Winter food habits of Barrow's Goldeneyes in southeast Alaska

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1. Abstract

Thirty-eight Barrow's Goldeneyes (*Bucephala islandica*) were collected in four neighbouring fiords of southeast Alaska in February 1980 and 1981. Esophageal and gizzard contents of the birds were examined separately to determine major prey species. Their diets consisted almost entirely of molluscs and crustaceans, with almost no insects or plants. The mean volumetric percentages of the most common foods in combined esophagi and gizzards were as follows: blue mussel (*Mytilus edulis*), 53.1; discord mussel (*Musculus discors*), 11.1; barnacle (*Balanus glandula*), 12.0; puppet margarite snail (*Margarites pupillus*), 8.3; hermit crab (*Pagurus hirsutiusculus*), 6.2; Sitka periwinkle (*Littorina sitkana*), 1.3; and algae, <0.1.

No difference in diet composition by sex was detected, but males selected larger blue mussels than did females. The number of food taxa consumed in 1981 ranged from 5 to 28 among fiords, and 1 to 18 among individual birds. The number of food taxa in birds from one fiord was 30 in 1980, and only 12 in 1981. This study suggests that goldeneyes feed within 2 m of the surface on a variety of foods depending upon tide height, but blue mussels are selected at depths through 4 m.

2. Résumé

En février 1980 et 1981, 38 Garrots de Barrow (*Bucephala islandica*) ont été recueillis dans quatre fiords voisins du sud-est de l'Alaska. Nous avons examiné séparément le contenu de l'œsophage et du gésier des oiseaux pour déterminer les principales espèces constituant leurs proies. Leur régime se composait presque entièrement de mollusques et de crustacés et ne comportait pratiquement pas d'insectes ni de plantes. Les pourcentages volumétriques moyens des aliments les plus fréquents dans les œsophages et gésiers combinés étaient : la moule bleue (*Mytilus edulis*), 53,1; la moule lisse (*Musculus discors*) 11,1; la balane (*Balanus glandula*) 12,0; la margarite pupille (*Margarites pupillus*), 8,3; le bernard-l'hermite (*Pagurus hirsutiusculus*), 6,2; la littorine sitka (*Littorina sitkana*), 1,3; et les algues, <0,1.

Nous n'avons pas trouvé de différences entre les régimes des deux sexes, mais les mâles prenaient des moules bleues plus grosses que ne le faisaient les femelles. Le nombre de taxons alimentaires consommés en 1981 variait de 5 à 28 selon les fiords et de 1 à 18 selon les oiseaux considérés individuellement. Le nombre de taxons alimentaires consommés par les oiseaux d'un fiord s'élevait à 30 en 1980, mais tombait à 12 en 1981. D'après cette étude, les garrots se nourriraient jusqu'à une profondeur de 2 m de toute une variété d'aliments, tout dépendant de la hauteur de la marée, mais iraient pêcher les moules bleues jusqu'à 4 m de profondeur.

3. Introduction

In 1980, personnel of the United States Fish and Wildlife Service (USFWS) initiated baseline studies of heavy-metal concentrations in marine birds and their prey to detect impacts of tailings disposal at the proposed Quartz Hill molybdenum mine in southeast Alaska. The areas of study, about 60 km east of Ketchikan in Misty Fjords National Monument, are characterized by long, granite-walled inlets with steep, rocky shores and a maximum tidal range of 7 m. A part of these studies is the analysis of food habits of the Barrow's Goldeneye (*Bucephala islandica*), the area's most abundant wintering seaduck. The diet of this species was first discussed by Munro (1918) and Yorke (1899, cited in Bent 1925). More complete descriptions of their food habits, including birds from British Columbia, were given by Munro (1939), Cottam (1939), and Vermeer (1982).

This study was designed to examine the major foods of wintering Barrow's Goldeneyes and to explore the effects that food availability may have on diet composition and foraging patterns.

4. Methods

All birds were taken with a shotgun from a skiff. Because they were wary, birds were seldom observed feeding. After collection, birds were labelled and taken to a research vessel where they were weighed, sexed by internal examination, and emptied of stomach contents.

