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Species Composition and Abundance of Juvenile Groundfishes Around Steller Sea Lion *Eumetopias jubatus* Rookeries in the Gulf of Alaska

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Abstract: We conducted bottom trawl surveys to determine species composition and abundance of juvenile groundfish communities around 6 Steller sea lion rookeries in the western Gulf of Alaska from 1994 to 1996. Overall, the most abundant species in our collections were rock sole *Pleuronectes bilineatus*, walleye pollock *Theragra chalcogramma*, Pacific halibut *Hippoglossus stenolepis*, northern sculpin *Icelinus borealis*, *Triglops* spp., *Gymnocanthus* spp., Pacific cod *Gadus macrocephalus*, slim sculpin *Radulinus asprellus*, and arrowtooth flounder *Atheresthes stomias*. Our results showed significant differences in species composition among rookeries within each of 3 depth strata and a greater abundance of juvenile groundfishes in the western part of the study area. Gadid and flatfish species were more abundant and had a higher probability of occurrence in the vicinity of sea lion rookeries on Akun, Ugamak, Atkins, and Chowiet Islands, compared to rookeries on Marmot and Sugarloaf Islands. The observed differences in species composition coincided with differences in topography, substrate composition, temperature, and salinity. A potential relationship between the abundance of juvenile groundfishes and sea lion survival is discussed.

INTRODUCTION

During recent decades major changes have taken place in the populations of marine life in the North Pacific. Stocks of shrimp, crab, and herring have declined, whereas pollock and salmon populations have increased. Concurrently, some marine mammal and seabird populations have flourished, but others have declined. A dramatic decline has been documented for the population of Steller sea lions *Eumetopias jubatus* in the western Gulf of Alaska and the eastern Bering Sea (Merrick et al. 1987). Estimates by the National Marine Fisheries Service (NMFS) using 1994 data indicate a population decline of over 75% since the late 1970s. One prominent hypothesis is that the abundance and composition of food available to Steller sea lions has changed (Merrick et al. 1987, 1997), and this change is affecting the health or survival of pups in the rookeries (Merrick et al. 1995).

Abundances of marine forage fishes have changed significantly since the 1970s. Abundances of shrimp and small forage fish species such as capelin *Mallotus villosus* in nearshore shrimp surveys in the western Gulf of Alaska declined precipitously in the late 1970s, whereas populations of large predatory fishes such as walleye pollock, Pacific cod, and flatfishes (Pleuronectidae) increased dramatically (Anderson et al. 1997; Mueter and Norcross 2000).

Changes in the composition of forage fish communities appear to coincide with shifts in the diets of marine mammals and birds. Capelin virtually disappeared from seabird diets in the late 1970s and were replaced by juvenile pollock and other species in the 1980s (Decker et al. 1994; Piatt and Anderson 1996). Between 1973 and 1978 Steller sea lions around Kodiak Island consumed mainly capelin and cephalopods (Pitcher 1981). In 1985–1986 sea lion diets were dominated by pollock, octopus, and flatfish, but no capelin were consumed. Steller sea lions in the Gulf of Alaska consumed primarily gadids and salmon in 1990–1993 (Merrick et al. 1997). In addition to a shift in diet, seabirds and marine mammals exhibited sev-

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eral signs of food stress (population declines, reduced productivity, and die-offs) throughout the 1980s and early 1990s (Piatt and Anderson 1996). Merrick et al. (1997) show that declines in sea lion populations differ among regions and are correlated with diet diversity. They suggest sea lions need a variety of prey for survival.

To assess the availability of prey fishes as food for marine mammals, the NMFS National Marine Mammal Laboratory (NMML), in conjunction with the University of Alaska Fairbanks, has conducted prey surveys around major sea lion rookeries in the eastern Aleutian Islands and in the western Gulf of Alaska since 1994 (Byrd et al. 1997). Our study examines abundance and distribution patterns of juvenile groundfishes around 6 sea lion rookeries based on results from opportunistic bottom trawl surveys associated with sea lion surveys. Differences in species composition and abundance of potential prey in the immediate vicinity of rookeries may be related to differences in sea lion survival because juvenile sea lions feed within a relatively short distance of the rookery (R. L. Merrick, NMML, Seattle, personal communication). Our objective was to compare the species composition and abundances of juvenile (ages 0 and 1) groundfishes found within foraging range of 6 major sea lion rookeries in the Gulf of Alaska and eastern Aleutian Islands and discuss potential relationships with sea lion survival.

METHODS

Field Collections

We conducted a bottom trawl survey to determine species composition and abundances of the juvenile groundfish community around each of 6 rookeries on Akun, Ugamak, Atkins, Chowiet, Marmot, and Sugarloaf Islands (Figure 1). These are volcanic islands with rugged underwater topography and a limited amount of trawlable area on sand and gravel substrate. Sampling was conducted from the M/V *Maritime Maid* between 10 and 25 July 1994 and from the M/V *Tiglax* between 25 June and 12 July in both 1995 and 1996. All collection timing, duration, and locations were constrained to coincide with Steller sea lion pup and prey distribution surveys conducted by NMML. The rookeries sampled during a given year and the time available for sampling depended on the

