	0	0	60	5	0	0	184
24	50	0	6	39	0	12	0	155
31	40	0	0	113	27	25	0	49
Apr. 7	24	0	0	67	22	26	0	171
14	0	0	4	85	8	23	0	172
21	7	--	--	--	--	--	--	--
28	12	0	0	14	0	0	0	43

[a]See Fig. 1 for location of sites

F=Freezing day

APPENDIX 2. CENSUS DATA FOR EACH SITE (continued)

Date (1980-81)	American wigeon numbers at coastal sites[a]							
	1	2	3	4	5	6	7	8
Oct. 6	0	0	0	112	0	2	0	177
10	0	0	193	268	0	0	0	149
15	33	0	373	520	0	15	0	281
24	23	0	356	192	17	6	0	388
Nov. 4	82	0	640	608	3	16	0	257
11	260	0	580	564	19	0	19	259
18	174	0	490	392	95	4	0	301
20	304	0	589	67	0	8	0	107
25	134	0	0	94	59	5	0	361
Dec. 2(F)	122	55	250	281	0	0	0	13
4(F)	268	82	44	601	24	0	0	540
8(F)	175	11	373	598	111	0	0	388
16	104	12	0	213	7	0	0	12
30	58	2	8	35	0	0	0	18
Jan. 6	62	67	98	73	0	0	0	34
13	149	28	312	10	57	0	0	56
20	73	0	4	201	0	0	0	14
27	119	15	0	231	0	0	0	50
Feb. 3	199	18	4	301	8	0	4	12
10(F)	287	45	0	271	74	0	51	544
11(F)	220	32	244	288	29	14	2	40
17	175	0	0	27	0	0	0	12
24	268	0	165	23	75	0	0	31
Mar. 6	248	0	195	134	55	0	0	94
10	298	0	12	160	90	5	0	28
17	109	0	0	159	52	9	0	166
24	116	0	0	183	21	8	0	280
31	281	0	0	274	60	19	0	122
Apr. 7	265	0	0	253	26	29	0	223
14	250	0	0	166	51	29	0	192
21	30	--	--	--	--	--	--	--
28	12	0	0	75	0	0	0	141

[a]See Fig. 1 for location of sites

F=Freezing day

APPENDIX 2. CENSUS DATA FOR EACH SITE (continued)

Date (1980–81)	Mallard numbers at farm sites[a]									
	A	B	C	D	E	F	G	H	I	J
Oct. 6	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0
Nov. 4	44	10	34	220	0	0	0	0	0	0
11	30	4	27	72	690	0	59	0	28	0
18	49	0	324	247	0	8	115	0	0	0
20	38	10	844	0	0	43	160	0	0	0
25	433	0	115	0	0	50	8	0	0	0
Dec. 2(F)	35	0	2	30	158	61	6	0	0	0
4(F)	0	0	56	93	0	0	0	0	0	0
8(F)	0	0	73	0	0	0	0	0	0	0
16	135	0	60	70	572	4	31	0	0	0
30	370	47	98	2	386	56	82	5	0	0
Jan. 6	90	10	136	31	80	8	57	0	0	0
13	104	16	68	25	180	5	13	0	0	0
20	130	3	0	146	354	8	2	0	0	0
27	47	3	127	94	77	102	4	0	0	0
Feb. 3	366	33	50	209	0	113	27	0	0	0
10(F)	17	4	4	0	0	4	0	0	0	0
11(F)	0	8	11	248	0	0	0	0	0	0
17	141	17	104	141	374	111	33	0	0	0
24	341	11	89	188	194	29	0	0	17	0
Mar. 6	59	118	77	121	17	38	31	0	0	0
10	108	62	75	56	0	0	14	0	0	0
17	24	46	6	37	0	0	0	0	0	0
24	22	23	4	12	0	0	0	0	0	0
31	23	12	15	0	0	5	2	0	0	0
Apr. 7	28	7	2	33	0	7	0	0	0	0
14	22	14	34	17	0	0	0	0	0	0
21	0	46	6	1	0	0	0	0	0	0
28	0	67	0	6	0	0	0	0	0	0

[a]See Fig. 1 for location of sites

F=Freezing day

APPENDIX 2. CENSUS DATA FOR EACH SITE (continued)

