Aquatic Mammals 2005, *31*(1), 62-82, DOI 10.1578/AM.31.1.2005.62

New Data on Proximate Composition and Energy Density of Steller Sea Lion (*Eumetopias jubatus*) Prey Fills Seasonal and Geographic Gaps in Existing Information

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Abstract

Energy density data of prey items are necessary to estimate food requirements of predators. The goal of this study was to provide proximate composition and energy density information for Steller sea lion (*Eumetopias jubatus*) prey species where there are seasonal and/or geographic gaps in the existing data. Opportunistic collections were made on board National Oceanic and Atmospheric Administration fisheries research surveys in the Aleutian Islands region, eastern Bering Sea, and Gulf of Alaska, targeting particular species of interest. Proximate analyses were conducted in the laboratory and energy density was calculated from lipid and protein content. Pacific herring, sand lance, and rockfish were found to contain the highest amount of lipid and provide the most energy. Atka mackerel, surf smelt, capelin, salmon, sandfish, pollock, yellow Irish lords, Pacific cod, squid, skates, and rock sole had intermediate energy densities. Smooth lumpsucker and snailfish were found to contain the least amount of energy. This study is the first to provide proximate composition data for adult pollock during the nonspawning seasons in the Gulf of Alaska and Aleutian Islands region. This study also provides the first proximate composition data for juvenile pollock in the Aleutian Islands region and eastern Bering Sea, and for Pacific cod in the eastern Bering Sea. This study fills another critical gap by presenting the only information on proximate composition of adult Atka mackerel, one of the most important prey of Steller sea lions in the Aleutian Islands region. These improvements in the seasonal and geographic coverage of fish proximate and energy density data will allow for seasonally and geographically specific estimates of Steller sea lion prey requirements, a necessary improvement over annual estimates made previously. These data can also contribute to bioenergetic modeling of prey requirements of other predators in Alaska such as groundfish, fur seals, and marine birds.

Key Words: Steller sea lion, *Eumetopias jubatus*, proximate composition, energy density, Alaska, fishes, bioenergetic modeling, prey

Introduction

Steller sea lion (*Eumetopias jubatus*) populations in Alaska declined by more than 80% over the past 30 years (Loughlin, 1998; Loughlin et al., 1992; National Research Council, 2003; Trites & Larkin, 1996). The western stock (west of longitude 144° W) was listed as endangered in 1997 under the U.S. Endangered Species Act. The eastern stock, although increasing in size, remains listed as threatened. One of the leading hypotheses proposed to explain the decline of the western stock of Steller sea lions is nutritional stress due to natural and/or anthropogenic-related declines in the quantity or quality of prey (National Research Council, 2003). To evaluate this hypothesis, it is necessary to estimate the prey requirements of Steller sea lions. A useful method for accomplishing this goal is bioenergetic modeling, whereby the energetic requirements of sea lions are calculated from estimates of energy used in respiration and production (e.g., growth, fat storage, gonad development, etc.) and energy egested as waste. Data on sea lion diet composition and energy content of prey are then used to convert estimates of energy required to estimates of prey biomass required (Winship et al., 2002). Thus, energy density of sea lion prey (kJ g^{-1} of fish) is critical for estimating the amount of fish required by Steller sea lions. Energy density can be measured directly through bomb calorimetry or calculated from proximate composition (percent lipid, protein, carbohydrate, ash, and moisture; e.g., Anthony et al., 2000; Payne et al., 1999; Van Pelt et al., 1997).

A number of published studies have provided information on proximate composition and/or energy density of Steller sea lion prey prior to this study (Anthony et al., 2000; Boldt, 2001; Buckley & Livingston, 1994; Davis, 2003; Davis

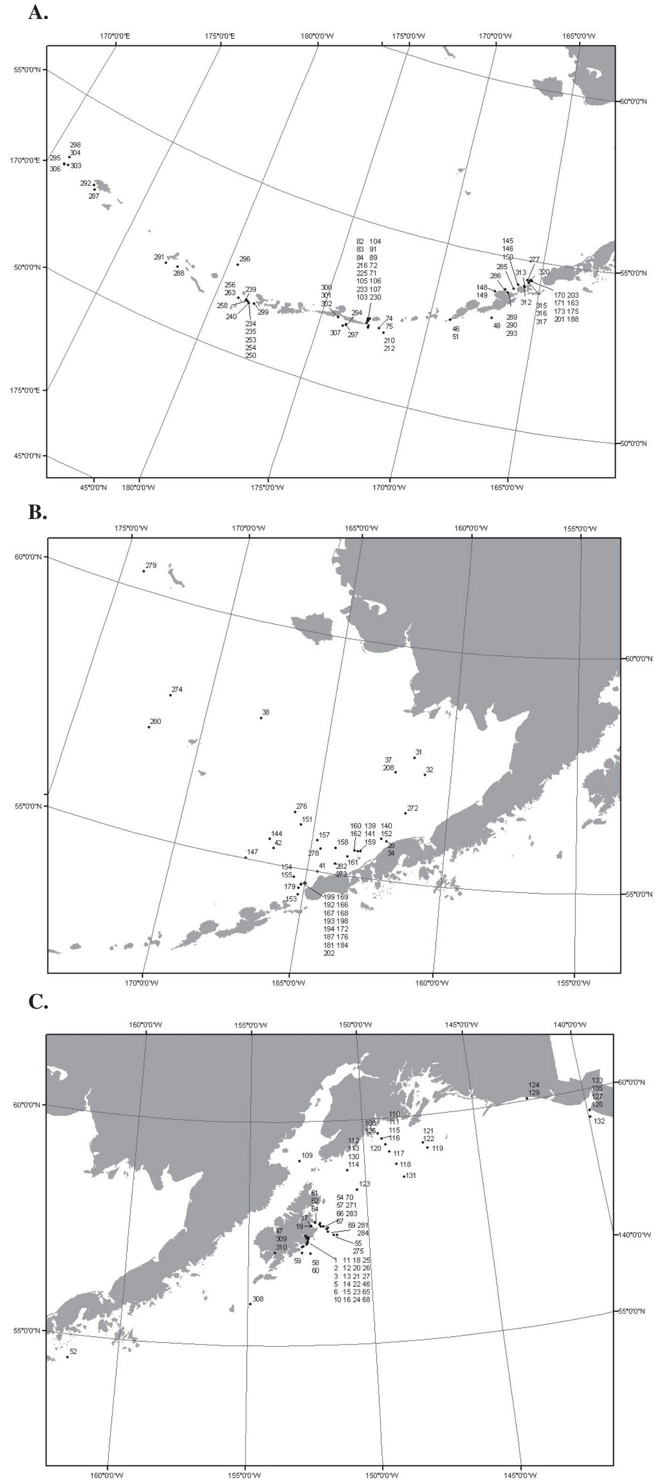


Figure 1. Locations of sampling stations; numbers refer to collection sites and are also referenced in the Appendices: (A) Aleutian Islands region, (B) Eastern Bering Sea, and (C) Gulf of Alaska.

et al., 1998; Harris et al., 1986; Hendry & Berg, 1999; Kizevetter, 1971; Paul & Paul, 1999; Paul & Willette, 1997; Payne et al., 1999; Perez, 1994; Robards et al., 1999; Sidwell, 1981; Smith et al.,1988, 1990; Van Pelt et al., 1997); however, there are many gaps in the seasonal and geographic coverage of existing data. In addition, there are virtually no published data for some important prey species, such as Atka mackerel (*Pleurogrammus monopterygius*), which is the dominant prey of Steller sea lions in the Aleutian Islands region (Sinclair & Zeppelin, 2002). The goal of this study was to fill some of these gaps in knowledge of the proximate composition and energy density of Steller sea lion prey species. We accomplished this goal by making collections on board National Oceanic and Atmospheric Administration (NOAA) fisheries research surveys. The collections, although opportunistic, were targeted at species, regions, and/or seasons for which published information on proximate composition or energy density did not yet exist. Proximate composition was determined in the laboratory, and energy density was calculated from lipid, protein, moisture, and ash content. Summary data are presented in tables and figures and detailed data are presented in Appendices with the goal of providing bioenergetic modelers the information necessary to estimate the prey requirements of Steller sea lions and other predators.

Materials and Methods

The fish species included in this study were collected opportunistically from the Aleutian Islands region, eastern Bering Sea, and Gulf of Alaska (Figure 1). Individuals collected were within the size range of fish consumed by Steller sea lions (Calkins, 1998; Merrick & Calkins, 1996; Pitcher, 1981). Samples were obtained from various National Marine Fisheries Service – Alaska Fisheries Science Center (AFSC) surveys onboard NOAA research vessels and chartered commercial fishing vessels. Whole fish were immediately frozen at approximately -20° C on board the vessels after collection and remained frozen until processed in the laboratory for proximate analysis. Some collections consisted of a single fish, whereas others were comprised of as many as 20 fish (Appendices A-C). Fish were measured and weighed, and sex and spawning state were determined for some, but not all, collections due to logistical constraints at sea. Age class also was estimated from length for some collections.

Proximate analyses were carried out by the Auke Bay Laboratory of the Alaska Fisheries Science Center or through a contract with Food Products Laboratory, Inc. (12003 Ainsworth Circle, Suite 105, Portland, OR 97220). Entire frozen fish were homogenized in a blender or a meat grinder with a 4.5-mm die. Three- to five-gram samples of the homogenate were selected randomly for analysis. Moisture and ash contents were determined gravimetrically while heating. Samples were incubated at 125°-135° C for two to four hours for total moisture determination, then baked at 525°-600° C for four to seven hours to determine ash content (Association of Official Analytical Chemists, 2002). The methods for determining lipid and protein content differed between the two laboratories. At Auke Bay Laboratory (ABL), the lipid fraction was extracted using the Folch method (Folch et al., 1957), whereas at Food Products Laboratory (FPL), lipids were extracted by acid hydrolysis and ether extraction (Anonymous, 2002). Protein content was determined with the Dumas method at ABL, and with the Kjeldahl method at FPL (Anonymous, 2002). Duplicate samples were analyzed for protein content at both laboratories. Studies comparing the results of these two protein analysis methods find that they compare well for most materials (Sweeney & Rexroad, 1987; Wiles et al., 1998). Both methods yield percent nitrogen, which is then converted to percent protein using 6.25 as the conversion factor (Anonymous, 2002).