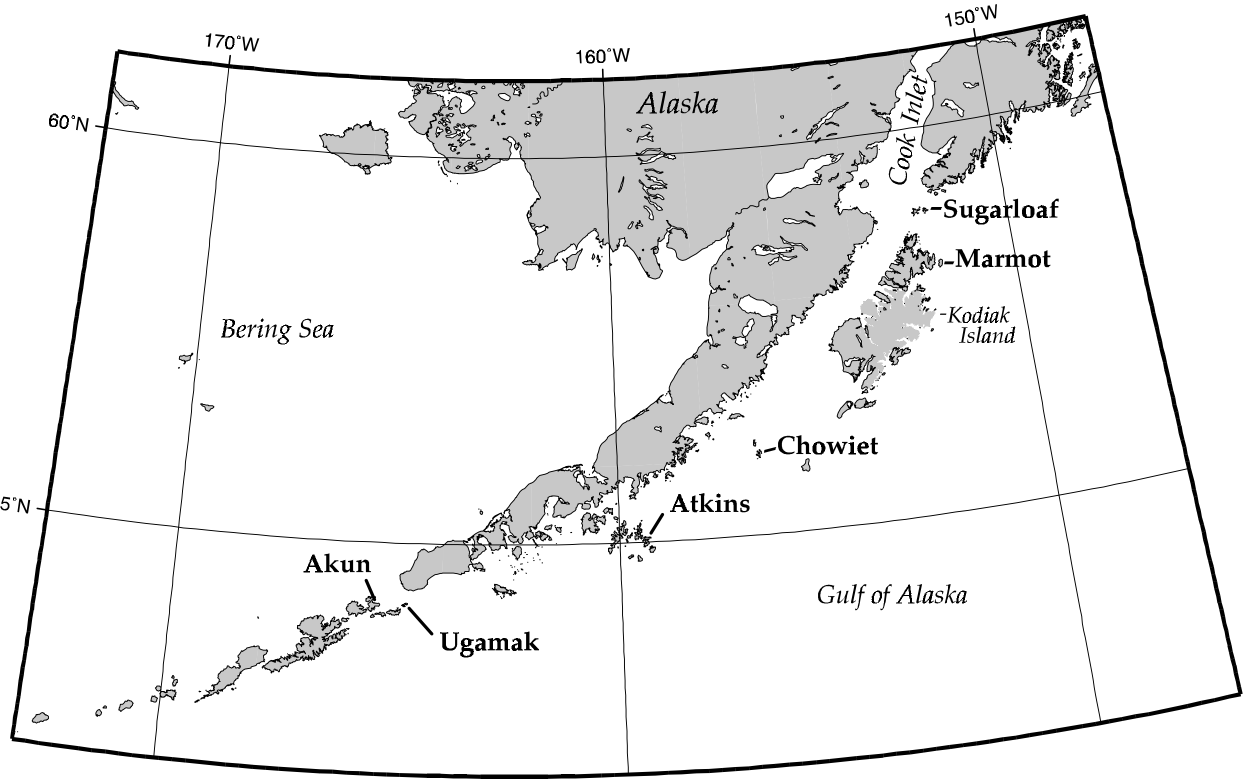

Figure 1. Map of Aleutian Islands and southcentral Alaska showing locations of 6 Steller sea lion rookeries around which juvenile groundfish were sampled between 1994 and 1996.

overall objectives of the NMML cruise. Additional samples near rookeries on Akun and Ugamak Islands were obtained on an opportunistic basis between 12 and 18 July 1995 during a seabird survey conducted by the U.S. Geological Survey Biological Resources Division.

We used a 3.05-m plumb staff beam trawl (Gunderson and Ellis 1986) with a 4-mm mesh at the codend as the primary sampling tool for all bottom trawl surveys in 1995 and 1996. A sled trawl with the same net and a reinforced beam with runners was used for some trawls in 1994. The gear was towed with the current for 10 min at approximately 0.5–0.8 m/s. Sampling followed a stratified design; however, the number of trawls at each rookery was often limited by time constraints imposed by the opportunistic nature of the trawl survey. Trawling was stratified by depth, and we attempted to trawl along transects radiating out from the rookery. Depth strata used in the sampling design were 15–40 m, 40–70 m, and over 70 m. Sampling locations within each stratum were selected without known bias. However, trawling locations were dictated by the availability of trawlable substrate and the inability of the vessel to sample at depths less than 15 m.

All fish were identified in the field to the lowest possible taxon or were frozen and taken whole to the laboratory for identification. Fish were counted and measured to the nearest millimeter. Catch per unit effort (CPUE, number/1,000 m^2) was calculated for each station and standardized to estimated area swept based on the effective width of the net (Gunderson and Ellis 1986). Distances were computed from global positioning system (GPS) positions at the start and end of each tow. Total CPUE was modeled as a function of gear type, depth, and location, and a power coefficient (0.69) was estimated to adjust CPUEs from the 20 sled trawl tows in 1994 to the beam trawl standard. We assumed selectivities were the same for the beam and sled trawls because the same net was used on both gear types and both were towed at the same speed.

In conjunction with the trawls, a portable conductivity–temperature–depth probe (CTD, Seabird Seacat Profiler SBE 19) was deployed at most stations to obtain salinity and temperature profiles for the entire water column. Where possible, missing temperature and salinity values were extrapolated from other CTD casts that were close in space and time. Substrate type at all trawlable stations was assessed using a Ponar grab. Sediment retrieved with the Ponar grab was retained and frozen for laboratory grain size analysis. Sediment type was classified following Folk (1980). If no sediment samples could be obtained, we determined sediment type visually by lowering a video camera to the bottom.