Date (1980-81)	American wigeon numbers at farm sites[a]									
	A	B	C	D	E	F	G	H	I	J
Oct. 6	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
24	2	0	0	0	0	0	0	0	0	0
Nov. 4	314	26	0	0	0	0	0	0	0	0
11	20	8	0	0	333	0	0	0	0	0
18	6	0	303	127	0	0	0	0	0	0
20	48	2	377	0	0	0	5	0	0	0
25	29	6	322	374	0	0	0	0	0	0
Dec. 2(F)	56	0	0	0	260	0	0	0	0	0
4(F)	0	25	92	0	0	0	0	0	0	0
8(F)	0	0	87	0	0	0	0	0	0	0
16	99	230	120	24	828	0	0	0	0	0
30	106	396	170	0	586	16	0	0	0	0
Jan. 6	308	80	173	39	90	0	6	0	0	0
13	130	266	56	10	0	3	0	0	0	0
20	470	6	0	32	175	0	0	0	0	0
27	197	205	99	9	84	0	0	0	0	0
Feb. 3	147	306	38	0	0	7	0	0	0	0
10(F)	74	133	0	0	0	0	0	0	0	0
11(F)	0	179	0	0	0	0	0	0	0	0
17	114	91	50	32	274	60	0	0	0	0
24	178	165	111	74	33	13	0	0	0	0
Mar. 6	31	252	16	102	0	0	0	0	0	0
10	148	370	15	0	0	0	0	0	0	0
17	4	133	22	0	0	0	0	0	0	0
24	15	81	11	0	0	0	0	0	0	0
31	0	57	40	0	0	0	0	0	0	0
Apr. 7	0	89	54	0	0	0	0	0	0	0
14	0	75	33	0	0	0	0	0	0	0
21	0	46	6	0	0	0	0	0	0	0
28	0	17	0	0	0	0	0	0	0	0

[a]See Fig. 1 for location of sites

F=Freezing day

APPENDIX 3. FLOODED AREA ESTIMATES AT FARM SITES

Date (1980-81)	Flooded area estimates at farm sites[a] (hectares)									
	A	B	C	D	E	F	G	H	I	J
Oct. 6	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0
Nov. 4	1.42	7.52	1.26	2.09	0.10	0.10	0	0	0	0
11	1.74	16.27	8.86	4.62	14.23	1.02	1.74	0.22	0.008	0
18	1.29	10.30	5.41	3.62	0.10	1.02	1.57	0	0.002	0
20	1.29	10.30	5.41	3.62	0.10	1.10	1.57	0	0	0
25	5.23	12.70	5.41	4.40	0.10	1.26	1.83	0	0	0
Dec. 2(F)	6.89	13.11	7.50	5.77	7.95	2.61	1.83	0	0	0
4(F)	0	0.10	3.45	1.75	0	0.10	0	0	0	0
8(F)	0	0	0.10	0	0	0	0	0	0	0
16	17.26	14.73	6.25	5.77	14.23	1.64	1.44	0	0.003	0
30	24.19	20.34	8.86	6.24	17.95	4.23	1.98	0.28	0.003	0
Jan. 6	10.47	13.78	4.82	2.83	3.28	1.18	1.60	0	0.002	0
13	4.70	9.84	3.35	1.53	1.67	1.05	1.07	0	0	0
20	2.25	11.94	5.69	4.18	11.60	1.28	1.60	0	0.003	0
27	2.25	8.13	4.82	3.35	3.91	1.28	1.07	0	0.002	0
Feb. 3	2.80	5.29	2.58	1.40	0.81	1.00	1.07	0	0	0
10(F)	0.20	0	0.10	0	0	0.17	0	0	0	0
11(F)	0	0.20	0.10	0.38	0	0	0	0	0	0
17	24.79	7.71	6.25	6.79	23.98	4.51	1.71	0.10	0.004	0
24	8.49	8.68	3.91	3.88	16.38	1.54	1.43	0	0.003	0
Mar. 6	3.00	6.70	2.58	3.06	0.10	0.50	1.31	0	0.001	0
10	2.60	5.03	1.25	3.00	0.10	0.20	0.87	0	0	0
17	1.70	4.60	1.00	1.23	0	0.20	0.65	0	0	0
24	0.91	4.21	0.63	0.87	0	0.20	0.35	0	0	0
31	1.39	4.81	1.20	0.62	0	0.35	0.35	0	0	0
Apr. 7	1.40	4.81	1.00	2.26	0	0.15	0.35	0	0	0
14	0.90	5.03	0.63	1.23	0	0.10	0.10	0	0	0
21	0.30	1.57	0.30	0.51	0	0.10	0	0	0	0
28	0.10	0.10	0.10	0.25	0	0.10	0	0	0	0

[a]See Fig. 1 for location of sites

F=Freezing day