Quality control procedures for lipid and protein analyses were carried out at both laboratories. Duplicate samples were analyzed for each group of 10-20 fish, and standard reference samples were analyzed for each group. Samples were reanalyzed if the deviation between duplicates was greater than 10%-15% of the mean (FPL), or if the deviation was > 1.5 SD from the mean (ABL). For all analyses, if the reference sample value was not within 2.5%-5.0% of the established value, the sample group was reanalyzed. In addition, a test of the distillation efficiency during the FPL protein analysis was run with ammonium sulfate. If the recovery of ammonium sulfate was less than 95%, the samples were retested. Similarly, the nitrogen content of EDTA was tested with each group at ABL, and if the value was less than 98% of the expected result, samples were retested.

Energy density (kJ g^{-1} wet weight) was calculated from proximate composition by multiplying the wet weight proportion of lipid and protein by 36.43 kJ g^{-1} and 20.10 kJ g^{-1}, respectively. These energetic conversion factors have been validated by bomb calorimetry (Vollenweider, 2004). We assumed the carbohydrate composition of fish was negligible (Brett & Groves, 1979).

Although previous studies showed that the different methods of protein analysis conducted by the two laboratories involved in this study can be expected to produce similar results (Sweeney & Rexroad, 1987; Wiles et al., 1998), we were

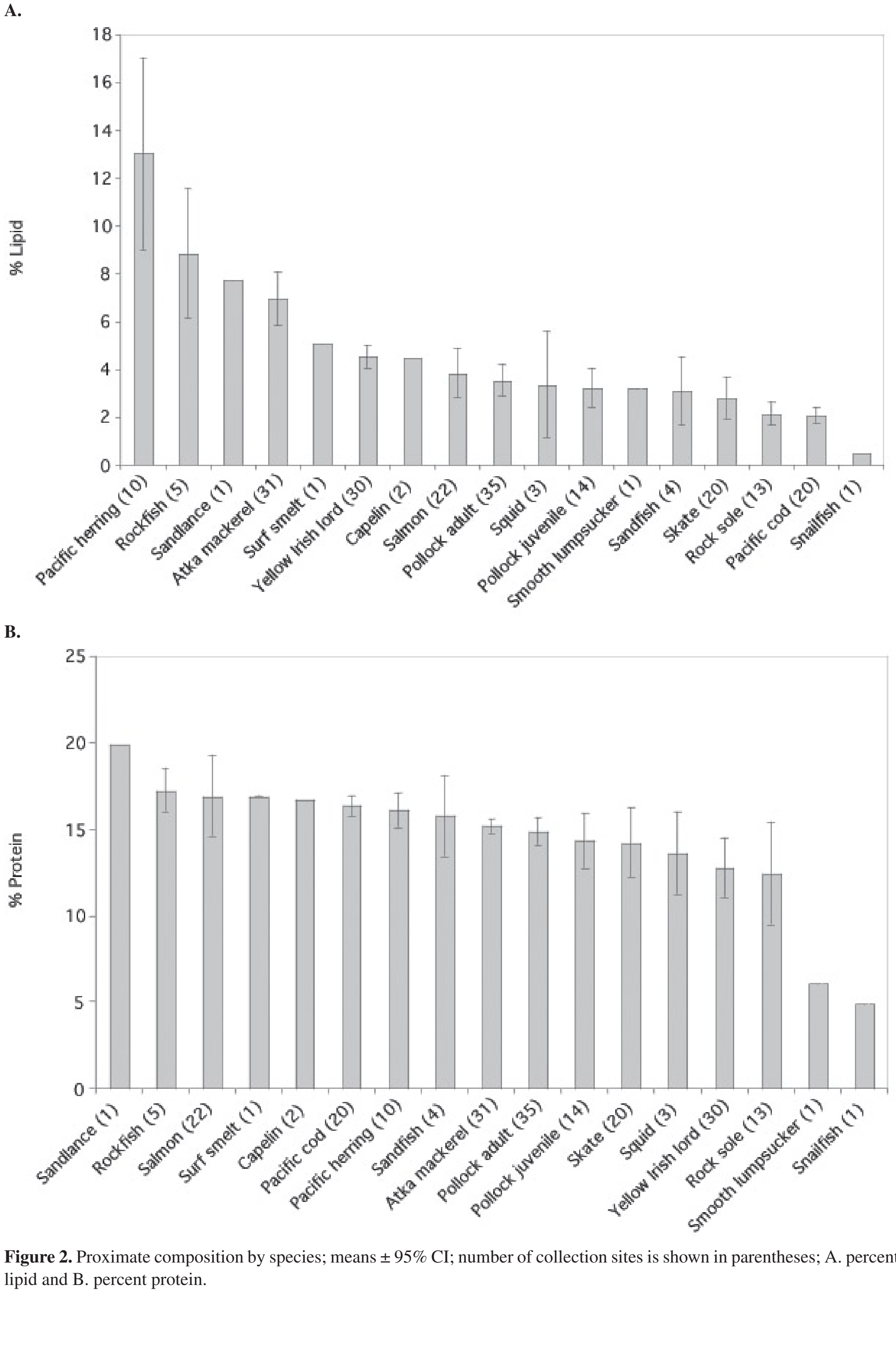
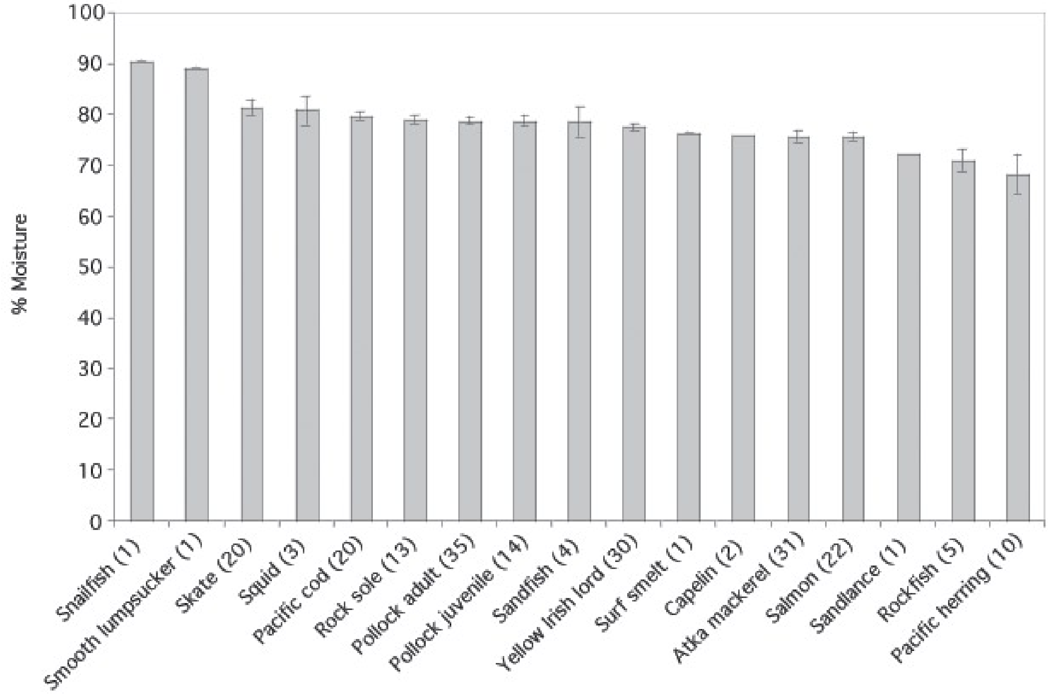


Figure 2. Proximate composition by species; means ± 95% CI; number of collection sites is shown in parentheses; A. percent lipid and B. percent protein.

C.



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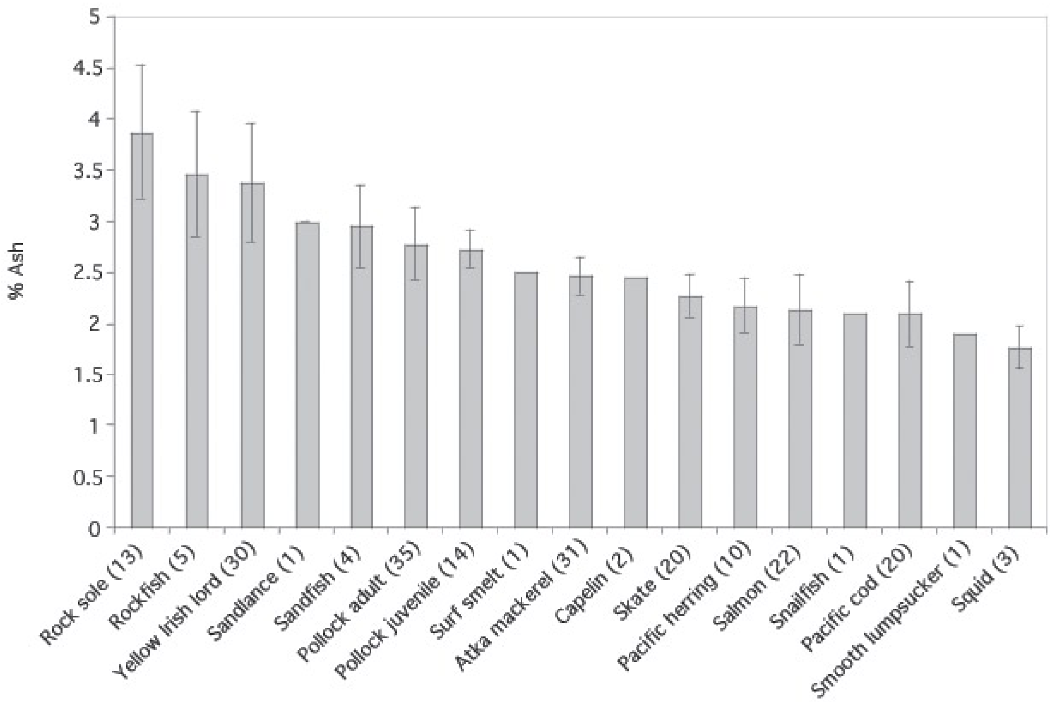

Figure 2 (cont.). Proximate composition by species; means ± 95% CI; number of collection sites is shown in parentheses; C. percent moisture and D. percent ash.