Data Analysis

We compared physical characteristics of the sampling sites among rookeries including their depth distribution, sediment composition, temperature, and salinity. Differences in sediment composition were qualitatively assessed, and differences in depth, bottom temperature, and bottom salinity among rookeries were compared using a nonparametric Kruskal–Wallis test. The observed differences were discussed in relation to species composition and abundance.

To assess the distribution and abundance of juvenile groundfishes, we examined and compared species composition among rookeries. Because not all rookeries were sampled in all years, the data are not sufficient for statistical analysis of interannual changes. Overall species composition was compared among rookeries within each depth stratum. Assuming there were no year-to-year differences in the depth distribution of fishes, we combined data from all years. Potential biases from combining several years were examined by plotting spatial trends within years and examining trends in catch rates of individual fishes by year.

We compared species composition using the complement of the Bray–Curtis distance measure as an index of similarity between each pair of stations (Bray and Curtis 1957). A fourth-root transformation of CPUE was used to reduce the influence of very abundant species, thereby focusing on differences in relative species composition. One thousand random permutations of the station-by-station similarity matrix were used to compare similarities within and between rookeries by depth stratum. Using an analysis of similarity (ANOSIM), we computed Clarke's R statistic for the data and for each random permutation to test the one-sided null hypothesis that within-group similarities do not exceed between-group similarities (Clarke and Green 1988). The probability of exceeding an observed R value under the null hypothesis can be estimated as

$$P = (x+1)/(N+1),$$

where N is the number of random permutations and x is the number of permutations for which R exceeded the R statistic computed from the data. Rejection of the null hypothesis indicates a significant difference in species composition among the 6 rookeries.

If significant differences were found within a depth stratum the ANOSIM procedure was performed on each pair of rookeries within the depth stratum, similar to multiple comparisons following an ANOVA. Species composition differed significantly between rookeries if the R statistic based on random permutations of the similarity matrix exceeded the observed R more than 95% of the time. Each pairwise comparison was evaluated at $\alpha = 0.05$ without adjusting for the fact that multiple comparisons were made.

We identified indicator species that contributed most strongly to the observed significant differences by their contribution to the overall average Bray–Curtis dissimilarity between rookeries (Clarke and Ainsworth 1993). For each species we computed the relative contribution to overall dissimilarity summed over all significantly different ($\alpha = 0.05$) pairs of rookeries. Only species that contributed at least 7.5% to the overall dissimilarity were considered indicator species, to limit the number of species included.

For the indicator species, species abundance at each rookery was indexed as the standardized CPUE of the selected species for all quantitative tows. All CPUEs were log-transformed prior to analysis because total CPUE of all species combined approximately followed a lognormal distribution (test of composite normality for log-transformed CPUE: $T = 0.066$, $P > 0.1$; Dallal and Wilkinson 1986). We compared total CPUE and the CPUE of indicator species among rookeries after adjusting for depth effects using linear models and generalized additive models. The CPUEs of individual species included many zero values and tended to be skewed even after transformation. To account for zero abundances we first modeled presence or absence data as a 0 or 1 Bernoulli random variable with probability P of observing a species at a given station (binomial model)

$$\log(P/(1-P)) = \alpha + (\text{rookery})_i + f(\text{Depth}) + \text{error},$$

where f is a smooth function of depth (smoothing spline with 3 equivalent degrees of freedom). This allowed for nonlinear relationships between the frequency of occurrence of a species and depth. Parameters were estimated using maximum likelihood, and a nonparametric F test was used to compare the nonparametric additive model to a linear model on rookery and depth (Hastie and Tibshirani 1990). If the nonlinear relationship was not significant, we adjusted for the depth effect and tested for differences in the probability or frequency of positive catches among rookeries by using a linear binomial model. If nonlinear depth effects were significant, we adjusted for depth effects using the additive binomial model with a smooth function of depth before testing for differences among rookeries. A significance test for the null hypothesis (no significant difference among rookeries) was based on the decrease in deviance resulting from removing the rookery variable from the model. This statistic has an approximate χ^2 distribution under the binomial model (McCullagh and Nelder 1989; Hastie and Tibshirani 1990).

Table 1. Depth distribution of all quantitative bottom trawl stations sampled between 1994 and 1996 at 6 sea lion rookeries in the Gulf of Alaska, by rookery and depth stratum.

Rookery	15–40 m	40–70 m	>70 m
Akun Island	4	7	7
Ugamak Island	9	9	3
Atkins Island	3	8	4
Chowiet Island	2	5	7
Sugarloaf Island	4	3	1
Marmot Island		9	18
Total	22	41	40

We subsequently ignored all zero catches and modeled CPUE, conditional on it being positive, using the additive model

$$\log(\text{CPUE}) = \alpha + (\text{rookery})_i + f(\text{Depth}) + \text{error},$$

where errors were assumed to be normally distributed. We used approximate F tests and graphical examination to test for nonlinearity in the depth response. If log(CPUE) and depth were related in a nonlinear way, an approximate F test was used to test the null hypothesis that CPUE did not differ among rookeries. Otherwise, a linear model and standard F tests were used. Residual analyses were performed to detect potential outliers and test the model's assumptions.

