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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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IDENTIFICATION OF MAMMAL TRACKS FROM SOOTED TRACK STATIONS IN THE PACIFIC NORTHWEST [1]

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Sooted aluminum tracking stations were used to investigate distribution patterns of medium and large mammals in Douglas-fir forest in northwestern California. Track stations consisted of two adjacent aluminum sheets covered by a thin layer of kerosene soot with a central bait. Stations were located at 166 sites and monitored for eight-day periods between 1 July and 15 September in 1981, 1982, and 1983. Tracks from 23 species were preserved with transparent tape and up to seven measurements were recorded. We found track impressions on the hard surface to be much smaller and more detailed than those in soil or snow; available measurements and drawings in field guides were useless for identification purposes. Therefore we present a standard method of measurement and a key to distinguish the tracks of medium to large sized mammals from sooted track stations in the Pacific Northwest.

INTRODUCTION

Wildife biologists have used various tracking techniques to assess mammal populations. The most common method is to attract animals to a baited station where tracks are detected in fine soil or snow (Cook 1949; Wood 1959; Linhart and Knowlton 1975; Lindzey, Thompson, and Hodges 1977). However, this technique is infeasible in areas where soils are rocky and fine soil cannot be easily transported (Barrett 1983). A sooted surface was first used by Mayer (1957) to track small mammals. Further modifications were made by Justice (1961) and Lord et al. (1970) to investigate small mammal populations. Barrett (1983) expanded the use of a sooted aluminum surface to determine the distribution of martens, *Martes americana,* and other carnivores in the Sierra Nevada. This method was used on a larger scale in the present study to investigate distribution patterns of medium and large mammals in Douglas-fir forests in northwestern California (Raphael and Barrett 1984). Tracks on a hard surface provided by aluminum track plates differ markedly in size and shape from those in softer substrates such as snow or fine soil, appearing much smaller and providing much more detail. As a result, measurements and drawings in available field guides are unreliable and confusing. Increasing numbers of researchers are using this method and a standardization of the technique is required. Therefore we present a standard method of measurement (Figure 1, Table 1) and a key to distinguish the tracks of medium to large sized mammals from aluminum track plates in the Pacific Northwest. The list of mammals

[1] Accepted for publication April 1987.

presented here is incomplete, as field work was restricted to forested areas of Northwestern California. We recommend that additional tracks and measurements be made available as they are identified.

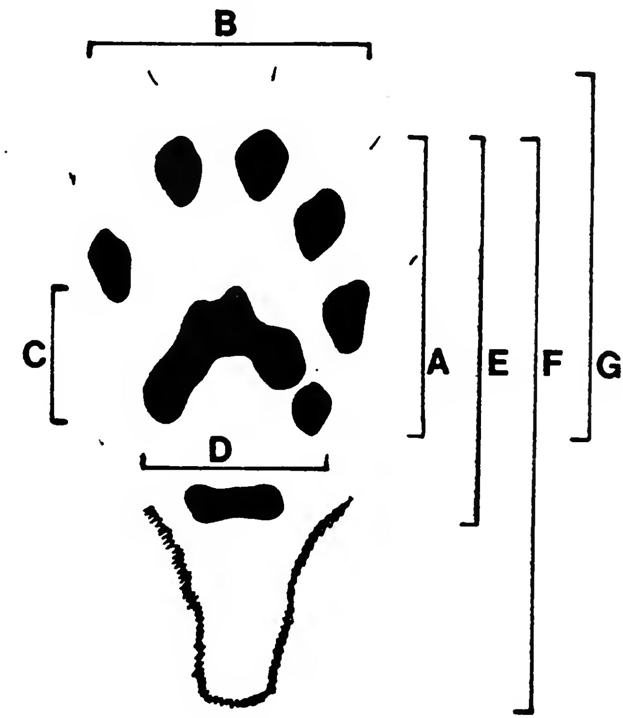

FIGURE 1. Standard measurements taken on all distinct tracks were as follows: A—Longest vertical line drawn from distal edge of foremost toe to back edge of palm pad; B—Horizontal line measuring widest spread of toes; C—Height of the palm pads; D—Width of palm pads; E—Vertical distance from foremost toe to back edge of heel pad; F—Distance from foremost toe to end of heel mark; G—Distance from foremost claw to back of palm pad.

TABLE 1. Means and 95% Confidence Intervals [1] for Track Measurements (mm) [2].

		FORE FOOT				HIND FOOT			
Species		*X*	*N*	*SD*	*95% C.I.*	*X*	*N*	*SD*	*95% C.I.*
Didelphis virginiana	A	20.5	2	0.7	20–21	21.0	1		
	B	35.5	2	0.7	35–36	40.0	1		
	C	10.0	2	1.4	9–11	8.0	1		
	D	16.0	2	1.4	15–17	21.0	1		
Tamias spp.	A	13.3	58	1.6	12.9–13.7	14.5	41	1.1	14.2–14.9
	B	14.7	58	2.0	14.1–15.2	16.6	40	2.2	15.8–17.3
	C	5.4	58	1.0	5.1–5.6	6.0	41	0.8	5.8–6.3
	D	6.5	58	0.8	6.3–6.7	8.3	41	1.0	8.0–8.7
	E	18.1	56	2.1	17.5–18.6				
	F					17.7	3	1.2	17–19

TABLE 1. Means and 95% Confidence Intervals [1] for Track Measurements (mm) [2].—Continued

		FORE FOOT				HIND FOOT			
Species		$\bar{X}$	*N*	*SD*	*95% C.I.*	$\bar{X}$	*N*	*SD*	*95% C.I.*
Spermophilus beecheyi.......	A	20.9	44	1.8	20.3–21.4	24.2	42	2.1	23.5–24.8
	B	19.0	44	2.6	18.2–19.8	23.8	42	4.1	22.5–25.1
	C	8.0	44	1.1	7.7–8.3	9.7	42	1.4	9.3–10.2
	D	10.4	44	1.5	10.0–10.9	14.1	42	1.9	13.5–14.6
	E	28.5	44	2.7	27.6–29.3				
	F					37.9	9	4.0	34.8–41.0
	G	27.9	7	3.8	24.4–31.3	30.9	12	4.2	28.2–33.6
Spermophilus lateralis........	A	14.7	6	2.7	11.9–17.5	16.3	6	1.9	15.3–17.4
	B	13.3	6	2.4	10.8–15.9	14.5	6	1.9	12.5–16.5
	C	5.8	6	1.2	4.6–7.1	6.3	6	1.4	4.9–7.8
	D	6.5	6	1.4	5.1–8.0	8.7	6	1.5	7.1–10.3
	E	20.4	5	1.8	18.2–22.7				
Sciurus griseus	A	30.6	20	1.8	29.7–31.4	35.1	16	2.3	33.9–36.3
	B	26.6	20	2.8	25.3–27.9	35.4	16	6.4	32.0–38.8
	C	11.4	20	1.7	10.6–12.2	13.9	16	2.1	12.8–15.1
	D	13.6	20	1.7	12.7–14.4	19.3	16	2.1	17.8–20.8
	E	42.2	19	2.1	41.1–43.2				
	F					58.0	2	1.4	57–59
	G					41.0	2	1.4	40–42
Tamiasciurus douglasii........	A	20.5	63	2.9	19.7–21.2	21.7	47	2.2	21.1–22.3
	B	20.2	63	2.8	19.5–20.9	23.9	47	4.1	22.7–25.1
	C	7.7	63	1.1	7.5–8.0	8.5	47	1.4	8.1–8.9
	D	9.2	63	1.1	8.9–9.5	11.8	47	1.7	11.3–12.3
	E	26.9	59	3.9	25.9–27.9				
	F					30.8	4	4.0	26–35
	G	26.2	5	5.0	22–33	27.3	10	3.7	24.6–30.0
Glaucomys sabrinus..........	A	14.2	49	1.4	13.8–14.6	14.3	69	1.1	14.1–14.6
	B	12.9	49	2.3	12.2–13.5	15.1	69	2.6	14.5–15.7
	C	5.0	49	0.7	4.8–5.2	6.0	69	1.1	5.8–6.3
	D	6.6	49	0.7	6.4–6.8	9.4	69	1.0	9.1–9.6
	E	19.5	48	1.3	19.1–19.9				
	F					31.3	12	3.3	29.3–33.4
	G	17.0	1			16.3	4	1.5	14–17
Neotoma fuscipes............	A	12.6	29	1.3	12.1–13.1	14.9	24	1.6	14.2–15.6
	B	15.1	29	1.7	14.4–15.7	16.7	24	2.7	15.6–17.9
	C	5.9	29	0.6	5.7–6.1	7.3	24	1.3	6.7–7.8
	D	7.5	29	0.9	7.1–7.8	8.0	24	1.1	7.5–8.4
	E	16.9	29	2.6	15.9–17.9	21.0	19	3.1	19.4–22.5
Erethizon dorsatum	C	47.7	3	2.1	46–50				
	D	35.7	3	2.3	33–37				
Canis latrans.................	A	67.0	1						
	B	50.0	1						
	C	36.0	1						
	D	31.0	1						
	G	71.0	1						
Urocyon cinereoargenteus ...	A	34.7	52	2.7	34.0–35.5				
	B	33.8	52	3.2	32.0–34.7				
	C	12.3	52	2.3	11.7–13.0				
	D	18.7	52	2.2	18.1–19.3				
Ursus americanus............	A	100.6	56	9.9	97.9–103.2	110.0	22	21.2	100.6–119.3
	B	105.3	56	8.8	102.9–107.6	99.4	22	12.4	93.9–104.9
	C	49.1	50	8.9	46.5–56.4	62.6	20	20.7	52.8–72.2
	D	88.9	50	11.1	85.8–92.1	83.9	20	15.3	76.8–91.0
Bassariscus astutus	A	24.0	23	1.7	23.3–24.8				
	B	21.6	23	2.8	20.4–22.8				
	C	12.4	23	1.6	11.7–13.1				

TABLE 1. Means and 95% Confidence Intervals[1] for Track Measurements (mm)[2].—Continued

Species		FORE FOOT				HIND FOOT			
		X	N	SD	95% C.I.	X	N	SD	95% C.I.
	D	14.0	23	1.9	13.1–14.8				
Procyon lotor	A	45.8	5	4.3	40–52	48.8	4	1.5	47–50
	B	36.6	5	3.5	33–42	37.3	4	5.5	32–45
	C	24.2	5	1.6	22–26	26.5	4	1.7	24–28
	D	25.4	5	1.1	24–27	25.3	4	2.8	22–28
	E					67.0	3	7.9	61–76
Martes americana	A	32.5	8	4.5	29.5–35.5	32.8	4	2.2	30–35
	B	30.8	8	5.3	27.2–34.4	31.8	4	4.2	29–38
	C	12.4	8	2.6	10.7–14.1	13.0	4	1.4	12–15
	D	16.0	8	3.8	13.5–18.5	18.3	4	2.6	16–22
	E	45.1	3	8.7	35–50				
Martes pennanti	A	45.9	14	5.1	42.9–48.8	46.7	16	3.5	44.8–48.6
	B	44.4	14	4.9	41.6–47.2	42.9	16	4.9	40.3–45.6
	C	20.5	14	5.0	17.6–23.4	19.6	16	3.5	17.7–21.4
	D	25.4	14	4.3	22.9–27.8	26.6	16	4.1	24.4–28.8
	E	72.5	2	5.0	70–75	58.0	5	7.0	49.4–66.7
Mustela erminea	A	11.0	6	1.7	9.6–12.4	11.0	2	0	11–11
	B	13.5	6	2.0	11.2–15.8	16.0	2	1.0	15–17
	C	4.2	6	1.1	3.4–5.0	5.0	2	0	5–5
	D	5.2	6	1.6	4.0–6.5	5.0	2	0	5–5
	E	19.5	3	1.5	18–21				
Mustela frenata	A	15.4	5	0.5	15–16	14.5	2	0.7	14–15
	B	14.6	5	0.5	14–15	20.5	2	0.7	20–21
	C	6.4	5	0.5	6–7	4.5	2	0.7	4–5
	D	8.4	5	0.9	7–9	8.0	2	0	8–8
	E	19.3	3	0.6	19–20				
Mustela vison	A	26.9	8	2.7	25.1–28.7	28.5	4	2.1	26–31
	B	29.5	8	2.3	28.0–31.0	28.3	4	2.1	26–30
	C	12.0	8	2.1	10.5–13.5	10.3	4	1.7	8–12
	D	13.5	8	2.1	12.0–15.0	14.5	4	1.3	13–16
	E	40.9	8	2.2	39.4–42.4				
Spilogale gracilis	A	17.9	33	2.0	17.2–18.6	19.1	36	2.0	18.4–19.8
	B	16.9	32	2.4	16.1–17.8	17.8	36	2.1	17.1–18.5
	C	7.6	33	1.4	7.1–8.1	8.4	36	1.3	7.9–8.8
	D	10.6	33	2.0	9.9–11.3	12.1	36	2.2	11.3–12.8
	E	23.7	20	2.8	22.4–24.9	25.7	32	2.4	24.9–26.6
Mephitis mephitis	A	24.3	7	1.6	22.8–25.8	29.3	4	4.4	25–33
	B	23.9	7	2.7	21.4–26.3	25.8	4	4.5	22–31
	C	11.6	7	1.3	10.4–12.8	15.5	4	3.5	12–19
	D	17.9	7	2.0	16.0–19.7	19.7	4	4.4	15–24
	E	36.0	2	1.4	35–37	40.3	4	6.1	34–46
Felis concolor	A	77.5	2	17.7	65–90				
	B	74.5	2	7.8	69–80				
	C	40.5	2	7.8	35–46				
	D	50.5	2	0.7	50–51				
Felis rufus	A	37.0	2	0	37–37				
	B	38.5	2	0.7	38–39				
	C	14.5	2	0.7	14–15				
	D	19.5	2	0.7	19–20				

[1] Actual ranges were used when sample size n ≤ 5.
[2] Codes for track measurements follow those outlined in Fig. 1.

METHODS AND MATERIALS

Track stations consisted of two adjacent 814×407×0.6 mm aluminum sheets covered by a thin layer of kerosene soot and baited with a can of tuna pet food (described by Barrett 1983). We checked each of 135 stations for an 8-day period between 1 July and 15 September during 1981, and 166 stations during the same period in 1982 and 1983. Tracks were preserved in the field by firmly pressing transparent tape over them, then transferring the tape to a white data sheet. We recorded up to seven measurements for each track; distinguishing front and hind tracks. Tracks of 23 species were collected.

All track stations were located in the Klamath Mountains in Humboldt, Trinity, and Siskiyou counties in northwestern California. All forest stands were dominated by Douglas-fir, *Pseudotsuga menziesii,* in association with tanoak, *Lithocarpus densiflora,* and Pacific madrone, *Arbutus menziesii.*

KEY TO MAMMAL TRACKS ON SOOTED ALUMINUM TRACKING STATIONS IN THE PACIFIC NORTHWEST

I. FOUR TOES ON FORE FEET (FF) AND HIND FEET (HF) (Figure 2)

A. CANIDAE: General shape is oval with the toes approximately ½ the size of the palm pad. Latter bi- or tri-lobed on posterior border, uni-lobed on anterior end. Fore foot slightly larger than similarly shaped hind foot, toes spread more widely on the forefoot.

1. *Canis latrans* (Coyote): Large dog track, greater than 40 mm in length and width. Claw marks present.
2. *Urocyon cinereoargenteus* (Gray fox): Small dog track in which the claws do not register. Palm pad small, anterior end rarely extends to a line drawn at halfway point on the posterior toes. Posterior end lacks protruding lobes found in bobcat track.

B. FELIDAE: Tracks generally round or slightly oval. Palm pad is larger than that of the Canidae in relation to toes, which are approximately ⅓ the size of the palm print. Tri-lobed on posterior end and bi-lobed on anterior end, the palm pad extends to or past halfway point on posterior toe prints. Claws do not register, prints of fore and hind feet are similar.

1. *Felis concolor* (Cougar): Large cat track greater than 60 mm in length and width.
2. *Felis rufus* (Bobcat): Small round track, about 38 mm in length and width. Posterior end of palm pad exhibits rounded, protruding lobes.

II. FOUR TOES ON FORE FEET, FIVE TOES ON HIND FEET (Figure 3)

A. SCIURIDAE: Squirrels of the Pacific Northwest exhibit following pattern: fore track has four toe pads, followed by three palm pads and two heel pads. Hind track has five toe pads followed by four palm pads in an arc.

1. *Tamias* spp. (Chipmunk): Small squirrel track, similar in size to *Glaucomys sabrinus* and *Spermophilus lateralis.* Species of chipmunk present must be determined through trapping.

FF: Central palm pad appears as one large pad while outer palm pads and heel pad are roughly kidney-shaped.

HF: Palm pads are kidney-shaped and are arranged in an exaggerated crescent shape. Toes irregularly spaced.

2. *Glaucomys sabrinus* (Northern flying squirrel): Size is similar to *Tamias* spp. and *Spermophilus lateralis.*
   - FF: Central palm pad is irregularly shaped or oval and outer pads are oval. Inner heel pad is twice the size of outer pad.
   - HF: Toe and palm pads are distinctly oval. Four palm pads occur in a smooth gradual arc and are evenly spaced. Three inner toes are evenly spaced in a tight linear array.
3. *Spermophilus lateralis* (Golden-mantled ground squirrel): Similar to previous two species.
   - FF: Palm and heel pads are more obviously kidney-shaped than in previous two species and the central pad is T-shaped.
   - HF: Palm pads are triangular in shape, the third palm pad extending forward of the second in a lopsided arc.
4. *Spermophilus beecheyi* (California ground squirrel): Similar in size to *Tamiasciurus douglasii.*
   - FF: Palm pads larger than toe pads; irregularly shaped.
   - HF: Palm pads larger than toe pads; irregularly shaped.
5. *Tamiasciurus douglasii* (Douglas' squirrel): Medium-sized squirrel track, similar in size to *Spermophilus beecheyi.*
   - FF: Palm pads oval to round, similar in size to toe and heel pads.
   - HF: Palm pads and toe pads oval, similar in size to toe pads.
6. *Sciurus griseus* (Western gray squirrel): Largest squirrel track.
   - FF: Palm pads irregularly shaped.
   - HF: Palm pads irregularly shaped. May register a long narrow heel pad on interior side of foot. This is the only squirrel to exhibit this auxillary pad.

B. CRICETIDAE: *Neotoma fuscipes* (Dusky-footed woodrat): Toes leave a distinct figure-eight pattern.
   - FF: Central pad of three palm pads is T-shaped while outer pads are exaggerated kidney-shaped. Three small, round heel pads occur in a row just posterior to palm pads.
   - HF: Three palm pads and three heel pads occur in groups of three, then two, then one. Central palm pad is T-shaped while all others are kidney-shaped.

III. FIVE TOES ON FORE AND HIND FEET (Figure 4)

Members of the families Didelphidae, Erethizontidae, Ursidae, Procyonidae, and Mustelidae exhibit this pattern.

A. *Didelphis virginiana* (Virginia Opossum): This odd track is easily distinguished.
   - FF: Five toes form a half circle around exaggerated crescent-shaped palm pad.
   - HF: First toe is widely separated from the other toes, points below palm pad on inner side of foot.

B. *Erethizon dorsatum* (Porcupine): This odd track is immediately recognizable. Toes rarely are evident; large, oval palm pads have a pebbled texture. Fore and hind prints are similar.

C. *Ursus americanus* (Black bear): Largest track in the Pacific northwest. Toes form gentle arc over large palm pad.
FF: One large crescent-shaped palm pad.
HF: One large, elongate palm pad.

D. *Bassariscus astutus* (Ringtail): Fore and hind feet leave similar impressions. Palm pad registers one large pad; very small second pad may appear posteriorly near the small first toe.

E. *Procyon lotor* (Raccoon): Five elongated toe impressions.
FF: The palm pad is thick and wide and usually appears as three to five large pads.
HF: Large palm pad is crescent shaped, may appear as a multi-lobed pad or four distinct pads. Smaller pad appears posterior to the palm pad on the outer side of the foot.

F. *Martes pennanti* (Fisher): Large weasel-like track greater than 40 mm in length and width. Toe prints are circular to oval, palm pad leaves a crescent-shaped impression.
FF: Small secondary palm pad occurs below first toe. A wide, thin heel pad lies posterior to the crescent-shaped palm pad.
HF: Similar to forefoot; no heel pad.

G. *Martes americana* (Marten): Similar to the fisher track, a male marten's track may overlap in size with a female fisher track. Marten track generally more hairy than fisher track, small first toe may not leave an impression. The palm pads register as three distinct pads.