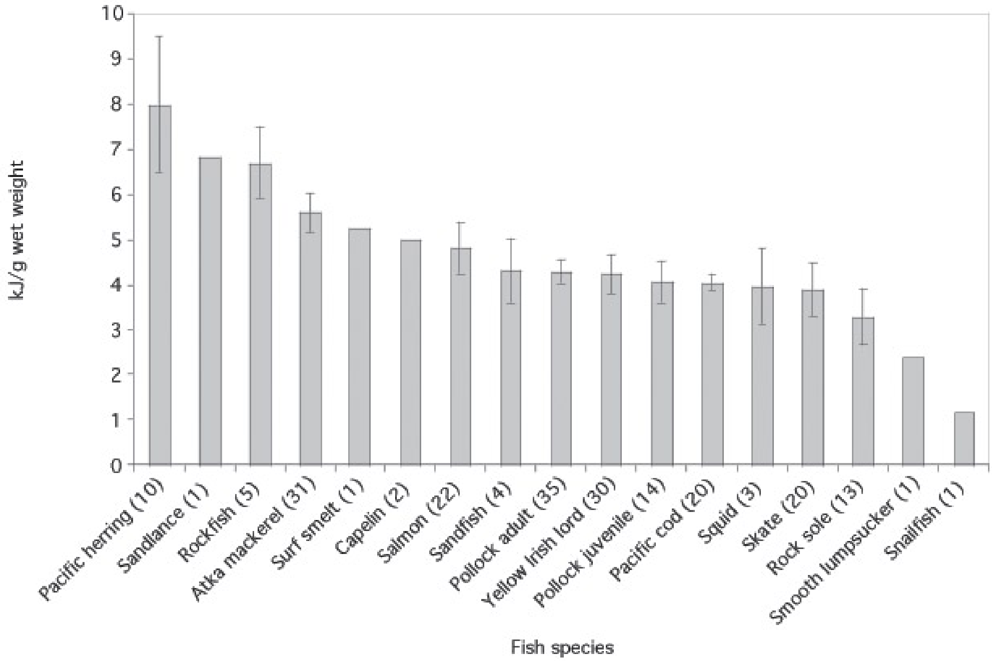

Figure 3. Mean energy density (kJ g^{-1} wet weight) ± 95% CI by fish species at *n* stations

nonetheless concerned with the potential for our data to be biased by laboratory and/or analysis methods. To check for such a bias, subsamples from a selection of fish were sent to each laboratory for parallel protein analyses.

Statistical analyses were performed to check for potential laboratory- or method-based bias in lipid, moisture, and ash content, instead of parallel laboratory analyses. Two-way analysis of variance (ANOVA) on the entire data set was conducted to test for the effect of laboratory differences while statistically controlling for the effect of species differences on proximate composition. Because the data were unbalanced (different sample sizes for each laboratory), sums-of-squares were obtained from Yates' weighted squares-of-means technique (Type III sums-of-squares) (Anonymous, 2001). Diagnostic plots (histogram and normal qq-plot of residuals; and residuals versus fit) were examined for departures from assumptions of ANOVA.

To further explore the effect of the laboratory on energy density and also to explore the laboratory-species interactions, ANOVA were conducted by species. Species included in these analyses were only those that were analyzed at both laboratories.

Table 1. Seasonal patterns in means ± SD of energy density of fish prey are reported when available. Energy density units chosen to conform with published data in Hendry & Berg (1999) and Perez (1994).

		Energy density				
	Month	Mean	SD	*n*	Units	Source
Pollock	November-March	4.94	0.55	13	kJ g^{-1} wet weight	This study
	May-August	3.99	0.82	35		This study
Salmon spp.	March	19.87	1.84	4	kJ g^{-1} dry weight	This study
	July	23.10	--	20		Hendry & Berg, 1999
Northern rockfish	February	25.10	0.28	10	kJ g^{-1} ash-free dry weight	Perez, 1994
	March	25.13	1.65	8		This study
	July	26.72	0.19	11		Perez, 1994
	November	22.10	2.19	6		This study

Table 2. Sex-related differences in Atka mackerel mean ± SD of energy density (kJ g^{-1} wet weight) at *n* stations

	Sex	Energy density Mean	SD	*n*	Units	Source
Atka mackerel	Male	6.01	1.11	16	kJ g^{-1} wet weight	This study
	Female	5.30	1.00	17		This study

Table 3. Geographic patterns in means ± SD of energy density of pollock and Pacific cod are reported when available. Energy density units chosen to conform with published data in Buckley & Livingston (1994) and Smith et al. (1990).

	Region	Energy density Mean	SD	*n*	Units	Source
Pollock	Aleutian Islands	4.99	1.07	44	kJ g^{-1} wet weight	This study
	Eastern Bering Sea	6.55				Buckley & Livingston, 1994
	Gulf of Alaska	3.91	0.75	50		This study
Pacific cod	Eastern Bering Sea	18.73	1.40	32	kJ g^{-1} dry weight	This study
	Gulf of Alaska	18.51		20		Smith et al., 1990

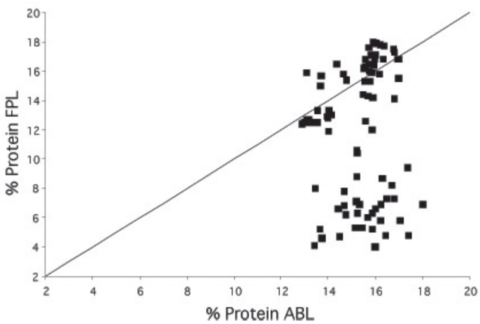

Figure 4. Comparison of parallel protein analyses, conducted on subsamples sent to Food Products Laboratory (FPL) and Auke Bay Laboratory (ABL); hypothetical line with slope=1 is shown.

Results

Mean proximate composition of fish collected in the Aleutian Islands region, eastern Bering Sea, and Gulf of Alaska ranged from 0.5% to 13.0% lipid, 4.9% to 19.9% protein, 68.1% to 90.5% moisture, and 1.8% to 3.9% ash (see Appendices A-C for proximate composition, biological characteristics, and scientific names of fish collected at each site). Pacific herring had the greatest lipid content and the lowest moisture content (Figure 2). Other high-ranking species in terms of lipid content were rockfish, sand lance, and Atka mackerel. Species with low lipid content were rock sole, Pacific cod, and snailfish. Similar to Pacific herring, these other species showed an inverse relationship between lipid and moisture content. Species with intermediate lipid content included surf smelt, yellow Irish lord, capelin, salmon, pollock, squid, smooth lumpsucker, sandfish, and skates (Figure 2A).

Table 4. Summary of two-way ANOVA, testing the main effects of laboratory and species on percent protein, percent lipid, percent moisture, and percent ash; main effects of laboratory and species are shown on the first two lines. "Lab*Species" indicates the interaction between the two main effects.

	Protein					Lipid					Moisture					Ash				
	DF	SS	MS	F	*p*	DF	SS	MS	F	*p*	DF	SS	MS	F	*p*	DF	SS	MS	F	*p*
Lab	1	122.8	122.8	15.9	0.00	1	1.8	1.8	0.4	0.55	1	16.7	16.7	2.7	0.10	1	0.6	0.6	1.0	0.32
Species	11	1034.3	94.0	12.2	0.00	11	2436.0	221.5	42.7	0.00	11	2551.9	232.0	38.0	0.00	11	109.8	10.0	15.6	0.00
Lab* Species	11	944.7	85.9	11.1	0.00	11	485.5	44.1	8.5	0.00	11	636.9	57.9	9.5	0.00	11	16.9	1.5	2.4	0.01
Residuals	580	4470.5	7.7			580	3006.2	5.2			580	3537.7	6.1			580	371.1	0.6		

Table 5. Summary of two-way ANOVA testing of the main effects of laboratory and fish species on energy density (kJ g^{-1} wet weight)

	kJ g^{-1} wet weight				
	DF	SS	MS	F	*p*
Lab	1	3.0	3.0	2.7	0.10
Species	11	513.3	48.7	41.5	0.00
Lab*Species	11	94.2	8.6	7.6	0.00
Residuals	580	652.0	1.1		

Pacific herring, the species with the highest lipid content, had the greatest energy density (Figure 3). The other high-lipid, high-energy species were sand lance and rockfish. The species with the lowest energy densities were smooth lumpsucker and snailfish (Cyclopteridea). Atka mackerel, surf smelt, capelin, salmon, sandfish, pollock, yellow Irish lords, Pacific cod, squid, skates, and rock sole showed intermediate energy densities.

Although our collections were made with the goal of filling seasonal and geographic gaps in existing information, the data also were sufficient to examine intraspecific variation in proximate composition or energy density. For instance, adult pollock collected between November and March, before the spawning season, showed a greater energy density than pollock collected between May and August, after the spawning season (Table 1; *t*-test assuming unequal variances: $t = 3.54$, DF = 14, $p < 0.01$). Atka mackerel showed sex-related variation during the summer spawning season; males had a greater energy density than females (Table 2; *t*-test assuming unequal variances: $t = 2.50$, DF = 17, $p < 0.05$).

Combining our data with previously published information allows for additional seasonal and geographic comparisons. This synthesis of data showed that Pacific salmon and northern rockfish had the greatest energy densities during July (Table 1). An example of geographic variability was the relatively high-energy density of pollock in the eastern Bering Sea (non-spawning season), followed by the Aleutian Islands region and Gulf of Alaska (Table 3). In contrast, Pacific cod energy density during the spawning season varied little between regions (Table 3).

Comparison of the parallel protein analysis results at each laboratory showed that the results for some subsamples were nearly 1:1, indicating that the two methods performed similarly (Figure 4); however, the results from a number of other subsamples show that Food Products Laboratory (FPL) produced lower measurements of protein than Auke Bay Laboratory (ABL) did.

