Fish changes in diets of nestling Rhinoceros Auklets and their implications

by Kees Vermeer
Canadian Wildlife Service, P.O. Box 340, Delta, B.C. V4K 3Y3
S. Jergen Westrheim
Pacific Biological Station, Nanaimo, B.C. V9R 5K6

Reprinted from "Marine birds: their feeding ecology and commercial fisheries relationships". Nettleship, D.N.; Sanger, G.A.; Springer, P.F. (eds.) Proc. Pacific Seabird Group Symp., Seattle, Washington, 6-8 Jan. 1982. Can. Wildl. Serv. Spec. Publ.

1. Abstract

The diet of nestling Rhinoceros Auklets (*Cerorhinca monocerata*) was investigated on offshore Triangle Island (1976–79) and on inshore Pine Island (1977–80) and Lucy Island (1979–80), British Columbia. Variations in the diet occurred between years and within each summer. The annual variations include the early predominance of Pacific sauries (*Cololabis saira*) in 1976, fluctuations in abundance of age groups of Pacific sandlance (*Ammodytes hexapterus*) and Pacific herring (*Clupea harengus*), a change in rockfish (*Sebastes*) species, and the appearance of bathypelagic bluethroat argentines (*Nansenia candida*) in 1978. In a given summer sandlance and rockfish predominated in July, and herring and sauries in August. Changes in age and size of sandlance species, composition of rockfish, and occurrence of sauries and bluethroat argentines at Triangle and Pine islands were synchronized over the years. Sauries were more prevalent in the diet of birds feeding in the offshore waters of Triangle Island, whereas herring was more prevalent at inshore Pine and Lucy islands.

Juvenile fish populations in surface waters are very difficult to study by conventional methods of pelagic sampling. The Rhinoceros Auklet diet, together with complementary net studies, provides a means of sampling populations and monitoring age-classes of juvenile fish.

2. Résumé

Nous avons étudié le régime alimentaire de jeunes Alques à bec cornu (*Cerorhinca monocerata*) dans l'île hauturière Triangle (1976 à 1979) et dans les îles côtières Pine (1977 à 1980) et Lucy (1979 et 1980) en Colombie-Britannique. Les variations du régime alimentaire se manifestent d'une année à l'autre et au cours de chaque été. Pour ce qui est des variations annuelles, citons d'abord la prédominance du balaou japonais (*Cololabis saira*) en 1976, certaines fluctuations de l'abondance des groupes d'âge du lançon du Pacifique (*Ammodytes hexapterus*) et du hareng du Pacifique (*Clupea harengus*), un changement dans les espèces de sébaste (*Sebastes*) et l'apparition d'argentines batypélagiques (*Nansenia candida*) en 1978. Au cours d'un été donné, le lançon et les sébastes ont dominé en juillet, alors que le hareng et le balaou ont été plus abondants en août. Les variations d'âge et de taille des espèces de lançon, la composition des sébastes et la fréquence d'apparition des balaous et des argentines aux îles Triangle et Pine sont synchronisées au cours des ans. Le balaou compose une plus grande proportion du régime alimentaire des oiseaux qui se nourrissent dans les eaux de l'île Triangle et est remplacé par le hareng dans les îles côtières Pine et Lucy.

Les populations de poissons juvéniles qui habitent les eaux de surface sont très difficiles à étudier par les méthodes classiques d'échantillonnage de la zone pélagique. Les études du régime alimentaire de l'Alque à bec cornu, complétées par des études de capture au filet, permettent donc d'échantillonner les populations et d'analyser les classes d'âge des poissons juvéniles.

3. Introduction

The Rhinoceros Auklet (*Cerorhinca monocerata*) breeds from the Farallon Islands, California to the Sandman Reefs in Alaska in the northeastern Pacific and from the central east coast of Japan to northern Sakhalin and Kuril islands in the northern western Pacific (Udvardy 1963, Vermeer 1979). The birds nest in burrows about 1 m in length and lay one egg that hatches at the beginning of July. The chicks spend about 7 weeks in their burrows and leave the nesting island between mid August and mid September. During the nestling period each parent brings one meal of fish per night to the chicks (Richardson 1961). The diet of nestling Rhinoceros Auklets consists almost entirely of small fish (Vermeer 1979). The adults carry the fish crosswise in their bills which leaves the prey mostly intact and facilitates identification and measurement. It is during the chick-rearing period in July and August that prey can be adequately sampled, and changes in species and size determined. The effects of such changes on the growth and reproduction of Rhinoceros Auklet were reported in Vermeer and Cullen (1979) and Vermeer (1980).

The objective of this paper is to document the changes in fish species in meals brought by parent birds to their chicks, and the differences between inshore and offshore breeding localities in British Columbia. Ashmole and Ashmole (1968) suggested that tropical marine birds are indicators of relative prey availability. We also address the potential use of the fish diets of Rhinoceros Auklet nestlings as indicators of prey occurrence in temperate waters and as a method of studying age-classes of certain fish species that are extremely difficult to sample with conventional techniques.

4. Methods

Fish were collected from adult Rhinoceros Auklets in July and August on Triangle Island (50°52′N; 129°05′W), Pine Island (50°58′N; 127°41′W), and Lucy Island

(45°18′N; 130°37′W), British Columbia (Table 1). Triangle Island is exposed to the open North Pacific Ocean, whereas Pine and Lucy islands are sheltered by nearby land masses (Fig. 1). Triangle Island has no trees, whereas Pine and Lucy islands are covered with dense forests. These islands were selected because they contain the largest breeding colonies of Rhinoceros Auklets in British Columbia. We began food sampling on Triangle Island in July 1976, Pine Island was added in 1977, and Lucy Island in 1979. A major seasonal change in diet was observed the first week of August 1977 on Triangle Island, and all subsequent sampling included that time period. Sampling times were synchronized between islands whenever possible.

Rhinoceros Auklets were caught by hand with the aid of a bright flashlight directed on them as they landed with fish in their bills. Fish were placed in plastic bags and the birds released immediately. Collection sites were changed each night and the sampling time kept within 1 h to minimize disturbance to the birds. Sampling locations ranged from 50 to 400 m apart around the periphery of the islands. Localities with moderate slope angles and free of dense underbrush were selected to facilitate bird capture in the dark. Samples were placed in cold tap water and processed the same night (23:30–07:00). Whole fish were identified, weighed to the nearest 0.1 g with Pesola scales and their fork length (tip of snout to the fork of the tail) was measured to the nearest millimetre. About 5–10% of the prey brought to the chicks were damaged or consisted of unmeasurable pieces. These were weighed and identified when possible. Fish which could not be identified immediately, such as rockfish, were preserved in 5% formaldehyde solution. Rockfish were later identified in the laboratory.

A prey was defined as principal if it made up 10% or more of the bird's food biomass sampled in a given year, as common if less than 10% of the biomass, and as occasional if the prey occurred not more than six times during the study period at any island.

Statistical tests of significance between means were determined with two-tailed t-tests, and between proportions with Fisher-Exact tests. Common and scientific names follow Hart (1973).

5. Results

5.1. Prey composition and changes

The 2165 Rhinoceros Auklet meals collected on the three islands contained at least 10 000 fishes and weighed 65 kg (Table 1). The average bird meal was 30 g. Meal size increased significantly over the summer season in certain years (Table 1). At least 29 prey species were observed (Table 2). The principal foods included Pacific sandlance[1] at all three islands, Pacific herring on Pine and Lucy islands, and Pacific sauries on Triangle Island. In certain years other species gained importance. Rockfish were important in the birds' diet in 1978 and 1980. Bluethroat argentines were a major prey on Triangle Island in 1978, and to a lesser extent salmon were so on Pine Island in 1980.