Length-frequency distributions were examined to determine the approximate age composition of the most abundant species. Age composition was determined based on major modes in the length-frequency distribution and was graphically compared among rookeries for the 4 most abundant species. Size-at-age of all fishes in the collections was compared among rookeries using a one-way ANOVA without accounting for depth effects.

RESULTS

During 1994 we sampled 28 stations (20 sled trawls, 8 beam trawls) in the vicinity of the sea lion rookeries on Akun Island (n=13), Atkins Island (n=2), and Marmot Island (n=13, Figure 1). In 1995, 37 stations were sampled at Akun (n=5), Ugamak (n=10), Chowiet (n=14), and Sugarloaf Islands (n=8). In 1996 we revisited Ugamak (n=11), Atkins (n=13), and Marmot Islands (n=14) and completed 38 tows.

Table 2. Numbers of juvenile groundfish, by taxon, collected with a small bottom trawl near 6 Steller sea lion rookeries in the western Gulf of Alaska during July 1994, 1995, and 1996.

Scientific name	Common name	1994	1995	1996	Total
Pleuronectes bilineata	Rock sole	994	2,883	462	4,339
Theragra chalcogramma	Walleye pollock	29	159	1,268	1,456
Hippoglossus stenolepis	Pacific halibut	109	592	226	927
Icelinus borealis	Northern sculpin	248	296	74	618
Triglops spp.		61	146	125	332
Gymnocanthus spp.		8	265	54	327
Gadus macrocephalus	Pacific cod	0	59	164	223
Radulinus asprellus	Slim sculpin	29	43	26	98
Atherestes stomias	Arrowtooth flounder	29	0	62	91
Podothecus acipenserinus	Sturgeon poacher	0	67	12	79
Aspidophoroides bartoni	Aleutian alligatorfish	49	4	24	77
Ammodytes hexapterus	Pacific sand lance	8	19	41	68
Hypsagonus quadricornis	Fourhorn poacher	44	9	12	65
Psychrolutes paradoxus	Tadpole sculpin	25	20	14	59
Liparis spp.	Snailfish	25	23	11	59
Myoxocephalus spp.		3	53	2	58
Hemilepidotus jordani	Yellow Irish lord	13	39	5	57
Bathymaster signatus	Searcher	12	32	7	51
Cottidae	Unidentified sculpins	13	16	20	49
Sarritor frenatus	Sawback poacher	38	1	3	42
Anoplagonus inermis	Smooth alligatorfish	5	18	18	41
Gadidae		0	39	0	39
Pleuronectes isolepis	Butter sole	34	0	2	36
Bathyagonus infraspinata	Spinycheek starsnout	11	7	23	41
Other		54	70	31	155
Total		1,841	4,860	2,686	9,387

Depth at the sampling stations ranged from 18 to 133 m. The number of stations sampled in each depth stratum varied among rookeries due to time and weather constraints and availability of trawlable substrate (Table 1). Because of the lack of trawlable substrate we were unable to sample stations in the 15–40-m stratum at Marmot Island. As a result, depth distribution of the tows differed significantly among rookeries (Kruskal–Wallis $\chi^2 = 23.5$, $P = 0.0003$) and created a potential for depth bias in comparisons among rookeries. To minimize this bias, analyses were performed within depth strata or with depth included as a continuous independent variable.

Water masses and substrate differed among the 6 rookeries. Bottom and surface temperatures tended to decrease from east to west along the Alaskan Stream with significantly (Kruskal–Wallis $\chi^2 = 47.22$, $P < 0.001$) higher temperatures at Marmot and Sugarloaf Islands, the 2 easternmost rookeries. Bottom salinities also differed significantly (Kruskal–Wallis $\chi^2 = 64.43$, $P < 0.001$) among rookeries. Highest salinities were observed at Akun Island, reflecting the influence of the Bering Sea, and the lowest salinities occurred around Atkins and Chowiet Islands. Differences in temperature and salinity were not included in the statistical analysis due to a lack of contrast in the data. Only 3 trawlable sediment classes, sand, gravelly sand (<30% gravel), and sandy gravel (>30% gravel), were encountered during our surveys. Due to the exposed nature of most rookeries and strong tidal currents extending to the bottom we did not find significant amounts of mud at any of the stations sampled. A large part of the gravel fraction of most sediment samples consisted of shells and shellhash (shell fragments). Substrates consisting of coarser sediment than gravel could not be sampled due to limitations of the sampling gear. Video observations indicated coarser sediments were present around all rookeries.

Rookeries differed in availability of trawlable substrate and bottom type. Although the substrate around Akun Island consisted of sand in a small bay and sandy gravel at deeper stations, it was characterized by irregular topography with steep, rocky pinnacles close to the rookery. Ugamak and Marmot Islands were similar with sand, gravelly sand, or sandy gravel in trawlable sites and hard bottom and reef structures in untrawlable areas. Sediment at Chowiet and Atkins Islands consisted mostly of sand, though Atkins Island also had untrawlable areas of cobble, boulders, and reefs. The area around Sugarloaf Island was mostly untrawlable rocky bottom with an area of mixed gravel and sand to the north.