H. *Mustela vison* (Mink), *Mustela frenata* (Long-tailed weasel), *Mustela erminea* (Ermine): These tracks exhibit the same pattern and may overlap in size. Five toes usually are evident though the first toe is smaller than the others. There are three palm pads, and heel pads rarely appear on forefoot track, resulting in similar fore and hind tracks.

I. *Spilogale gracilis* (Western spotted skunk):
FF: Three to four pads, central pad heart-shaped. Two small heel pads register posterior to the palm pads. Claw marks occur well past the toes.
HF: Typically show four palm pads and two heel pads. Larger palm pad is heart-shaped while other pads are oblong and more elongate than in the fore foot. Claw marks appear close to the toes.

J. *Mephitis mephitis* (Striped skunk):
FF: Five toes are oblong, large palm pad is wider than long. Elongated claws always leave scratch marks well past toes.
HF: Large palm pad is adjoined by one or two round heel pads.

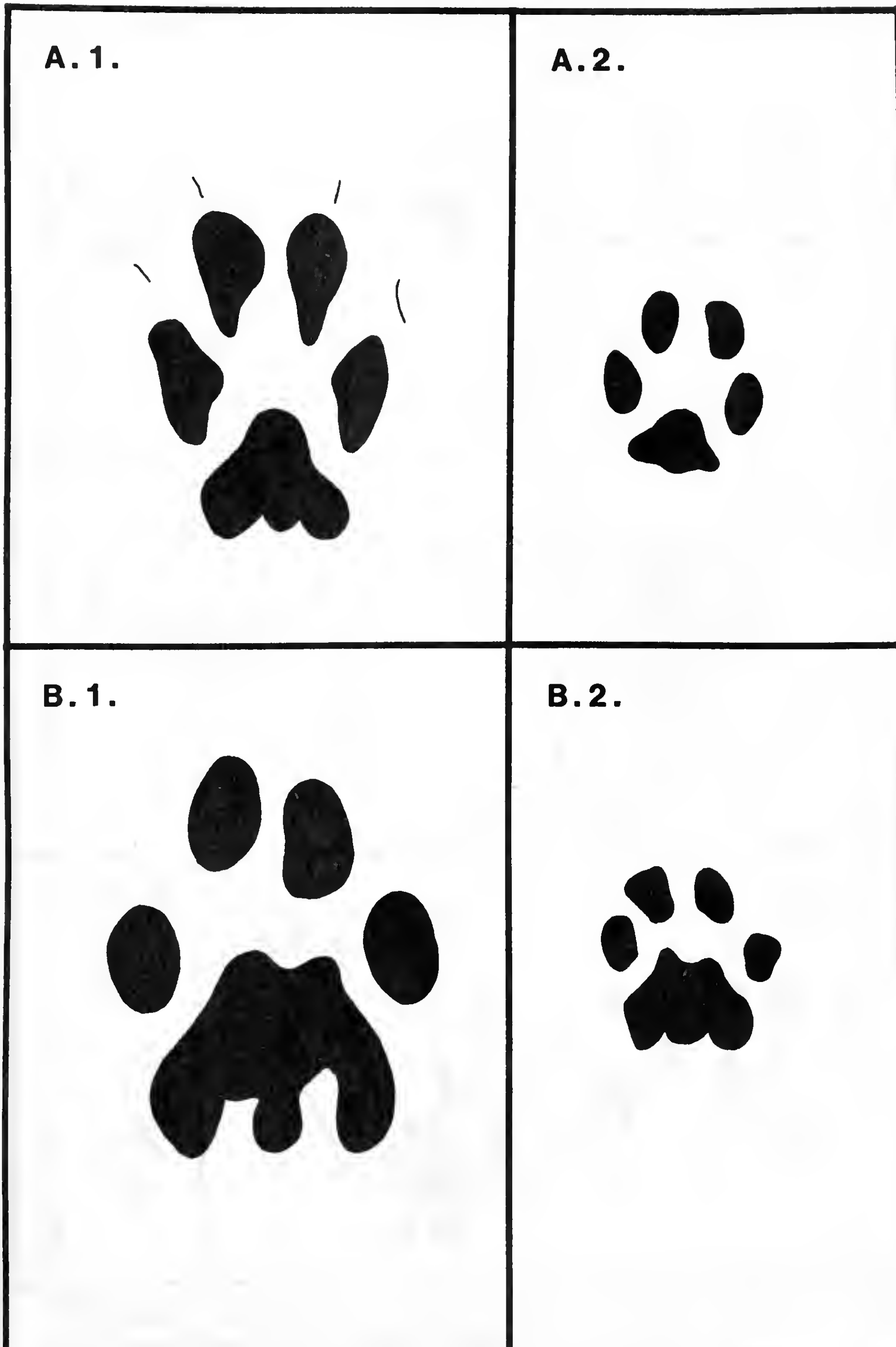

FIGURE 2. Mammals with four toes on fore feet and hind feet. A.1. *Canis latrans* A.2. *Urocyon cinereoargenteus* B.1. *Felis concolor* B.2. *Felis rufus.*

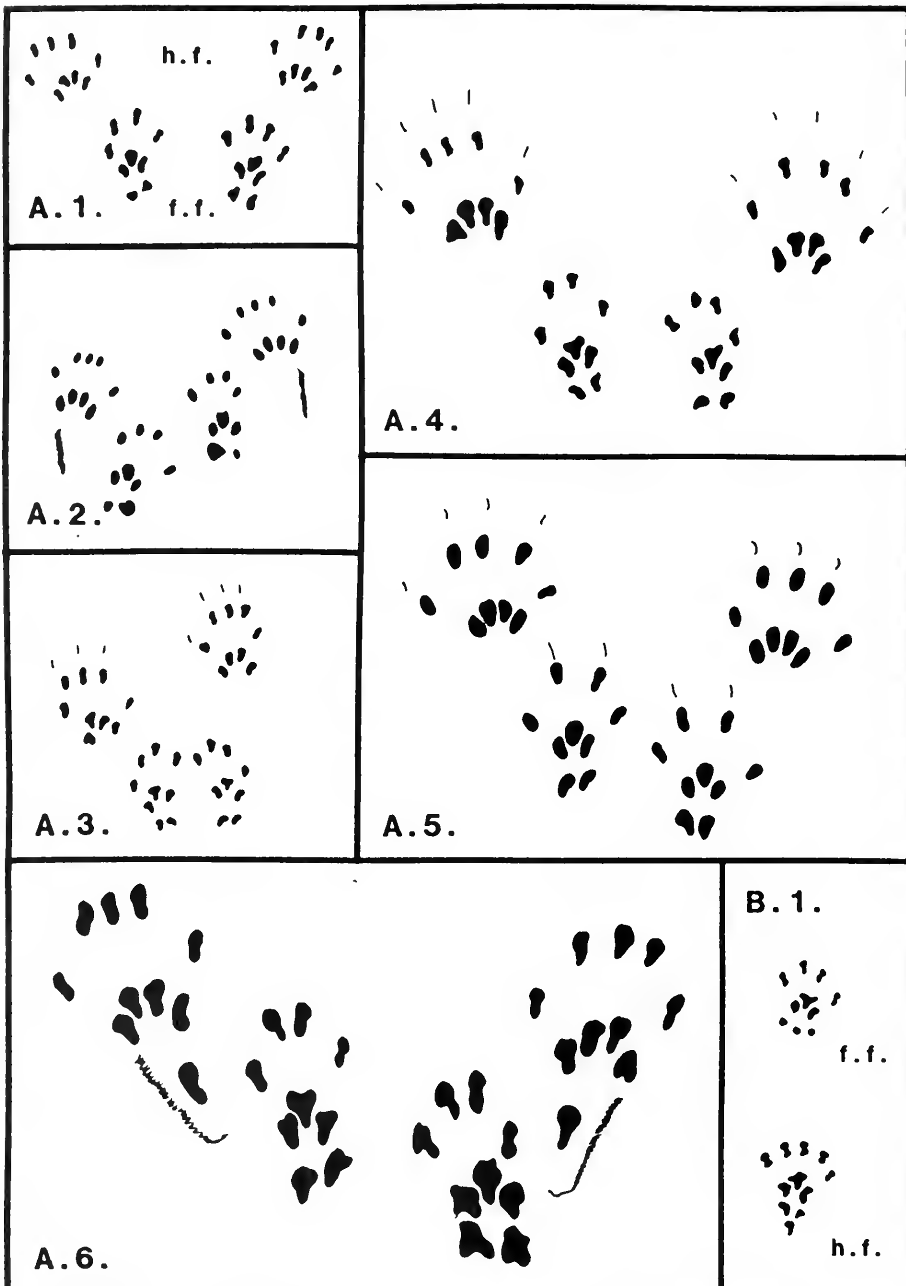

FIGURE 3. Mammals with four toes on fore feet and five toes on hind feet. A.1. *Tamias* spp. A.2. *Glaucomys sabrinus* A.3. *Spermophilus lateralis* A.4. *Spermophilus beecheyi* A.5. *Tamiasciurus douglasii* A.6.*Sciurus griseus* B.1. *Neotoma fuscipes.* Tracks A.2. through A.6. exhibit the same pattern as that of A.1. (f.f. = fore feet; h.f. = hind feet).

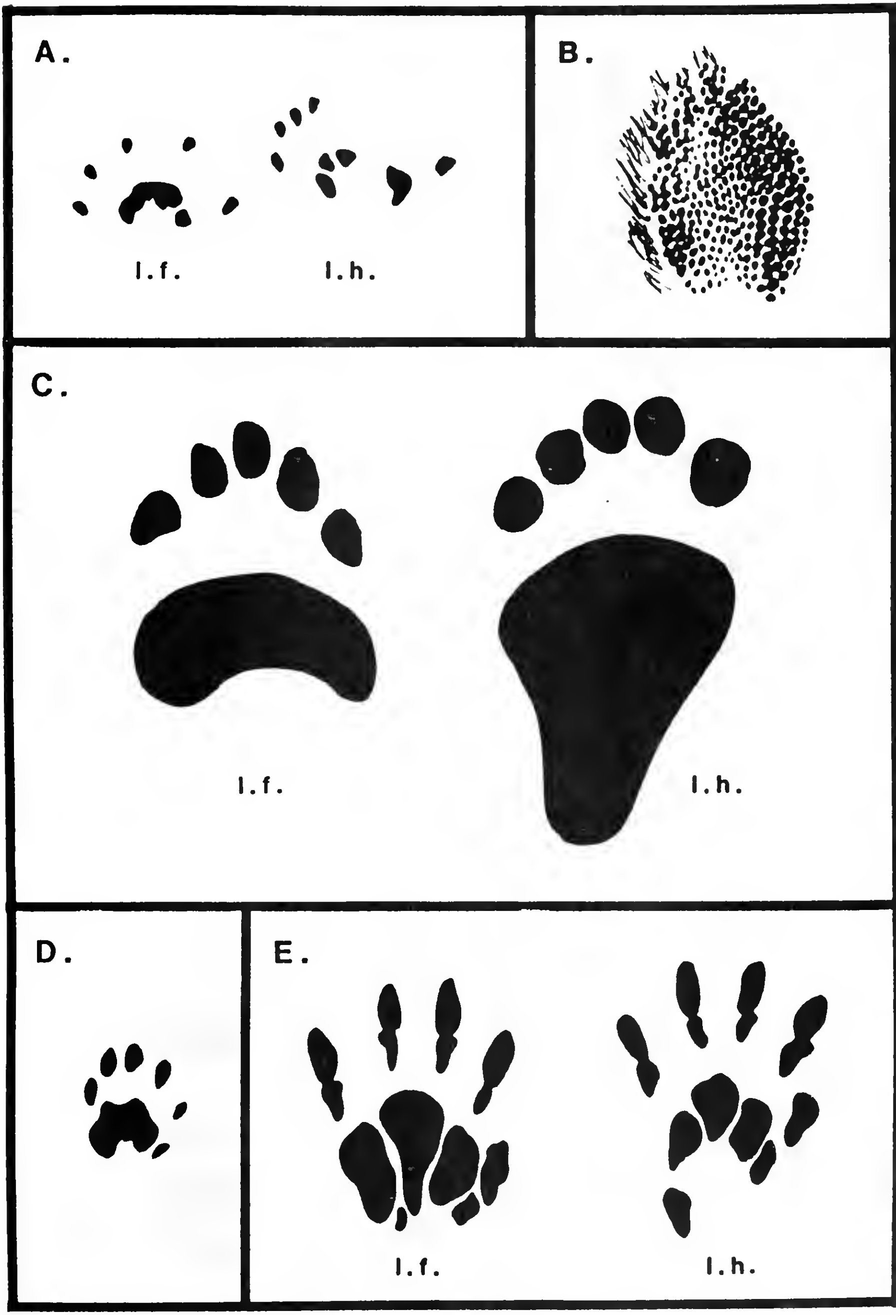

FIGURE 4. Mammals with five toes on fore and hind feet. A. *Didelphis virginiana* B. *Erethizon dorsatum* C. *Ursus americanus* D. *Bassariscus astutus* E. *Procyon lotor.* (continued)

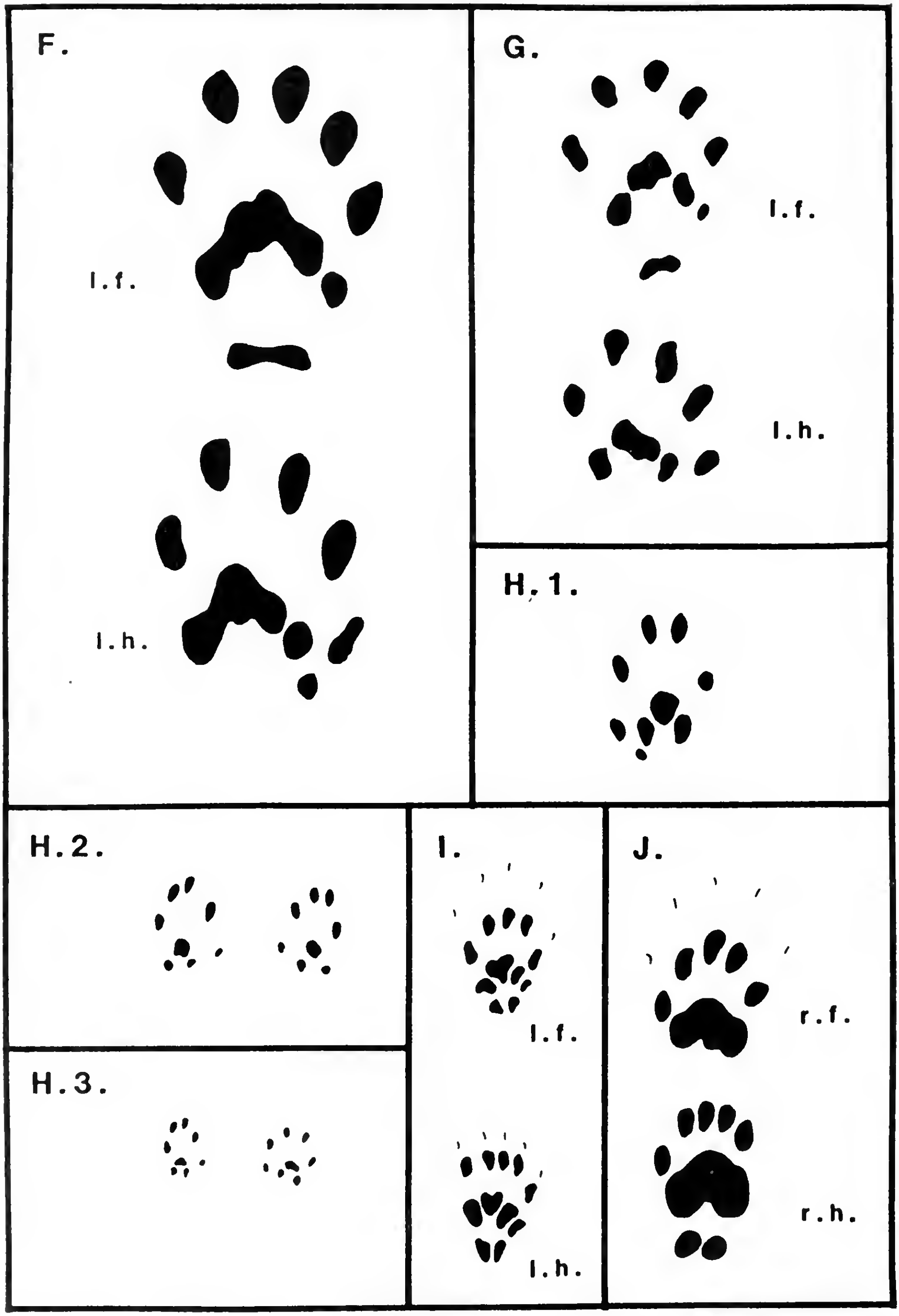

FIGURE 4. (continued) F. *Martes pennanti* G. *Martes americana* H.1. *Mustela vison* H.2. *Mustela frenata* H.3. *Mustela erminea* I. *Spilogale gracilis* J. *Mephitis mephitis.* (l.f. = left fore; l.h. = left hind; r.f. = right fore; r.h. = right hind).

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FEEDING ECOLOGY OF TEN SPECIES OF ROCKFISHES (SCORPAENIDAE) FROM THE GULF OF ALASKA [1]

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Summer diets of ten species of rockfish collected in the inshore waters of southeastern Alaska during 1980–82 are presented and compared with studies of rockfish food habits from other regions of the Pacific coast.

All species utilized a variety of food and usually capitalized on the most accessible prey types. The bottom-dwelling species were most dependent on detrital based food sources, whereas schooling or pelagic rockfish consumed substantial quantities of zooplankton and fish. A number of common food items (e.g., crabs, shrimps, brittle stars, and fish) were shared by the bottom-dwellers. Pacific sand lance, a key component in the inshore forage base, was the dominant food of the more pelagic black, yellowtail and widow rockfishes. Two other pelagic schoolers, the Puget Sound and dusky rockfishes ate significant amounts of pelagic crustacea and gelatinous zooplankton.

Dietary overlaps for these common pelagic and demersal rockfish species were strong during the three summers of observation. Geographic variations in diet suggested that rockfish were capable of substituting prey as long as these foods are of the same general size and type.

INTRODUCTION

The assemblage of reef-dwelling fishes that inhabit the exposed waters of the Gulf of Alaska adjacent to the Alexander Archipelago (Figure 1) are visually dominated by rockfish of the genus *Sebastes* (Carlson and Straty 1981; Rosenthal et al. 1982). Rockfish landings dominate commercial bottomfish catches off California, Oregon and Washington (Gunderson and Lenarz 1980). This group of fish is also important to west coast sport or party-boat fleets (Miller and Geibel 1973). Over the past few decades increased fishing effort has resulted in stock depletions, and produced changes in the size structure of rockfish populations (Love 1980). Despite their commercial value, relatively little information is available in the literature on the foods used by rockfish. Information on the types of prey consumed by this group is critical to understanding the functional role of *Sebastes* in the nearshore system.

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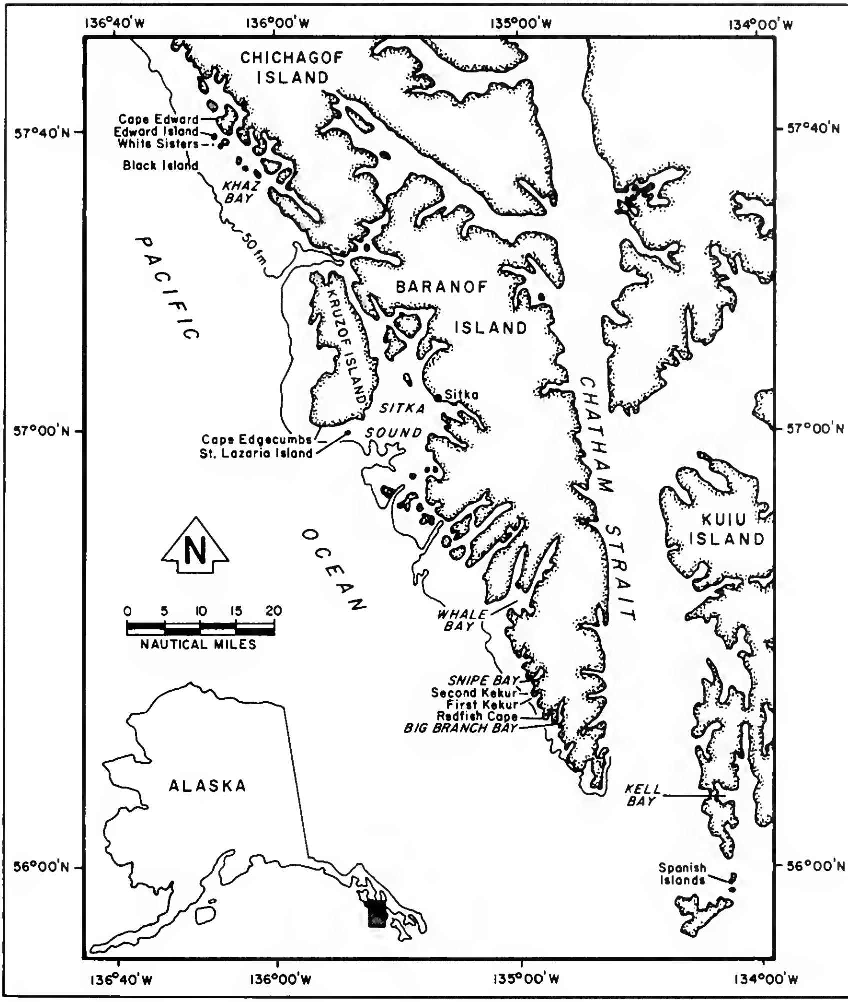

FIGURE 1. Primary study region in the outside waters of southeast Alaska.