Figure 1
Location of Pine, Lucy, and Triangle islands on the British Columbia coast

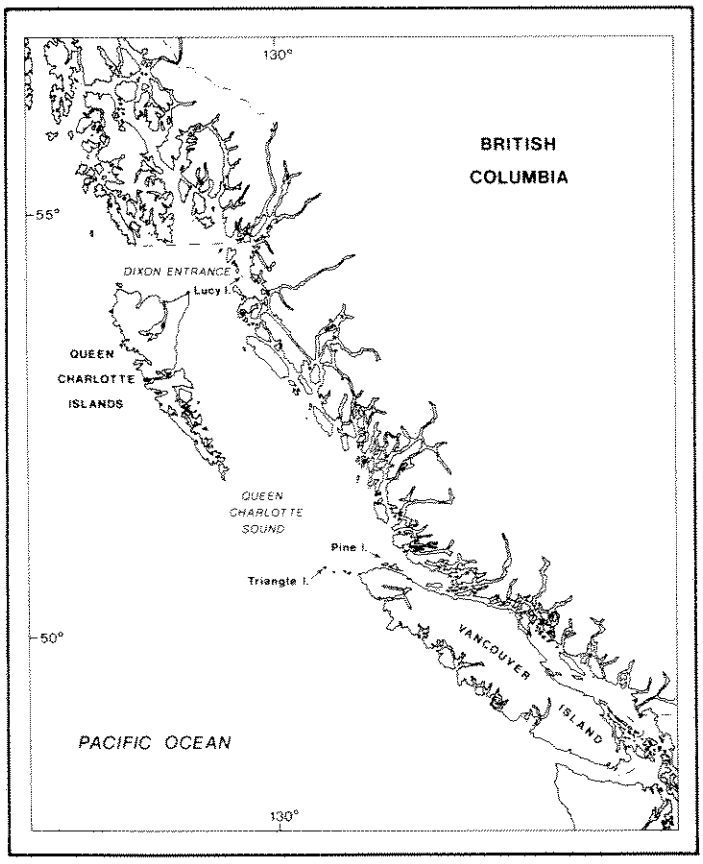


Table 1
Collection periods of food samples and meal sizes of Rhinoceros Auklets on Triangle, Pine, and Lucy islands, 1976–80

Location and year of sampling		Sampling periods	No. meals collected	Mean meal size and 95% confidence intervals, g	Meal range, g
Triangle Island	1976	16–25 July	14	34.6 ± 7.1	17.0–61.0
		1–15 August	16	38.8 ± 7.6	20.0–60.0
		16–31 August	17	35.8 ± 6.5	10.0–49.0
	1977	9–21 July	31	25.8 ± 5.7	9.0–48.5
		2–5 August	34	28.8 ± 4.9	9.0–59.0
		16–21 August	30	37.2 ± 5.2	13.0–51.0
	1978	4–12 July	36	25.0 ± 2.6*	4.0–47.0
		2–8 August	37	31.7 ± 2.7	16.0–51.0
		15–18 August	42	31.2 ± 3.0	11.5–52.0
	1979	1–6 July	55	21.0 ± 2.0*	10.5–42.4
		1–8 August	48	32.5 ± 2.9	14.9–57.4
		21–23 August	18	30.9 ± 4.8	7.1–49.8
Pine Island	1977	2–5 August	86	31.2 ± 3.2	9.4–68.0
	1978	5–11 July	152	29.4 ± 1.5*	8.0–56.0
		2–8 August	180	34.3 ± 1.4	13.0–63.0
		23–27 August	79	32.2 ± 1.8	16.0–61.0
	1979	1–6 July	111	28.5 ± 1.5	12.5–52.5
		1–8 August	186	28.6 ± 1.6	11.3–62.6
		17–20 August	128	27.6 ± 1.5	13.7–49.0
	1980	1–6 July	149	23.4 ± 1.6*	7.2–54.0
		1–5 August	152	32.6 ± 1.8	11.7–62.0
		18–21 August	133	32.8 ± 1.4	17.0–56.5
Lucy Island	1979	11–14 July	105	30.9 ± 1.8	12.4–61.1
		10–13 August	100	31.1 ± 2.0	13.0–55.7
	1980	10–13 July	99	29.0 ± 1.6*	14.2–53.3
		11–14 August	127	33.6 ± 1.8	14.5–63.5

*Mean significantly less than succeeding mean meal size ($P<0.05$).

[1] Table 2 gives scientific names of prey species.

Table 2
Prey species in Rhinoceros Auklet meals on Triangle, Pine, and Lucy islands, 1976–80 (P = principal, C = common, O = occasional; years in parentheses indicate predominance of particular prey species in those years only)

Prey species	Triangle 1976–79	Pine 1977–80	Lucy 1979–80
Pacific herring (*Clupea harengus*)	O	P	P
Northern anchovy (*Engraulis mordax*)	—	O	—
Chum salmon (*Oncorhynchus keta*)	O	C	C
Coho salmon (*Oncorhynchus kisutch*)	—	O	—
Sockeye salmon (*Onchorhynchus nerka*)	C	P (1980)	C
Whitebait smelt (*Allosmerus elongatus*)	—	O	—
Surf smelt (*Hypomesus pretiosus*)	—	—	O
Capelin (*Mallotus villosus*)	—	—	C
Eulachon (*Thaleichthys pacificus*)	O	O	—
Bluethroat argentine (*Nansenia candida*)	P (1978)	C (1978)	—
Slender barracudina (*Lestidium ringens*)	O	O	—
Blue lanternfish (*Tarletonbeania crenularis*)	O	—	—
Pacific cod (*Gadus macrocephalus*)	O	O	—
Walleye pollock (*Theragra chalcogramma*)	—	O	O
Pacific saury (*Cololabis saira*)	P	P (1977)	—
Pacific sandfish (*Trichodon trichodon*)	—	C	C
Pacific sandlance (*Ammodytes hexapterus*)	P	P	P
Pacific ocean perch (*Sebastes alutus*)	C (1979)	P (1979)	—
Dark-blotched rockfish (*Sebastes crameri*)	—	O	—
Widow rockfish (*Sebastes entomelas*)	P (1978)	P (1978,1980)	—
Yellowtail rockfish (*Sebastes flavides*)	P (1977)	P (1977)	—
Redstripe rockfish (*Sebastes proriger*)	—	O	—
Rockfish (*Sebastes* sp.)	—	—	O
Sablefish (*Anoplopoma fimbria*)	C	C	C
Kelp greenling (*Hexagrammos decagrammus*)	C	C	C
Ling cod (*Ophiodon elongatus*)	—	—	O
Cabezon (*Scorpaenichthys marmoratus*)	—	O	—
Flathead sole (*Hippoglossoides elassodon*)	—	O	—
Squid (*Loligo opalescens*)	C	C	C
Squid (*Beryteuthis anonychus*)	—	O	—

Sandlance, herring, and sauries made up 75% or more of the weight of bird meals. Sandlance accounted for 27, 31, and 59% of the food weights on Triangle, Pine, and Lucy islands, respectively (Table 3). Herring accounted for 43% on Pine Island and 33% on Lucy Island. Sauries made up 47% of the biomass on Triangle Island. These three species of prey, and rockfish, argentines, and salmon, together made up 95% or more of the total food biomass.

The incidence and weight of food species of Rhinoceros Auklet chicks varied among years (Table 3, Fig. 2). On Triangle Island, sandlance were scarce in 1976 but relatively abundant in later years. Sauries were the only prey of significance in 1976, but declined in importance as sandlance occurrence increased in other years. In 1978, however, both prey species were displaced by argentines in frequency of occurrence and percent biomass. On Pine Island, herring complemented sandlance in occurrence and biomass. In any given year, when sandlance were less important, herring were dominant in the birds' diet. The near doubling of herring biomass from 1977 to 1978 and from 1979 to 1980 relate to the predominance of first-year fish in 1977 and 1979 and second-year fish in 1978 and 1980. Similar complementary occurrences between sandlance and herring were observed on Lucy Island.

Rockfish occurred in the diet of Rhinoceros Auklet chicks on Triangle and Pine islands. They were high in occurrence but relatively low in biomass due to their small sizes. A distinct, remarkably similar yearly shift in rockfish species took place in both locations (Table 4). In 1977, the yellowtail rockfish was the sole species occurring at Triangle and Pine islands except for one occurrence of redstripe rockfish. In 1978, the widow rockfish was the sole rockfish species on both islands; in 1979, it was the Pacific ocean perch.

The incidence and weight of principal prey changed over the summer months (Table 5 and Fig. 3). Sandlance and rockfish occurred more frequently in the diet in July ($P<0.05$). Sauries and herring occurred more in August ($P<0.05$), except for 1976 when sauries predominated throughout the nesting period.