Because this work was ancillary to the investigation of heavy metals in seaducks, some procedures recommended for food habits studies (Swanson and Bartonek 1970) were not followed. In 1981, esophageal and gizzard contents were removed, weighed, sealed in jars and frozen 1–3 h after collection. Samples were thawed, preserved in 10% Formalin, and examined 6 weeks later. The gut contents of birds collected in 1980 were preserved in 10% Formalin and examined 13 months later.

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Preserved food items were sorted to taxon, identified to species when possible, then air-dried and weighed, measured volumetrically by liquid displacement, and counted. We estimated the percentage composition of food items in four birds because the gizzard contents could be identified but were inseparable. Frequency of occurrence, mean of volumetric percentages, and percentage of total volume were calculated for each prey species (Swanson *et al.* 1974).

We used two-way analysis of variance tests on arc sine transformed percentage data to compare diets of male and female ducks, and one-way analysis of variance tests on l*n* transformed count data to test for differences in diet by tide stage. We used t-tests to compare sizes of invertebrates (Sokal and Rohlf 1969); sizes are expressed as $\bar{x} \pm$ SE. Vertical distributions of intertidal prey species were observed in the field and verified in the literature (Ricketts and Calvin 1968, Abbott 1974) and by Richard T. Myren, National Marine Fisheries Service, Juneau (pers. comm.).

References used for identifying prey are Abbott (1974), Barnard (1969), Butler (1980), Foster (1981), Keen and Coan (1974), Kozloff (1974), McLaughlin (1974), Oldroyd (1925–27), Pennak (1978), Pilsbry (1916), Smith and Carlton (1975), and Wiggins (1978).