During the 3 years of the study we captured a total of 9,387 fishes in 103 quantitative tows in the vicinity of the 6 sea lion rookeries (Table 2). Overall, the most abundant species by number were rock sole (46.2%), walleye pollock (15.5%), Pacific halibut (9.9%), northern sculpin (6.6%), *Triglops* spp. (3.5%), *Gymnocanthus* spp. (3.5%), Pacific cod (2.4%), slim sculpin (1.0%), and arrowtooth flounder (1.0%). Other species made up the remaining 10.4% of the total catch. Total CPUE decreased from west to east (Figure 2), and the species composition varied by rookery (Figure 3).

Differences in species composition among rookeries were highly significant within each depth stratum (Table 3). All but 2 of the significant pairwise comparisons among rookeries involved either Akun or Atkins Island, and most of these occurred in the 40–70-m depth stratum. In this stratum the species composition at Akun and Atkins Islands differed significantly from each other ($P < 0.001$) and from all other rookeries ($P < 0.01$) except Sugarloaf Island. In addition, the species composition at Ugamak Island differed significantly from Sugarloaf Island at 15–40 m, and Chowiet Island differed significantly from Marmot Island below 70 m.

Table 3. Analysis of similarity in the species composition of juvenile groundfishes collected around 6 sea lion rookeries within and between rookeries by depth stratum. Clarke's *R* statistic is the standardized difference between the average within-group (r_w) and between-group (r_b) rank similarity, computed from a station-by-station matrix of similarities. Within each depth stratum a *P* value was computed by comparing Clarke's *R* from 1,000 random permutations of the similarity matrix to the data-based *R* statistic.

Depth Stratum	r_w	r_b	*R*	*P*
15–40 m	152	105	0.410	< 0.001
40–70 m	498	394	0.254	< 0.001
> 70 m	446	371	0.191	0.016

Six juvenile groundfish species were identified as indicator species and contributed at least 7.5% to the observed differences in species composition in at least

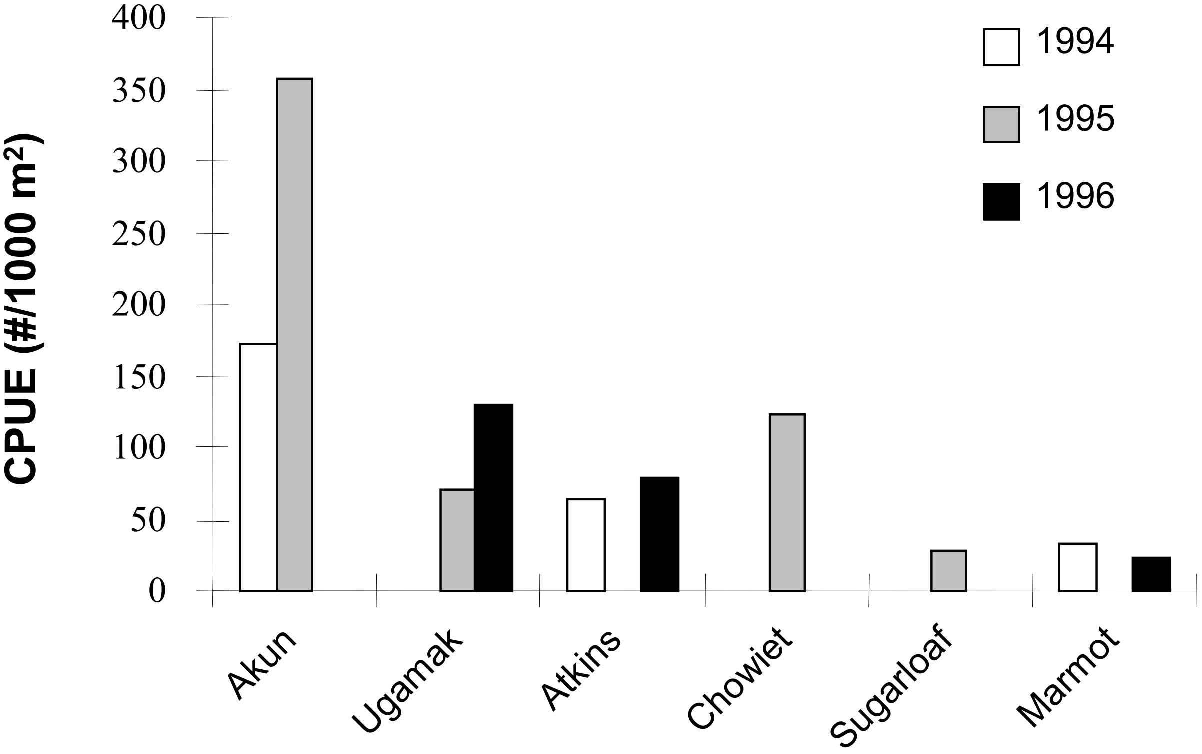

Figure 2. Catch per unit effort of all juvenile groundfish species collected in 103 quantitative tows around 6 Steller sea lion rookeries in the Gulf of Alaska, by rookery and year. Rookeries are arranged on the abscissa from west (Akun) to east (Marmot).