Table 3
Percentage occurrence (%O) and biomass (%B) of various fish in Rhinoceros Auklet meals

	Sandlance		Herring		Sauries		Rockfish		Argentines		Salmon		Other fish and squid
Year	%O	%B	%O	%B	%O	%B	%O	%B	%O	%B	%O	%B	%B
Triangle Island													
1976	6.4	3.7	2.1	1.8	95.7	90.7	—	—	—	—	4.3	2.4	1.4
1977	62.1	45.8	2.1	1.0	38.3	44.3	27.6	3.5	—	—	1.1	0.9	4.5
1978	11.3	7.4	0.9	0.4	23.8	22.7	33.0	15.5	78.3	48.6	0.9	1.0	4.4
1979	54.5	41.5	1.7	0.9	44.6	52.9	12.4	1.8	0.8	0.1	0.8	0.3	2.5
1976–79($\bar{x}$)	37.3	26.6	1.3	0.8	42.9	47.3	20.8	6.1	24.1	14.9	1.3	1.0	3.2
Pine Island													
1977	66.3	42.5	34.1	15.3	19.8	29.2	27.1	5.5	—	—	5.8	4.4	3.1
1978	31.4	28.0	45.7	48.0	5.4	4.3	16.5	8.9	5.6	4.5	5.4	4.8	1.5
1979	63.9	51.5	43.6	30.8	4.9	5.2	5.4	2.4	0.2	0.03	8.6	6.7	3.4
1980	22.1	12.0	51.4	56.3	1.1	1.1	25.6	12.7	—	—	15.9	13.1	4.8
1977–80($\bar{x}$)	40.9	30.9	46.3	43.3	4.8	5.2	16.5	7.9	1.8	1.5	9.8	7.9	3.3
Lucy Island													
1979	75.6	68.5	20.5	22.1	—	—	1.0	0.05	—	—	7.3	5.8	3.5
1980	59.3	50.2	46.5	42.8	—	—	—	—	—	—	5.3	2.8	4.2
1979–80($\bar{x}$)	65.9	58.9	34.1	32.9	—	—	0.5	0.02	—	—	6.3	4.2	4.0

5.2. Yearly changes in size of principal prey

The length of sandlance in Rhinoceros Auklet meals varied significantly among years (Table 6, Fig. 4). There are no data on the age of Pacific sandlance in British Columbia waters, so we assumed that those in the 40–110 mm length increment represent first-year fish and those in the 100–180 mm increment were second-year and older fish. This assumption agrees approximately with the age distribution of sandlance in Alaskan waters (Hatch, this volume; Dick and Warner, in press). First-year sandlance predominated on Triangle and Pine islands in 1977 and 1979, and on the latter in 1980. Second-year and older fish occurred most frequently on both islands in 1978. A bimodal distribution of sandlance lengths was observed on Lucy Island in 1979 and 1980, representing first-year and older age groups. Comparison of the overall length and biomass distribution of sandlance on Triangle, Pine, and Lucy islands indicate that first-year fish far outnumbered older ones, but the biomass of the latter was of about equal importance to the birds (Fig. 5).

Herring, like sandlance showed a distinct year-to-year difference in average length (Table 6) and in length distribution (Fig. 6). The 40–100 mm and the 100–180 mm length increments represent first- and second-year fish, respectively (Taylor *et al.* 1957). The bimodal distribution of

Table 4
Percentage occurrence (%O) and biomass (%B) of rockfish species in Rhinoceros Auklet meals on Triangle and Pine islands, 1977–80

	1977		1978		1979		1980	
Rockfish species	**%O**	**%B**	**%O**	**%B**	**%O**	**%B**	**%O**	**%B**
Triangle Island								
Yellowtail rockfish	27.6	3.5	—	—	—	—	—	—
Widow rockfish	—	—	33.0	15.5	—	—	—	—
Pacific ocean perch	—	—	—	—	12.4	1.8	—	—
Pine Island								
Yellowtail rockfish	25.9	5.4	—	—	—	—	—	—
Widow rockfish	—	—	16.5	8.9	—	—	25.1	12.4
Pacific ocean perch	—	—	—	—	5.4	2.4	—	—
Dark-blotched rockfish	—	—	—	—	—	—	1.4	0.3
Redstripe rockfish	1.2	0.07	—	—	—	—	—	—

Figure 2
Changes in food biomass of Rhinoceros Auklet nestlings among years

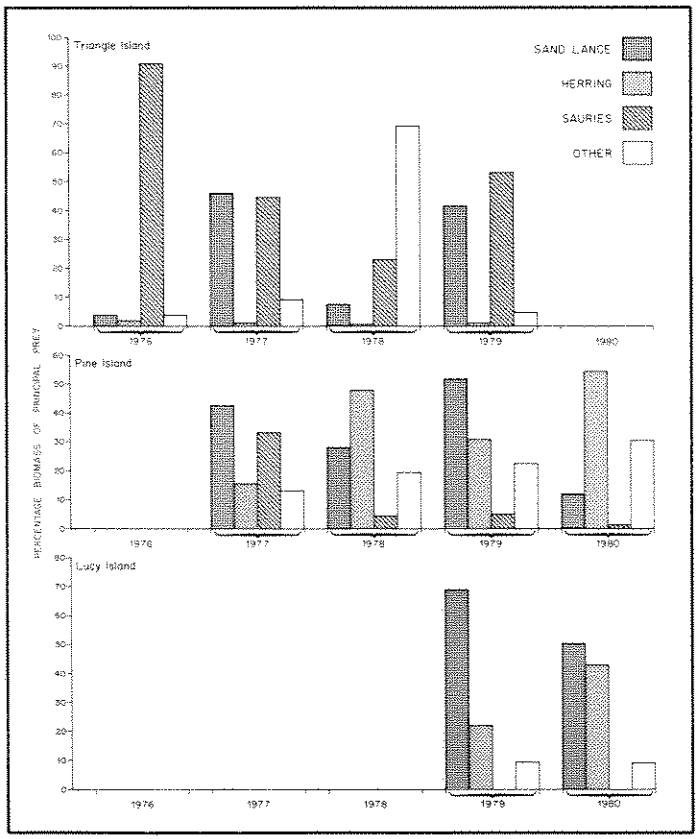
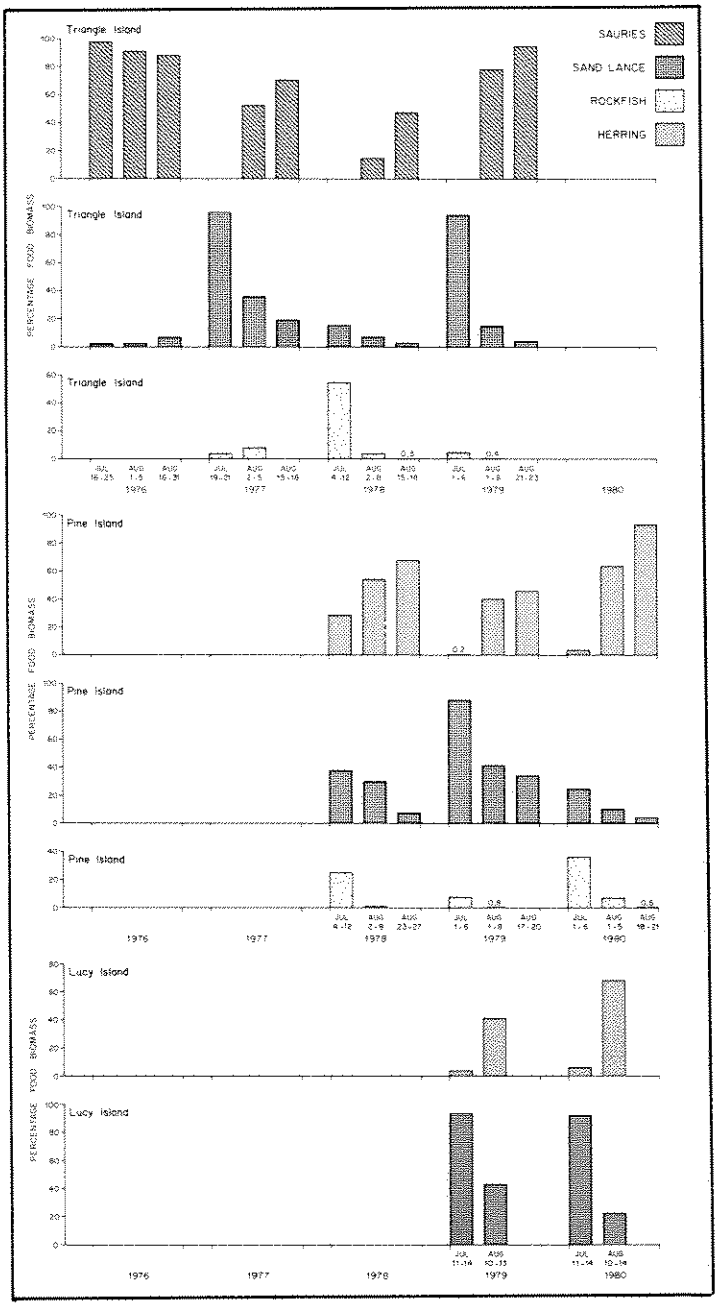


Figure 3
Changes in food biomass of Rhinoceros Auklet nestlings over the summer months



herring in 1978 and 1980 on Pine Island, and in 1980 on Lucy Island represent first- and second-year fish. The overall size distribution of herring on Pine and Lucy islands showed that first- and second-year age-classes are more distinct than those of sandlance (Figs. 4 and 6). As with sandlance first-year herring vastly outnumbered second-year fishes but the latter were much more substantial as a food source to the birds (Fig. 7).