We present data on the summer food habits of ten species of rockfish found off the west coast of southeast Alaska. Trophic information on co-occurring species was obtained simultaneously to provide preliminary information on niche breadth and dietary overlap. Differences in rockfish diet along the west coast of North America has been linked to the availability of certain kinds of prey and to changes in species composition of the *Sebastes* community at different latitudes. As most of the shallow exposed waters of the Gulf of Alaska remain in a relatively pristine state, with large stocks of inshore rockfish (Rosenthal et al. 1982), we were able to study fish foraging behavior prior to intense exploitation.

MATERIALS AND METHODS

Samples of rockfish were obtained during the summers of 1980–82 while conducting resource assessment studies in the outside waters of southeast Alaska. Automatic electric jigging machines on the 47-ft *SEARCHER* were the major fishing gear (Rosenthal 1982). Additional specimens were taken with hand spears while scuba diving. All fish collections and samples were taken at depths between 25 and 110 m.

Rockfish were identified to species, weighed and measured (fork length) to the nearest centimeter. The stomach contents of each fish were removed at the time of capture and either preserved in 10 percent buffered formalin or examined fresh. When a rockfish regurgitated food at the sea surface, the contents were also recorded. Preserved stomachs were rinsed in fresh water, and the percent fullness was estimated before the contents were removed. Food items were examined under dissecting microscope and identified to the lowest possible taxonomic level. The number, stage of digestion and percent volume of the various prey taxa were recorded for each stomach. Percent volume was used to estimate the amount of a prey item in a stomach when counts were not possible due to advanced stage of digestion. All data were recorded using the NOAA, NODC (1981) taxonomic code. The data were analyzed at the Computer Center of the NMFS Auke Bay Laboratory. We used the program ECO-INDEX to estimate index values (Vadopich and Hoover 1981).

Frequency of occurrence was determined for each species on the basis of percentage of samples in which a specific prey type occurred. The percent total count was arrived at by dividing total number of individuals in a prey taxa by total number of individuals counted in all prey groups. A third parameter recorded was percent volume. These three measures were used in calculating an Index of Relative Importance (IRI) as described by Pinkas et al. (1971). Prey categories were ranked according to the computed IRI values and the percentages of the total IRI. Prey categories with the highest numerical rank were considered major food items in the diets of these fish. In this way, more representative prey are not dominated by numerically rare but high biomass prey, or by numerically abundant prey which may contribute little to the total biomass of prey.

The ten rockfish species were classified as pelagic or demersal for comparison of dietary indices. Classification was based on the position and location of these species in the water column as observed by scuba divers in the nearshore waters of southeast Alaska. Pelagic or schooling species included black, yellowtail, dusky, widow, and Puget Sound rockfishes. China, yelloweye, quillback, copper, and tiger rockfishes were considered demersal or bottom-dwelling species.

Niche breadth for the 10 species of rockfishes was measured with three indices: Levin's niche breadth (Hurlbert 1978), Shannon-Weaver niche breadth, and Simpson's niche breadth (Petraitis 1979) (Appendix 1). The three indices were used to indicate the degree to which a species was a dietary generalist or specialist.

Dietary overlap for schooling and demersal species was measured with three overlap indices: Schoener's niche overlap, Levin's directional overlap, and Lloyd's directional overlap (Hurlbert 1978) (Appendix 2). Schoener's niche overlap is a measure of "dietary similarity"; similarity in resources consumed, not similarity in consumer electivity. Levin's directional overlap measures the degree species X impinges on species Y and vice versa. Lloyd's directional overlap was re-expressed in percentages to simplify its interpretation: species X or Y consumes * percent of the total volume of dietary items that species X and Y have in common.

The overlap indices used do not account for variation in the food resources because data on the availability of food resources in the environment were not obtained. The availability of food resources was therefore assumed equal. Overlap indices measure the degree that two species share a group of common resources or utilize the same parts of the environment. Overlap measures are functions of the proportion of food type *i* in the diet of consumer *j*. These proportions depend on the availability of food resources and the consumers' electivity. Differences in resource abundance between environments can yield misleading conclusions when comparing species inhabiting different communities. Similar species may not bear any resemblance if they occur in considerably different environments. Dissimilar species may appear quite similar because of species-environment interactions (Lawlor 1980). Dietary indices for schooling and demersal species were therefore examined separately.

RESULTS

A total of 1,030 rockfish, representing ten different species was captured and examined for food items. Prey of various stages of digestion and size were found in 635 of the specimens (Figure 2). All collections were made during daylight between 0800 and 2000 hrs.

Black Rockfish, *Sebastes melanops*

Black rockfish was observed feeding just beneath the sea surface to depths of at least 40 m. Fish was a key component of the summer diet, and occurred in 98% of the samples (total prey volume of 90%; Table 1). Pacific sand lance, *Ammodytes hexapterus,* (Figure 2) was the most important forage species, and accounted for 67% of the total prey volume and occurred in 60% of the 142 stomachs that contained food (Table 1). Juvenile sablefish, *Anoplopoma fimbria,* was eaten by 8.5% of the specimens, and accounted for 9.1% of the total percent volume. Other fish identified from stomach contents included Pacific herring, *Clupea harengus pallasi;* juvenile greenling, *Hexagrammus* spp.; juvenile salmon, *Oncorhynchus* spp., and Puget Sound rockfish, *Sebastes emphaeus.* Unidentified fish remains accounted for another 10.8% of total percent volume.

Zooplankton was also present in the food samples. Crustacea, particularly brachyuran crab larvae (frequency of occurrence 14.8%), and mysids (5.6%) were the predominant invertebrate groups. Other zooplanktors in the diet included pteropods, particularly *Limacina* sp.; gammarid amphipods; caridean shrimps and thalaceans (Table 1). In all, 38 different prey taxa occurred in the summer diet of *S. melanops.*

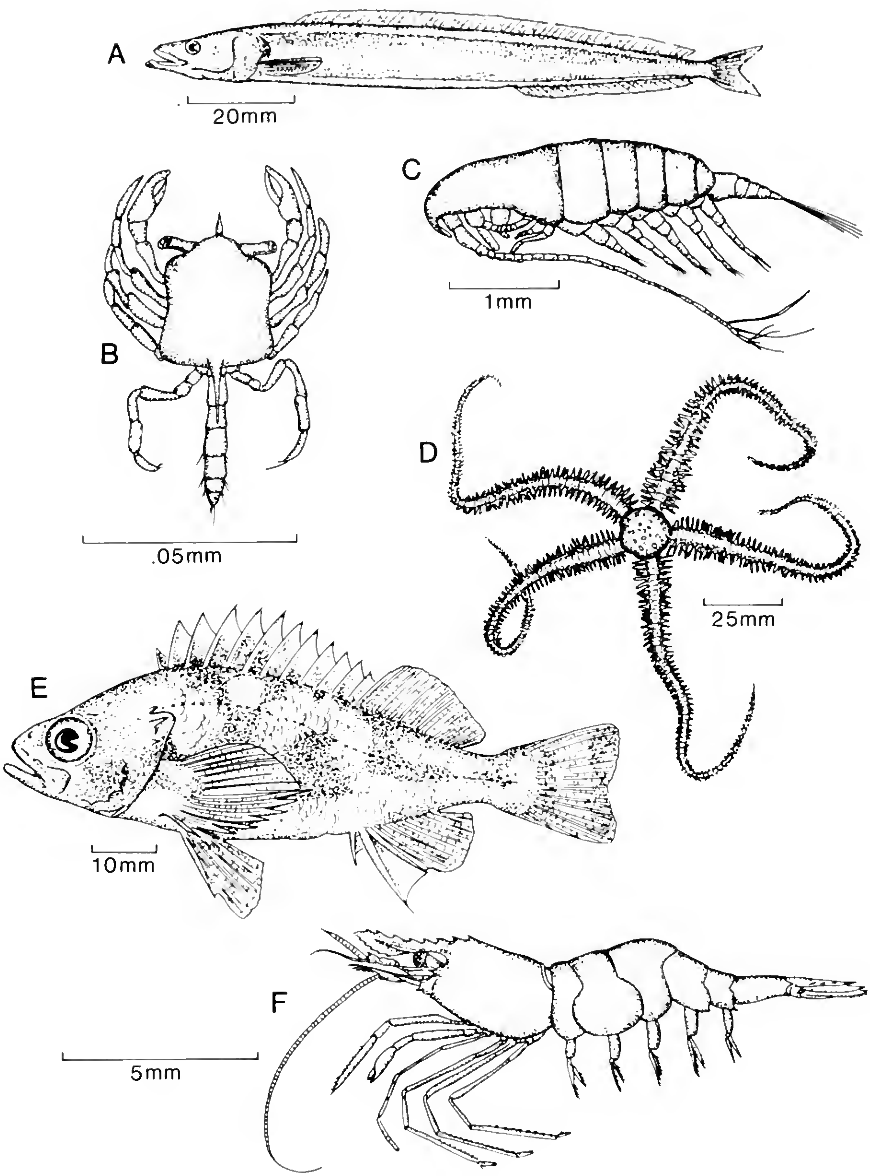

FIGURE 2. Representative prey items in the summer diets of ten species of rockfishes collected in the inshore waters of southeastern Alaska. A. Pacific sand lance; B. brachyuran crab; C. calanoid copepod; D. brittle star; E. Puget Sound rockfish; and F. caridean shrimp.

The importance of fish in the diet of the black rockfish has been substantiated by other investigators. For example, Rosenthal (1983) found that 51% of the black rockfish captured in Prince William Sound, Alaska, had eaten Pacific sand lance. Leaman (1980) observed that 35% of the black rockfish taken in the outside waters of southern British Columbia had consumed herring. Additional studies by Moulton (1977) in northern Puget Sound concluded that 53% of the *S. melanops* examined had fish remains in their stomachs. Further south off Oregon, Steiner (1978) found that smelt (*Allosmerus* spp.), herring, anchovy (*Engraulis mordax),* and juvenile rockfishes comprised 71.4% of the total volume of black rockfish stomachs.

TABLE 1. Food of the Black Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Phaeophyta	0.007	0	0.0000	20.00	0.14	0.0018	0.1244
Laminariales	0.007	0	0.0000	20.00	0.14	0.0018	0.1244
Nereocystis luetkeana	0.007	1	0.0003	80.00	0.56	0.0071	0.5202
Siphonophora	0.007	1	0.0003	49.50	0.35	0.0044	0.3304
Beroidae	0.007	1	0.0003	10.00	0.07	0.0009	0.0846
Gastropoda	0.007	1	0.0003	0.50	0.00	0.0000	0.0255
Limacinidae	0.021	296	0.0940	40.50	0.29	0.0036	20.6148
Gymnosomata (Clione)	0.007	200	0.0635	10.00	0.07	0.0009	4.5349
Crustacean remains	0.028	3	0.0010	114.50	0.81	0.0101	3.1182
Barnacle cirri	0.007	1	0.0003	1.00	0.01	0.0001	0.0286
Mysidacea	0.021	489	0.1553	110.25	0.78	0.0097	34.8653
Mysidae	0.035	1315	0.4176	283.45	2.00	0.0250	155.8585
Tanaidacea	0.007	1	0.0003	0.25	0.00	0.0000	0.0239
Idoteidae	0.007	1	0.0003	37.50	0.26	0.0033	0.2556
Isopoda	0.007	1	0.0003	1.00	0.01	0.0001	0.0286
Idotea fewkesi	0.007	1	0.0003	2.00	0.01	0.0002	0.0348
Gammaridae	0.042	16	0.0051	22.95	0.16	0.0020	3.0037
Hyperiidae	0.021	5	0.0016	0.85	0.01	0.0001	0.3513
Caprellidae	0.007	4	0.0013	2.50	0.01	0.0001	0.1050
Caridea	0.021	10	0.0032	9.00	0.06	0.0008	0.8389
Anomuran	0.007	4	0.0013	1.00	0.01	0.0001	0.0957
Paguridae	0.007	3	0.0010	0.50	0.00	0.0000	0.0702
Brachyura (larvae)	0.148	183	0.0581	112.15	0.79	0.0099	100.5976
Salpidae	0.007	0	0.0000	15.00	0.11	0.0013	0.0933
Fritillariidae	0.007	5	0.0016	3.00	0.02	0.0003	0.1305
Fish remains	0.239	10	0.0032	1223.25	8.61	0.1081	266.3982
Clupea harengus	0.014	2	0.0006	100.00	0.70	0.0088	1.3339
Juvenile salmonidae	0.021	4	0.0012	132.50	0.93	0.0117	1.2853
Sebastes emphaeus	0.007	1	0.0003	40.00	0.28	0.0035	0.2713
Juvenile Hexagrammidae	0.007	1	0.0003	75.00	0.53	0.0066	0.4890
Hexagrammos decagrammus	0.007	1	0.0003	40.00	0.28	0.0035	0.2713
Anoplopoma fimbria	0.085	28	0.0089	1034.00	7.28	0.0914	84.7222
Ammodytes hexapterus	0.599	544	0.1728	7584.75	53.41	0.6702	5045.7208
Gelatinuous zooplankton, unid.	0.014	0	0.0000	33.75	0.24	0.0030	0.4200
Spines, unid.	0.007	2	0.0006	1.50	0.01	0.0001	0.0541
Scale, unid.	0.042	11	0.0035	5.75	0.04	0.0005	1.6907
Stone	0.007	1	0.0003	5.00	0.04	0.0004	0.0535
Organic matter	0.085	2	0.0006	94.60	0.67	0.0084	7.6004
Total	1.000	3149	1.0000	11317.50	79.70	1.0000	5736.1698

142 = Total number of stomachs
38 = Number of prey taxa

Yellowtail Rockfish, *Sebastes flavidus*

Yellowtail rockfish was found in offshore waters near the surface to depths of 110 m. Fish was the most important prey in the summer diets of *S. flavidus.* Pacific sand lance occurred in 44.6% of the 112 stomachs (Table 2). The IRI for this food category was 2,645.8, and the percent total volume was 47.9. Juvenile sablefish; larval gadids; unidentified greenlings and rockfish were also present. Unidentified fish remains accounted for another 11.6% of the total volume, and occurred in 23.0 of the specimens.

Frequency of occurrence and percent total volume was also significant for brachyuran crab larvae (36.6% and 7.9%, respectively), mysids (16.1% and 10.8%), pteropods *(Limacina* and *Clione),* and caridean shrimp (Table 2).

TABLE 2. Food of the Yellowtail Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Polychaete	0.009	2	0.0006	20.00	0.18	0.0023	0.2661
Gymnosomata (Clione)	0.009	260	0.0830	50.00	0.45	0.0059	7.9371
Limacina	0.072	833	0.2660	462.50	4.13	0.0541	199.7238
Crustacean remains	0.116	22	0.0070	81.25	0.73	0.0095	19.1988
Mysidacea	0.009	0	0.0000	1.00	0.01	0.0001	0.0104
Mysidae	0.152	1015	0.3242	921.50	8.23	0.1079	655.8381
Amphipoda	0.009	2	0.0006	50.00	0.45	0.0059	0.5798
Gammaridae	0.071	20	0.0064	8.75	0.08	0.0010	5.2945
Hyperiidae	0.036	5	0.0016	6.50	0.06	0.0008	0.8422
Caridea	0.080	15	0.0048	169.50	1.51	0.0198	19.7989
Anomuran (larvae)	0.009	53	0.0169	4.00	0.04	0.0005	1.5532
Paguridae (larvae)	0.009	8	0.0026	8.00	0.07	0.0009	0.3118
Brachyura (larvae)	0.366	464	0.1482	676.00	6.04	0.0792	832.2721
Salpidae	0.018	3	0.0010	50.00	0.45	0.0059	1.2166
Fish remains	0.232	26	0.0083	991.75	8.85	0.1161	288.8647
Gadid Larvae	0.063	35	0.0112	207.50	1.85	0.0243	22.1725
Sebastes sp.	0.009	1	0.0003	20.00	0.18	0.0023	0.2376
Hexagrammidae	0.009	1	0.0003	60.00	0.54	0.0070	0.6558
Anoplopoma fimbria	0.045	10	0.0032	497.00	4.44	0.0582	27.4065
Ammodytes hexapterus	0.446	356	0.1137	4090.25	36.52	0.4790	2645.77540
Gelatinous Zooplankton, unid.	0.018	0	0.0000	27.00	0.24	0.0032	0.5646
Organic matter	0.054	0	0.0000	137.50	1.23	0.0161	8.6254
Total	1.000	3131	1.0000	8540.00	76.25	1.0000	4739.1459

112 = Total number of stomachs
22 = Number of prey taxa

Moulton (1977) found fish remains in 52.5% of the stomachs from Puget Sound. However, megalops and zoeal crab larvae occurred most frequently (66.5%). Euphausiids, mysids and chaetognaths comprised the other major food categories. Pereyra et al. (1969) found lanternfish, sergestid shrimps and euphausiids in the stomachs of yellowtail rockfish taken while trawling at depths of 58 to 70 m, in the Columbia River Canyon off Washington. These studies in Washington and observations made off southeast Alaska indicate that *S. flavidus* forage throughout the water column, with fish being the principal food item.

Dusky Rockfish, *Sebastes ciliatus*

Dusky rockfish pick and seize food items that are either drifting or suspended in the water column. Off southeast Alaska, the diet was heavily comprised of invertebrate zooplankton (Table 3). Brachyuran crab larvae, both megalops and zoea, were the most important food items taken during summer (Figure 2). Crab larvae occurred in 34% of the 44 stomachs containing food, and comprised 75.6% of the total number of prey counted. Total volume of crab larvae was 25.4% with an IRI of 3,442.9. Salps, hyperiid and gammarid amphipods, calanoid copepods, crustacean remains, jellyfish and pteropods were also consumed. Fish were rarely eaten. For example, the frequency of sand lance was only 6.8% in these samples. Simenstad et al. (1977) reported that mysids, amphipods, copepods, polychaete worms and sand lance were found in the stomachs of *S. ciliatus* captured in the shallow subtidal zone off Amchitka Island. Northeast of the Aleutian Chain at latitude 60°N in Prince William Sound, Rosenthal (1983) recorded the major prey groups from stomach samples of dusky rockfish to be copepods, pteropods, larval fishes, mysids, chaetognaths and tomopterid worms.

TABLE 3. Food of the Dusky Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Scyphozoan medusae	0.045	2	0.0058	21.50	0.49	0.0209	12.1308
Hoplonemertea	0.023	2	0.0058	0.00	0.00	0.0000	1.3214
Polychaeta	0.068	2	0.0058	1.75	0.04	0.0017	5.1225
Limacina	0.045	3	0.0087	5.25	0.12	0.0051	6.2809
Crustacea remains	0.114	2	0.0058	29.25	0.66	0.0284	38.8773
Copepoda	0.045	4	0.0116	25.75	0.59	0.0250	16.6490
Mysidacea	0.023	1	0.0029	2.00	0.05	0.0019	1.1020
Mysidae	0.045	2	0.0058	0.70	0.02	0.0007	2.9516
Amphipoda	0.023	2	0.0058	0.25	0.01	0.0002	1.3765
Gammaridae	0.114	5	0.0145	15.25	0.35	0.0148	33.3417
Hyperiidae	0.114	12	0.0349	11.00	0.25	0.0107	51.7765
Caprellidae	0.023	1	0.0029	1.25	0.03	0.0012	0.9365
Caridea	0.023	1	0.0029	1.25	0.03	0.0012	0.9365
Anomuran (larvae)	0.023	2	0.0058	0.50	0.01	0.0005	1.4317
Brachyura (larvae)	0.341	260	0.7558	261.75	5.95	0.2541	3442.9778
Salpidae	0.114	22	0.0640	30.30	0.69	0.0294	106.1034
Fish remains	0.091	1	0.0029	145.00	3.30	0.1408	130.6215
Gadid larvae	0.045	4	0.0116	77.00	1.75	0.0748	39.2660
Ammodytes hexapterus	0.068	8	0.0233	172.00	3.91	0.1670	129.7133
Gelatinous zooplankton unid.	0.273	4	0.0116	122.25	2.78	0.1187	355.4106
Scale, unid.	0.045	4	0.0116	10.50	0.24	0.0102	9.9191
Organic material	0.228	0	0.0000	95.50	2.17	0.0928	175.5295
Total	1.000	344	1.0000	1030.00	23.41	1.0000	4563.7762

44 = Total number of stomachs
22 = Number of prey taxa

Widow Rockfish, *Sebastes entomelas*

Widow rockfish stomachs contained substantial numbers of fish, crustaceans and gelatinous plankton (Table 4). A total of 23 different prey taxa were found in the 27 stomachs containing food. Fish accounted for 78.8% of the total volume. A major prey item both by number and percent volume was sand lance with an IRI of 1014.2 (Table 4). Most of the sand lance were eaten whole. Juvenile sablefish and walleye pollock, *Theragra chalcogramma,* also occurred in these same stomach samples.