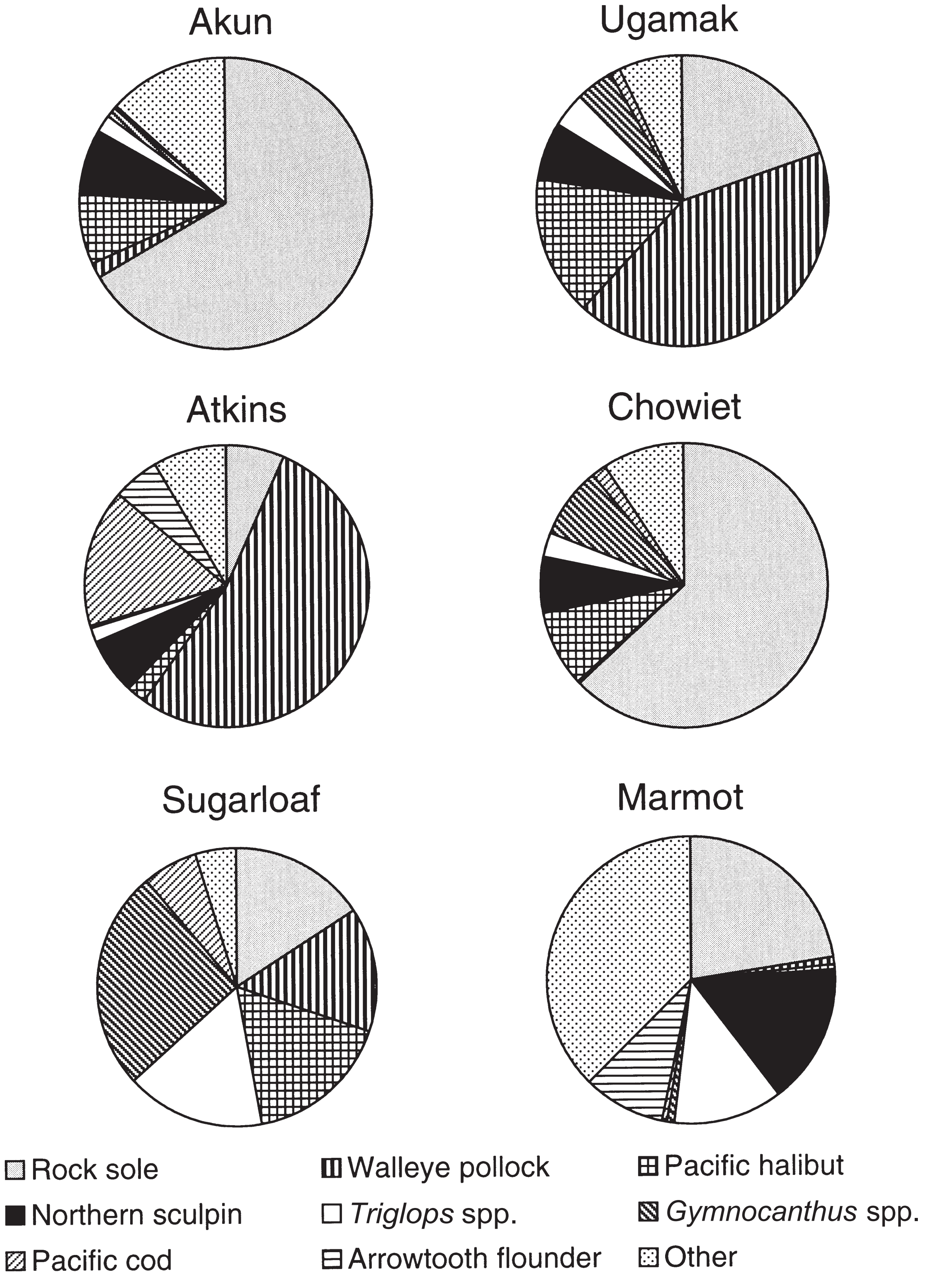

Figure 3. Relative species composition of juvenile groundfish catches around 6 Steller sea lion rookeries based on standardized abundances by rookery, pooled across years from 1994 to 1996.

Table 4. List of indicator species by depth stratum for the juvenile groundfish community around sea lion rookeries. Percentages indicate the fraction of the overall dissimilarity in species composition among rookeries that can be attributed to a species. Only species that contributed at least 7.5% to the overall dissimilarity in one of the depth strata are shown.

Species	15–40 m	40–70 m	> 70 m
Theragra chalcogramma	21.5%	7.5%	
Gadus macrocephalus	14.1%		
Pleuronectes bilineatus	9.8%	11.7%	9.2%
Hippoglossus stenolepis		7.7%	9.3%
Gymnocanthus spp.	10.6%		
Triglops spp.	7.9%		
Icelinus borealis			7.8%

one depth stratum (Table 4). Walleye pollock and Pacific cod were largely responsible for observed differences in species composition in the shallow depth stratum. Together they accounted for 36% of the overall dissimilarity among those pairs of rookeries that showed significant differences in species composition. In the intermediate and deep strata, rock sole and Pacific halibut were the most important contributors; however, their combined contribution to overall dissimilarity was less than 20% in each stratum. In these strata, 74% and 76% of the observed dissimilarity was due to other species that were not identified as indicator species. Other taxa that contributed at least 7.5% to overall dissimilarity were the sculpins *Gymnocanthus* spp., *Triglops* spp., and the northern sculpin (Table 4).

The frequency of positive catches, after adjusting for depth effects, differed significantly among rookeries for 4 of the 7 indicator species. Walleye pollock were caught with a higher frequency at the 3 westernmost rookeries. Pacific halibut and *Gymnocanthus* spp. had low frequencies of capture at Marmot Island and Atkins Island, and Pacific cod had the lowest frequency of capture at Akun Island (0%). Rock sole were caught more frequently at Akun Island, but differences among the other rookeries were not significant.