Pacific sauries were the largest fish in the diet of nestling Rhinoceros Auklets (Table 6). The mean lengths of sauries collected at Triangle and Pine islands were not significantly different. Saury lengths in the diets on Triangle and Pine islands showed a 30–230 mm length range (Fig. 8). The 30–230 mm long sauries may all be first-year fish because Hughes (1974) reported two spawning periods per year (April–June and August–November) in this region.

Rockfish lengths were unimodal and represent only one age group of each species (Fig. 9). Differences between lengths of rockfish from Triangle and Pine islands were not significant (Table 6). All specimens were probably in their first year because they averaged much shorter than 1-year-olds (Phillips 1964, Westrheim and Harling 1975).

Bluethroat argentine lengths were unimodal and, like sandlance, rockfish, and sauries, of similar size on Triangle and Pine islands (Table 6 and Fig. 10). We found no information to establish the age of the argentines. Mean lengths of sockeye salmon were similar on Pine and Lucy islands (Table 6) and were most likely second-year fish (Foerster 1968).

Sizes of bluethroat argentines (Fig. 10) and first-year sandlance (Table 7) also varied over a given summer. Hatch (this volume) ascribed the increase in prey size in the

Figure 4
Length distribution of Pacific sandlance in Rhinoceros Auklet meals

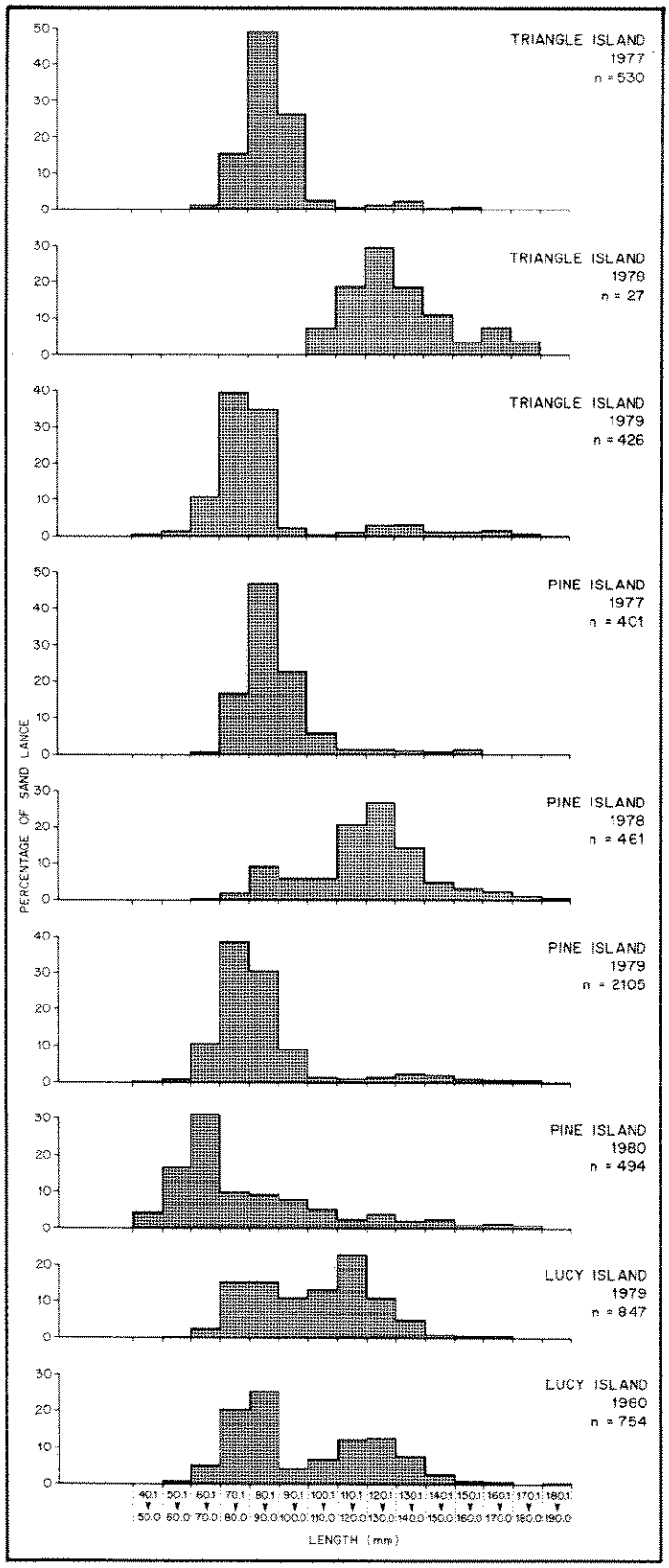
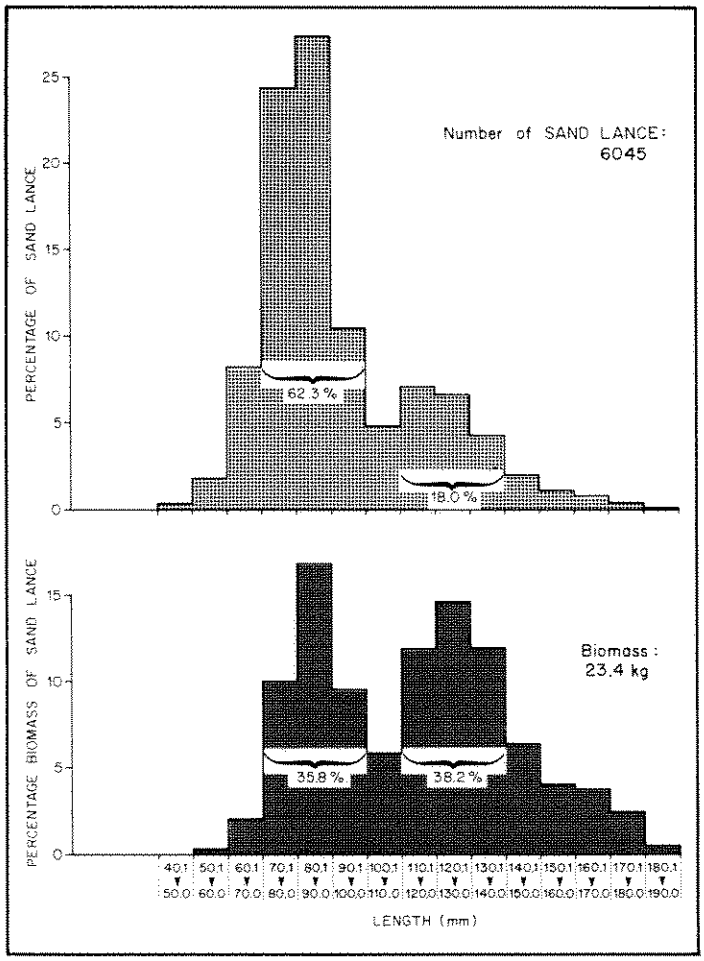


Figure 5
Overall frequency distribution of lengths and weights of Pacific sandlance in Rhinoceros Auklet meals



northern Gulf of Alaska during the summer months to growth. This cannot be ascertained from our data because auklets fed on fish of different year-classes over the summer which may or may not overlap in size (e.g. see Fig. 11), and the length of fish may vary among schools of the same year-class.