TABLE 4. Food of the Widow Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Caprellidae	0.037	0	0.0000	1.25	0.05	0.0006	0.2055
Cnidaria	0.074	1	0.0044	25.00	0.93	0.0111	11.4693
Physonectid colony	0.037	0	0.0000	22.50	0.83	0.0100	3.6992
Aequorea aequorea	0.037	3	0.0132	75.00	2.78	0.0333	17.2039
Polychaete	0.037	0	0.0000	7.50	0.28	0.0033	1.2331
Limacinidae	0.074	5	0.0219	5.25	0.19	0.0023	17.9706
Octopus sp.	0.037	1	0.0044	10.00	0.37	0.0044	3.2685
Crustacean remains	0.111	1	0.0044	92.75	3.44	0.0412	50.6199
Copepoda	0.037	1	0.0044	0.25	0.01	0.0001	1.6655
Mysidae	0.111	3	0.0132	3.00	0.11	0.0013	16.0996
Gammaridae	0.074	3	0.0132	1.75	0.06	0.0008	10.3220
Hyperiidae	0.148	87	0.3816	9.00	0.33	0.0040	571.2208
Caridea	0.037	0	0.0000	7.50	0.28	0.0033	1.2331
Brachyura (larvae)	0.111	4	0.0175	2.75	0.10	0.0012	20.8495
Salpidae	0.111	7	0.0307	53.50	1.98	0.0237	60.5006
Fish remains	0.185	4	0.0175	1016.00	37.63	0.4510	867.6818
Theragra chalcogramma	0.074	8	0.0351	109.00	4.04	0.0484	61.8319
Anoplopoma fimbria	0.037	1	0.0044	74.25	2.75	0.0330	13.8317
Ammodytes hexapterus	0.259	31	0.1360	575.00	21.30	0.2552	1014.2443
Gelatinous zooplankton, unid.	0.185	66	0.2895	95.50	3.54	0.0424	614.5673
Gill, unid.	0.037	1	0.0044	0.50	0.02	0.0002	1.7066
Eggs, unid.	0.037	1	0.0044	0.30	0.01	0.0001	1.6738
Organic material	0.022	0	0.0000	65.20	2.41	0.0289	64.3165
Total	1.000	228	1.0000	2252.75	83.44	1.0000	3427.4148

27 = Total number of stomachs
23 = Number of prey taxa

The frequency of crustacea zooplankton (62.9%) was also high. Hyperiid amphipods were the numerical dominant from this group. Others included brachyuran crab larvae, mysids, gammaridean amphipods and caridean shrimps.

Gelatinous plankton—a general category containing groups such as *Aequorea* (a cnidarian), physonectid colonies, salps, and scyphozoan medusae or "jellyfish"—occurred frequently enough to have a combined IRI of 707.4 (Table 4).

Gunderson (pers. comm.) has found that widow rockfish aggregate off bottom in large schools during nocturnal hours, but disperse to feed during daylight. Widow rockfish feed in the daytime off southeast Alaska, as a high percentage of specimens captured during this time period had fresh food in their stomachs.

Puget Sound Rockfish, *Sebastes emphaeus*

Puget Sound rockfish school off bottom in the water column during daylight hours and feed on a variety of small zooplankters. Seventeen different prey types were identified from the stomach contents of 19 specimens that retained food in their stomachs after capture (Table 5). Calanoid copepods dominated these samples both in number, frequency and percent volume (Figure 2). The IRI for copepods alone was 3206.8. Other important prey included gammarid amphipods, unidentified gelatinous plankton, physonectid (siphonophore) fragments, pteropods, salps, mysids and fish eggs.

TABLE 5. Food of the Puget Sound Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Physonectid colony	0.053	1	0.0083	22.50	1.18	0.0244	17.1763
Calliostoma annulatum	0.053	1	0.0083	25.00	1.32	0.0271	18.6014
Margarites sp.	0.053	1	0.0083	10.00	0.53	0.0108	10.0504
Margarites puppillus	0.053	1	0.0083	15.00	0.79	0.0162	12.9007
Crustacean remains	0.105	1	0.0083	8.00	0.42	0.0087	17.8205
Cladocera	0.053	1	0.0083	30.00	1.58	0.0325	21.4518
Ostracoda	0.105	4	0.0331	6.25	0.33	0.0068	41.9236
Copepoda	0.368	70	0.5785	269.50	14.18	0.2919	3206.7958
Mysidae	0.053	1	0.0083	7.50	0.39	0.0081	8.6252
Gammaridae	0.211	11	0.0909	57.50	3.03	0.0623	322.5033
Caprellidae	0.211	3	0.0248	196.75	10.35	0.2131	341.2779
Caridea	0.053	1	0.0083	100.00	5.26	0.1083	61.3566
Salpidae	0.053	2	0.0165	37.50	1.97	0.0406	30.0770
Fish remains	0.053	2	0.0165	5.00	0.26	0.0054	11.5498
Gelatinous zooplankton, unid.	0.263	16	0.1322	101.25	5.33	0.1097	636.5746
Eggs, unid.	0.053	5	0.0413	2.50	0.13	0.0027	23.1738
Organic material	0.158	0	0.0000	29.00	1.53	0.0314	49.5959
Total	1.000	121	1.0000	923.25	48.59	1.0000	4831.4546

19 = Total number of stomachs
17 = Number of prey taxa

China Rockfish, *Sebastes nebulosus*

Forty-four different prey taxa were found in the stomachs of 59 China rockfish (Table 6). Although a wide variety of food items were taken as prey, only seven groups occurred in 10% or more of the samples. These included: brittle star, *Ophiopholis aculeata* (Figure 2); rock crab, *Cancer oregonensis;* decorator crab, *Pugettia gracilis;* brachyuran crab larvae; caridean shrimps; hermit crabs and fish remains.

Most observed feeding was directed toward the bottom, as China rockfish forage on sedentary invertebrates comprising the living turf. Brittle star, *Ophiopholis aculeata,* was the dominant food item in terms of frequency, occurring in 78% of the stomach samples with a total volume of 38.5% (Table 6). Brittle stars were usually eaten whole, and as many as 65 *O. aculeata* have been recorded from a single stomach sample. Crustacea was the next most important group both by number and volume with a combined frequency of occurrence of 89%. Fish were only occasionally found in these samples.

These data from southeast Alaska agree with the findings of Rosenthal (1983) for China rockfish taken in the exposed water of the northeastern Gulf of Alaska where brittle stars occurred in 94.7% of the stomachs sampled. Rosenthal also found that *S. nebulosus* consumed decorator crabs; small rock crabs and caridean shrimps. China rockfish, feeding off the coast of Oregon, consumed crustacea, particularly decorator or spider crabs and *Cancer oregonensis* (Steiner 1978).

TABLE 6. Food of the China Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Rhodophyta	0.017	2	0.0046	7.50	0.13	0.0023	1.1750
Alglaophenia sp.	0.017	0	0.0000	2.00	0.03	0.0006	0.1060
Rhynchocoela	0.017	1	0.0023	1.25	0.02	0.0004	0.4550
Haliotis kamtschatkana	0.034	8	0.0183	88.75	1.50	0.0278	15.6287
Homalopoma luridum	0.017	1	0.0023	1.00	0.02	0.0003	0.4417
Velutina sp.	0.034	2	0.0046	5.00	0.08	0.0016	2.0850
Polyplacophora	0.034	2	0.0046	35.00	0.59	0.0109	5.2655
Cyanoplax dentiens	0.017	1	0.0023	2.50	0.04	0.0008	0.5213
Balanus crenatus	0.017	1	0.0023	7.50	0.13	0.0023	0.7863
Mysidaceae	0.017	3	0.0069	2.50	0.04	0.0008	1.2987
Mysidacea	0.017	37	0.0849	3.75	0.06	0.0012	14.5822
Gammaridae	0.017	0	0.0000	1.25	0.02	0.0004	0.0662
Caridea	0.153	10	0.0229	39.25	0.67	0.0123	53.7117
Hippolytidae	0.017	1	0.0023	7.50	0.13	0.0023	0.7863
Heptacarpus sp.	0.017	1	0.0023	12.50	0.21	0.0039	1.0513
Pandalus spp.	0.017	3	0.0069	20.00	0.34	0.0063	2.2264
Crab, unid.	0.017	1	0.0023	5.00	0.08	0.0016	0.6538
Paguridae	0.034	4	0.0092	23.50	0.40	0.0073	5.6013
Pagurus spp.	0.068	5	0.0115	11.75	0.20	0.0037	10.2662
Rhinolithodes wosnessenskii	0.017	1	0.0023	70.00	1.19	0.0219	4.0993
Acantholithodes hispidus	0.034	2	0.0046	170.00	2.88	0.0532	19.5775
Phyllolithodes papillosus	0.017	1	0.0023	15.00	0.25	0.0047	1.1836
Cryptolithoides sp.	0.017	1	0.0023	80.00	1.36	0.0250	4.6293
Cryptolithodes typicas	0.017	1	0.0023	33.75	0.57	0.0106	2.1777
Petrolisthes eriomerus	0.017	1	0.0023	15.00	0.25	0.0047	1.1839
Petrolithes cinctipes	0.017	1	0.0023	0.00	0.00	0.0000	0.3887
Brachyura	0.203	22	0.0505	82.50	1.40	0.0258	155.1053
Hyas lyratus	0.051	4	0.0092	38.75	0.66	0.0121	10.8270
Pugettia sp.	0.034	3	0.0069	150.00	2.54	0.0469	18.2347
Pugettia richii	0.034	2	0.0046	22.50	0.38	0.0070	3.9403
Pugettia gracilis	0.119	10	0.0229	203.75	3.45	0.0637	102.8139
Scyra acutifrons	0.051	4	0.0092	57.50	0.97	0.0180	13.8087
Cancridae	0.068	3	0.0069	11.75	0.20	0.0037	7.1563
Cancer oregonensis	0.305	33	0.0757	312.50	5.30	0.0977	529.0800
Ophiuroidae	0.051	31	0.0711	109.00	1.85	0.0341	53.4865
Ophiopholis aculeata	0.780	220	0.5046	1229.75	20.84	0.3846	6392.6249
Boltenia villosa	0.017	1	0.0023	5.00	0.08	0.0016	0.6538
Fish remains	0.102	4	0.0092	90.75	1.54	0.0284	38.1924
Hemilepidotus jordani	0.017	1	0.0023	8.00	0.14	0.0025	0.8128
Ammodytes hexapterus	0.068	3	0.0069	50.00	0.85	0.0156	15.2664
Shell, unid.	0.017	0	0.0000	5.00	0.08	0.0016	0.2650
Scale, unid.	0.017	0	0.0000	0.50	0.01	0.0002	0.0265
Stone	0.051	3	0.0069	125.00	2.12	0.0391	23.3765
Organic material	0.068	1	0.0023	34.00	0.58	0.0106	8.7640
Total	1.000	436	1.0000	3197.50	54.19	1.0000	8064.3842

59 = Total number of stomachs
44 = Number of prey taxa

Yelloweye Rockfish, *Sebastes ruberrimus*

The yelloweye rockfish is a large predatory reef fish that usually feeds close to the bottom. It has been observed underwater capturing smaller reef fishes with rapid bursts of speed and agility. Stomach samples were examined from 48 specimens. Of these, 33 regurgitated prey at the surface after capture. The analysis (Table 7), however, is only for 15 specimens with stomachs and food items completely intact. Fishes were the major food item in their diet. Rockfish prey included Puget Sound rockfish; quillback rockfish, *S. maliger;* rosethorn rockfish, *S. helvomaculatus;* redstripe rockfish, *S. proriger;* and juvenile yelloweye rockfish. Other prey included juvenile gadids, sand lance, herring, and lumpsucker (family: Cyclopteridae). Puget Sound rockfish was the most important prey both by number and volume in the regurgitated samples (Figure 2). As many as three adult Puget Sound rockfish have been found in a single yelloweye rockfish stomach. Herring and other unidentified fish remains comprised 27 and 30% of the total volume, respectively (Table 7). Caridean shrimp; a lithodid crab, *Acantholithodes hispidis; C. oregonensis;* green sea urchin, *Strongylocentrotus droebachiensis;* gastropod snails, and lingcod, *Ophiodon elongatus,* eggs were also consumed by yelloweye rockfish.

TABLE 7. Food of the Yelloweye Rockfish.

Prey	% Freq occur	Total count	%Total count	Total volume	Average volume	%Total volume	Relative importance
Fish remains	0.067	0	0.0000	30.00	2.00	0.0235	15.6863
Caridea	0.067	4	0.0606	4.00	0.27	0.0031	42.4955
Pandalus spp.	0.133	2	0.0303	30.00	2.00	0.0235	71.7766
Pandalus tridens	0.067	1	0.0152	25.00	1.67	0.0196	23.1729
Brachyura	0.067	0	0.0000	1.00	0.07	0.0008	0.5229
Fish remains	0.333	7	0.1061	380.00	25.33	0.2980	1346.9994
Clupea harengus	0.333	5	0.0758	350.00	23.33	0.2745	1167.5579
Gadid larvae	0.067	4	0.0606	50.00	3.33	0.0392	66.5478
Sebastes spp.	0.133	0	0.0000	125.00	8.33	0.0980	130.7190
Sebastes emphaeus	0.133	2	0.0303	80.00	5.33	0.0627	124.0642
Cyclopteridae	0.067	1	0.0152	60.00	4.00	0.0471	41.4736
Ammodytes hexapterus	0.133	40	0.6061	140.00	9.33	0.1098	954.4860
Total	1.000	66	1.0000	1275.00	85.00	1.0000	3985.5021

15 = Total number of stomachs
12 = Number of prey taxa

Rosenthal (1983) found juvenile flounder (family: Pleuronectidae); snail, *Calliostoma ligatum;* lithodid crabs, *Placetron wosnessenskii;* and fish remains in the stomachs of yelloweye rockfish taken in Prince William Sound. The major food items in terms of percent biomass off Oregon (Steiner 1978) included cancroid crabs; cottids, *Artedius* spp.; righteye flounders; adult rockfish; and pandalid shrimps.

Quillback Rockfish, *Sebastes maliger*

Quillback rockfish is another solitary reef-dwelling fish that lives close to, or on the bottom. Sixty-seven of the specimens examined had food present in their stomachs. A list of 45 identifiable prey taxa is presented in Table 8. Crustacea dominated these prey groups both by number, frequency and volume. Caridean shrimps; cancroid crabs; decorator crabs of the genera *Pugettia, Oregonias, Scyra* and *Chorilla;* hermit crabs; mysids and sphaeromatid isopods were the major crustacea in terms of IRI. Caridean shrimps occurred in 37.4% of the samples.

TABLE 8. Food of the Quillback Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Sertularella	0.015	0	0.0000	1.00	0.01	0.0003	0.0421
Polychaete	0.030	2	0.0041	13.00	0.19	0.0037	2.3083
Bivalve shell	0.015	1	0.0020	2.50	0.04	0.0007	0.4086
Musculus sp.	0.015	2	0.0020	3.75	0.06	0.0011	0.4613
Pectinidae	0.015	0	0.0000	10.00	0.15	0.0028	0.4211
Octopus sp.	0.015	1	0.0020	85.00	1.27	0.0240	3.8826
Crustacean remains	0.075	3	0.0061	35.00	0.52	0.0099	11.9195
Mysidae	0.075	140	0.2846	183.75	2.74	0.0518	251.0406
Tanaidacea	0.015	1	0.0020	1.50	0.02	0.0004	0.3665
Sphaeromatidae	0.090	10	0.0203	108.50	1.62	0.0306	45.6147
Gammaridae	0.075	10	0.0203	18.50	0.28	0.0052	19.0631
Caprellidae	0.015	5	0.0102	3.75	0.06	0.0011	1.6747
Thysanoessa raschii	0.015	88	0.1789	100.00	1.49	0.0282	30.9067
Caridae	0.299	37	0.0752	273.45	4.08	0.0771	454.7822
Pandalus spp.	0.060	5	0.0102	95.00	1.42	0.0268	22.0687
Crangonidae	0.015	0	0.0000	5.00	0.07	0.0014	0.2105
Crab, unid.	0.119	5	0.0102	121.00	1.81	0.0341	52.8961
Anomuran	0.015	0	0.0000	25.00	0.37	0.0071	1.0527
Pagurus spp.	0.060	20	0.0407	74.25	1.11	0.0209	36.7753
Acantholithodes hispidus	0.030	2	0.0041	110.00	1.64	0.0310	10.4775
Cryptolithoides sitchensis	0.015	1	0.0020	0.00	0.00	0.0000	0.3034
Rhinolithodes wosnessenskii	0.015	1	0.0020	40.00	0.60	0.0113	1.9877
Brachyura (larvae)	0.015	2	0.0041	10.00	0.15	0.0028	1.0278
Oregonia gracilis	0.030	1	0.0020	51.25	0.76	0.0145	4.9229
Pugettia spp.	0.030	2	0.0041	45.00	0.67	0.0127	5.0033
Pugettia gracilis	0.075	8	0.0163	116.25	1.74	0.0328	36.6104
Scyra acutifrons	0.015	1	0.0020	0.00	0.00	0.0000	0.3034
Chorilla longipes	0.030	2	0.0041	80.00	1.19	0.0226	7.9509
Cancridae	0.045	8	0.0163	148.75	2.22	0.0420	26.0719
Cancer branneri	0.015	1	0.0020	30.00	0.45	0.0850	1.5666
Cancer oregonensis	0.104	12	0.0244	261.25	3.90	0.0737	102.4894
Ectopocta	0.030	1	0.0020	2.25	0.03	0.0006	0.7962
Microporina borealis	0.015	0	0.0000	3.75	0.06	0.0011	0.1579
Myriozoum	0.015	0	0.0000	11.25	0.17	0.0032	0.4737
Ophiopholis aculeata	0.045	27	0.0549	102.50	1.53	0.0289	37.5208
Holothuroidea	0.015	1	0.0020	30.00	0.45	0.0085	1.5666
Boltenia villosa	0.015	0	0.0000	1.00	0.01	0.0003	0.0421
Salpidae	0.030	5	0.0102	25.00	0.37	0.0071	5.1391
Fish remains	0.209	7	0.0142	361.00	5.39	0.1018	242.5490
Clupea harengus	0.030	2	0.0041	170.00	2.54	0.0480	15.5306
Sebastes emphaeus	0.030	2	0.0041	110.00	1.64	0.0310	10.4775
Ammodytes hexapterus	0.149	70	0.1423	602.50	8.99	0.1700	466.0604
Shell, unid.	0.075	3	0.0061	9.75	0.15	0.0028	6.6032
Stone	0.060	3	0.0061	15.50	0.23	0.0044	6.2511
Organic material	0.030	1	0.0020	47.50	0.71	0.0134	4.6071
Total	1.000	492	1.0000	3544.45	52.90	1.0000	1932.3860

67 = Total number of stomachs
45 = Number of prey taxa

Quillback rockfish are not only skilled at foraging for sedentary or slow-moving invertebrates, but are also adept at capturing small fish from the water column. Sand lance and fish remains had an IRI of 466.1 and 242.5, respectively. Sand lance occurred in 15% of the specimens. Herring and small rockfish were also present in these samples.

Dock shrimp, *Pandalus danae;* brachyuran crabs; gammarid amphipods; euphausiids and calanoid copepods were the principal components of the diet of quillback rockfish taken from an artificial reef in Puget Sound, Washington (Hueckel and Stayton 1982). The results of their study concur with our dietary observations for *S. maliger* off southeast Alaska, despite the wide differences in habitats and geographic location.