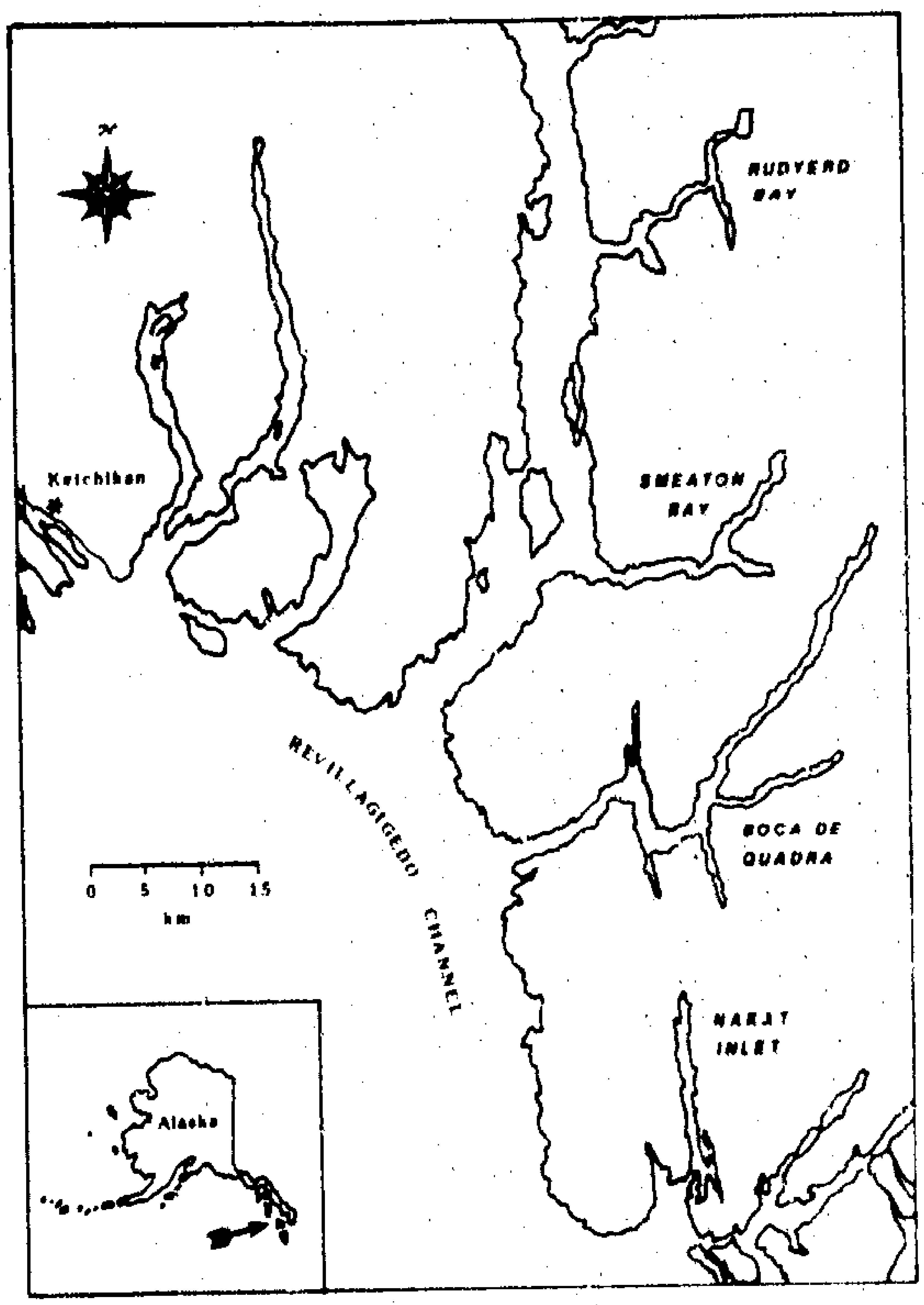
5. Results

Thirty-eight Barrow's Goldeneyes were collected in Misty Fjords National Monument: 10 from Boca de Quadra in February 1980, and 7 each from Boca de Quadra, Nakat Inlet, Smeaton Bay, and Rudyerd Bay (Fig. 1) in February 1981. Of 43 food taxa identified, five comprised over 90% of the combined mean volumetric percentage (Table 1). They were the blue mussel (*Mytilus edulis*), the discord mussel (*Musculus discors*), the puppet margarite snail (*Margarites pupillus*), a barnacle (*Balanus glandula*), and a hermit crab (*Pagurus hirsutiusculus*). Animals smaller than 10 mm were probably ingested incidentally with larger prey species. For example, the molluscs *Granulina margaritula*, *Spiroglyphus lituellus*, and *Hiatella arctica* were only found entangled in the byssal "cocoons" of discord mussels, and very small blue mussels were found clustered with larger mussels. Encrusting ectoprocts (bryozoans) were associated exclusively with gastropods. Although half of the stomachs contained algae, their mean volumetric percentage was less than 0.1. Algal fragments were usually attached to or entangled with byssal threads of mussels.

Only nine birds had esophageal contents. Two-way analysis of variance was used to test for differences in the volumetric percentages of five major food taxa between esophagi and gizzards. No significant difference ($P>0.05$) in proportions of foods was found, so data were combined for each of these birds.

The diets of 23 male and 15 female Barrow's Goldeneyes were compared, but no significant differences in the mean volumetric percentages of five major food taxa were found ($P>0.05$). However, significantly larger blue mussels ($t=4.83$, $P<0.05$) were eaten by males ($\bar{x}=16.6 \pm 1.3$ mm, $n=36$) than by females ($\bar{x}=9.9 \pm 0.4$ mm, $n=145$), although no significant differences in sizes of other prey could be detected. Ingested blue mussels, the largest prey eaten, ranged from 2.3 to 37.0 mm ($\bar{x}=11.3 \pm 0.5$, $n=181$) in length. Other prey sizes ranged from 2.2 to 22.2 mm ($\bar{x}=10.6 \pm 0.6$, $n=62$) for discord mussels, up to 12.4 mm for barnacles, and to 23.3 mm for shells (*Nucella lamellosa*) used by hermit crabs.

Figure 1
Four fiords in southeast Alaska where Barrow's Goldeneyes were collected, February 1980 and 1981



Numerous bays and several river deltas provide diverse sand and cobble habitats for prey species in Boca de Quadra. Birds collected in that fiord ate a total of 32 taxa in both years of our study, and they ate 13 taxa that were not found in birds from the other fiords. We suspect that a decline in food variety from 30 taxa in 1980 to 12 in 1981 is an artifact of collecting birds at different tide stages between years. Birds from Rudyerd Bay contained only five taxa, and those from Smeaton Bay contained eight. Both Rudyerd and Smeaton Bays have near vertical walls and little diversity of intertidal habitats; several birds from these fiords had fed exclusively on blue mussels. Nakat Inlet, with more gently sloping shores, has more extensive intertidal sand and gravel beaches. Nakat goldeneyes consumed 28 taxa, including six foods not found in the other fiords; a single bird from Nakat Inlet contained 18 prey species. Prey availability may differ among fiords; however, over half the birds from Nakat Inlet were collected at low tides, whereas all but one of the Rudyerd Bay birds were collected at high tides.