The two-way ANOVA showed that there was no significant effect of the laboratory on lipid, moisture, or ash content (Table 4). As expected, there was a significant effect of species. There also were significant interactions between laboratory and species, indicating that, for some species, the laboratory did have an effect on proximate composition. Two-way ANOVA showed that the laboratory did not have a significant effect on energy density (Table 5). ANOVA conducted on a species-by-species basis further illustrates the laboratory-species interactions (Table 6). Some, but not all, species showed significant laboratory-based differences in energy density. In addition, the "sign" of the effect was not consistent among species. For some species, FPL results were greater, and for some, ABL results were greater. The percent difference between the two laboratory results varied from 1% to 51%.

Discussion

Our study fills several gaps in the seasonal and geographic scope of existing information on the proximate composition and energy density of

Table 6. Summary of one-way ANOVAs testing the effect of lab on energy density; *n* = number of fish analyzed at each laboratory. Mean kJ g^{-1} wet weight estimated from data collected at each laboratory is shown under FPL and ABL.

	n		Mean kJ g^{-1} wet weight							
Species	FPL	ABL	FPL	ABL	% diff.	DF	SS	MS	F	*p*
Atka mackerel	17	59	5.5	6.6	-9%	1	36.9	36.9	19.2	0.00
Northern rock sole	21	4	2.0	4.2	-35%	1	15.7	15.7	17.7	0.00
Northern rockfish	6	8	6.0	7.3	-10%	1	6.5	6.5	21.1	0.00
Pacific cod	28	4	4.1	4.0	1%	1	0.0	0.0	0.2	0.65
Pollock adult	109	21	4.6	4.2	5%	1	3.5	3.5	3.9	0.05
Pollock juvenile	111	30	4.1	3.9	2%	1	0.6	0.6	0.7	0.41
Sandfish	3	6	4.2	4.0	2%	1	0.1	0.1	0.6	0.46
Southern rock sole	10	12	1.2	3.7	-51%	1	34.7	34.7	282.7	0.00
Squid	7	15	4.0	3.7	4%	1	0.4	0.4	1.6	0.21
Yellow Irish lord	45	15	4.1	4.2	-2%	1	0.2	0.2	0.2	0.69

Steller sea lion prey. For instance, we provide the only data on proximate composition of adult pollock during nonspawning seasons in the Gulf of Alaska and Aleutian Islands region. We also present the first data on proximate composition of juvenile pollock in the Aleutian Islands region and eastern Bering Sea. Previous to this study, there was no published information on Pacific cod proximate composition or energy density in the eastern Bering Sea. We also present the only information on proximate composition of adult Atka mackerel—one of the most important prey of Steller sea lions in the Aleutian Islands region (Sinclair & Zeppelin, 2002).

Species with high lipid content tended to have relatively high energy density and low moisture content. A positive relationship between lipid content and energy density has been observed by other researchers (Anthony et al., 2000; Van Pelt et al., 1997), as has the inverse relationship between energy density and moisture content (Payne et al., 1999; Van Pelt et al., 1997). "Forage fish" (such as Pacific herring) are expected to have high lipid content and energy density relative to "groundfish" (such as pollock and cod) (Anthony et al., 2000; Payne et al., 1999; Van Pelt et al., 1997). Our results generally were consistent with these expectations; however, not all groundfish species had energy densities lower than forage fish. In particular, rockfish had energy densities similar to Pacific herring. Our results also showed that not all forage fish had energy densities higher than groundfish—capelin had intermediate energy densities similar to walleye pollock and Pacific cod.

The energetic demands of spawning are expected to cause seasonal variation in fish energy density. For instance, pollock lose approximately 37% of their prespawning body weight and 46% of their energy content during spawning (Smith et al., 1988). Pacific cod expend approximately 30% of their total energy during the month in which spawning occurs. Although much of these energy losses are due to loss of body mass, decreases in energy density of tissues occurs in both species. Pacific cod energy density remains low during the first few months postspawning and then begins to increase as fish replenish their body stores (Smith et al., 1990). Similarly, we found that adult pollock energy density was lowest during the postspawning period (May to August), but then increased during the months previous to spawning (November to March).

Synthesis of our data with published information highlighted other seasonal patterns. We found that energy density of northern rockfish and salmon was greatest during summer months. Other studies similarly show that energy density of Alaska fish (juvenile herring) increased from spring to summer during good feeding conditions and then declined later in the year as fish use stored energy to survive poor winter feeding conditions (Foy & Paul, 1999; Paul & Paul, 1998). These spawning- and overwintering-related patterns in fish energy density emphasize the need for season-specific bioenergetic models of sea lion prey requirements.

Comparison of our data with previously published information also suggested geographic patterns in fish energy density, at least for some species. Pollock energy density was greater in the eastern Bering Sea than in the Aleutian Islands region or the Gulf of Alaska. Pacific cod, on the other hand, showed no geographic variability in energy density.

In addition to seasonal and geographic patterns, we also found sex-specific differences in energy density. Atka mackerel males had a greater energy density than females during the summer spawning season. This result is in contrast to previous studies of groundfish (pollock and Pacific cod), which showed no sex-related differences in energy density during the breeding season (Smith et al., 1988, 1990). Studies of forage fish (such as capelin and sand lance) demonstrated sex-related differences in energy density, although in these studies, females (and, in particular, gravid females) had the greatest energy density, presumably due to the high energy content of their egg masses (Anthony et al., 2000; Montevecchi & Piatt, 1984; Robards et al., 1999). Our results would be consistent with these studies, if all the female Atka mackerel were spawned out; however, of the four female fish whose spawning state was recorded, two were in prespawning condition, one was ripe, and one was spawned out. More detailed sampling of Atka mackerel energy content with relation to spawning state is needed to determine how spawning state affects energy density. Another hypothesis is that Atka mackerel males have greater energy density than females during the spawning season because of the energetic demands of nest-guarding. Batches of eggs are spawned in rock crevices by females and guarded by brightly colored males until hatching (Zolotov, 1993).

Parallel protein analyses showed that although the two laboratory methods performed similarly for many samples, for a number of samples, the Kjeldahl method employed at FPL produced lower estimates of protein content than the Dumas method employed at ABL. In fact, estimates of protein content less than 12% wet weight rarely are seen in the literature (Montevecchi & Piatt, 1984; Payne et al., 1999). This leads us to conclude that data on protein content measured by the Kjeldahl method should be treated with caution, particularly when the reported values are less than approximately 10%. Fish were sent to both laboratories for analysis to ensure that the potential for exceptionally low percent protein values for a given species, which could result from anomalous protein data from FPL, was balanced by protein data from ABL. Nonetheless, seven of the 17 species included in this study were processed only at FPL: salmon, surf smelt, capelin, Pacific herring, rock sole, smooth lumpsucker, and snailfish. Thus, there exists the potential for the protein composition of these species to be underestimated. The protein content of most of these species were reported to be 14%-20%, however, well within the range of expected values. The exceptions were smooth lumpsucker and snailfish, for which protein contents of 5%-7% were reported.

The two-way ANOVA of the entire data set indicated no statistically significant effect of laboratory on energy density. Furthermore, it is arguable that the biological effect is not significant. For most of the species included in the ANOVA, the difference between energy density values estimated from FPL and ABL data was less than 10% (Table 6), which is within the margin of error of the quality control analyses routinely performed during proximate analysis. The two species for which the difference was greater than 10% were northern and southern rock sole.

It should be pointed out that the proximate total of our samples (percent lipid + percent protein + percent moisture + percent ash) occasionally deviated from 100%. One of the reasons likely stems from the fact that neither of the protein analysis methods directly measures protein content. Instead, nitrogen content is directly measured, and a standard conversion factor, 6.25, is used to convert from percent nitrogen to percent protein (Anonymous, 2002); even so, the precise relationship between nitrogen and protein depends on the amino acid composition of the sample because different amino acids contain different percentages of nitrogen. Since each fish species is likely to have a slightly different amino acid composition, the 6.25 conversion factor may result in a slight over- or underestimate of protein content and, thus, a proximate total greater or less than 100% (Jones, 1931). In our data, deviations around 100% ranged from 0.5% to 1.5%.

In summary, this study provides data which improve the seasonal and geographic coverage of information on proximate composition and energy density of fish from Alaskan waters. These data are critical for seasonally and geographically explicit estimates of Steller sea lion prey requirements, a necessary improvement over previous model estimates of annual prey requirements (Winship et al., 2002). These data also can contribute to bioenergetic modeling of the prey requirements of other predators in Alaska such as groundfish, fur seals, and marine birds.

Acknowledgments

This project would not have been possible without the cooperation of the scientific crew on board the chartered survey vessels during the 2001 eastern Bering Sea and Gulf of Alaska trawl surveys and the 2002 Aleutian Islands region trawl survey of the RACE Division (AFSC); the 2001 Atka mackerel tag recovery and 2002 Atka mackerel tag release surveys of the REFM Division (AFSC); the 2002 Pacific cod pot pilot and feasibility surveys of the REFM Division; and the 2001 OCC salmon survey of Auke Bay Laboratory (AFSC). Samples also were collected on board the NOAA ship *Miller Freeman* during the 2002 eastern Bering Sea Echo-Integration Trawl surveys (RACE) and the 2001 and 2002 East Kodiak fishery interaction surveys (REFM). K. Aydin, G. Duker, L. Fritz (AFSC), and two anonymous reviewers provided comments that improved the quality of the manuscript.

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Appendix A. Proximate analysis of fish collected in the Aleutian Islands; "Date" refers to the time of collection, "#" is the collection number (used to identify collection sites on Figure 1a), "*n*" is the number of fish analyzed, "f" refers to female fish, "m" refers to male fish, "pre" indicates fish in prespawning condition, "ripe" indicates fish in spawning condition, "run" indicates fish in the process of spawning, and "post" indicates fish in postspawning condition. Blank cells indicate that data were not collected. Mean among fish ± SD of length, weight, percent fat, percent protein, percent moisture, percent ash, and energy density on a wet weight basis (energy conversions: lipid 36.43 kJ/g, protein 20.10 kJ/g) are shown. "Lab" refers to the laboratory in which the samples were analyzed; Food Products Laboratory (FPL) or Auke Bay Laboratory (ABL).