Copper Rockfish, *Sebastes caurinus*

Copper rockfish usually forage close to the bottom, although some individuals were observed to catch small fish that hovered in the water column. Twenty-five specimens were collected and examined for food items. All of the sampled stomachs contained some type of food, with 18 different prey taxa represented (Table 9). The diet consisted heavily of crustacea and small fish. Eleven percent of the identifiable food items were shrimp, and another 23% were fish. Sand lance occurred in 32% of the samples, and this accounted for 32.8% of the total volume. The IRI value of sand lance was 1681.2 (Table 9). Puget Sound rockfish and juvenile greenlings were also preyed upon by copper rockfish. Other noteworthy prey include mysids (IRI 516.5) and cancroid crabs such as *Cancer oregonensis* and *C. branneri.*

TABLE 9. Food of the Copper Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Octopodidae	0.040	1	0.0052	30.00	1.20	0.0249	12.0207
Crustacean remains (A)	0.120	1	0.0052	20.50	0.82	0.0170	26.6114
Balanidae	0.040	1	0.0052	3.75	0.15	0.0031	3.3161
Mysidae	0.080	107	0.5544	110.00	4.40	0.0912	516.4767
Rocinela belliceps	0.040	1	0.0052	15.00	0.60	0.0124	7.0466
Caridea	0.240	20	0.1036	67.50	2.70	0.0560	383.0052
Pandalus spp.	0.080	2	0.0104	30.00	1.20	0.0249	28.1865
Brachyura (larvae)	0.080	2	0.0104	13.00	0.52	0.0108	16.9119
Cancridae	0.120	3	0.0155	67.50	2.70	0.0560	85.8031
Cancer branneri	0.040	1	0.0052	75.00	3.00	0.0622	26.9430
Cancer oregonensis	0.080	4	0.0207	81.25	3.25	0.0674	70.4663
Microporina borealis	0.040	0	0.0000	2.00	0.08	0.0017	0.6632
Fish remains	0.120	1	0.0052	42.50	1.70	0.0352	48.4974
Sebastes emphaeus	0.080	4	0.0207	170.00	6.80	0.1409	129.3264
Juvenile Hexagrammidae	0.040	2	0.0104	50.00	2.00	0.0415	20.7254
Ammodytes hexapterus	0.320	38	0.1969	396.25	15.85	0.3285	1681.2435
Shell	0.120	2	0.0104	4.75	0.19	0.0039	17.1606
Stone	0.120	3	0.0155	27.25	1.09	0.0226	45.7617
Total	1.000	193	1.0000	1206.25	48.25	1.0000	3120.1658

25 = Total number of stomachs
18 = Number of prey taxa

Fish, shrimp and crab were the major components of the diet of *S. caurinus* captured from Puget Sound (Moulton 1977, Patten 1973). Off northern California, brachyuran crabs, gammarid amphipods, caprellids, caridean shrimps and fish were the most frequently eaten food items. In that study, copper rockfish were examined from an artificial reef in Humboldt Bay (Prince and Gotshall 1976). Based on previous findings and information collected by us off southeast Alaska, copper rockfish feed heavily on crabs, shrimps and fish. This preference held despite major differences in habitat and distance between the aforementioned locations.

Tiger Rockfish, *Sebastes nigrocinctus*

Tiger rockfish forage by picking food items from the sea floor. A total of 19 different prey taxa were found in the stomachs of 16 tiger rockfish (Table 10). Caridean shrimp (Figure 2) was the most important prey group in terms of frequency of occurrence (50%), percent total volume (19.5%) and number (Table 10). The IRI value for this group alone was 3144.4. Stomach samples also contained substantial amounts of brachyuran crabs, particularly rock crab, *C. oregonensis,* and decorator crabs of the genus *Pugettia, Oregonia,* and *Scyra.* Other important foods included gammarid amphipods, hermit crabs and small fishes such as herring and juvenile rockfish. Despite the occurrence of fish in the stomachs, tiger rockfish seemed to be more adept at feeding on macroinvertebrates associated with the bottom than they were at catching fish from the water column. This was substantiated by diving observations and from samples taken from commercial fishing boats based out of Sitka during 1980–82.

TABLE 10. Food of the Tiger Rockfish.

Prey	*% Freq occur*	*Total count*	*%Total count*	*Total volume*	*Average volume*	*%Total volume*	*Relative importance*
Nereidae	0.063	0	0.0000	23.75	1.48	0.0403	25.1589
Gammaridae	0.063	4	0.0755	15.00	0.94	0.0254	63.0596
Caridea	0.500	23	0.4340	115.00	7.19	0.1949	3144.3876
Pandalidae	0.063	2	0.0377	10.00	0.63	0.0169	34.1781
Pandalus montagui	0.063	1	0.0189	25.00	1.56	0.0424	38.2755
Pandalus danae	0.063	3	0.0566	0.25	0.02	0.0004	35.6422
Paguridae	0.063	1	0.0189	10.00	0.63	0.0169	22.3857
Pagurus sp.	0.125	2	0.0377	48.50	3.03	0.0822	149.9240
Brachyura	0.063	1	0.0189	1.25	0.08	0.0021	13.1166
Oregonia gracilis	0.063	1	0.0189	5.00	0.31	0.0085	17.0891
Pugettia gracilis	0.063	1	0.0189	2.50	0.16	0.0042	14.4408
Scyra acutifrons	0.063	3	0.0566	10.00	0.63	0.0169	45.9706
Cancer oregonensis	0.063	2	0.0377	22.50	1.41	0.0381	47.4197
Ophiopholis aculeata	0.063	4	0.0755	18.75	1.17	0.0318	67.0321
Fish remains	0.188	1	0.0189	42.50	2.66	0.0720	170.4409
Clupea harengus	0.063	1	0.0189	40.00	2.50	0.0678	54.1653
Sebastes sp.	0.063	1	0.0189	80.00	5.00	0.1356	96.5382
Gelatenous plankton	0.063	0	0.0000	10.00	0.63	0.0169	10.5932
Organic matter	0.125	2	0.0377	110.00	6.88	0.1864	280.2207
Total	1.000	53	1.0000	590.00	36.88	1.0000	4330.0388

16 = Total number of stomachs
19 = Number of prey taxa

Niche Breadth

Niche breadths for pelagic and demersal species of rockfishes are presented in Table 11. All three indices exhibit similar niche breadth trends for each species; however, the Shannon-Weaver index results in relatively wider niche breadth estimates than Simpson's and Levin's indices. The relative niche widths are determined by expressing niche breadth values as percent of the maximum value. Species with relatively high index values are dietary generalists as opposed to specialists.

TABLE 11. Niche Breadth Values [1] for 10 Species of Rockfishes Collected During Summer Months in Coastal Waters of Southeast Alaska.

	Total No. of Stomachs	*Total No. of Prey Taxa*	*Levin's Niche Breadth* [2]	*Maximum Value*	*Shanon-Weaver Niche Breadth* [3]	*Maximum Value*	*Simpson's Niche Breadth* [3]	*Maximum Value*
Pelagic Species								
Black rockfish	142	38	.053	1	.594	1.60	2.125	38
Dusky rockfish	44	22	.305	1	.968	1.36	7.020	22
Yellowtail rockfish	112	22	.162	1	.800	1.36	3.723	22
Widow rockfish	27	23	.156	1	.765	1.36	3.594	23
Puget Sound rockfish	19	17	.359	1	.970	1.25	6.465	17
Demersal Species								
Yelloweye rockfish	15	12	.427	1	.829	1.08	5.127	12
Quillback rockfish	67	45	.329	1	1.334	1.65	14.815	45
China rockfish	59	44	.131	1	1.095	1.64	5.745	44
Copper rockfish	25	18	.356	1	.990	1.25	6.408	18
Tiger rockfish	16	19	.456	1	1.054	1.28	8.662	19

[1] *See* Appendix 1.
[2] Hurlbert 1978.
[3] Petraitis 1979.

Pelagic species have more specialized diets than demersal species. Black rockfish are the most specialized of pelagic species, yet consume the greatest number of dietary items. In contrast, Puget Sound rockfish are most generalized of pelagic species but utilize the least number of dietary items. Dusky, yellowtail, and widow rockfishes ate equal numbers of prey taxa. Dusky rockfish are dietary generalists compared to yellowtail and widow rockfishes.

Demersal species are intermediate between dietary specialists and dietary generalists, with the exception of China rockfish. China rockfish are the most specialized of demersal species, although they consumer 44 different prey taxa. Quillback rockfish also consume a large number of prey taxa (45) but are more dietary generalists. Yelloweye rockfish feed on the fewest number of prey taxa of the demersal species. Copper and tiger rockfishes consume similar numbers of prey taxa. However copper rockfish are more specialized than tiger rockfish, which is the most generalized of demersal rockfish.

Dietary Overlap

Among pelagic rockfish species, the Puget Sound rockfish had the lowest dietary overlap values (Tables 12–14). Puget Sound rockfish are much smaller than black, dusky, yellowtail, and widow rockfishes and therefore are restricted to a smaller size of dietary items. Puget Sound rockfish show little overlap with other rockfishes in the food resources they consume.

Black rockfish is dietarily the most specialized pelagic species. Black rockfish consume a greater percentage of the dietary items they have in common with dusky, yellowtail, and widow rockfishes, and consequently show a greater degree of impingement on these species than they do on black rockfish. Food resources common to the black rockfish and each of the other pelagic species are more important in the specialized diet of the black rockfish.

TABLE 12. Schoener's Niche Overlap (Hurlbert 1978). "Dietary Similarity" Between Pelagic Rockfishes X and Y During the Summer Months in Coastal Waters of Southeast Alaska.

	Y				
X	*Black*	*Dusky*	*Yellowtail*	*Widow*	*Puget Sound*
Black		.314	.716	.430	.042
Dusky	.314		.428	.452	.227
Yellowtail	.716	.428		.451	.068
Widow	.430	.452	.451		.125
Puget Sound	.042	.227	.068	.125	

TABLE 13. Levin's Directional Overlap (Hurlbert 1978). The Degree Pelagic Rockfish X Impinges on Pelagic Rockfish Y During the Summer Months in Coastal Waters of Southeast Alaska.

	Y				
X	*Black*	*Dusky*	*Yellowtail*	*Widow*	*Puget Sound*
Black		.920	1.276	.804	.012
Dusky	.279		.449	.417	.171
Yellowtail	.729	.846		.640	.032
Widow	.476	.815	.663		.065
Puget Sound	.004	.186	.018	.036	

TABLE 14. Lloyd's Directional Overlap (Hurlbert 1978). Pelagic Rockfish X Consumes * Percent of the Total Volume of Dietary Items That Pelagic Rockfishes X and Y have in Common During the Summer Months in Coastal Waters of Southeast Alaska.

	Y				
X	*Black*	*Dusky*	*Yellowtail*	*Widow*	*Puget Sound*
Black		91.7	57.0	83.4	92.5
Dusky	8.3		10.8	31.4	52.7
Yellowtail	43.0	89.2		79.1	90.2
Widow	16.6	68.6	20.9		70.9
Puget Sound	7.5	47.3	9.8	29.1	

Yellowtail and widow rockfishes both consume a greater percentage of the food items they have in common with dusky rockfish and impinge on dusky rockfish to a greater degree than dusky rockfish impinge on yellowtail or widow rockfishes. The food resources common to yellowtail and dusky rockfishes and widow and dusky rockfishes are more important in the diets of the yellowtail and widow rockfishes.

Examination of Tables 15–17 shows several patterns in overlap measures for demersal species pairs. Quillback rockfish consume a greater percentage of the total volume of common food resources than any of the other demersal species. All the demersal species show the highest degree of impingement on quillback rockfish. Quillback rockfish are dietary specialists compared to yelloweye, tiger, or copper rockfishes.

The China rockfish is more of a dietary specialist than the quillback rockfish; however, each consumes approximately 50% of the total volume of each species diet are in common items. China rockfish have their greatest dietary similarity with, and degree of impingement on, quillback rockfish. Conversely, quillback rockfish have their lowest dietary similarity with, and degree of impingement on, China rockfish. A change in the common resources consumed by either the quillback rockfish or China rockfish would have a greater effect on the China rockfish.

TABLE 15. Schoener's Niche Overlap (Hurlbert 1978). "Dietary Similarity" Between Demersal Rockfishes X and Y During the Summer Months in Coastal Waters of Southeast Alaska.

	Y				
X	*Quillback*	*Yelloweye*	*China*	*Tiger*	*Copper*
Quillback		.318	.271	.319	.465
Yelloweye	.318		.054	.261	.234
China	.271	.054		.156	.165
Tiger	.319	.261	.156		.131
Copper	.465	.234	.165	.131	

TABLE 16. Levin's Directional Overlap (Hurlbert 1978). The degree Demersal Rockfish X Impinges on Demersal Rockfish Y During the Summer Months in Coastal Waters of Southeast Alaska.

	Y				
X	*Quillback*	*Yelloweye*	*China*	*Tiger*	*Copper*
Quillback		.333	.172	.294	.508
Yelloweye	.963		.060	.475	.360
China	.444	.053		.203	.094
Tiger	.503	.281	.135		.103
Copper	1.175	.288	.085	.139	

TABLE 17. Lloyd's Directional Overlap (Hurlbert 1978). Demersal Rockfish X Consumes * Percent of the Total Volume of Dietary Items that Demersal Rockfishes X and Y Have in Common During the Summer Months in Coastal Waters of Southeast Alaska.

	Y				
X	*Quillback*	*Yelloweye*	*China*	*Tiger*	*Copper*
Quillback		73.5	52.6	85.7	74.6
Yelloweye	26.5		28.5	68.4	51.4
China	47.4	71.5		84.4	72.6
Tiger	14.3	31.6	15.6		32.8
Copper	25.4	48.6	27.4	67.2	

The X, Y species pairs—yelloweye and tiger rockfishes, yelloweye and copper rockfishes, China and tiger rockfishes, and the copper and tiger rockfishes—exhibit similar patterns in percentage of total volume consumed and degree of impingement. Species X consumes a greater percentage of the total volume of dietary items that species X and Y have in common. The degree of impingement is greater for species X than species Y. The food resources common to the X, Y species pairs are of greater importance in the diet of species X.

DISCUSSION

The rockfish species complex has radiated into a number of different habitats and depth strata in the northeast Pacific ocean. The success displayed by this group from Baja California to Prince William Sound, Alaska, is exemplified by a highly opportunistic foraging behavior.

Rockfishes utilize a broad spectrum of food types during summer months in shallow waters of the Gulf of Alaska. Of the ten species of *Sebastes* examined in this study, most demonstrated a remarkable flexibility in diet, while capitalizing on the most accessible types of prey. Stomach contents of these ten species included 128 identifiable prey taxas or groups.

Demersal species are more dependent on detrital sources of food than pelagic species which consume substantial quantities of zooplankton and fish. Plankton and forage fish production in the nearshore waters of Alaska during spring and summer contribute vast amounts of energy to higher trophic levels. A cornerstone of the forage base is the Pacific sand lance, termed the "anchovy of the north" because of its widespread distribution and importance as a forage species. A planktivore, the Pacific sand lance eats mostly drifting organisms (e.g., copepods, amphipods, mysids, etc.), and in doing so provides a means of "energy transfer between zooplankton and the piscivorous fishes" (Simenstad et al. 1977). Sand lance is a major food item in the summer diets of black, yellowtail and widow rockfishes. However, dusky and Puget Sound rockfishes depart from the fish eating trend in that they feed more on small crustacea and gelatinous zooplankton.

Black, yellowtail, and dusky rockfishes co-occur over several depth strata in the eastern Gulf of Alaska. Black rockfish decrease in abundance with depth while yellowtail and dusky rockfishes increase in abundance with depth (Rosenthal et al. 1982, Field 1984). Black and yellowtail rockfishes are dietary specialists that feed most heavily on fish. A surplus of food resources common to both black and yellowtail rockfishes may be responsible for their extensive overlap (Pianka 1978). In comparison, dusky rockfish are dietary generalists and consume primarily invertebrate zookplankton.

Resource partitioning between yellowtail and dusky rockfishes, habitat partitioning by black and yellowtail rockfishes, and an abundant supply of some food resources appear to be contributing factors in the nearshore distribution of black, yellowtail, and dusky rockfishes.

Puget Sound rockfish occur with subadult black and yellowtail rockfishes in the shallow sublittoral zone. The Puget Sound rockfish is a generalist, despite being confined to picking tiny epipelagic crustacea from the water column due to its small size. It shows little dietary overlap with the other pelagic rockfish species. Like the ubiquitous Pacific sand lance, the Puget Sound rockfish is an important converter of plankton in the nearshore system, for it is eaten by a number of reef-dwelling rockfish.

Demersal species with the exception of the China rockfish are intermediate between dietary specialists and generalists. China rockfish exhibit a strong preference for substrate-oriented prey, particularly brittle stars. This specialization in diet is probably important in reducing competition with other bottom-dwelling rockfish. Yelloweye rockfish increase in abundance with depth and feed primarily on fish. Quillback rockfish is most abundant at intermediate depths and consumes a wide variety of crustacea and small fishes. Quillback rockfish consume a greater percentage of the dietary items that are shared with yelloweye rockfish; however, the degree of impingement on yelloweye rockfish by quillback rockfish is relatively low. The consumption of common food resources may have a minimal effect on the co-occurrence of these two species.

The dietary overlaps for pelagic and demersal rockfishes in the Gulf of Alaska were strong during summer when food resources are known to be high. This appears to be characteristic of the group as Love and Ebeling (1978) also found considerable overlap in the diet of California rockfishes particularly during periods (summer-fall) when prey were abundant. Most rockfishes are opportunists that take advantage of the most abundant prey available to them in the nearshore zone. Geographic variations in diet suggest that substitution of prey is possible as long as the foods are of the same general size and type, and the species stocks similar.

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APPENDIX 1
Niche Breadth

Levin's niche breadth (Hurlbert 1978):

$$B = 1/n \sum_{i} p_{ij^2}$$

Shannon-Weaver niche breadth (Petraitis 1979):

$$H_i' = -\sum_{j=1}^{r} p_{ij} \log p_{ij}$$

Simpson's niche breadth (Petraitis 1979):

$$B_i = 1/\sum_{j=1}^{r} p_{ij^2}$$

p_{ij} = Percent total volume of prey *j* in predator *i.*

n,r = Number of prey taxa utilized by predator *i.*

APPENDIX 2
Dietary Overlap

Schoener's niche overlap (Hurlbert 1978):

$$C_{xy} = 1 - \tfrac{1}{2} \left(\sum_i \left| P_{xi} - P_{yi} \right|\right)$$

Levin's directional overlap (Hurlbert 1978):

$$ax(y) = \sum_i (P_{xi} P_{yi}) \,/\, \sum_i P_{xi}^2$$

$$ay(x) = \sum_i (P_{yi} P_{xi}) \,/\, \sum_i P_{yi}^2$$

Lloyd's directional overlap (Hurlbert 1978):

$$Zx(y) = \sum_i (X_i Y_i / X)$$

$$Zy(x) = \sum_i (Y_i X_i / Y)$$

x = predator 1

y = *predator 2*

i = prey

P_{xi} = X_i / X = Percent total volume of prey i in predator x.

P_{yi} = Y_i / Y = Percent total volume of prey i in predator y.

X_i = Total volume of prey i in predator x stomachs.

X = Total volume of predator x stomachs.

Y_i = Total volume of prey i in predator y stomachs.

Y = Total volume of predator y stomachs.

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GROWTH OF YOUNG-OF-THE-YEAR AND JUVENILE PACIFIC HERRING FROM SAN FRANCISCO BAY, CALIFORNIA [1]

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Young-of-the-year (YOY) and juvenile (1+ yr old) Pacific herring, *Clupea harengus pallasi,* were sampled from April to June 1983 and 1986 and from April to July 1984 and 1985 by midwater trawl in San Francisco Bay, California. The majority of YOY herring ranged from 40 to 70 mm body length (BL) during these months while most juveniles ranged from 105 to 150 mm BL. Fifteen-meter bay temperatures during hatching and early development were directly related to YOY growth rate. El Niño conditions during 1982 and 1983 adversely affected growth of the 1982 yr class as juveniles in the ocean.

INTRODUCTION

The Pacific herring, *Clupea harenqus pallasi,* spawning population in San Francisco Bay supports a roe fishery that has yielded an average of approximately 6000 tons of whole fish during the last 12 seasons. The California Department of Fish and Game (CDFG) manages the fishery by quota based on spawn escapement estimates and commercial catch from the previous season. Life history parameters, such as age and growth rates, are essential for proper management of this valuable resource.

Little is known about young-of-the-year (YOY) and juvenile herring in California. Hubbs (1925) used length frequencies and scales to determine age of young herring from San Francisco Bay in 1922 and 1923. Miller and Schmidtke (1956) sampled yearling herring from the Monterey Bay lampara fishery in 1947, 1948, and 1952 and aged them by scales. More recently, Spratt (1981) reported average length of YOY and juvenile herring caught incidentally in the winter Monterey Bay anchovy fishery and in the summer bait fishery.