6. Discussion

6.1. Diet composition and prey occurrence

The composition of prey species in the food of nestling Rhinoceros Auklets may be influenced by the feeding location (offshore *vs.* inshore and northern *vs.* southern waters), random availability in the marine environment, timing of prey occurrence, and water temperatures.

The predominance of certain fish species in bird meals reflects their occurrence near auklet colonies. On the basis of observations by Cody (1973) and Wahl *et al.* (1979), more than 30% of the Rhinoceros Auklet breeding population should feed within 50–60 km of their respective islands. Sandlance are common prey for many commercial fish species and several fish-eating birds from Alaska to Washington (Hart 1973, Harris and Hartt 1977, Ainley and Sanger 1979, Vermeer 1979). In summer they are numerous inshore at depths of less than 50 m (Harris and Hartt 1977). Herring are numerous inshore during their first summer (Hourston 1958, 1959) and are important for many inshore subarctic birds (Ainley and Sanger 1979). The Pacific saury is an abundant warm-water and offshore species (Inoue and Hughes 1971) and is important as prey of Sooty Shearwaters (*Puffinus griseus*) (Chu, this volume; Ogi, this volume). The predominance of sauries in the auklet diet only at offshore Triangle Island, and that of herring only at inshore Pine and Lucy islands suggest differences in available prey species in offshore and inshore waters.

Figure 6
Length distribution of Pacific herring in Rhinoceros Auklet meals

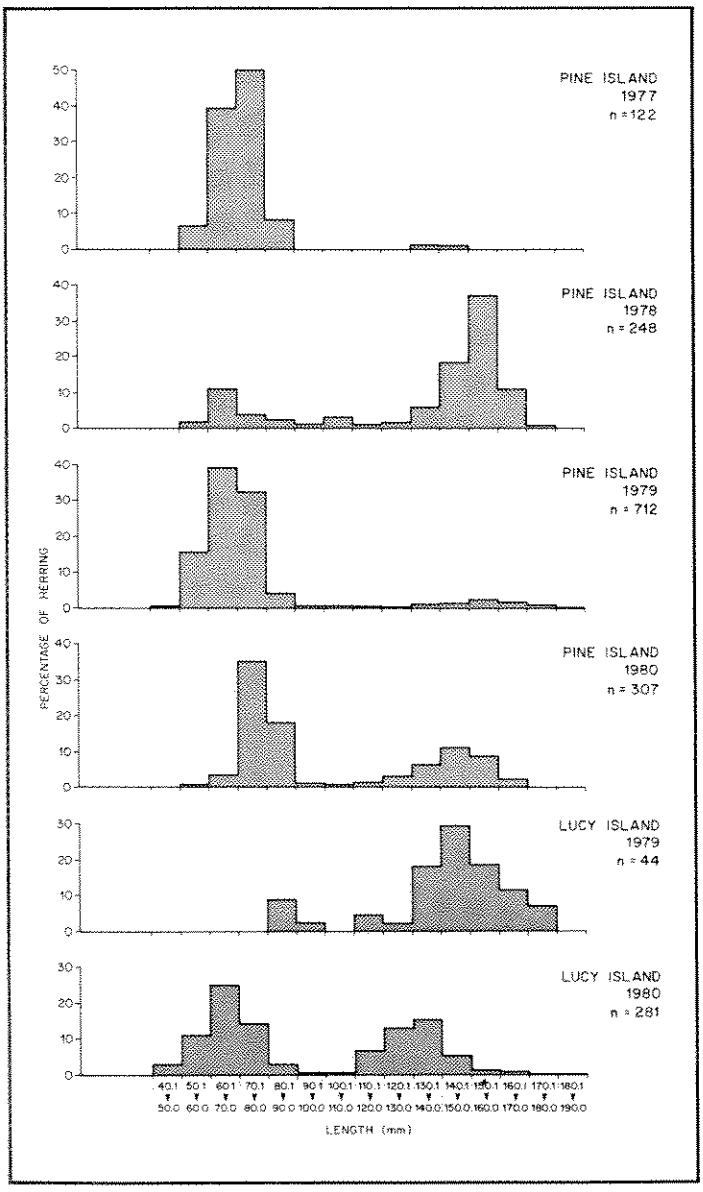
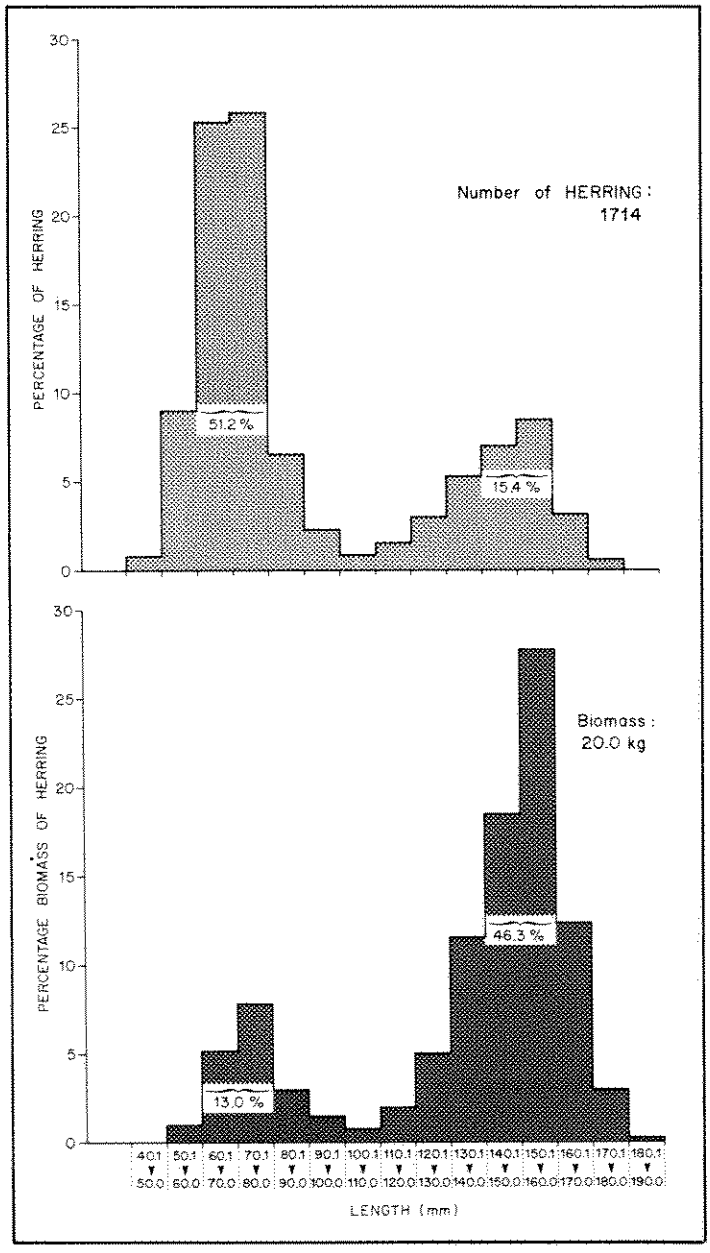


Figure 7
Overall frequency distribution of lengths and weights of Pacific herring in Rhinoceros Auklet meals



The common appearance of capelin as bird food at Lucy Island and their absence at Triangle and Pine islands suggests availability of capelin in northern British Columbia waters. Capelin is one of the most numerous fish and constitutes the main prey of many fish in Alaska (Harris and Hartt 1977). It is an important food for several fish-eating bird species in the northern North Pacific and Bering Sea but not farther south (Ainley and Sanger 1979; Vermeer 1979; Krasnow and Sanger, in press; Sanger, in press). Rockfish were principal prey of Rhinoceros Auklets in more southern waters of Triangle and Pine islands, and an occasional prey at northern Lucy Island. Rockfish are uncommon in the diet of fish-eating birds in northern areas (Ainley and Sanger 1979).

Bluethroat argentines, a cold water, bathypelagic species (Hart 1973) suddenly occurred in Rhinoceros Auklet food almost exclusively in 1978 (except for one fish in 1979). It was also a major prey of chinook (*Oncorhynchus tshawytsha*) and sockeye salmon along the northwest coast of Vancouver Island in 1978, an unusual phenomenon not previously recorded (A. Ostrom, pers. comm.). The occurrence of argentines in salmon stomachs that year supports the view that a species abundant in the birds' diet may also be abundant in the marine waters.