Thirty-one goldeneyes in this study and at Port Valdez in southcentral Alaska (Derksen, unpubl. data), contained whole or undigested organisms. By relating the tide stage at the time of collection to the vertical distribution of prey species in the intertidal zone, we estimated the depths to which goldeneyes dove to feed. We used this

Table 1
Volumes and frequencies of food items from Barrow's Goldeneyes in southeast Alaska, February 1980 and 1981

Taxon	Esophageal contents ($N = 9$)			Gizzard contents ($N = 37$)			Combined contents ($N = 38$)		
	Mean vol., %	% total vol.	% occur.	Mean vol., %	% total vol.	% occur.	Mean vol., %	% total vol.	% occur.
Algae	tr*	tr	56	tr	tr	46	tr	tr	50
Mollusca									
Polyplacophora									
Tonicella insignis	—	—	—	tr	0.1	8	tr	tr	8
Tonicella lineata	0.1	0.1	33	tr	0.1	19	0.1	0.1	18
Mopalia lignosa (?)	—	—	—	tr	0.1	3	tr	tr	3
Gastropoda									
Acmaea mitra	—	—	—	0.1	0.1	3	0.1	0.1	3
Collisella spp.	—	—	—	tr	tr	16	tr	tr	16
Cryptobranchia alba	tr	0.1	33	tr	tr	8	tr	tr	8
Calliostoma ligatum	—	—	—	0.1	tr	5	0.1	tr	5
Lirularia lirulata	—	—	—	tr	tr	3	tr	tr	3
Margarites helicinus	0.2	0.1	22	tr	tr	5	tr	tr	8
Margarites pupillus	1.2	2.0	22	9.1	9.0	30	8.3	7.6	29
Lacuna spp.	0.1	tr	44	tr	tr	22	tr	tr	24
Littorina scutulata	tr	tr	11	0.3	0.4	14	0.3	0.3	13
Littorina sitkana	tr	tr	22	1.4	1.2	24	1.3	1.0	32
Alvania compacta	—	—	—	tr	tr	5	tr	tr	5
Spiroglyphus lituellus (?)	tr	tr	33	tr	tr	16	tr	tr	16
Bittium sp.	—	—	11	0.7	0.9	14	0.7	0.8	13
Melanella sp.	—	—	—	tr	tr	3	tr	tr	3
Natica clausa	—	—	—	1.8	2.0	5	1.7	1.6	5
Ocenebra interfossa	—	—	—	0.3	0.2	16	0.3	0.1	16
Urosalpinx lurida	—	—	—	tr	tr	8	tr	tr	8
Amphissa columbiana	tr	tr	11	0.8	1.2	8	0.8	1.0	11
Nassarius mendicus	—	—	—	0.3	0.4	5	0.3	0.3	5
Oenopota sp.	—	—	—	tr	tr	8	tr	tr	8
Granulina margaritula	tr	tr	11	tr	tr	8	tr	tr	11
Odostomia sp.	—	—	—	tr	tr	5	tr	tr	5
Unidentified spp.	—	—	—	0.2	0.2	11	0.2	0.1	11
Bivalvia									
Musculus discors	29.9	46.3	44	10.9	18.1	24	11.1	21.9	24
Mytilus edulis	66.6	49.2	89	54.5	39.9	87	53.1	40.1	84
Saxidomus gigantea	—	—	—	1.7	2.5	5	1.7	2.1	5
Hiatella arctica	tr	0.1	33	tr	t.	11	tr	tr	11
Crustacea									
Balanus glandula	tr	tr	78	12.5	15.0	78	12.0	12.2	84
Gnorimosphaeroma oregonensis	tr	tr	22	tr	tr	3	tr	tr	5
Amphipoda (Gammaridae)	—	—	—	tr	tr	8	tr	tr	8
Pandalus tridens	—	—	—	—	—	—	0.2	0.3	3
Heptacarpus sp.	—	—	—	—	—	—	0.2	0.3	3
Hemigrapsus nudus	—	—	—	0.3	0.6	14	0.7	1.0	16
Pagurus hirsutiusculus	—	—	—	4.6	8.0	14	6.2	8.7	16
Unidentified spp.	tr	tr	11	tr	tr	14	tr	tr	13
Insecta									
Trichoptera (larva)									
Limnephilus sp.	—	—	—	tr	tr	3	tr	tr	3
Diptera (pupa)	—	—	—	tr	tr	3	tr	tr	3
Ectoprocta									
Hippothoa hyalina	tr	tr	22	—	—	—	tr	tr	5
Echinodermata									
Asteroidea	1.8	2.0	11	tr	tr	3	0.1	0.3	3
Strongylocentrotus droebachiensis	0.1	0.1	22	tr	tr	11	tr	tr	13