Herring spawn in San Francisco Bay from late October to March and YOY herring remain in the bay until mid-summer. The following spring many juvenile herring return to the bay and mix with the next year class of YOYs. CDFG's Bay-Delta Project, Stockton has provided an opportunity to study growth of YOY and juvenile herring from San Francisco Bay within and between years. From 1983 to 1986 intensive midwater trawling was conducted during spring and summer primarily to sample out-migrant salmon smolts. Length measurements of the incidental catch of herring, primarily YOYs, have provided a wealth of data to follow growth.

METHODS

All San Francisco Bay samples were obtained with a midwater trawl with a 10-ft by 30-ft mouth opening. Towing was conducted throughout each month from April to June or July with the exception of April 1984 (mid- to late April

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only) and July 1985 (late July only). The net was towed at 3 to 7 knots between the surface and 30 ft (Charles Armor, CDFG, Stockton, pers. commun.). All tows were conducted in daytime along one standard transect between the Golden Gate Bridge and Alcatraz Island (Figure 1). A maximum of 30–50 randomly selected herring was measured from each of three general overlapping length classes from each tow: (i) small herring were usually less than 90 mm; (ii) medium herring ranged from 80 to 130 mm; (iii) large herring were usually greater than 120 mm. All herring were counted from small catches; large catches were subsampled by a volumetric aliquot and total number of herring captured was calculated. Fork length (FL) was measured in the field by Bay-Delta Project personnel and subsequently converted to body length (BL) using the regression:

$$BL = 0.62668 + 0.93059\ FL,\ N = 123,\ r = 0.99$$

BL is the standard measurement for herring in California and is the distance from the snout tip to the end of the pigment underneath the last column of scales on the caudal peduncle.

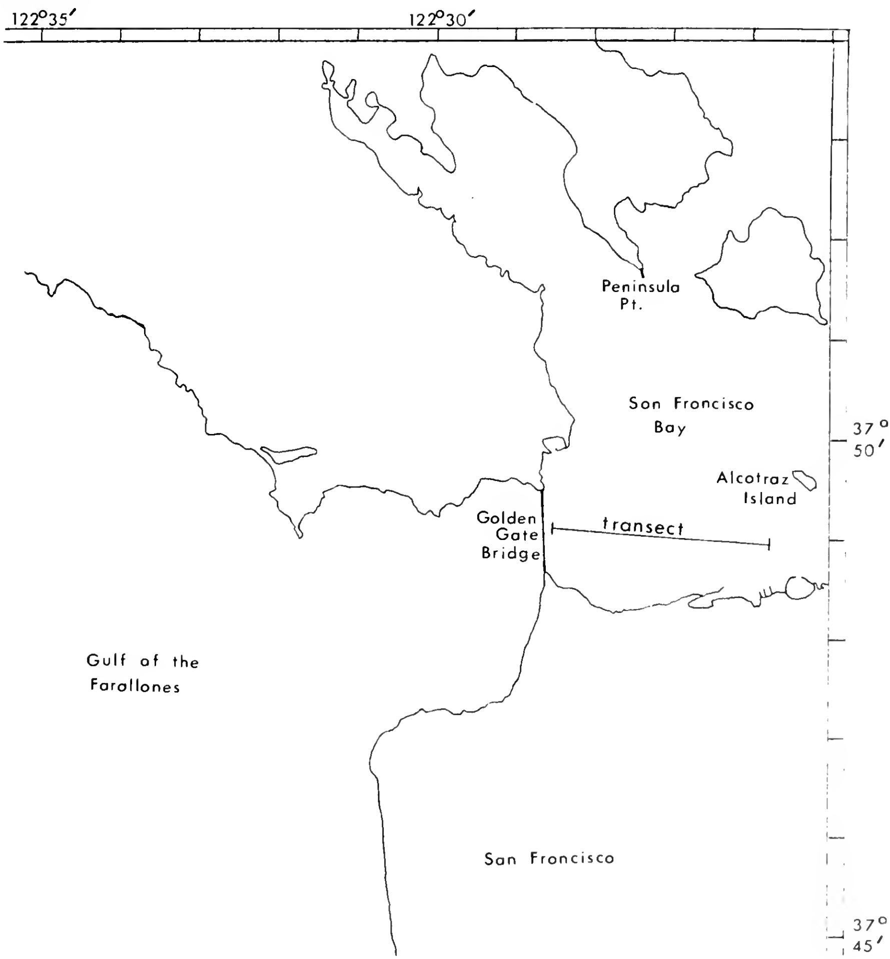

FIGURE 1. Location of Pacific herring sampling area.

On an approximately monthly basis from April to July, subsamples of herring were frozen for later age and growth analysis. A correction factor of 1.021 was applied to BL of thawed herring to account for shrinkage (Reilly and Moore 1983). Adult herring (age 2+ yr) were included in these samples. Overlap occurred in length frequency distributions of 1+ and 2+ yr old herring. The largest 1+ yr old fish each year was used as the cutoff on length frequency histograms for juveniles. Number of 1+ yr old fish in each 2-mm BL interval within the overlap range were calculated based on the proportion of 1+ yr old fish among those aged by otoliths. Rarely did ages overlap between YOY and juvenile fish for a particular month. When this did occur, a cutoff point between year classes was determined from the distribution of otolith ages.

In a separate study, San Francisco Bay temperature profiles between the surface and 25 m at 5-m intervals were determined approximately three times per week, usually at high tide, from November to March at Peninsula Point (Figure 1), using a Martek Mark VI Water Quality Analyzer (Reilly and Moore 1982, 1983, 1984, 1985, 1986).

RESULTS

Total Catch

During four years of trawl sampling, approximately 1.37 million YOY herring were caught and about 2% were measured (Table 1). Approximately 14,175 juvenile herring were caught and about 52% were measured. Thus, relative numbers of YOY and juvenile herring in length frequency histograms for a particular year are not indicative of year class strength. The analysis reported here is based only on samples from April to June in 1983 and 1986 and from April to July in 1984 and 1985.

TABLE 1. Total Catch of YOY and Juvenile Herring from Midwater Trawls in San Francisco Bay, April to August, 1983 to 1986.

Part 1. YOY

	1983		*1984*		*1985*		*1986*	
Month	*Number of tows*	*Total catch*	*Number of tows*	*Total catch*	*Number of tows*	*Total catch*	*Number of tows*	*Total catch*
April	67	10,245	50	14,530	90	122,785	87	50,705
May	180	67,985	110	74,536	230	255,255	88	80,475
June	150	16,995	110	132,505	70	157,240	162	340,040
July	30	28	150	34,175	49	13,350	–	–
August	40	16	30	78	–	–	–	–
Total	467	95,269	450	255,824	439	548,630	337	471,220
Total measured for study		3,563		6,685		8,980		7,320

Part 2. Juveniles

Year	*Number of tows*	*Total catch*	*Total measured for study*
1983	467	1,538	875
1984	450	2,374	1,966
1985	439	7,146	2,581
1986	337	3,119	1,883

Length Frequencies

Length frequency histograms during all 4 yr show a distinct separation between the majority of YOY and juvenile herring (Figures 2 and 3); few herring are in the 80–100 mm BL range. In 1983 and 1986 a slight amount of overlap occurred between year classes, while in 1984 and 1985 a wide separation existed. In general, from April to July most YOY herring in San Francisco Bay ranged from 30 to 90 mm BL, with the peak in length frequency distribution at 40 to 70 mm and monthly mean BL from 45 to 68 mm (Table 2). Juveniles ranged from 90 to 160 mm BL with peak distribution from 105 to 150 mm and monthly mean BL from 108 to 147 mm (Table 2). Each season, approximately 90% of spawning occurred within a 2-month period ranging from mid-December to mid-March (Spratt 1983, 1984, 1985, 1986a). Thus, the majority of YOY herring from April to July will be from 1 to 7 months old, while juvenile herring will be 13 to 19 months old.

TABLE 2. Mean BL and Standard Deviation of YOY and Juvenile Herring Samples by Month, Spring and Summer 1983 to 1986, from San Francisco Bay.

Part 1. Age 0+

Year	*Month*	*N*	*Mean BL*	*Standard deviation*
1983	May	2327	52.4	6.8
	June	1236	63.8	8.9
1984	April	675	51.0	6.6
	May	1818	54.0	6.3
	June	2322	62.9	7.2
	July	1870	68.2	5.6
1985	April	1781	46.7	8.5
	May	4452	44.7	7.4
	June	1699	49.5	5.7
	July	958	60.3	3.1
1986	April	1689	57.2	6.6
	May	1813	54.2	10.3
	June	3818	59.2	11.7

Part 2. Age 1+

Year	*Month*	*N*	*Mean BL*	*Standard deviation*
1983	April	104	107.2	12.0
	May	408	109.6	11.8
	June	363	121.7	10.6
1984	April	53	125.7	6.8
	May	463	130.9	7.0
	June	777	133.4	7.1
	July	673	137.2	6.8
1985	April	268	138.8	9.4
	May	2138	146.8	6.8
	June	175	146.2	8.4
1986	April	252	108.2	10.4
	May	458	119.1	14.5
	June	1173	135.4	8.5

Usually from nine to 13 herring schools enter San Francisco Bay and spawn at approximately 2-wk intervals from late October to mid-March; however, only from four to seven schools are large (greater than 1000 tons) and these

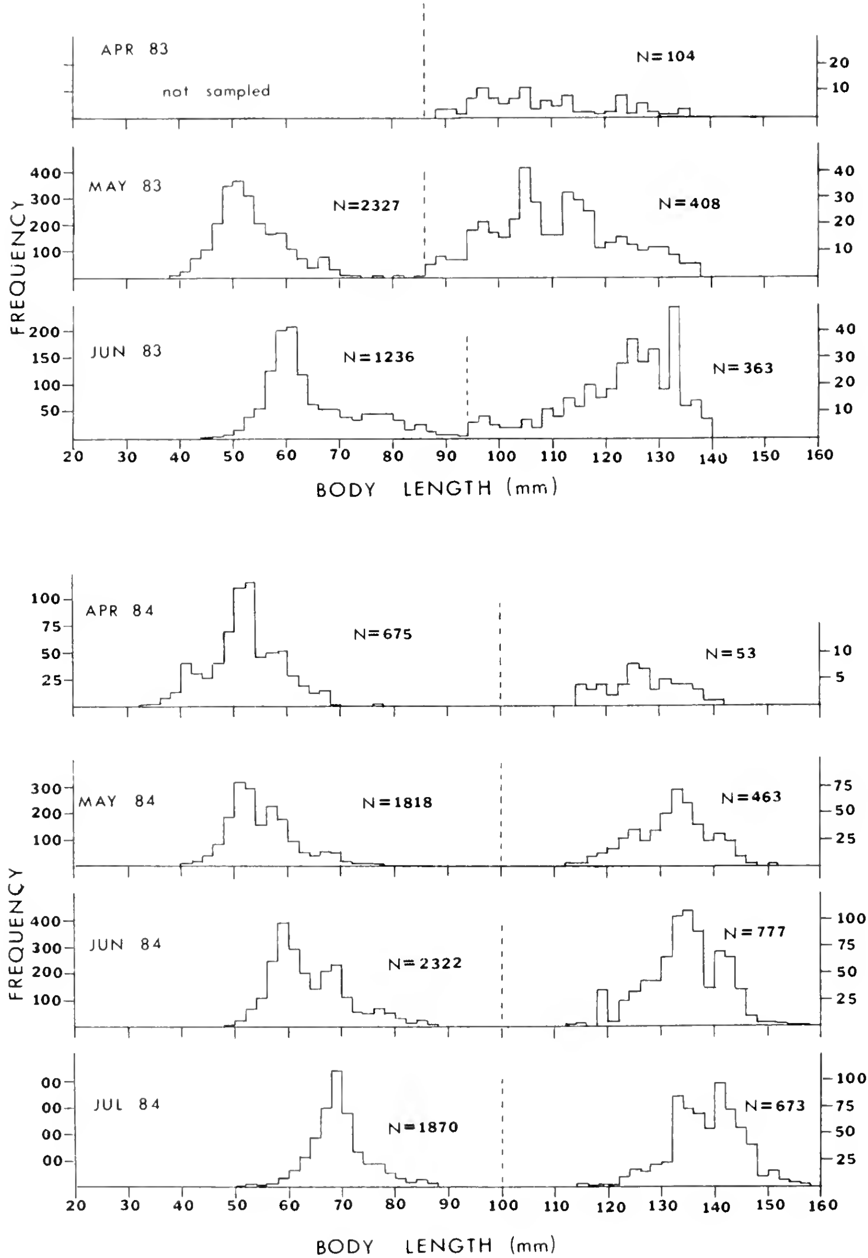

FIGURE 2. Number of YOY and juvenile Pacific herring (2-mm intervals) from midwater trawl samples, San Francisco Bay, April–June 1983 and April–July 1984.

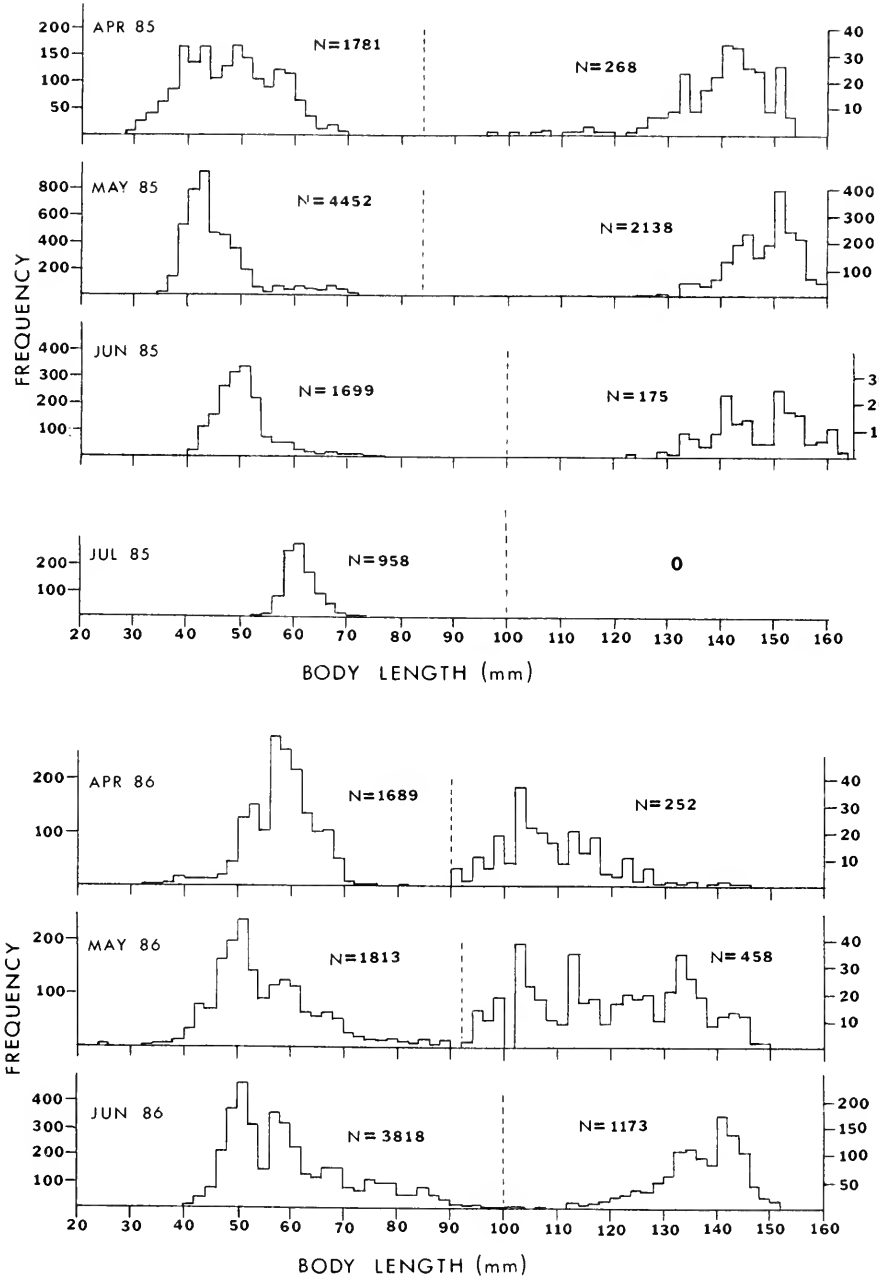

FIGURE 3. Number of YOY and juvenile Pacific herring (2-mm intervals) from midwater trawl samples, San Francisco Bay, April–July 1985 and April–June 1986.

contribute the bulk of the total spawning biomass (Reilly and Moore 1983, 1984, 1985, 1986; Spratt 1983, 1984, 1985, 1986a). Larvae from each spawn can be considered a cohort and would be responsible for the occurrence of multiple modes in the length frequency histograms.

The shift in median BL for YOY herring from month to month cannot always be interpreted as growth, such as from April to May 1986, due to the appearance of different cohorts in the sampling area. Most YOY herring leave the bay by mid-summer, and, based on the large number of herring collected, the sampling location appears to be along the emigration route.

An approximation of average growth can be obtained from examining the frequency distribution of the peak farthest left in the histograms during June of each year (Figure 4). This most likely represents the cohort from the last major spawn each year which occurred from early February to mid-March. Thus, herring may grow to 50–60 mm BL in 3 to 4 months.

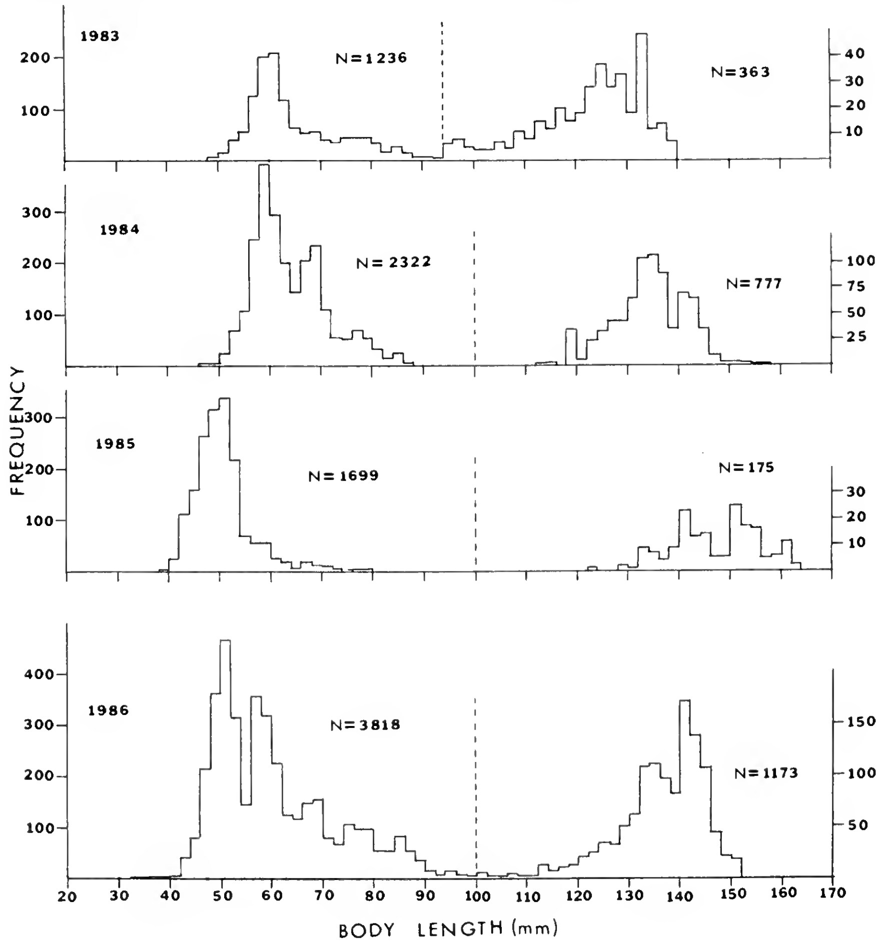

FIGURE 4. Number of YOY and juvenile Pacific herring (2-mm intervals) from midwater trawl samples, San Francisco Bay, June, 1983 to 1986.

Single modes from large samples, such as in May, June, and July 1985 (Figure 3), reflect the growth of the major YOY cohort or cohorts. In May, the mode was 42–43 mm, in June 50–51 mm, and in July 60–61 mm, a growth rate of approximately 10 mm per month.