The timing of prey occurrence is critical to its appearance in the bird diet. Sockeye and pink salmon (*O. gorbuscha*) are abundant in Hecate Strait and Queen Charlotte Sound (Aro *et al.* 1977). Sockeye salmon are common prey of Rhinoceros Auklets in July and August but pink salmon are not. The migration of pink salmon from those waters to the North Pacific Ocean in May and June (LeBrasseur and Parker 1964) explains their absence in the diet of nestling Rhinoceros Auklets.

Sauries are warm-water fish and their increase in the Rhinoceros Auklet diet in August (except in 1976) may be explained by the increasing surface water temperatures, which on the average increase at least 1°C per month from June to August in British Columbia waters (Dodimead 1980, Vermeer 1980). It is unknown why sauries predominated in auklet meals before August in 1976 at Triangle Island, because nearshore surface water temperatures then were generally lower than in August of succeeding years (Vermeer 1980). The changes in occurrence of herring and rockfish over the summer are not understood. Rockfish may be affected by surface water temperatures like the sandlance which move into deeper water in late summer and fall (Andriyashev 1954). Herring appear simultaneously with sauries in late summer, and may be positively influenced by the higher surface water temperatures at that time.

6.2. Changes in prey size

The repetitive seasonal changes in diet composition, age classes of prey, and in appearance of argentines and species of rockfish in the diet at both Triangle and Pine islands over several years indicate that Rhinoceros Auklets fed upon fish of the same age group and species each year but they differed between years. Along with the auklets, Tufted Puffins (*Fratercula cirrhata*) on Triangle Island fed on the same age groups of sandlance and the same species of rockfish each year, and on bluethroat argentines in 1978 (Table 8). All these observations support the hypothesis that the diet of nestling Rhinoceros Auklets reflects changes in availability of juvenile fish in coastal waters.

Table 5
Occurrence (%) of principal prey in Rhinoceros Auklet meals (see Table 1 for sample size). Statistically significant changes are shown by pairs of letters (Stat. test: $P<0.05$)

	Triangle Island			Pine Island				Lucy Island	
Collection date	**Sandlance**	**Saury**	**Rockfish**	**Sandlance**	**Saury**	**Rockfish**	**Herring**	**Sandlance**	**Herring**
1976									
16–25 July	—	100	—	—	—	—	—	—	—
1–5 August	—	94	—	—	—	—	—	—	—
16–31 August	—	94	—	—	—	—	—	—	—
1977									
9–21 July	100[a]	0[c]	35	—	—	—	—	—	—
2–5 August	50[a]	44[c]	44[f]	66	19	27	34	—	—
16–21 August	37	70	0[f]	—	—	—	—	—	—
1978									
4–12 July	19	0[d]	86[g]	40	0	40[m]	24[p]	—	—
1–8 August	11	19[d]	14[g]	32[n]	2[t]	4[m]	55[p]	—	—
15–18 August	5	8	5[g]	—	—	—	—	—	—
23–27 August	—	—	—	13[s]	24[t]	0	66	—	—
1979									
1–6 July	100[b]	0[e]	25[h]	95[j]	0	18[n]	4[q]	—	—
11–14 July	—	—	—	—	—	—	—	97[s]	3[u]
1–8 August	21[b]	77[e]	2[h]	57[j]	4	2[n]	58[q]	—	—
10–13 August	—	—	—	—	—	—	—	53[s]	39[u]
17–20 August	—	—	—	49	11	0	59	—	—
21–23 August	6[b]	94	0	—	—	—	—	—	—
1980									
1–6 July	—	—	—	40[k]	0	53[o]	4[r]	—	—
11–14 July	—	—	—	—	—	—	—	97[t]	8[v]
1–5 August	—	—	—	16[k]	3	20[o]	62[r]	—	—
10–14 August	—	—	—	—	—	—	—	30[t]	76[v]
18–21 August	—	—	—	8	1	2[o]	93	—	—

6.3. Rhinoceros Auklets as sampling devices

Juvenile fish populations in surface waters are very difficult and extremely expensive to study by conventional sampling methods. The distribution of juvenile fish populations is highly patchy and sample variability with nets is so great that even species composition can be barely touched. Determination of density distributions even for small areas are very costly. The bird's diet provides a means of sampling juvenile fish populations and could prove to be useful in monitoring age-classes of certain fish species. We recognize the need for complementary sampling with nets to establish the relationships of juvenile fish in marine waters to those observed in the diets of nestling Rhinoceros Auklets. Joint efforts between fisheries and seabird biologists would enhance our understanding of the distribution and structure of juvenile fish populations and their availability to marine birds. Neither discipline in itself can provide an understanding of the changes that occur in these juvenile populations and their implications for the marine-bird food chain.

Table 6
Length of principal prey in Rhinoceros Auklet meals on Triangle, Pine, and Lucy islands, 1976–80

Species and location	Year	No. of fishes	Average length and 95% conf. int., mm
Pacific sandlance			
Triangle	1976	14	122.6 ± 14.6
	1977	530	88.6 ± 1.0
	1978	27	131.7 ± 9.5
	1979	426	84.5 ± 2.0
Pine	1977	401	89.7 ± 1.4
	1978	461	120.4 ± 2.7
	1979	2105	84.9 ± 0.9
	1980	494	79.4 ± 2.6
Lucy	1979	847	102.2 ± 1.5
	1980	754	98.8 ± 1.8
Herring			
Pine	1977	122	71.7 ± 1.9
	1978	248	133.1 ± 4.3
	1979	708	74.4 ± 1.8
	1980	307	99.8 ± 3.5
Lucy	1979	44	141.1 ± 7.0
	1980	277	95.1 ± 4.0
Pacific saury			
Triangle	1976	75	179.1 ± 6.2
	1977	59	173.8 ± 8.0
	1978	43	179.1 ± 5.8
	1979	89	144.1 ± 5.2
Pine	1977	31	179.2 ± 5.8
	1978	49	140.9 ± 7.0
	1979	37	151.8 ± 8.7
Yellowtail rockfish			
Triangle	1977	64	52.7 ± 1.3
Pine	1977	92	55.0 ± 1.5
Widow rockfish			
Triangle	1978	160	66.8 ± 1.0
Pine	1978	302	66.6 ± 0.8
	1980	514	61.2 ± 0.7
Pacific ocean perch			
Triangle	1979	19	61.6 ± 3.0
Pine	1979	73	63.1 ± 1.5
Bluethroat argentine			
Triangle	1978	279	100.0 ± 1.2
Pine	1978	103	102.6 ± 1.6
Sockeye salmon			
Pine	1977–80	95	124.8 ± 2.9
Lucy	1979–80	21	122.8 ± 8.4

Table 7
Comparison of length of Pacific sandlance brought by Rhinoceros Auklets to their chicks on Triangle and Pine islands, 1977 and 1978

Sample location	Time of sampling	No. of fishes	Mean length and 95% conf. int., mm
Triangle Island	July 1977	369	85.5* ± 0.9
	August 1977	161	95.1 ± 2.5
Pine Island	July 1978	209	120.5 ± 2.7
	August 1978	252	120.3 ± 2.7

*Statistically significant from succeeding mean ($P<0.05$).