After excluding zero catches CPUE differed significantly among rookeries for 5 of the 7 indicator species and for all species combined. The CPUE of most species (walleye pollock, rock sole, Pacific cod, Pacific halibut, and northern sculpin) was significantly lower at the easternmost rookeries, and total CPUE increased from east to west (Figure 2). A regression of total CPUE on longitude by depth stratum was highly significant for the deeper strata, but not for the shallow stratum (15–40 m: $F = 3.148$, $P = 0.091$; 40–70 m: $F = 14.07$, $P = 0.001$; over 70 m: $F = 9.113$, $P = 0.005$). A visual examination of residual plots indicated no obvious trends in the residuals with respect to year, time of day, or tidal stage.

In addition to differences in abundance among rookeries, the size and age composition of the most abundant species in the catches differed. Size differed significantly among rookeries (ANOVA, $P < 0.001$) for age-0 and age-1 fish of all indicator species. Walleye pollock and Pacific cod consisted almost exclusively of age-0 fish with only a few older Pacific cod captured at Sugarloaf and Marmot Islands (Table 5). Age-0 gadids were largest at the eastern rookeries (Table 5). Rock sole consisted primarily of 2 clearly separated size modes, recently settled age-0 juveniles and age-1 fish. The proportion of age-0 fish was much higher at Akun and Chowiet Islands than at the other rookeries. Age-0 rock sole were significantly smaller at Akun Island, and age-1 fish were smallest at Chowiet Island (Table 5). Most Pacific halibut were age-0 fish, and the proportion of age-1 fish tended to increase to the east. Of the 3 sculpin taxa, *Gymnocanthus* spp. tended to increase in size to the east, but the other taxa showed no clear pattern. Between 50% and 89% of all *Gymnocanthus* spp. and 75% to 100% of all *Triglops* spp. were age-0 fish. In contrast, the northern sculpin catches consisted almost entirely of age-1+ fish, and only few age-0 fish were caught at Ugamak and Marmot Islands.

DISCUSSION

This research describes the distribution and abundance of juvenile groundfishes in the vicinity of Steller sea lion rookeries. We show significant differences in species composition among the 6 rookeries and a greater abundance of juvenile groundfishes including walleye pollock, rock sole, Pacific halibut, and northern sculpin in the western part of the study area. For several indicator species and for all species combined we found lower abundances around rookeries on Marmot and Sugarloaf Islands in the eastern part of the study area, and in some cases lower abundances around Chowiet or Atkins Islands. Estimates of CPUE for the most abundant species collected during this study at Marmot and Sugarloaf Islands were much lower than CPUEs for the same species collected with the same gear on similar substrates inside bays around Kodiak Island and on the Alaska Peninsula (Norcross et al. 1999).

Table 5. Size composition of 7 indicator species for the juvenile groundfish community around 6 sea lion rookeries by age and rookery. Sizes in mm ± 1 SD, except where only one specimen was caught. Islands are arranged in this table from west (Akun) to east (Marmot).

	Akun		Ugamak		Atkins		Chowiet		Sugarloaf		Marmot	
Age	Size	*n*	Size	*n*	Size	*n*	Size	*n*	Size	*n*	Size	*n*
Theragra chalcogramma												
0	31.3 ± 4.6	29	28.4 ± 6.2	882	26.8 ± 5.4	490	38	1	37.6 ± 7.4	49	48.0 ± 4.9	5
Gadus macrocephalus												
0	—	—	35.6 ± 5.4	28	30.7 ± 5.1	140	50.3 ± 6.2	33	50.2 ± 5.1	6	54	1
1	—	—	88	1	191	1	—	—	191.9 ± 11.4	9	195.0 ± 11.3	2
2+	—	—	—	—	406	1	—	—	265	1	—	—
Pleuronectes bilineatus												
0	18.6 ± 2.6	2,128	20.4 ± 2.7	89	20.2 ± 1.8	36	19.8 ± 3.1	745	—	—	20.6 ± 3.8	15
1	66.0 ± 9.5	500	59.1 ± 10.1	303	68.6 ± 13.3	19	55.9 ± 10.0	164	70.25 ± 18.9	14	61.5 ± 12.7	49
2+	261.0 ± 96.3	47	190.1 ± 87.2	71	172.2 ± 94.5	22	216.2 ± 124.9	59	156.1 ± 65.8	28	196.6 ± 82.8	49
Hippoglossus stenolepis												
0	27.7 ± 3.6	338	27.1 ± 3.3	324	31.2 ± 5.6	20	26.5 ± 3.4	141	33.4 ± 3.9	18	29.0 ± 1.4	2
1	103	1	88.5 ± 12.6	16	115.3 ± 5.9	2	81.2 ± 18.7	34	115 ± 12.5	13	—	—
2+	385	1	338 ± 151	3	—	—	—	—	252 ± 105	9	195	1
Gymnocanthus spp.												
0	23.2 ± 3.1	51	25.4 ± 4.5	56	—	—	21.7 ± 2.9	74	25.7 ± 2.6	48	30.5 ± 2.1	2
1	89.5 ± 19.7	4	94.5 ± 10.3	31	96	1	91.5 ± 11.0	40	113.6 ± 11.9	16	—	—
2+	297 ± 23.3	2	—	—	—	—	—	—	—	—	246.5 ± 65.8	2
Triglops spp.												
0	51.3 ± 9.0	38	35.1 ± 8.0	79	51.7 ± 11.6	20	40.9 ± 8.5	47	34.0 ± 6.8	39	49.1 ± 8.8	51
1	127	1	131 ± 9.9	16	122 ± 8.9	5	99.8 ± 7.3	5	—	—	136 ± 12.4	15
2+	206 ± 28.1	12	175 ± 4.2	2	—	—	209	1	—	—	206	1
Icelinus borealis												
0	—	—	19.0 ± 1.2	4	—	—	—	—	—	—	22.7 ± 2.1	19
1+	48.6 ± 8.2	161	48.2 ± 6.8	185	54.2 ± 6.6	29	46.6 ± 8.7	122	—	—	57.7 ± 11.2	98