						Length (cm)		Weight (g)		Fat (%)		Protein (%)		Moisture (%)		Ash (%)		kJ/g wet weight		
Date	#	*n*	Sex	Spawn state	Age (yr)	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Lab
Alaska skate (*Bathyraja parmifera*)																				
	323	1				39.0	---	482.0	---	2.0	---	16.55	---	80.5	---	2.63	---	---	---	ABL
Atka mackerel (*Pleurogrammus monopterygius*)																				
13 Nov. 01	105	5	f			---	---	---	---	6.6	0.38	17.3	2.71	73.2	0.76	2.2	0.74	5.9	0.63	FPL
13 Nov. 01	107	3	m			---	---	---	---	6.1	0.82	17.1	2.06	74.9	1.30	2.3	0.49	5.7	0.41	FPL
15 Nov. 01	71	5	f			34.0	2.92	484.0	120.33	6.1	0.69	16.2	1.92	74.9	0.87	2.9	1.23	5.5	0.25	FPL
15 Nov. 01	89	5	m			41.8	3.11	---	---	9.3	5.28	14.9	1.34	73.6	4.03	2.7	0.75	6.4	1.89	FPL
17 Nov. 01	82	5	f			42.4	2.07	---	---	6.6	1.15	15.8	2.01	75.9	1.72	3.1	0.99	5.6	0.69	FPL
17 Nov. 01	84	5	m			42.0	1.58	---	---	10.6	7.03	14.8	1.51	73.5	5.87	2.9	0.80	6.8	2.52	FPL
9 June 02	300	11	m	pre		37.3	2.61	737.4	166.50	13.2	3.78	15.6	0.53	69.1	2.81	2.5	0.35	8.0	1.43	ABL
9 June 02	301	5	f	pre		34.1	2.33	434.2	194.24	8.5	1.01	16.2	0.26	73.8	0.76	2.7	0.08	6.4	0.35	ABL
9 June 02	302	4	m			38.7	0.58	786.8	80.38	11.2	2.05	15.8	0.87	69.3	1.96	2.7	0.36	7.3	0.76	ABL
14 June 02	299	5	f	ripe		33.9	1.98	490.6	119.77	5.3	2.62	16.1	0.42	76.8	2.57	2.7	0.20	5.2	1.00	ABL
19 June 02	298	4	f			35.8	3.30	457.0	77.52	7.3	2.23	15.7	0.58	74.5	1.30	2.6	0.20	5.8	0.74	ABL
19 June 02	298	1	m			33.0	---	354.0	---	5.7	---	15.7	---	77.2	---	2.7	---	5.3	---	ABL
21 June 02	287	8	?			28.5	0.53	273.5	34.97	11.9	3.33	15.2	0.28	71.2	2.83	2.5	0.19	7.4	1.17	ABL
23 June 02	239	1	?			---	---	---	---	2.7	---	12.6	---	81.0	---	1.6	---	3.5	---	FPL
27 June 02	250	2	m			38.0	2.83	645.0	49.50	6.0	0.57	14.0	0.21	78.9	0.14	1.8	0.00	5.0	0.16	FPL
27 June 02	253	2	?			---	---	---	---	3.5	2.12	15.0	2.90	79.9	0.92	1.9	0.57	4.3	0.19	FPL
27 June 02	254	3	m	pre		---	---	---	---	10.8	1.07	14.0	1.18	73.8	0.20	1.8	0.15	6.7	0.18	FPL
27 June 02	256	5	m			41.0	1.22	794.8	67.33	5.7	2.62	13.4	2.39	77.9	2.68	2.8	1.56	4.8	1.18	FPL
27 June 02	258	3	f	pre		40.3	3.21	728.0	179.88	5.2	1.96	14.6	0.55	77.2	2.36	3.0	1.21	4.8	0.63	FPL
27 June 02	263	5	f			41.6	0.89	770.0	24.82	4.9	1.73	14.7	0.61	78.3	0.95	2.0	0.66	4.7	0.57	FPL
28 June 02	234	3	m			41.0	0.00	874.7	75.11	8.0	1.87	15.6	0.27	74.4	0.07	3.2	0.07	6.0	0.74	ABL
28 June 02	234	2	m			43.5	0.71	886.0	42.43	3.0	0.21	13.8	0.14	81.5	0.07	1.8	0.21	3.9	0.05	FPL
28 June 02	235	1	f			40.0	---	794.0	---	0.8	---	14.9	---	81.0	---	3.6	---	3.3	---	ABL
28 June 02	240	4	f			41.0	1.63	754.5	39.64	5.3	3.55	14.7	0.66	77.8	3.40	1.8	0.32	4.9	1.30	FPL

3 July 02	216	3	f		46.7	2.08	1,066.0	104.75	8.6	2.34	15.6	0.35	73.6	2.59	2.9	0.23	6.3	0.92	ABL
3 July 02	216	2	f		47.0	0.00	1,100.0	56.57	7.5	1.20	16.4	0.49	76.2	2.26	1.5	0.14	6.0	0.54	FPL
3 July 02	225	5	m		39.8	3.90	806.8	196.38	5.8	2.52	16.8	0.48	76.1	2.48	1.5	0.15	5.5	0.94	FPL
3 July 02	230	3	m		42.7	2.52	939.3	243.52	7.2	3.78	15.1	0.82	76.1	3.10	3.0	0.30	5.7	1.54	ABL
3 July 02	230	2	m		41.0	4.24	888.0	229.10	8.4	2.19	14.4	2.62	75.7	2.19	1.6	0.00	5.9	1.32	FPL
3 July 02	233	2	f		46.0	1.41	1,002.0	65.05	5.9	4.56	15.9	0.86	75.6	4.36	3.0	0.16	5.4	1.83	ABL
3 July 02	233	3	f		39.0	3.46	41.7	4.16	5.8	2.86	15.1	0.58	76.6	2.62	2.0	1.05	5.8	0.93	FPL
4 July 02	210	4	m		37.8	1.89	737.0	167.35	12.6	3.13	16.0	0.38	70.1	2.36	2.6	0.37	7.8	1.11	ABL
4 July 02	210	1	m		42.0	---	940.0	---	6.5	---	15.9	---	75.7	---	1.9	---	5.6	---	FPL
4 July 02	212	4	f		41.0	5.23	824.8	235.90	7.9	2.20	15.9	0.27	74.0	2.03	2.8	0.32	6.1	0.82	ABL
4 July 02	212	1	f		36.0	---	512.0	---	7.7	---	15.6	---	73.6	---	3.1	---	5.9	---	FPL
14 July 02	296	1	f	spent	35.0	---	332.0	---	0.7	---	12.0	---	83.9	---	3.4	---	2.7	---	ABL
Bering skate *(Bathyraja interrupta)*																			
3 July 02	291	1	m		25.0	---	76.0	---	1.1	---	15.2	---	84.4	---	2.0	---	3.5	---	ABL
Commander squid *(Berrytheuthis magister)*																			
21 June 02	292	2	f		26.5	0.71	566.0	39.60	4.4	1.89	13.4	0.52	79.8	2.11	1.7	0.14	4.3	0.79	ABL
21 June 02	292	13	m		21.2	2.44	313.5	81.83	2.9	1.10	12.8	0.54	82.1	1.23	1.8	0.03	3.6	0.44	ABL
Pacific herring *(Clupea pallasii)*																			
18 June 02	277	1	?		---	---	---	---	17.9	---	14.5	---	64.5	---	1.9	---	9.4	---	FPL
Mud skate *(Rhina ancylostoma)*																			
8 June 02	307	2	f		45.0	1.41	524.0	171.12	3.5	0.36	14.8	0.04	81.5	0.44	2.3	0.09	4.2	0.14	ABL
8 June 02	307	1	m		52.0	---	532.0	---	1.1	---	14.6	---	83.0	---	3.1	---	3.3	---	ABL
18 June 02	295	1	m		52.0	---	850.0	---	2.1	---	15.4	---	83.5	---	2.2	---	3.9	---	ABL
18 June 02	306	1	m		45.0	---	468.0	---	5.5	---	16.3	---	79.5	---	2.1	---	5.3	---	ABL
Northern rock sole *(Lepidopsetta polyxystra)*																			
3 June 02	286	4			29.8	8.42	358.5	273.93	2.4	1.47	16.6	1.28	78.1	2.54	3.4	0.79	4.2	0.61	ABL
Northern rockfish *(Sebastes polyspinis)*																			
14 Nov. 01	91	1	?		---	---	---	---	8.4	---	16.7	---	71.9	---	3.0	---	6.4	---	FPL
17 Nov. 01	72	5	?		36.6	1.14	772.8	155.62	5.8	1.62	18.6	2.76	73.4	1.81	3.0	0.59	5.9	0.60	FPL
19 May 02	320	8	?		40.4	3.78	1,021.4	304.82	10.6	1.44	17.3	0.69	69.8	0.87	4.1	0.48	7.3	0.53	ABL
Pacific cod *(Gadus macrocephalus)*																			
1 March 02	145	1	?		---	---	---	---	2.9	---	16.6	---	76.8	---	1.7	---	4.4	---	FPL
10 April 02	175	1	m	pre	58.0	---	2,104.0	---	2.2	---	16.2	---	77.6	---	3.1	---	4.1	---	FPL
10 April 02	163	1	m	pre	58.7	---	2,179.0	---	1.3	---	16.7	---	79.5	---	3.3	---	3.8	---	ABL
10 April 02	163	3	m	pre	---	---	---	---	1.6	0.59	17.9	0.40	79.6	0.71	2.0	0.06	4.2	0.37	FPL