*tr = values less than 0.05.

information to identify some general prey-use patterns. We defined the mid-intertidal zone as 1.0–3.2 m above Mean Lower Low Water, which is approximately the middle third of the extreme, local tide range (−1.4 to 5.8 m). The plant and animal communities we observed in the upper, middle, and lower intertidal zones typify those described by Ricketts and Calvin (1968) for rocky shores of bays and estuaries in the northern Pacific. The intertidal zonation is similar to that of Port Valdez (Myren, pers. comm.), and depths at which molluscs are found have been described by Abbott (1974) for nearby geographic locations.

Goldeneyes feeding during low tides both in our study area and at Port Valdez ate a significantly greater variety of prey ($F = 10.78$, $P < 0.01$) than did those feeding at higher tide stages (Table 2). Twenty-three species, including 13 gastropods, 2 chitons, a bivalve, and 5 polychaete annelids were eaten by goldeneyes only when the tides were low. The purple shore crab (*Hemigrapsus nudus*), the yellow-legged shrimp (*Pandalus tridens*), and two freshwater insect taxa were taken solely during high tides. Gut contents of birds collected on high and mid tides (above 1.0 m) consisted predominantly of blue mussels with attached barna-

Table 2
Mean number of prey taxa consumed by Barrow's Goldeneyes at different tide stages

Fiord	High tide above 3.2 m	Mid tide 1.0–3.2 m	Low tide below 1.0 m
	$\bar{x}$ ± SE (N)	$\bar{x}$ ± SE (N)	$\bar{x}$ ± SE (N)
Nakat Inlet	6.0 ± 0.0 (3)	—	9.8 ± 3.1 (4)
Boca de Quadra	3.7 ± 1.3 (3)	4.8 ± 1.1 (4)	—
Smeaton Bay	2.0 ± 0.3 (5)	—	5.5 ± 2.5 (2)
Rudyerd Bay	2.3 ± 0.3 (6)	4.0 (1)	—
Port Valdez*	2.6 ± 0.5 (5)	2.0 (1)	11.0 ± 4.0 (2)
All areas	3.0 ± 0.4 (22)	4.2 ± 0.8 (6)	9.0 ± 1.9 (8)

*From a separate study (Derksen, unpubl. data).

cles and periwinkles, and rarely of prey normally found at lower elevations. Goldeneyes collected at low-water stages (below 1.0 m), when blue mussels were exposed and unavailable, had eaten lower intertidal and sub-tidal prey, such as the discord mussel; the gastropods *Margarites pupillus*, *Bittium* sp., *Calliostoma ligatum*, *Natica clausa*, *Amphissa columbiana*; and the urchin *Strongylocentrotus droebachiensis*.

Except for blue mussels, all undigested prey species found in these goldeneyes and those collected throughout the winter near Valdez are known to inhabit intertidal and sub-tidal areas that were within 2 m of the water's surface at the time we collected the birds. Undigested blue mussels, however, the most commonly eaten food, were found in birds that we collected when water levels were more than 4 m above mussel beds.