Seasonal Differences in Growth

Length distribution of juveniles from 1986 changed dramatically from April to June, with the majority of 1+ yr old fish ranging from 90 to 130 mm BL in April (Figure 3). Medium-sized herring were all but absent in June, when most juveniles ranged from 120 to 150 mm BL. The smaller juveniles had a definite annulus on the otolith and most likely represent a slow growing cohort from a late spawn during the 1984–85 season. The presence of the annulus precludes the possibility of their origin from early spawns in the 1985–86 season. Samples in June probably are more representative of the growth of the majority of the year class; in 1986 the ratio of juveniles caught greater than 120 mm to those less than 120 mm was 5.1:1.

Juveniles in 1983 and 1986 averaged less in BL and had a wider length distribution than those in 1984 and 1985 (Figures 2 and 3). A comparison of growth between years is best seen, however, in samples from June of each year (Figure 4). Sample size is large and this is usually the last month of high relative abundance of YOY and juvenile herring in the bay before their departure. In 1985 and 1986 YOY modes were less than those of 1983 and 1984. A noticeable lack of YOY herring greater than 70 mm was characteristic of June and July 1985 (Figure 3). Since major spawns occurred at approximately the same time each year (more than 50% of all spawning occurred from January 5 to February 7), conditions for growth in the bay must have been more favorable in 1983 and 1984 than in 1985 and 1986.

An examination of mean 15-m temperatures from profiles at Peninsula Pt. in San Francisco Bay from December to February (the period of hatching and early development for the majority of larvae) indicates that temperature may have a direct influence on YOY growth in the bay (Table 3). In 1983 and 1984, temperatures were relatively warm, while in 1985 mean temperature was relatively cold. Temperatures during the 1981–82 spawning season were unusually low; thus the 1982 year class hatched during a period of unfavorable temperatures for growth. Surface temperatures are more affected by ambient air temperatures and show greater variation than 15-m temperatures (Table 3). The relationship between surface temperature and YOY growth is not as clear as that of 15-m temperature.

Length frequency distributions of juveniles reflect growth conditions during part of their first year, in the bay, and during the remainder of their first and part of their second year, in the ocean, before they return to the bay in spring. The magnitude of growth differences among the four year classes of juveniles is greater than that of YOY fish (Figure 4). The 1982 year class, shown as juveniles in June 1983, exhibited relatively poor growth. These herring were undoubtedly influenced by El Niño conditions in the eastern Pacific during 1982 and 1983 (Wooster and Fluharty 1985), as were all adult herring from central California (Spratt, in press). The additional factor of lower temperatures in the bay in 1982 resulted in the relatively small mean BL of this year class as juveniles in 1983. In contrast, the 1984 year class, shown as juveniles in June 1985, experienced relatively warm bay temperatures and normal oceanic conditions, resulting in exceptionally good growth. The growth of the 1983 year class is most likely average for San Francisco Bay herring. Normal oceanic conditions probably aided the 1985 year class after a slow start in San Francisco Bay, but the presence of juveniles in April and May 1986 between 90 and 120 mm probably reflects the earlier influence of poor growth in the bay.

TABLE 3. Mean and Range of 15-m and Surface Temperature, December to February, at Peninsula Pt., San Francisco Bay and mean BL for YOY herring, June.

Herring year class affected	*Range Dec–Feb*	*Mean Dec–Feb*	*Mean BL YOY June*
15-m temperature (C)			
1982	9.5–10.4	10.1	–
1983	10.0–13.8	12.5	63.8
1984	11.4–13.6	12.3	62.9
1985	10.2–12.7	11.2	49.5
1986	9.7–13.2	11.7	59.2
Surface temperature (C)			
1982	8.4–11.4	9.6	–
1983	9.6–13.4	11.4	63.8
1984	10.0–13.3	11.7	62.9
1985	9.3–12.6	11.0	49.5
1986	9.4–13.5	11.5	59.2

DISCUSSION

Hubbs (1925) found YOY herring in San Francisco Bay to range from 36 to 71 mm (mode 47 mm) in early June 1923. A small amount of herring collected in the bay from October to December 1922 ranged from 63 to 90 mm (mode 75–78 mm). The distribution of San Francisco Bay's YOY herring during fall and winter is unknown; however, in October 1982 Reilly and Moore (1983) collected 400 YOY herring 1 n.m. west of San Francisco in the Gulf of the Farallones. They ranged from 63 to 82 mm BL and averaged 70 mm. This is consistent with the slower growth rate observed for this year class in general. Spratt (1981) reported that YOY herring in Monterey Bay reach 90 mm BL by September.

Hubbs (1925) also found "yearling" herring, 79 to 115 mm (mode 91–92 mm), in mid-April in San Francisco Bay. These were most likely from a cohort hatched late in the previous season.

Spratt (1981) found that Monterey Bay herring averaged 113 mm as 1-yr olds in January. Miller and Schmidtke (1956) found one annulus on juvenile herring from Monterey Bay in June 1948; these fish averaged 145 mm BL, similar to those from San Francisco Bay in 1985. Estimated lengths for 1-yr old Pacific herring in other states include 112–120 mm for Alaska (Barton 1979) and 120–134 mm for Washington (Gonyea 1985, Chapman, Katz and Erickson 1941).

Growth rates observed in this study are consistent with those of 2-yr old herring sampled from the San Francisco Bay fishery. Spratt (1986b, in press) found 2-yr olds in the 1983–84 season (1982 yr class) to average only 152 mm BL, due to El Niño effects, while the 1983 and 1984 yr classes averaged 163 and 162 mm BL, respectively. Other studies report average length of 2-yr olds to be 157–166 mm in Humboldt Bay, California (Rabin and Barnhart 1986) and 160 mm in Washington (Gonyea 1985). However, isolated stocks of Pacific herring exist with much lower growth rates. Barton and Steinhoff (1980) report that herring from Kotzebue, Alaska reach only 126 mm by their second yr. A "Fidalgo" stock of herring from Washington averages only 139 mm as 2-yr olds (Buchanan 1985). Lower growth rates may also be characteristic of a local population near Fort Bragg in northern California. Reilly and Moore (CDFG, Menlo Park, unpub. data) found all of 15 herring aged in the range 160–169 mm BL to be 3 or 4 yr old.

Growth regulatory mechanisms are often classified as either density independent or density dependent. Density independent factors are usually environmental, such as temperature and salinity, while density dependent factors include food supply, cannibalism, and year class size. Pacific herring growth may reflect both types of mechanisms during their first 2 yr. A direct relationship between bay temperature and growth of YOY herring, as measured by mean BL in June, was found for the period 1983 to 1986. Moores and Winters (1982) found evidence that temperature regulated growth of Atlantic herring during their first year. Anthony and Fogarty (1985) found that temperature during the first growing season of Atlantic herring was positively correlated with mean length at age 2 yr, while no correlation was found between the latter and temperature during the second growing season.

Although the El Niño of 1982–83 was characterized by above normal temperatures for coastal California waters, growth of herring was inhibited. This infers that the direct physiological link between elevated temperatures and increased metabolic rate (causing increased growth for YOY herring in the bay) was superseded by other factors, such as a reduction of food supply in the ocean. Winters, Wheeler and Dalley (1986) found that growth of juvenile Atlantic herring was not correlated with temperature but was inversely correlated with year class size (which could indirectly affect food supply through competition). The 1982 year class of herring from San Francisco Bay was more than twice as abundant as 2-yr olds than each of the next three year classes (Reilly, unpublished data). The 1982 year class, as 1+ yr olds, had the smallest mean BL in June of the four year classes studied; this year class also experienced El Niño conditions during its first season in the ocean. Other workers have found density dependent relationships for growth of juvenile Atlantic herring (Anthony 1971, Hubold 1978). Haist and Stocker (1985) concluded that Pacific herring in British Columbia exhibit density dependent growth as juveniles moderated by environmental factors, and they found an optimum temperature range for growth. Results from this study support the fact that growth is controlled by a complex interraction between environmental factors and population size.

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DIET OF JUVENILE AND SUBADULT WHITE STURGEON IN THE LOWER COLUMBIA RIVER AND ITS ESTUARY [1]

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This note describes the diet of white sturgeon, *Acipenser transmontanus,* from the lower Columbia River and its estuary (Washington and Oregon). Samples were collected from 1980 to 1983. White sturgeon were captured by bottom trawl, purse seine, and hook and line and ranged from 5 to 129 cm in total length. Diet varied with length. The amphipod *Corophium salmonis* was primary prey for white sturgeon $<$ 80 cm long but not white sturgeon $\geq$ 80 cm. Larger white sturgeon consumed fish and large invertebrates. In general, diet diversity increased with length.

INTRODUCTION

This note provides information on food habits of juvenile and subadult white sturgeon, *Acipenser transmontanus,* in the lower Columbia River and its estuary. White sturgeon occur in large rivers and their estuaries and in marine waters on the Pacific coast of North America from the Aleutian Islands of Alaska to Monterey, California, (Scott and Crossman 1973). They are anadromous, although in some rivers are landlocked by hydroelectric dams (Haynes and Gray 1981).

The Columbia River has the highest commercial and sport catches of white sturgeon on the Pacific coast; the commercial catch peaked in 1892 at more than 5 million pounds. This peak was followed by a rapid decline in landings due to overfishing; by 1899 less than 100,000 pounds were landed (Craig and Hacker 1940). Commercial and sport fishermen have recently targeted on white sturgeon because of their availability and the decline of Pacific salmon, *Oncorhynchus* spp. In 1969 only 13,000 white sturgeon were captured (total sport and commercial) in the lower Columbia River below Bonneville Dam; in 1984 over 59,000 were captured (King 1985). Despite the monetary value of white sturgeon, limited life history information is available, especially for juveniles.

MATERIALS AND METHODS

A total of 174 white sturgeon were collected; 120 were obtained between River Kilometers (RKm) 3 and 62 during a comprehensive study of Columbia River estuarine fishes in 1980–1981 (McConnell et al. 1983). The sampling gears were an 8-m semiballoon shrimp trawl, 200-m purse seine, and hook and line (Table 1). An additional 54 white sturgeon were collected in July–September

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1983 using a 5-m semiballoon shrimp trawl between RKm 47 and 161 (Figure 1).

TABLE 1. Number of White Sturgeon Captured Using Various Gear Types in the Columbia River and Its Estuary.

	Sampling gear			
Month	*Trawl*	*Purse seine*	*Hook and line*	*Total*
Jan	2	2	–[1]	4
Feb	6	0	–	6
Mar	5	0	–	5
Apr	2	0	–	2
May	11	2	–	13
Jun	3	8	39	50
Jul	17	4	–	21
Aug	27	5	–	32
Sep	30	0	–	30
Oct	1	2	–	3
Nov	2	1	–	3
Dec	5	0	–	5
Total	111	24	39	174

[1] Indicates no collections were made.

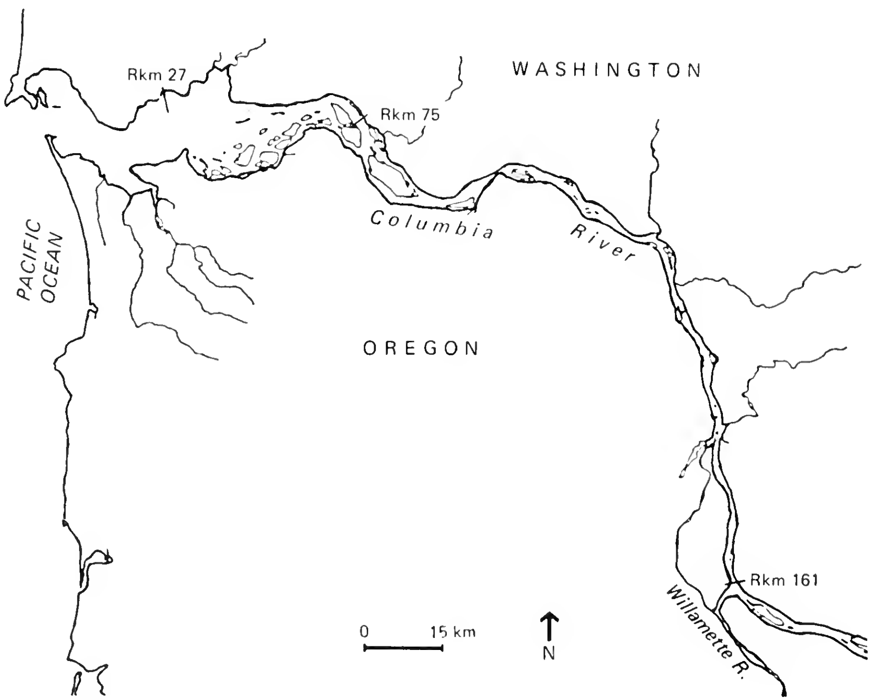

FIGURE 1. The lower Columbia River and its estuary.

Stomachs were initially preserved in the field with a buffered 8% formaldehyde solution, and transferred to vials containing 70% ethyl alcohol in the laboratory. Stomach and esophageal contents were examined with a 10X binocular dissecting microscope. Food organisms were identified to the lowest practical taxon (usually species), blotted, air-dried for 10 min, and weighed to the nearest 0.0001 g.

All data were stratified by fish length to examine the effect of size on white sturgeon feeding habits. White sturgeon <80 cm total length (TL) were stratified by 20-cm size increments; those ≥80 cm were combined into one group. Percent weight, percent number and percent frequency of occurrence were calculated for each prey.

RESULTS

The amphipod *Corophium salmonis* was the dominant food item for white sturgeon <80 cm (Figure 2). Other invertebrates, including the mysid *Neomysis mercedis,* the decapod shrimp *Crangon franciscorum,* and the isopod *Saduria entomon* were also utilized by smaller white sturgeon. Fish became increasingly important as prey for white sturgeon ≥60 cm; especially the northern anchovy, *Engraulis mordax,* which was the dominant food item by weight for white sturgeon ≥ 80 cm. White sturgeon ≥ 60 cm consumed a wide variety of prey species, including large invertebrates and fishes.

The white sturgeon examined ranged in length from 5 to 129 cm (TL). It is important to note that 94% of the white sturgeon <60 cm were captured above RKm 27, whereas only 7% of the white sturgeon ≥60 cm were captured above RKm 27. Therefore, differences in diet may partially reflect different areas of capture.

The estuary appears to be a particularly important feeding area for white sturgeon ≥80 cm. From 1979 to 1984, the estuary (RKm 1-61) was the most productive sport fishing area; in 1984, 55% (21,900) of the total white sturgeon sport catch occurred here (King 1985).

Our results generally agree with similar studies in the Sacramento-San Joaquin estuary, California (Schreiber 1962; Radtke 1966; and McKechnie and Fenner 1971) and the Fraser River, British Columbia (Semakula 1963; and Semakula and Larkin 1968). These studies also showed that small white sturgeon ate small invertebrates, and that larger white sturgeon ate fish and large invertebrates. Specific differences in food habits between our and other studies probably relate to the occurrence and abundance of prey in the different drainages. For example, eulachon, *Thaleichthys pacificus,* was seasonally dominant in the Fraser River study, and was also a seasonally important prey in larger white sturgeon in the Columbia River (Dees 1961). We did not find many eulachon in Columbia River white sturgeon, but collected few stomachs in winter when eulachon are abundant.

Our study documents the diet of juvenile and subadult white sturgeon in the Columbia River system. This is valuable because of the growing interest in white sturgeon by sport and commercial fishermen in the Columbia River. Accurate sturgeon life history information is essential for resource managers. Small

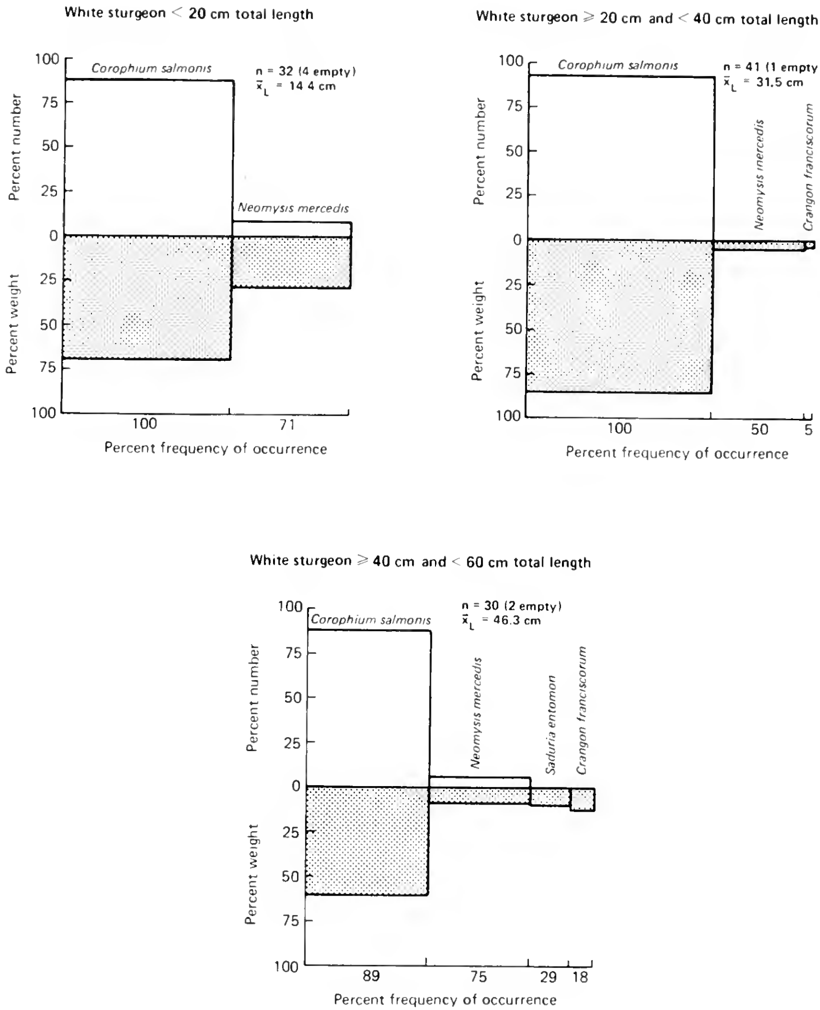

FIGURE 2. Food of different size groups of white sturgeon, *Acipenser transmontanus,* in the lower Columbia River. Food is represented by % composition by number and weight and by frequency of occurrence. Prey items that had number and weight comprising less than 3.0% are not shown.

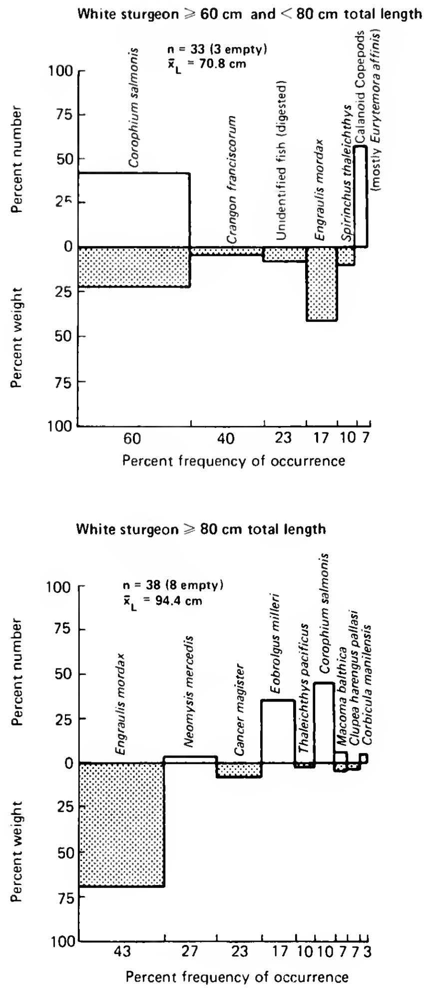

FIGURE 2. (continued)

sturgeon, as well as juvenile salmonids and many other species (McCabe et al. 1983), feed extensively on *Corophium salmonis* in the Columbia River estuary. Although benthic invertebrates in the Columbia River estuary have been well studied (Durkin and Emmett 1980; Higley et al. 1983), very little information is available on the benthic invertebrates of the Columbia River upstream from the estuary to Bonneville Dam (RKm 233). We believe a more comprehensive study to determine the life history, distribution, and abundance of white sturgeon and *C. salmonis* in the Columbia River is essential for the proper management of white sturgeon resources of the lower Columbia River.

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HERD SEGREGATION IN HARBOR SEALS AT POINT REYES, CALIFORNIA [1]

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A mixed class aggregation of harbor seals resides at Double Point, California. Seals are present year round but are more abundant during the March through June breeding season. Seals were segregated by sex and age class within the herd, and patterns changed during the season. Early in the 1984 and 1985 breeding seasons the herd was equally composed of males, females, and immatures, but mid-way was composed of mostly females and pups. Late in the season more males and immatures were present. We hypothesize that changes in segregation patterns are related to intolerance of males and immatures by pregnant females and females with pups.