Pollock adult *(Theragra chalcogramma)*																				
13 Nov. 01	83	3	f			---	---	---	---	7.3	0.76	16.7	0.44	74.0	1.01	2.1	0.12	6.0	0.36	FPL
13 Nov. 01	106	1	m			---	---	---	---	6.7	---	14.7	---	76.6	---	2.0	---	5.4	---	FPL
18 Nov. 01	104	20	?			---	---	---	---	7.6	1.25	16.1	0.58	74.0	1.60	1.9	0.56	6.0	0.44	FPL
1 March 02	146	1	f	spent		---	---	---	---	4.4	---	14.6	---	78.1	---	1.4	---	4.5	---	FPL
19 May 02	315	5	?			47.8	4.15	841.4	92.05	3.0	1.01	15.1	0.53	79.1	1.41	2.6	0.33	4.1	0.42	ABL
19 May 02	316	15	?			46.7	2.16	759.1	80.32	3.5	1.14	15.2	0.79	78.4	1.60	3.0	0.32	4.3	0.44	ABL
20 May 02	312	3	f			29.3	2.69	201.3	55.94	2.9	1.34	15.0	0.49	80.5	1.93	2.5	0.27	4.1	0.56	ABL
20 May 02	312	2	m			29.3	0.14	208.0	2.83	2.1	0.24	15.1	0.21	80.7	0.00	2.4	0.03	3.8	0.05	ABL
Pollock juvenile *(Theragra chalcogramma)*																				
22 May 01	48	15	?		2	---	---	---	---	1.2	0.23	6.3	2.26	79.0	2.58	3.5	0.66	1.7	0.47	FPL
20 May 02	313	10	?		2	29.7	2.11	210.0	33.54	2.2	0.69	15.1	0.75	80.8	1.11	2.5	0.30	3.8	0.33	ABL
8 June 02	297	11	?		1	17.2	0.60	36.9	3.67	2.6	0.63	14.9	0.40	80.8	0.37	2.6	0.26	3.9	0.24	ABL
8 June 02	294	3	?			17.0	1.00	32.7	5.13	2.8	0.33	14.5	0.33	80.8	0.60	2.6	0.19	3.9	0.18	ABL
Pacific ocean perch *(Sebastes alutus)*																				
19 May 02	321	8	?			29.4	4.00	406.1	170.46	8.2	2.93	17.7	0.61	71.3	3.48	3.7	0.54	6.5	1.15	ABL
Rock sole (*Lepidopsetta* spp.)																				
15 Nov. 01	74	1	m			35.0	---	458.0	---	3.7	---	13.7	---	78.2	---	3.9	---	4.1	---	FPL
15 Nov. 01	75	4	f			43.5	3.87	967.0	256.64	2.5	0.81	17.2	1.88	79.3	0.74	3.5	0.84	4.4	0.40	FPL
Salmon *(Oncorhynchus* spp.*)*																				
5 March 02	149	3	?			---	---	---	---	2.3	0.60	20.0	0.55	76.3	0.50	1.3	0.29	4.9	0.25	FPL
Pacific sandfish *(Trichodon trichodon)*																				
3 July 02	288	4	?			12.3	0.50	19.5	3.87	2.8	0.57	14.2	0.62	80.3	0.77	3.1	0.47	3.9	0.28	ABL
23 May 02	290	2	?			22.5	0.71	131.0	2.83	3.6	1.15	14.9	0.59	79.7	0.04	2.6	0.15	4.3	0.30	ABL
Skate (*Bathyraja* spp.)																				
18 Nov. 01	103	11	?			---	---	---	---	9.0	4.85	16.0	1.56	75.2	3.93	1.7	0.40	6.5	1.55	FPL
Snailfish *(Cyclopteridea)*																				
5 March 02	148	1	?			---	---	---	---	0.5	---	4.9	---	90.5	---	2.1	---	1.2	---	FPL
Southern rock sole *(Lepidopsetta bilineata)*																				
30 May 02	285	5	?			30.2	3.27	300.6	111.66	1.7	0.47	15.6	0.83	79.2	0.94	3.9	0.86	3.8	0.29	ABL
3 June 02	289	1	?			37.0	---	672.0	---	1.7	---	14.2	---	78.6	---	6.0	---	3.5	---	ABL
3 June 02	293	3	f			29.7	2.08	287.0	85.58	2.0	0.99	15.9	0.65	78.6	1.43	3.7	0.48	3.9	0.47	ABL
3 June 02	293	3	m			29.0	1.00	262.7	27.21	1.7	0.93	14.9	0.80	80.2	1.74	3.1	0.63	3.6	0.49	ABL

Squid																		
1 March 02	150	7	?	---	---	---	---	2.8	0.83	14.7	0.24	80.6	1.04	1.8	0.07	4.0	0.32	FPL
White blotched skate *(Bathyraja maculata)*																		
18 June 02	303	2	m	42.5	0.71	451.0	5.66	2.1	0.16	13.9	0.87	82.9	0.56	2.2	0.27	3.6	0.12	ABL
18 June 02	303	1	f	37.0	---	379.0	---	1.8	---	13.9	---	84.6	---	2.0	---	3.4	---	ABL
18 June 02	303	1	?	37.0	---	379.0	---	2.4	---	12.5	---	85.2	---	2.0	---	3.4	---	ABL
19 June 02	304	2	f	27.0	14.14	261.0	12.73	2.7	0.52	15.1	1.73	83.1	2.88	2.2	0.01	4.0	0.54	ABL
19 June 02	304	1	m	41.0	---	575.0	---	2.5	---	14.7	---	83.4	---	2.0	---	3.9	---	ABL
Yellow Irish lord *(Hemilepidotus jordani)*																		
20 May 01	46	5	?	---	---	---	---	3.0	0.48	4.9	1.84	79.8	0.97	3.5	0.97	2.1	0.43	FPL
20 May 01	51	5	?	---	---	---	---	3.4	1.18	11.1	5.34	80.9	1.24	2.9	0.64	3.5	1.25	FPL
10 April 02	173	1	?	---	---	---	---	4.4	---	14.6	---	80.0	---	3.0	---	4.5	---	FPL
10 April 02	188	2	?	---	---	---	---	5.1	0.21	15.5	0.14	77.6	1.27	3.2	1.77	4.8	0.22	FPL
10 April 02	171	1	?	---	---	---	---	4.4	---	14.6	---	80.1	---	1.5	---	4.5	---	FPL
10 April 02	170	3	?	---	---	---	---	4.3	0.67	15.4	0.76	78.0	0.87	3.5	2.11	4.7	0.10	FPL
10 April 02	201	2	?	---	---	---	---	7.3	0.92	16.2	0.21	75.8	0.07	2.7	0.35	5.9	0.38	FPL
10 April 02	203	3	?	---	---	---	---	6.5	0.62	15.1	2.22	75.7	0.90	3.2	0.74	5.4	0.33	FPL
19 May 02	317	15	?	37.9	7.54	689.6	267.10	3.7	1.26	14.3	0.41	78.2	1.64	3.7	0.44	4.2	0.50	ABL

Appendix B. Proximate analysis of fish collected in the eastern Bering Sea; "Date" refers to the time of collection, "#" is the collection number (used to identify collection sites on Figure 1b), "*n*" is the number of fish analyzed, "f" refers to female fish, "m" refers to male fish, "pre" indicates fish in prespawning condition, "ripe" indicates fish in spawning condition, "run" indicates fish in the process of spawning, and "post" indicates fish in postspawning condition. Blank cells indicate that data were not collected. Mean among fish ± SD of length, weight, percent fat, percent protein, percent moisture, percent ash, and energy density on a wet weight basis (energy conversions: lipid 36.43 kJ/g, protein 20.10 kJ/g) are shown. "Lab" refers to the laboratory in which the samples were analyzed: Food Products Laboratory (FPL) or Auke Bay Laboratory (ABL).

						Length (cm)		Weight (g)		Fat (%)		Protein (%)		Moisture (%)		Ash (%)		kJ/g wet weight		
Date	#	*n*	Sex	Spawn state	Age (yr)	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Lab
Alaska skate *(Bathyraja parmifera)*																				
3 June 01	34	2	?			---	---	---	---	1.7	0.00	7.6	2.90	83.3	0.64	1.9	0.21	2.1	0.58	FPL
7 June 01	32	5	?			---	---	---	---	1.0	0.13	8.3	5.22	84.4	0.68	2.3	0.26	2.1	1.03	FPL
Atka mackerel *(Pleurogrammus monopterygius)*																				
13 June 02	273	1	?			---	---	---	---	8.8	---	14.6	---	73.4	---	2.1	---	6.1	---	FPL
Bering skate *(Bathyraja interrupta)*																				
18 June 01	42	3	?			---	---	---	---	1.0	0.25	4.8	1.45	83.5	0.55	3.4	0.12	1.4	0.29	FPL
Coho salmon *(Oncorhynchus kisutch)*																				
3 March 02	147	1	?			---	---	---	---	5.1	---	18.2	---	76.5	---	1.8	---	5.5	---	FPL
King salmon *(Oncorhynchus tshawytscha)*																				
13 June 02	282	1	?			---	---	---	---	9.9	---	18.5	---	71.5	---	1.4	---	7.3	---	FPL
Northern rock sole (*Lepidopsetta polyxystra*)																				
2 June 01	37	10	?			---	---	---	---	2.3	0.86	7.4	5.00	76.8	3.14	4.5	0.78	2.3	1.14	FPL
Pacific cod *(Gadus macrocephalus)*																				
2 March 02	144	1	?			---	---	---	---	2.5	---	13.3	---	79.4	---	1.6	---	3.6	---	FPL
10 April 02	175	1	m	pre		58.0	---	2,104.0	---	2.2	---	16.2	---	77.6	---	3.1	---	4.1	---	ABL
10 April 02	192	1	f	pres		---	---	---	---	3.5	---	14.8	---	80.0	---	1.6	---	4.3	---	FPL
10 April 02	194	2	f	post		---	---	---	---	1.8	0.78	15.4	0.92	82.5	0.42	2.1	0.21	3.7	0.10	FPL
10 April 02	172	1	m	ripe		53.8	---	2,121.0	---	1.7	---	15.7	---	80.4	---	2.5	---	3.8	---	ABL
10 April 02	176	5	m	post		---	---	---	---	1.9	0.74	16.5	0.84	80.1	0.74	2.0	0.25	4.0	0.29	FPL
10 April 02	187	1	f	ripe		---	---	---	---	1.9	---	17.3	---	79.6	---	1.6	---	4.2	---	FPL
10 April 02	193	3	f	pre		---	---	---	---	2.1	0.72	17.6	0.87	79.2	1.35	2.2	0.70	4.3	0.12	FPL
10 April 02	199	1	f	pre		---	---	---	---	1.5	---	14.0	---	79.5	---	3.1	---	3.4	---	FPL
10 April 02	169	2	m	ripe		---	---	---	---	2.1	0.35	16.4	1.56	79.8	0.28	1.9	0.21	4.0	0.18	FPL
10 April 02	166	1	f	post		---	---	---	---	0.9	---	17.6	---	82.0	---	1.3	---	3.9	---	FPL