6. Discussion

The bias associated with using gizzard contents to assess the relative importance of different foods in waterfowl diets is primarily due to differential digestion of plant and animal tissues (Bartonek and Hickey 1969, Swanson and Bartonek 1970). This bias is probably minimal in our results for wintering goldeneyes because (1) plant foods comprised a very small part of diets; (2) calcareous-shelled animals and animals with calcified, chitinous exoskeletons comprised over 95% by volume of esophageal and gizzard contents; (3) except for the ectoproct, *Hippothoa hyalina*, whose volume was not measurable, no prey were found in esophagi that were not also found in gizzards; and (4) for nine goldeneyes with esophageal contents, there were no significant differences in relative food volumes between esophagi and gizzards.

The gut contents of each bird collected represent a small temporal sample of its complete diet. Swanson and Bartonek (1970) found in Blue-winged Teal (*Anas discors*) that all amphipods, 82% of snails (*Gyraulus* spp.), and 24% of diptera larvae were not identifiable 10 min after ingestion. Grandy (1972) demonstrated that Black Ducks (*Anas rubripes*) can pass blue mussels through their digestive tracts in 30–45 min. Mallards (*Anas platyrhynchos*) can excrete crayfish (*Cambarus* spp.) within 45 min of ingestion (Malone 1963). Because of rapid digestion rates, we assumed that nearly whole or undigested animals found in either the esophagus or gizzard were recently eaten, and could therefore be related to the tide stage at the time of collection.

Munro (1939) and Vermeer (1982) found that blue mussels were the main diet of Barrow's Goldeneyes wintering in British Columbia marine habitats. Cottam (1939) did not present his data by season, but stated that mussels and, moreover, insects were important foods. Vermeer's (1982) study more clearly demonstrates seasonal differences in goldeneye diets. He found that they feed mostly on herring eggs during their northward migration in spring.

The diet and feeding ecology of the Common Goldeneye (*Bucephala clangula*) are better known and present some opportunities for a comparison of feeding strategies. In British Columbia, where winter ranges of goldeneyes overlap, Common Goldeneyes seem to rely more on crustaceans and less on mussels than do Barrow's Goldeneyes (Munro 1939, Vermeer and Levings 1977, Vermeer 1982). A single Common Goldeneye that we collected from Smeaton Bay contained amphipods (*Anisogammarus confervicolus*), isopods (*Gnorimosphaeroma oregonensis*, *Idotea wosnesenskii*), hermit crabs (*Pagurus hirsutiusculus*), trichopteran larvae (*Limnephilus* sp.), pieces of plant material, fish probably Pacific sandlance (*Ammodytes hexapterus*), and a limpet (*Notoacmea fenestrata*). Common Goldeneyes in Denmark (Madsen 1954) and Great Britain (Olney and Mills 1963) also ate mostly crustaceans, but those wintering off the coast of Sweden fed predominantly on mussels and secondarily on crustaceans (Nilsson 1972), similar to the Barrow's Goldeneyes in our study.

Nilsson (1970) demonstrated that Common Goldeneyes feed with great intensity during winter, and only during daylight hours. He concluded that thermal stress and limited daylight in winter could put goldeneyes in a marginal position in meeting their nutritional requirements. If we infer the same limitations for Barrow's Goldeneyes, selection pressure would seem to greatly encourage optimization of food selection and foraging effort.

We have presented evidence that Barrow's Goldeneyes select foods differentially at various tide stages. The influence of tides in feeding has also been observed in Common Scoters (*Melanitta nigra*) (Mudge and Allen 1980), Common Eiders (*Somateria mollissima*) (Player 1971, Cantin *et al.* 1974, Campbell 1978), and Black Ducks (Grandy and Hagar 1971). We suggest that Barrow's Goldeneyes minimize their diving efforts by shifting to different prey species with tide changes. The food value gained per unit of foraging effort for blue mussels may be sufficiently high to benefit goldeneyes diving deeper than 2 m. Such an opportunistic feeding strategy would be advantageous during periods of high energy expenditures.

Aerial surveys by Conant and King (1981) indicate that as many as 30 000 goldeneyes winter in the northern half of southeast Alaska. More information on the behaviour and habitats of these birds is needed to assure their protection from shoreline modifications, oil spills, and mine-waste pollution. Blue mussels, a favoured prey, are well known for their ability to concentrate pollutants at high levels (Goldberg 1975). Mining and petroleum activities are expected to increase dramatically in southeast Alaska, challenging all of us to see that coastal resources are considered in the process.

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