INTRODUCTION

The harbor seal, *Phoca vitulina,* is gregarious when hauled out on shore. Scheffer and Slipp's (1944) contention that harbor seal aggregations are composed of mixed ages and sexes, has been modified by observations that groups can be composed almost exclusively of one class; for example, nursery (Knudtson 1977, Naito and Konno 1979, Brown and Mate 1983, and Slater and Markowitz 1983), bachelor (Knudtson 1977), and juvenile aggregations (Payne and Schneider 1984). These variations in group structure have been correlated to availability of haul-out space and reproductive and feeding strategies.

Little is known about spatial segregation within mixed aggregations. We studied such segregation during the breeding season with two objectives: (i) to identify herd composition; (ii) and to determine whether the relative space-use pattern of various age/sex categories changed as the season progressed.

METHODS

Double Point is a coastal habitat named for its concave, steep, cliff-backed beach enclosed by two jagged promontories and is located in Marin County, California (lat 37° 56′ N, long 122° 46′ W). We censused a mixed sex/age group of seals at south Bolsa Beach, a pocket beach at Double Point, nine times during the 1984 and 12 times during the 1985 breeding seasons. Observations were conducted during midday, low to medium low tides when maximum numbers of seals were assumed to be present (Stewart 1984, Allen et al. 1985). South

[1] Accepted for publication October 1987.

Bolsa Beach contained 75–100% of the total seals present at Double Point. We divided the breeding season into Early (March to mid-April), Middle (mid-April to mid-May), and Late (mid-May to mid-June) periods. These periods were based on the reproductive status of the majority of females and on the age of the pups (early = mostly pregnant females and few pups, middle = majority of females with pups, late = older and weaned pups). We censused each period three times in 1984 and four times in 1985. Censuses were done a week apart and were conducted by one observer from the cliff 30 m above the haul-out.

We classified seals as adult male, adult female, immature, and pup. Immature seals were distinguished from adults based on relative size. Seals mature at ages 3–5 (Boulva and McLaren 1979) so some overlap would be expected between the immature and other categories. Pups were easily distinguished by their small size and bright silver pelage at a time when adults and immatures are in their pre-molt condition. Females were further categorized as pregnant, non-pregnant, or with pup. Males were distinguished from females by the penal opening on the ventrum. Because adult male and female seals are almost identical in size and seals often lay on their ventrum, we were not able to sex all adult animals but were able to classify an average of 71% of the herd. We assumed that males and females were equally likely to lay on their ventrum.

We calculated the average percent representation of each sex/age category and standard deviation for each period. To determine relative spatial position, we divided the herd into quadrants from the south to the north end of the herd (A south, B, C, D north). Each quadrant equaled one quarter of the total number of seals hauled out on south Bolsa Beach on a given day; throughout the season, quadrant A was bordered by tide pools and B,C,D by deep water. We tested the null hypothesis for independence of position with sex and age class for each breeding period for each season with a Chi-square test of independence and analysis of residuals (Bishop, Fienberg and Holland 1975, Fienberg 1980).

RESULTS

The prevalence of each sex/age class changed as the breeding season progressed in both 1984 and 1985 (Table 1). During the early period, males, females, and immatures were equally abundant, and pups began to appear; during the middle period the herd was composed primarily of females and pups; and during the late period females and pups still were most abundant, although in 1985 the percentage of males began to increase then.

The level of spatial sex/age segregation also changed over the course of the season. The null hypothesis, independence of position in the herd with respect to sex and age class, was rejected for all three periods for both years (Table 2). Analysis of residuals indicated that in the early period most females hauled out in quadrant D, most immatures were in quadrant A, and males tended to be in quadrants B and C. In the middle period females and pups were uniformly present in all quadrants, fewer males were in quadrant D and immatures tended to be absent from quadrant D. In the late period most females were present in quadrant D, more males were present in quadrant B or C, and immatures and weaned pups tended to be in quadrant A or B. For all three periods except late 1984 there was a strong tendency for immatures to be in the extreme opposite quadrant (A) of the herd from females (D).

TABLE 1. Percent Composition by Sex and Age Class at Double Point, California.

	1984		*1985*	
	$\bar{x}$*	*SD*	$\bar{x}$	*SD*
	n = 3		*n = 4*	
Early				
Male	31	2	22	9
Female	32	2	33	9
pregnant	(61)	–	(50)	–
with pup	(19)	–	(39)	–
non-preg	(20)	–	(11)	–
Immature	31	4	27	15
Pup	7	5	16	18
Count	170	90	249	65
Middle				
Male	12	5	8	3
Female	40	3	44	3
pregnant	(15)	–	(3)	–
with pup	(83)	–	(91)	–
non-preg	(2)	–	(6)	–
Immature	10	2	5	1
Pup	38	8	44	2
Count	296	103	299	46
Late				
Male	13	5	21	11
Female	38	7	44	10
pregnant	(1)	–	(0.2)	–
with pup	(62)	–	(51)	–
non-preg	(37)	–	(49)	–
Immature	17	11	10	5
Pup	32	8	25	7
Count	267	56	294	101

* $\bar{x}$ is the average for each period, SD is the standard deviation, and n is the number of censuses.
Percentages of pregnant females, females with pups, and non-pregnant females are taken with respect to total females.

Females of different reproductive status (pregnant or with pup) also tended to segregate within the herd (Table 1). Pregnant females seen primarily in the early period were mostly present in quadrant D whereas those with pups were present uniformly. During the middle and late periods, females with pups were still seen evenly distributed throughout all quadrants, and females that were neither pregnant nor with pup were primarily counted in quadrant C or D.

TABLE 2. Numbers of Seals by Sex and Age Class at Double Point, for Each Quadrant and Period Within the 1984 and 1985 Breeding Seasons.

		1984				*1985*			
		Quadrant				*Quadrant*			
Period	*Sex/Age Class*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*
Early............	Male/adult	33 *	49	42	32	62	66	61	33 *
	Female/adult	35	41	33	50 *	48 *	65	103	141 *
	Immature	75 *	36	32	21 *	118 *	59	56	32 *
	Pup	13	9	5	5	22	29	47	52
		$X^2 = 42$	$p < 0.005$			$X^2 = 140$	$p < 0.005$		
Middle..........	Male/adult	22	33	31	13 *	26	28	35	9 *
	Female/adult	87	83	86	98	105	125	128	163
	Immature	37 *	16	18	13	32 *	10	10	3 *
	Pup	97	90	80	83	126	125	126	144
		$X^2 = 29$	$p < 0.005$			$X^2 = 62$	$p < 0.005$		
Late	Male/adult	26	13 *	28 *	18	54 *	103 *	50	34
	Female/adult	66	56	54	77 *	140	101	112	126 *
	Immature	37	26	36 *	23	110 *	19 *	24	20
	Pup	76	61	37 *	46	129	64	47	41
		$X^2 = 24$	$p < 0.005$			$X^2 = 141$	$p < 0.005$		

* The standardized residuals and Freeman-Tukey deviates for these cells are significant at $\alpha = 0.05$.

DISCUSSION

Segregation by haul-out location has been observed by others; however, these observations often occurred in estuaries or bays where ample haul-out space is available. On a rugged coastal site such as Double Point, haul-out space is limited, and seals form a mixed aggregation in one location. During the breeding season, the mixed aggregation of seals at Double Point is not random, but instead is structured by sex, age, and female reproductive status. We hypothesize that segregation on land is in part related to intolerance of males and immatures by females. The degree of segregation, which changed over the season, may be related to changes in the biological condition of females (parturition, weaning, and estrous). Segregation appeared most pronounced during the middle period when the majority of females were with pups; such females are particularly aggressive and will threaten nearby seals. The numbers of males and immatures were greatly reduced in all quadrants at that time, and females with pups were evenly distributed throughout all quadrants.

Many advantages exist for females to form sub-clusters within a herd while on shore. They are able to form and maintain tighter bonds with their offspring and to rest and nurse without interference from sexually active males. At the same time, they are able to retain the benefits of gregariousness (i.e. protection from predators, and proximity to males during the mating period). For segregation to persist into the late breeding period is not unexpected because mating occurs primarily in the water. While on shore, females in estrous rest and generally rebuff males (Allen 1985).

Some researchers have stated that topography and/or male social interactions dictate the spacing patterns of harbor seals on shore (Sullivan 1982, Slater and Markowitz 1983). At Double Point, topography may have partially influenced herd segregation. Ample haul-out space was available at all but the highest of tides; however, ready access to deep water was limited to quadrants B, C, and D. Our observations indicated that in the early breeding period, females, the majority of which are pregnant, may choose quadrant D over the others because there is more space for birthing. Later, females nursing pups shift to quadrants A and B because of proximity to tide pools which are ideal "nursery pens" providing warm, calm water. During very low tides we consistently observed females with pups in these pools. In the late period, immatures and weaned pups may have been relegated to quadrant A because females, most probably in estrous, would be intolerant to them. Most males were in quadrant B with ready access to deep water and departing females.

Our observations provided no evidence for or against a male dominance hierarchy. A few males were present in quadrant D which could be interpreted as active exclusion of other males; these males, however, were often clustered rather than dispersed within the quadrant.

In conclusion, our results indicate that spatial segregation occurs within a mixed aggregation of harbor seals and that the relative space-use pattern of the different age/sex categories changed over the course of the breeding season as the reproductive status of females changed. We hypothesize that segregation is related to female intolerance of males and immatures. Proof that females are actively excluding other categories would require quantification of interactions between females of different reproductive status and males and immatures.

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Calif. Fish and Game 74(1): 60–63 1988

NOTES

RECORD OF THE CHAMELEON GOBY, *TRIDENTIGER TRIGONOCEPHALUS*, FROM THE SACRAMENTO-SAN JOAQUIN DELTA

On 5 March 1987 a chameleon goby, *Tridentiger trigonocephalus* (Gill), was collected during routine fish salvage operations at the John E. Skinner Delta Fish Protective Facility near Byron, Contra Costa County, California, approximately 130 km upstream from the Golden Gate Bridge (Skinner 1974). This Facility is located at the head of the California Aqueduct ahead of the Harvey O. Banks Delta Pumping Plant which exports water from the Sacramento-San Joaquin Delta via Old River. This species has been observed in Los Angeles Harbor and San Francisco Bay (Miller and Lea 1972) and most recently in Suisun Bay (P. B. Moyle and K. Hieb, pers. comm.), however, this is the first record of occurrence this far upriver in the Sacramento-San Joaquin Delta. The surface water temperature and salinity during the time of collection was approximately 12.5°C and 3.2 0/00.

Identification of the specimen was confirmed by K. Hieb, California Department of Fish and Game, Stockton. The specimen was 91 mm TL and weighed 11.4 g. Identification was based on the following characteristics: black spot at base of caudal fin; dark bar followed by a yellow arch on base of pectoral fin; teeth tricuspid; fin ray counts D VI+I, 12 and A I, 11; midlateral scales 50 (see Miller and Lea 1972). The specimen is being retained in the collection of California Department of Fish and Game, Bay-Delta Project, Stockton, California.

The chameleon goby was inadvertently introduced from the Orient into San Francisco Bay (Miller and Lea 1972). The most likely mechanism of introduction involves the transport of eggs laid on fouling organisms of ships hulls in the Orient; minimum ship transit time from the Orient, average incubation time of eggs and seawater along shipping routes are favorable for egg development and hatching upon arrival to the west coast of the United States (Haaker 1979). It is a shallow-water form that has not been collected in fresh water in California (Moyle 1976) until this occurrence.

Larry Neyman, California Department of Water Resources, Delta Fish Protective Facility Operator, deserves special commendation for his alertness in recognizing this specimen. I would like to thank Kathy Hieb for verifying the identification of the specimen.

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—*Paul F. Raquel, Bay-Delta Project, California Department of Fish and Game, 4001 N. Wilson Way, Stockton, California 95205.* *Accepted for publication August 1987.*

ADDITIONAL NOTES ON MIGRATIONAL DISTRIBUTION OF NORTHERN PINTAIL BANDED IN CALIFORNIA

During 1948–79, the California Department of Fish and Game banded 245,174 northern pintail, *Anas acuta,* mostly on seven banding stations located throughout California. Analysis of approximately 18,000 band recoveries from these pintails resulted in a comprehensive study of their migration patterns and distribution (Rienecker 1987). The objective of the present study is to document and evaluate pintail band recovery areas, emphasizing those out-of-state. Only indirect band recoveries from the following banding stations were used: Klamath Basin National Wildlife Refuges, Honey Lake Wildlife Area including Mountain Meadows, South San Francisco Bay, Suisun Marsh, Gray Lodge Wildlife Area, Imperial Valley and Los Banos Wildlife Area. Indirect recoveries are bands recovered in subsequent band recovery years (May 1 through April 30) following the year of banding.

RECOVERY AREAS

California

About 79% (N=13,784) of all indirect band recoveries were recovered in California. The Sacramento Valley (23.4%,N=4,096) and the San Francisco Bay-Delta (24.3%, N=4,258) were the two most important recovery areas, followed by the San Joaquin Valley (14.8%, N=2,586), Imperial Valley (8.2%, N=1,439) and northeastern California (5.9%, N=1,029).

Washington and Oregon

About 1% (N=174) of recoveries were from Washington, with three quarters of them from Western Washington. Many were recovered in December and January, which suggests that they had either wintered there or were at some point in a round-robin migration. Oregon accounted for over 2% (N=409) of recoveries with nearly all from the coastal and southern (Klamath Basin) regions.

Idaho, Nevada, Utah and Arizona

Less than 1% (N=41) of the total recoveries from California bandings were from Idaho, which suggests that there is little stopover by pintails in Idaho during the hunting season. About 1% (N=182) of recoveries were from Nevada, mostly Western Nevada. The majority of these birds had been banded in Imperial, San Joaquin and Sacramento Valleys. This suggests that Nevada is within the migration routes to both the Central Valley and the Imperial Valley. Utah was an important recovery area, as nearly 3.5% (N=601) of all recoveries were taken there with most in the Bear River Marshes of Northern Utah. Many of these pintails were banded in the Imperial Valley. Most of the harvest in Utah took place during October and November, and by January few pintails were left in the state. Less than 1% (N=66) of recoveries were from Arizona, most of which were from birds banded in Imperial Valley. Few pintails banded north of Imperial Valley migrate to or stop over in Arizona.

Alaska

Alaska, with less than 1% (N=142) of recoveries, was not an important recovery area for pintails banded in California, but was an important breeding area for pintails wintering in California (Bellrose 1976). Band recoveries (N=798) from pintails banded in Alaska showed 41% were taken in California (Patuxent Bird Banding Laboratory, unpubl. data). Major recovery areas for California-banded pintails were the Yukon-Kuskokwim Delta and Cook Inlet. About half of the recoveries were obtained during the hunting season, mostly September, and half during spring and summer months. Half of the spring and summer recoveries, mostly during May, were from shot birds. During the spring, pintails sustain the greatest harvest among ducks due to their relative abundance throughout the Yukon-Kuskokwim Delta (Klein 1966).

Canada

Almost 4.4% (N=767) of recoveries were from Canada, mostly from Alberta (2.3%, N=406). Most of the Alberta bands were recovered during September and October, the remainder during spring and summer. Approximately 1% (N=204) of recoveries were from Saskatchewan, about half of which were recovered in September and October and half during the spring and summer months. Most spring and summer recoveries were from birds found dead from unknown causes and from miscellaneous causes. e.g., hit by farm machinery, entanglement in fishing gear, caught due to injury, steel traps or by raptors. All other areas in Canada combined produced less than 1% (N=157) of recoveries.

Mexico

Recoveries from Mexico comprised about 3% (N=513) of the total and were recovered during all months of the year, but primarily December and January. The west coast of Mexico was the main recovery area, accounting for over half of the recoveries, most of which were from Imperial Valley bandings.

Other Flyways

From pintail bandings in California, over 3% (N-551) of recoveries were from the Central Flyway and about 1% (N=141) from the Mississippi Flyway. Approximately half of Central Flyway recoveries were from Los Banos and Imperial Valley bandings. Most of the recoveries from the northern half of the Central Flyway States were obtained in October and November, and from the southern half in December and January. Over 2% (N=385) of recoveries were from the Central Flyway wintering grounds, mainly Texas. Recoveries from the Mississippi Flyway were found among all of the states in the Flyway except Ohio. Louisiana, the major wintering area on the Flyway, accounted for over half of the recoveries.

USSR

Less than 1% (N=110) of recoveries were from the USSR, and all but two were from the north and south coasts of northeastern Siberia. Two recoveries were from farther west, one of which was from a Gray Lodge banded pintail recovered near Lugansk, north of the Black Sea. This is the longest migration on record, half way around the world, for a pintail banded in California. Over half of the Siberian recoveries were from birds shot during May. Henny (1973) suggested that a portion of the pintails wintering in the western United States annually nest in Siberia.

Pacific Islands and Eastern Asia

In addition to 11 pintails banded in Northern California and retrapped in Hawaii, 9 were recovered at points south and west of the Hawaiian Islands. Three of these distant recoveries were direct recoveries of 58 days from Suisun Marsh to the Line Islands, 82 days from the Klamath Basin National Wildlife Refuges to the Tokelau Islands and 91 days from the Klamath Basin National Wildlife Refuges to the Cook Islands. Medeiros (1958) suggested that pintails fly west on the tradewinds from the California coast and return on the westerlies which reach North America in an extended area from Crescent City, California to the Gulf of Alaska. The pintail is the only duck common to California that migrates this far from its breeding grounds.

Band recoveries of pintails from areas outside the normal pattern of breeding in Alaska and Canada and wintering in California add to our knowledge of pintail migrations and distributions. This knowledge is, however, valued more as a curiosity than as a management tool, although it does indicate the pintail's capacity to find and adapt to new habitats. Rienecker (1987) states that the vast majority of pintails banded in California migrate from staging areas in southeastern Alberta, southwestern Saskatchewan and Alaska to the Central Valley of California, where they spend the winter. All other routes are of minor importance.

ACKNOWLEDGMENTS

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—Warren C. Rienecker, California Department of Fish and Game, 1416 Ninth Street, Sacramento, CA, 95814. *Accepted for publication August 1987.*

BOOK REVIEWS

Seashore Discoveries

By Wesley M. Farmer. Available from: Dr. Wesley M. Farmer, P.O. Box 1323, Santee, Calif. 92071, [no date]; 124 p. $14.95 soft cover.

This apparently recent field guide is primarily designed for the novice, occasional, or casual visitor to the seashore. Two hundred and thirty-five species are covered with 240 line drawings and four photographs. The primary emphasis is on southern California and San Diego county in particular. As one might expect, invertebrates make up the bulk of the subject matter with eleven fish, four birds, two mammals, and only ten algae included. The drawings are well detailed, but more photographs would be helpful for species closely resembling others or those with distinctive coloration.

Most of the text consists of brief yet concise descriptions, ranges, distributions, and in some cases, notes on ecology or natural history for each organism. I noticed a few discrepancies, which seem mostly editorial in nature, such as describing *Phyllospadix* as both an alga and a flowering plant, green abalone commonly being 10 inches long, the maximum size of red sea urchins being only 100 mm, and some confusion about the relative sizes of *Pisaster giganteus* and *ochraceus*. An encouraging feature is the emphasis on conservation of our intertidal resources. A typical nature walk in the rocky intertidal is described, and a creel census (although dated) of tidepool visitors is presented which documents the considerable impact on intertidal populations that even casual collecting can have.

This would be a useful book for anyone seeking to learn about or introduce someone to the seashore life along the southern California coast.

—David O. Parker

Mammals in Hawaii, Second Edition.

A synopsis and notational bibliography.

By P. Quentin Tomich. Bishop Museum Press, Honolulu, Hawaii, 1986; 375 p. $42.95 plus $1.00 for handling and shipping.

As with the 1969 edition, this book offers excellent species accounts with extensive details and bibliographic references documenting 22 Hawaiian mammals both historically and naturally. About half the book is dedicated to useful references for each species; while the text of individual species accounts is written in a scholarly, easily understood style for the scientist or the lay person. The accounts are packed with pertinent information such as dates of arrival for introduced species, range in Hawaii, habitat requirements, conflicts with other species. . . .

For some of the species accounts, it is somewhat distracting that the author has obviously updated the first edition (to include recent publications) by adding paragraphs to the 1969 text instead of rewritting the original account. Many of the species accounts (especially marine mammals) are well illustrated with 27 black and white photographs which further enhance a skillfully constructed synopsis.

The author has provided a great deal of information about each animal and references that allow more complete investigation as desired. The annotated bibliography is very well done. Each reference contains important notes about the reference, thus creating a readable and useful bibliography. The marine mammal descriptions are excellent and highlight the book. The author provides additional comments on the environmental perils of introduced species and other aspects of mammals in Hawaii that make the book interesting and a valuable asset.

—Doyle A. Hanan

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