10 April 02	184	1	f	ripe		---	---	---	---	2.5	---	17.4	---	77.9	---	1.2	---	4.4	---	FPL
10 April 02	181	1	f	post		---	---	---	---	1.3	---	15.5	---	81.8	---	2.4	---	3.6	---	FPL
10 April 02	198	1	f	ripe		---	---	---	---	3.4	---	18.6	---	77.7	---	1.7	---	5.0	---	FPL
10 April 02	179	1	m	ripe		---	---	---	---	1.0	---	16.6	---	83.3	---	1.5	---	3.7	---	FPL
	174	1	f	ripe		64.0	---	4,069.0	---	2.7	---	16.4	---	76.7	---	2.7	---	4.3	---	ABL
	197	1	f	post		---	---	---	---	2.5	---	16.2	---	79.9	---	1.8	---	4.2	---	FPL
	180	1	?			---	---	---	---	1.7	---	17.4	---	80.2	---	3.8	---	4.1	---	FPL
Pacific herring *(Clupea pallasii)*																				
3 June 01	28	15	?			---	---	---	---	5.6	1.16	12.8	4.69	75.2	2.78	2.3	0.36	4.6	1.09	FPL
4 June 01	208	4	?			---	---	---	---	15.1	3.42	16.0	1.05	67.1	2.99	1.8	0.22	8.7	1.17	FPL
10 June 02	272	1	?			---	---	---	---	12.2	---	17.1	---	68.0	---	1.6	---	7.9	---	FPL
10 July 02	279	1	?			---	---	---	---	4.4	---	16.8	---	76.7	---	1.9	---	5.0	---	FPL
Pacific sandfish *(Trichodon trichodon)*																				
23 Feb. 02	152	1	?			---	---	---	---	4.1	---	17.0	---	76.0	---	2.9	---	4.9	---	FPL
Pollock adult *(Theragra chalcogramma)*																				
22 Feb. 02	159	3	f	run		---	---	---	---	5.2	1.38	15.2	1.50	77.0	1.27	1.6	0.26	5.0	0.36	FPL
22 Feb. 02	139	9	f	pre		---	---	---	---	4.9	1.25	16.2	0.70	77.0	1.28	2.0	0.57	5.0	0.48	FPL
24 Feb. 02	162	2	f	ripe		---	---	---	---	5.6	0.42	15.6	0.71	77.0	0.99	1.5	0.21	5.2	0.30	FPL
24 Feb. 02	161	2	f	ripe		---	---	---	---	2.9	0.14	14.2	0.85	82.3	0.92	2.3	0.99	3.9	0.12	FPL
27 Feb. 02	153	2	f	ripe		---	---	---	---	6.0	1.41	16.2	0.28	76.6	1.13	2.4	1.63	5.4	0.46	FPL
27 Feb. 02	155	1	f	spent		---	---	---	---	0.9	---	15.1	---	82.1	---	2.3	---	3.4	---	FPL
27 Feb. 02	154	2	m	spent		---	---	---	---	4.3	0.07	15.0	1.41	79.8	0.64	3.0	0.64	4.6	0.31	FPL
Pollock juvenile *(Theragra chalcogramma)*																				
2 June 01	31	6	?			---	---	---	---	1.8	0.17	13.6	3.10	79.7	0.71	3.4	0.27	3.4	0.64	FPL
25 Feb. 02	158	2	?		2	---	---	---	---	2.3	0.64	17.3	0.42	78.6	0.85	2.6	0.14	4.3	0.32	FPL
27 Feb. 02	151	2	?		1	---	---	---	---	3.0	0.85	18.8	0.21	75.7	0.49	2.7	0.64	4.9	0.35	FPL
14 June 02	278	13	?		2	---	---	---	---	4.2	0.63	14.8	0.42	78.2	0.64	2.7	0.48	4.5	0.18	FPL
16 June 02	276	33	?		1	---	---	---	---	4.5	0.41	14.4	0.29	77.8	0.77	2.7	0.42	4.5	0.17	FPL
30 June 02	274	8	?			---	---	---	---	5.7	0.16	13.7	0.25	78.3	0.18	2.7	0.42	4.8	0.08	FPL
2 July 02	280	18	?		1	---	---	---	---	4.0	1.43	14.3	0.30	78.6	0.40	2.7	0.54	4.3	0.16	FPL
	209	14	?		2	---	---	---	---	2.2	0.59	15.4	0.39	79.9	0.78	2.8	0.36	3.9	0.24	FPL
Rock sole *(Lepidopsetta* spp.*)*																				
23 Feb. 02	141	4	?			---	---	---	---	1.4	0.42	15.9	0.60	77.5	3.62	5.3	2.74	3.7	0.26	FPL
Rock fish *(Sebastes* spp.*)*																				
	136	15	?			---	---	---	---	11.3	3.66	16.0	0.69	69.0	2.87	3.6	1.00	7.3	1.28	FPL

Salmon spp. subadult *(Oncorhynchus* spp.*)*																		
26 Feb. 02	157	1	?	---	---	---	---	2.3	---	19.2	---	77.3	---	2.0	---	4.7	---	FPL
Smooth lumpsucker *(Aptocyclus ventricosus)*																		
24 Feb. 02	160	5	?	---	---	---	---	3.2	1.58	6.1	0.80	89.1	1.16	1.9	0.07	2.4	0.64	FPL
Southern rock sole *(Lepidopsetta bilineata)*																		
10 June 01	41	10	?	---	---	---	---	1.0	0.32	4.2	1.44	81.1	1.10	4.0	0.57	1.2	0.33	FPL
Yellow Irish lord *(Hemilepidotus jordani)*																		
21 June 01	38	1	?	---	---	---	---	3.4	---	6.6	---	78.3	---	1.9	---	2.6	---	FPL
10 April 02	202	1	?	---	---	---	---	5.0	---	14.8	---	78.5	---	4.7	---	4.8	---	FPL
10 April 02	167	1	?	---	---	---	---	7.6	---	15.2	---	75.3	---	2.0	---	5.8	---	FPL
10 April 02	168	1	?	---	---	---	---	6.0	---	15.0	---	76.7	---	2.3	---	5.2	---	FPL

Appendix C. Proximate analysis of fish collected in the Gulf of Alaska; "Date" refers to the time of collection, "#" is the collection number (used to identify collection sites on Figure 1c), "*n*" is the number of fish analyzed, "f" refers to female fish, "m" refers to male fish, "pre" indicates fish in prespawning condition, "ripe" indicates fish in spawning condition, "run" indicates fish in the process of spawning, and "post" indicates fish in postspawning condition. Blank cells indicate that data on sex, spawn state, age, or length were not collected. Mean among fish ± standard deviation (SD) of length, weight, percent fat, percent protein, percent moisture, percent ash, and energy density on a wet weight basis (energy conversions: lipid 36.43 kJ/g, protein 20.10 kJ/g) are shown. "Lab" refers to the laboratory in which the samples were analyzed: Food Products Laboratory (FPL) or Auke Bay Laboratory (ABL).

										Fat (%)		Protein (%)		Moisture (%)		Ash (%)		kJ/g wet weight		
Date	#	*n*	Sex	Spawn state	Age (yr)	Length (cm)	SD	Weight (g)	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Lab
Alaska skate (*Bathyraja parmifera*)																				
25 Aug. 01	55	1	?			---	---	---	---	3.7	---	6.6	---	76.5	---	2.8	---	2.7	---	FPL
Bering skate (*Bathyraja interrupta*)																				
24 Aug. 01	54	2	?			---	---	---	---	3.1	2.12	19.0	1.13	78.3	0.99	2.6	0.71	5.0	0.55	FPL
	53	1	?			---	---	---	---	3.2	---	21.0	---	76.5	---	2.3	---	5.4	---	FPL
	56	1	?			---	---	---	---	3.9	---	19.8	---	77.9	---	1.7	---	5.4	---	FPL
Capelin (*Mallotus villosus*)																				
30 July 01	123	10	?			---	---	---	---	3.7	0.37	15.9	0.95	77.5	0.24	2.4	0.24	4.6	0.26	FPL
	126	13	?			---	---	---	---	5.3	0.54	17.5	0.72	74.6	0.89	2.6	0.42	5.5	0.27	FPL
Chinook salmon (*Oncorhynchus tshawytscha*)																				
27 Aug. 01	58	1	?			---	---	---	---	3.9	---	3.4	---	75.7	---	1.4	---	2.1	---	FPL
15 Aug. 02	281	2	?			---	---	---	---	8.2	5.09	19.3	0.28	72.6	5.30	1.4	0.07	6.9	1.80	FPL
28 Aug. 02	283	1	?			45.0	---	---	---	4.4	---	19.5	---	76.3	---	1.3	---	5.5	---	FPL
28 Aug. 02	284	1	?			---	---	---	---	8.3	---	19.2	---	71.2	---	1.3	---	6.9	---	FPL
Coho salmon (*Oncorhynchus kisutch*)																				
24 July 01	121	5	?			---	---	---	---	1.8	0.25	16.8	0.99	77.4	0.88	2.6	0.44	4.0	0.25	FPL
29 July 01	112	5	?			---	---	---	---	2.3	0.08	15.5	0.88	77.6	0.75	2.3	0.60	4.0	0.19	FPL
29 July 01	113	2	?			---	---	---	---	1.9	0.21	16.8	2.55	78.2	0.35	2.3	0.49	4.0	0.43	FPL
Commander skate (*Bathyraja lindbergi*)																				
26 June 01	308	1	m			51.0	---	707.0	---	1.6	---	14.6	---	82.4	---	2.3	---	3.5	---	ABL
Greenling (*Hexagrammos spp*)																				
19 July 01	132	1	?			---	---	---	---	2.8	---	15.2	---	75.2	---	3.6	---	4.1	---	FPL
19 July 01	133	1	?			---	---	---	---	2.8	---	15.2	---	75.2	---	3.6	---	4.1	---	FPL
Longnose skate (*Raja rhina*)																				
5 June 01	52	1	?			---	---	---	---	3.2	---	17.9	---	80.2	---	2.0	---	4.8	---	FPL