Figure 8
Length distribution of Pacific sauries in Rhinoceros Auklet meals

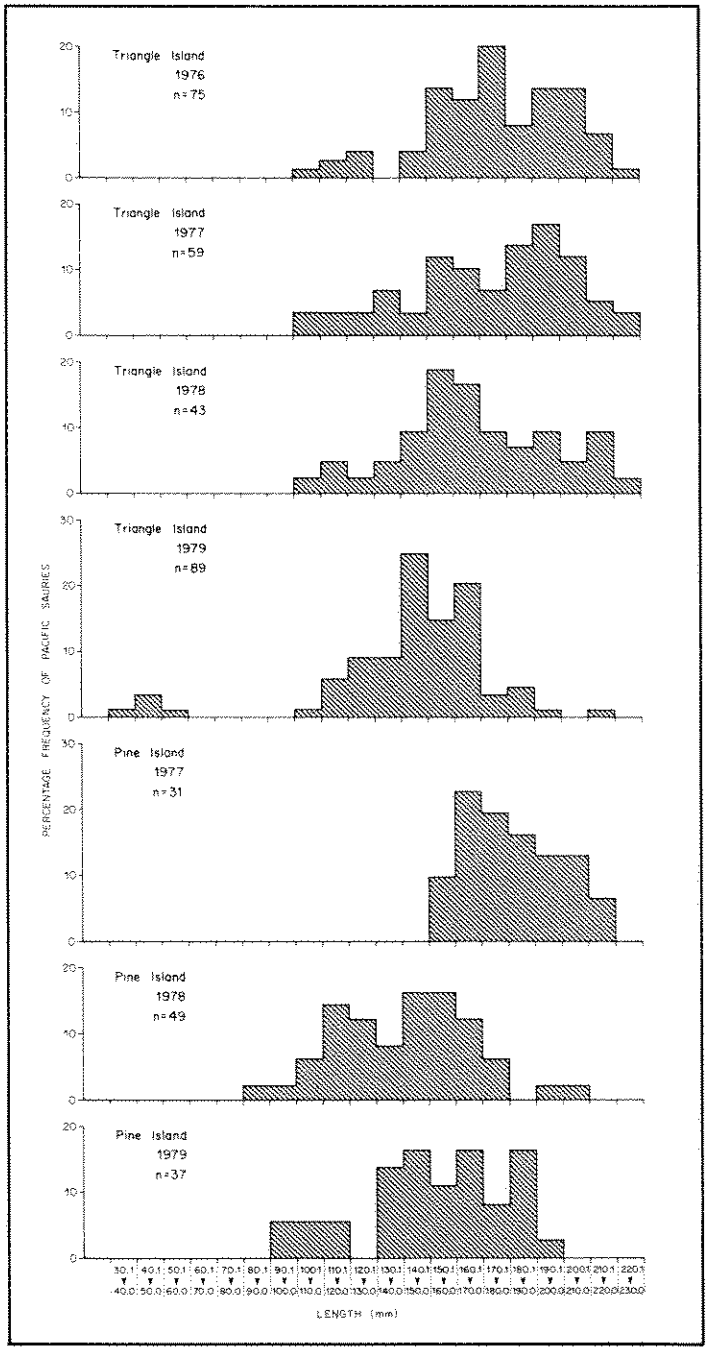


Figure 9
Length distribution of rockfish in Rhinoceros Auklet meals

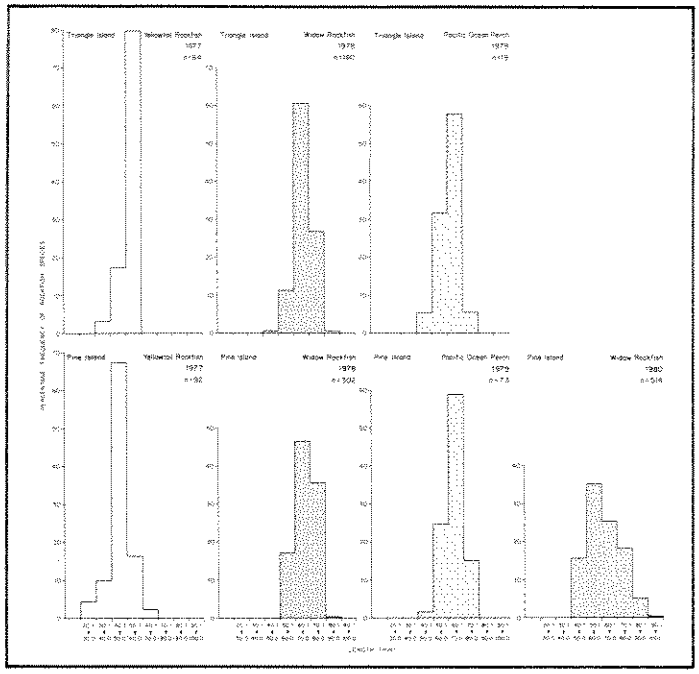


Figure 10
Length distribution of bluethroat argentines in Rhinoceros Auklet meals, Pine and Triangle islands, 1978

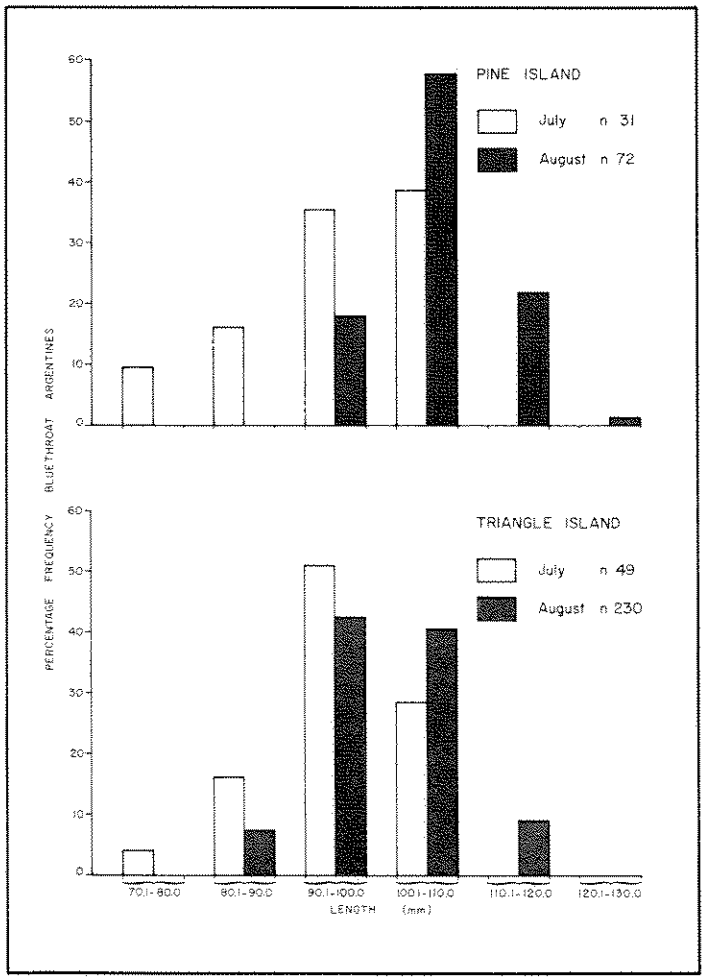


Figure 11
Length distribution of Pacific herring in Rhinoceros Auklet meals on Pine Island for different periods in 1978

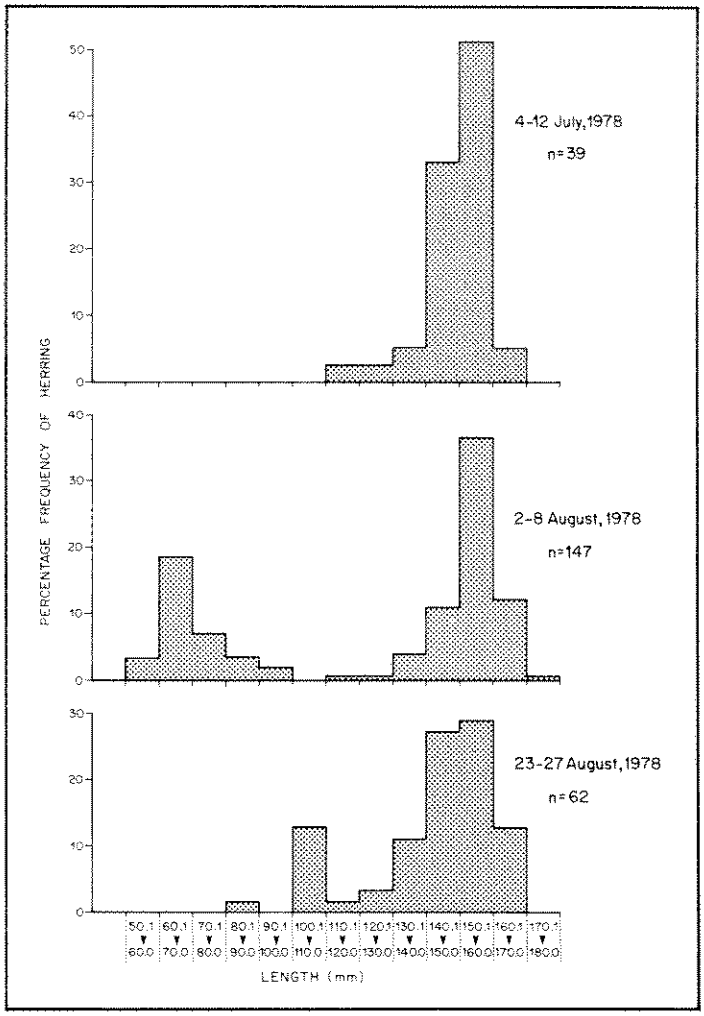


Table 8
Comparison of lengths of Pacific sandlance, yellowtail and widow rockfish, and bluethroat argentines brought by Rhinoceros Auklets and Tufted Puffins to their chicks on Triangle Island in July and August 1977 and 1978