The 2 most abundant groups of fishes in our survey, flatfish and gadids, serve as potential prey for sea lions. Low abundances of these species at Marmot and Sugarloaf Islands coincide with higher rates of decline of Steller sea lion populations at those rookeries. Pup counts at Ugamak, Atkins, and Marmot Islands changed by 23%, 13%, and –21%, respectively, between 1994 and 1996 (R. L. Merrick, personal communication). Thus low abundances of these potentially important prey species in the eastern part of the study area, particularly at Marmot Island, coincided with the area of the highest observed declines in sea lion populations between 1994 and 1996, suggesting a potential link between the availability of bottom fish as prey and sea lion declines.

While the correlation does not imply causality, reduced availability of preferred prey is one hypothesis that has been advanced to explain observed declines in sea lion populations (Merrick et al. 1987, 1995, 1997). The relevance of bottom trawl survey results to this hypothesis depends on numerous factors including the spatial overlap between our survey area and sea lion foraging areas, the importance of species and size classes captured by our gear in the diet of foraging sea lions, and the temporal overlap between these surveys and the period when sea lions are vulnerable to food limitation.

Little is known about the spatial extent of sea lion feeding at different times in their life history, but juvenile sea lions typically feed in less than 100 m of water and within 15 km of the rookeries (R. L. Merrick, personal communicaion). There is at least a partial overlap between the species composition in our catches and in sea lion diets. Flatfish were the most common species in bottom trawls, but sea lions consumed only a small percentage of flatfish in the Gulf of Alaska and in the eastern Aleutian Islands based on stomachs collected from 1990 to 1993 (Merrick et al. 1997). Flatfish were found in the diet of 17.6% of adult sea lions (Calkins and Goodwin 1988) and were common in earlier collections (Pitcher 1981). Gadids were common in our surveys and sea lion diets. Small forage fish like capelin, herring, and sand lance, the second most common group in juvenile sea lion stomachs, were very rare in our bottom trawl collections because they are primarily pelagic species.

The size range of juvenile groundfish in our samples was at the low end of the range that typically serves as food for sea lions. The most recent data are stomach collections from the mid 1980s, when walleye pollock were the most common fish consumed by juvenile sea lions in the Gulf of Alaska (Calkins and Goodwin 1988; Merrick and Calkins 1996). The size of pollock consumed by juvenile sea lions ranged from 70 mm to 550 mm, although the number of pollock over 250 mm was very small (Merrick and Calkins 1996). The average size of pollock consumed was 208 mm, suggesting they were mostly age-1 pollock. In comparison, the pollock in our samples were exclusively age-0 pollock. Thus pollock and other age-0 fish in our collections potentially serve as food for sea lions in the following winter, but were unlikely to be an important component of sea lion diets at the time of sampling.

Many factors may be responsible for the observed differences in species composition and abundance of small groundfishes among the 6 rookeries. Topography, substrate composition, and water mass characteristics, including temperature and salinity, differed among rookeries. For example, the presence of colder and more saline Bering Sea water around Akun Island may explain, in part, observed differences in species composition between this and other rookeries. Similarly, the lack of shallow, sandy substrate around Marmot Island undoubtedly contributes to the low abundance of rock sole and halibut near this rookery. However, significant differences in abundance among rookeries were found in each depth stratum and after accounting for depth effects. We could not account for sediment effects because of the limited number of replicates. Some of the observed differences in CPUE probably were due to differences in sediment composition around the 6 rookeries.

Year-to-year variations in the abundance of juvenile groundfishes could introduce biases in our results because sampling extended over a 3-year period. Rock sole was the most commonly caught species in 1994 and 1995, but walleye pollock dominated catches in 1996 (Table 2). Very few walleye pollock were caught in 1994. Unfortunately, the limited number of samples does not allow us to do a year-to-year comparison. Additional sampling is required to identify temporal trends in the data and to separate year effects from rookery effects. However, because no obvious trends were detected in model residuals over time (years), we believe potential year effects did not significantly bias the results. The same is true for the effects of tidal stage and time of day.

Because of our inability to sample large parts of the nearshore area due to limitations of the trawling gear, comparisons among rookeries apply to trawlable areas only. For a full comparison of small groundfishes among rookeries, nontrawlable areas need to be included in the sampling. Stomach contents of opportunistic feeders can serve as a proxy for the availability of common prey species (Fahrig et al. 1993). Stomach sampling and other surveys, such as visual surveys, will also be useful in assessing the abundance of pelagic species such as capelin and in more accurately assessing semidemersal species like cod and walleye pollock.

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