Northern rock sole *(Lepidopsetta polyxsystra)*																			
24 Aug. 01	57	1	?		---	---	---	---	3.6	---	5.1	---	77.4	---	3.8	---	2.3	---	FPL
	45	10	?		---	---	---	---	1.6	0.57	5.8	3.98	79.7	1.94	3.9	1.05	1.8	0.81	FPL
Pacific herring *(Clupea pallasii)*																			
19 July 01	135	1	?		---	---	---	---	6.8	---	17.0	---	74.0	---	2.8	---	5.9	---	FPL
22 July 01	124	20	?		---	---	---	---	14.3	5.55	16.6	0.72	66.7	4.95	2.6	0.45	8.5	1.95	FPL
27 July 01	110	10	?		---	---	---	---	17.3	2.27	17.3	0.44	62.3	3.04	2.3	0.33	9.8	0.79	FPL
27 July 01	115	10	?		---	---	---	---	16.4	2.95	17.0	0.74	64.5	2.83	2.3	0.39	9.4	0.99	FPL
27 July 01	108	6	?		---	---	---	---	20.4	1.15	16.1	0.93	62.1	1.47	2.3	0.34	10.7	0.46	FPL
Pacific sandfish *(Trichodon trichodon)*																			
22 July 01	129	3	?		---	---	---	---	2.1	0.70	17.0	0.50	78.1	0.50	3.2	0.31	4.2	0.22	FPL
Pink salmon *(Oncorhynchus gorbuscha)*																			
24 July 01	122	7	?		---	---	---	---	2.3	0.47	17.5	0.99	77.3	0.53	3.0	0.32	4.3	0.15	FPL
29 July 01	130	1	?		---	---	---	---	2.8	---	20.6	---	75.8	---	3.7	---	5.2	---	FPL
Pollock adult *(Theragra chalcogramma)*																			
18 June 01	10	1	?		70.0	---	---	---	2.7	---	15.5	---	80.4	---	2.2	---	4.1	---	FPL
18 June 01	12	1	?		63.0	---	---	---	2.4	---	18.1	---	79.1	---	2.3	---	4.5	---	FPL
19 June 01	11	1	?		57.0	---	---	---	1.0	---	14.9	---	80.3	---	4.6	---	3.4	---	FPL
19 June 01	13	1	?		62.0	---	---	---	3.3	---	15.2	---	79.5	---	5.3	---	4.3	---	FPL
19 June 01	14	1	?		63.0	---	---	---	2.0	---	15.3	---	81.5	---	1.7	---	3.8	---	FPL
19 June 01	21	1	?		61.0	---	---	---	1.2	---	16.0	---	79.7	---	2.9	---	3.7	---	FPL
19 June 01	22	1	?		58.0	---	---	---	2.0	---	16.3	---	78.1	---	4.1	---	4.0	---	FPL
19 June 01	23	1	?		59.0	---	---	---	0.8	---	16.5	---	81.4	---	2.7	---	3.6	---	FPL
19 June 01	24	1	?		61.0	---	---	---	0.9	---	12.6	---	80.5	---	4.2	---	2.9	---	FPL
19 June 01	25	1	?		66.0	---	---	---	2.4	---	15.7	---	79.7	---	4.9	---	4.0	---	FPL
19 June 01	26	1	?		64.0	---	---	---	2.9	---	14.9	---	80.0	---	3.7	---	4.0	---	FPL
19 June 01	27	1	?		53.0	---	---	---	0.8	---	16.0	---	81.2	---	4.9	---	3.5	---	FPL
30 June 01	47	15	?	3+	---	---	---	---	4.2	0.36	10.2	4.16	78.3	0.83	3.4	1.52	3.6	0.83	FPL
30 June 01	310	1	m	3+	52.0	---	1,137.0	---	3.1	---	15.3	---	78.3	---	3.2	---	4.2	---	ABL
21 July 01	109	5	?		---	---	---	---	3.7	0.23	15.3	1.03	78.8	0.40	2.3	0.62	4.4	0.14	FPL
27 July 01	111	5	?		---	---	---	---	3.6	0.60	15.0	0.48	77.0	0.86	3.1	1.00	4.3	0.26	FPL
27 July 01	116	5	?		---	---	---	---	4.9	0.38	16.2	0.73	76.7	0.30	2.3	0.76	5.1	0.26	FPL
27 July 01	125	1	?		---	---	---	---	4.3	---	15.1	---	77.4	---	2.8	---	4.6	---	FPL
9 Aug. 01	61	5	?	3+	---	---	---	---	5.8	1.35	13.0	5.25	77.4	2.33	2.4	0.67	4.7	0.97	FPL
9 Aug. 01	64	1	?	3+	---	---	---	---	5.3	---	3.8	---	77.1	---	1.5	---	2.7	---	FPL
Pollock juvenile *(Theragra chalcogramma)*																			
30 June 01	309	6	?		26.2	4.43	144.3	66.10	3.1	1.28	15.2	1.30	78.1	2.29	2.5	0.36	4.2	0.47	ABL

9 Aug. 01	62	15	?	2	---	---	---	---	5.9	1.58	13.1	3.27	75.1	2.01	2.4	0.53	4.8	0.73	FPL
Rock sole *(Lepidopsetta* spp.)																			
15 Aug. 02	271	1	?		---	---	---	---	2.3	---	15.7	---	81.6	---	1.4	---	4.0	---	FPL
Salmon spp. *(Oncorhynchus* spp.)																			
25 July 01	131	1	?		---	---	---	---	2.4	---	20.9	---	75.4	---	3.8	---	5.1	---	FPL
16 Aug. 02	275	2	?		---	---	---	---	4.5	0.49	19.7	0.14	75.3	0.07	1.4	0.00	5.6	0.21	FPL
Sand lance *(Ammodytes hexapterus)*																			
19 July 01	127	1	?		---	---	---	---	7.7	---	19.9	---	72.1	---	3.0	---	6.8	---	FPL
Sockeye salmon *(Onchorhynchus nerka)*																			
24 July 01	119	10	?		---	---	---	---	2.2	0.36	19.3	0.61	75.7	0.62	2.6	0.42	4.7	0.18	FPL
26 July 01	117	11	?		---	---	---	---	2.5	0.71	19.4	1.52	75.6	0.50	2.7	0.38	4.8	0.36	FPL
26 July 01	118	5	?		---	---	---	---	2.7	0.49	19.8	1.47	74.6	1.75	2.4	0.51	5.0	0.47	FPL
26 July 01	120	6	?		---	---	---	---	2.4	0.77	19.3	1.01	76.2	1.12	2.7	0.58	4.8	0.20	FPL
29 July 01	114	20	?		---	---	---	---	2.4	0.30	19.8	1.07	74.9	1.12	2.4	0.42	4.9	0.26	FPL
27 Aug. 01	60	1	?		---	---	---	---	4.1	---	5.1	---	75.5	---	1.6	---	2.5	---	FPL
28 Aug. 01	59	1	?		---	---	---	---	6.3	---	4.6	---	76.5	---	1.6	---	3.2	---	FPL
Surf smelt *(Hypomesus pretiosus)*																			
19 July 01	128	1	?		---	---	---	---	5.1	---	16.9	---	76.4	---	2.5	---	5.3	---	FPL
Yellow Irish lord *(Hemilepidotus jordani)*																			
15 June 01	4	1	?		36.0	---	---	---	3.4	---	16.8	---	79.2	---	2.2	---	4.6	---	FPL
15 June 01	15	1	?		36.0	---	---	---	5.1	---	15.3	---	76.0	---	4.2	---	4.9	---	FPL
15 June 01	16	1	?		37.0	---	---	---	4.2	---	16.6	---	76.8	---	4.6	---	4.9	---	FPL
15 June 01	18	1	?		36.0	---	---	---	3.2	---	16.2	---	76.0	---	8.4	---	4.4	---	FPL
16 June 01	2	1	?		44.0	---	---	---	4.9	---	15.4	---	76.5	---	4.0	---	4.9	---	FPL
16 June 01	5	1	?		42.0	---	---	---	6.2	---	16.6	---	76.3	---	2.4	---	5.6	---	FPL
16 June 01	6	1	?		38.0	---	---	---	5.5	---	15.4	---	78.4	---	3.8	---	5.1	---	FPL
17 June 01	1	1	?		44.0	---	---	---	4.0	---	16.2	---	77.1	---	2.4	---	4.7	---	FPL
17 June 01	3	1	?		36.0	---	---	---	5.8	---	15.9	---	74.8	---	1.9	---	5.3	---	FPL
20 June 01	17	1	?		40.0	---	---	---	3.6	---	15.4	---	77.1	---	7.0	---	4.4	---	FPL
20 June 01	19	1	?		33.0	---	---	---	2.9	---	16.6	---	76.2	---	5.7	---	4.4	---	FPL
24 Aug. 01	67	1	?		---	---	---	---	3.4	---	4.5	---	78.6	---	1.8	---	2.1	---	FPL
24 Aug. 01	66	2	?		---	---	---	---	3.8	0.00	11.3	7.50	79.0	1.06	3.5	0.78	3.7	1.51	FPL
24 Aug. 01	70	1	?		---	---	---	---	5.1	---	2.7	---	79.4	---	4.4	---	2.4	---	FPL
25 Aug. 01	69	1	?		---	---	---	---	3.6	---	6.5	---	79.8	---	3.2	---	2.6	---	FPL
29 Aug. 01	65	1	?		---	---	---	---	3.1	---	5.1	---	78.5	---	2.4	---	2.2	---	FPL
29 Aug. 01	68	1	?		---	---	---	---	4.4	---	4.6	---	70.5	---	1.7	---	2.5	---	FPL