Bird species, year	Fish species	No. of fish	Mean length and 95% conf. int., mm
Rhinoceros Auklet, 1977	Pacific sandlance	530	88.6 ± 1.0*
Tufted Puffin, 1977	Pacific sandlance	80	84.9 ± 5.8
Rhinoceros Auklet, 1978	Pacific sandlance	27	131.7 ± 9.5
Tufted Puffin, 1978	Pacific sandlance	35	125.0 ± 5.2
Rhinoceros Auklet, 1977	yellowtail rockfish	64	52.7 ± 1.3
Tufted Puffin, 1977	yellowtail rockfish	14	54.3 ± 2.8
Rhinoceros Auklet, 1978	widow rockfish	160	66.8 ± 1.0
Tufted Puffin, 1978	widow rockfish	16	67.2 ± 3.1
Rhinoceros Auklet, 1978	bluethroat argentine	279	100.0 ± 1.2
Tufted Puffin, 1978	bluethroat argentine	47	100.0 ± 6.9

*Vermeer (1980) reported significantly longer Pacific sandlance in Rhinoceros Auklets than in Tufted Puffins for smaller August samples only, which included second-year fish for Rhinoceros Auklets, but not for puffins.

7. Acknowledgements

We thank Captain W.M. Exley and E. Harris of the Canadian Coast Guard for accommodation and lightkeepers A. Babitz, K. Nuttall, C. Plumpton, and G. Watson and their families for their generous hospitality extended to the senior author and his daughter, Lotus, at the light stations on Pine and Lucy islands. Lotus assisted with field work. We are much obliged to J.B. Foster for permission to work on the ecological reserve of Triangle Island and to L. Cullen, R. Billings, and K. Summers for assistance with field work. W.R. Harling and A. Peden helped identify prey items and D. Ainley, G.A. Sanger, R.A. Vermeer, and two anonymous referees reviewed an earlier draft of the manuscript and made pertinent comments. This study was financially supported by the Canadian Wildlife Service.

8. Literature cited

Ainley, D.G.; Sanger, G.A. 1979. Trophic relations of seabirds in the northeastern Pacific Ocean and Bering Sea. Pages 95–122 *in* Bartonek, J.C.; Nettleship, D.N. eds. Conservation of marine birds of northern North America. U.S. Fish and Wildl. Serv. Rep. No. 11. Washington, D.C. 315 pp.

Andriashev, A.P. 1954. Fishes of the northern seas of the USSR. Zool. Inst. U.S.S.R. Acad. Sci. (Transl. by Isr. Program for Sci. Transl. Jerusalem. 1964.) 617 pp.

Ashmole, M.J.; Ashmole, N.P. 1968. The use of food samples from seabirds in the study of seasonal variation in the surface fauna of tropical oceanic areas. Pac. Sci. 22:1–10.

Aro, K.V.; Miller, P.L.; McDonald, J. 1977. Catches and escapements of Pacific salmon in British Columbia, 1965–1975. Fish Mar. Serv. Data Rep. No. 39. 67 pp.

Chu, E.W. This volume. Sooty Shearwaters off California: diet and energy gain.

Cody, M.L. 1973. Coexistence, coevolution, and convergent evolution in seabird communities. Ecology 54:31–44.

Dick, M.H.; Warner, I.M. In press. A contribution to the biology of the Pacific sandlance, *Ammodytes hexapterus*, from the Kodiak Archipelago, Alaska. Syesis.

Dodimead, A.J. 1980. A general review of the oceanography of the Queen Charlotte Sound – Hecate Strait – Dixon Entrance Region. Can. Manuscr. Rep. Fish. and Aquat. Sci. No. 1574. 248 pp.

Foerster, R.E. 1968. The sockeye salmon, *Onchorhynchus nerka*. Fish. Res. Board Can. Bull. 162. 422 pp.

Harris, C.K.; Hartt, A.C. 1977. Assessment of pelagic and nearshore fish in three bays on the east and south coasts of Kodiak Island, Alaska. Environ. Assess. Alaskan Cont. Shelf Natl. Oceanic Atmos. Adm. Outer Cont. Shelf Environ. Assess. Program No. 485. Q. Rep. April–June 1:483–688.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can. Bull. 180. 740 pp.

Hatch, S.A. This volume. Nestling diet and feeding rates of Rhinoceros Auklets in Alaska.

Hourston, A.S. 1958. Population studies on juvenile herring in Barkley Sound, British Columbia. J. Fish. Res. Board Can. 15:909–960.

Hourston, A.S. 1959. Effects of some aspects of environment on the distribution of juvenile herring in Barkley Sound. J. Fish. Res. Board Can. 16:283–308.

Hughes, S.E. 1974. Stock composition, growth, mortality, and availability of Pacific saury, *Cololabis saira*, of the northeastern Pacific Ocean. Fish. Bull. 72:121–131.

Krasnow, D.L.; Sanger, G.A. In press. Feeding ecology of marine birds in the nearshore waters of Kodiak Island. Environ. Assess. Alaskan Cont. Shelf. Final Rep. Natl. Oceanic Atmos. Adm. Bur. Land Manage. Outer Cont. Shelf Environ. Assess. Program. Boulder, Colo.

Inoue, M.S.; Hughes, S. 1971. Pacific saury (*Cololabis saira*). A review of stocks, harvesting techniques, processing methods, and markets. Oreg. State Univ. Bull. 43:1–102.

LeBrasseur, R.J.; Parker, R.R. 1964. Growth rate of central British Columbia pink salmon (*Oncorhynchus gorbuscha*). J. Fish. Res. Board Can. 21:1101–1128.

Ogi, H. This volume. Feeding ecology of the Sooty Shearwater in the western subarctic North Pacific Ocean.

Phillips, B. 1964. Life history studies on 10 species of rockfish (*Genus Sebastodes*). Calif. Dep. Fish. Game. Fish. Bull. 126. 70 pp.

Richardson, F. 1961. Breeding biology of the Rhinoceros Auklet on Protection Island, Washington. Condor 63:456–473.

Sanger, G.A. In press. Diets and food web relationships of seabirds in the Gulf of Alaska and adjacent marine regions. Environ. Assess. Alaskan Cont. Shelf. Final Rep. Natl. Oceanic Atmos. Adm. Bur. Land Manage. Outer Cont. Shelf Environ. Assess. Program. Boulder, Colo.

Taylor, F.H.C.; Hourston, A.S.; Outram, N. 1957. The status of major herring stocks in British Columbia in 1956–57. B.C. Prov. Dep. Fish. Rep. 1956:45–77.

Udvardy, M.D.F. 1963. Zoogeographic study of the Pacific Alcidae. Pac. Sci. Congr. Proc. (1961):85–111.

Vermeer, K. 1979. Nesting requirements, food and breeding distribution of Rhinoceros Auklets, *Cerorhinca monocerata*, and Tufted Puffins, *Lunda cirrhata*. Ardea 67:101–110.

Vermeer, K. 1980. The importance of timing and type of prey to reproductive success of Rhinoceros Auklets (*Cerorhinca monocerata*). Ibis 122:343–350.

Vermeer, K.; Cullen, L. 1979. Growth of Rhinoceros Auklets and Tufted Puffins, Triangle Island, British Columbia. Ardea 67:22–27.

Wahl, T.R.; Speich, S.M.; Miller, T.S. 1979. Daily movement of Rhinoceros Auklets in northern Puget Sound and the Strait of Juan de Fuca. Pac. Seabird Group Bull. 6:35.

Westrheim, S.J.; Harling, W.R. 1975. Age–length relationship for 26 scorpaenids in the northeast Pacific Ocean. Fish. Res. Board Can. Tech. Rep. No. 565. 12 pp.