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ABSTRACT

Atlantic salmon *(Salmo salar)* escapees from marine aquaculture facilities in British Columbia and Washington state have been caught in Alaska fisheries each year since 1990. Based on 82 of 89 fish retrieved from 1990 through 1995 by Alaska Department of Fish and Game port samplers, this report provides conversion regressions for lengths and weights, and a preliminary analysis of genetic variation for Atlantic salmon in Alaska waters.

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INTRODUCTION

Atlantic salmon *(Salmo salar)* are known to have escaped from British Columbia or Washington state marine aquaculture facilities as early as 1987 (Burt et al. 1992; McKinnell and Thomson 1997; McKinnell et al. 1997). Escapees were first documented in Alaska waters in 1990 (Wing et al. 1992) and subsequently have been observed each year in Alaska fisheries (McKinnell and Thomson 1997; McKinnell et al. 1995, 1997). Most of these fish have been caught in gill-net and purse seine fisheries of southern southeastern Alaska, but some have been observed in the sports fishery in the Ketchikan and Sitka areas, in the troll fishery of northern southeastern Alaska, and in the set gill-net fishery near the Shumagin Islands in the western Gulf of Alaska. Recently, an Atlantic salmon was caught near the Pribilof Islands in the eastern Bering Sea (Brodeur and Busby 1998). The continued presence of these fish in Alaska waters poses questions about their growth, survival, and interactions with native salmonids in the marine environment as well as the potential for their invasion into freshwater spawning grounds. From 1990 through 1995, 89 Atlantic salmon were identified in commercial salmon landings in Alaska. This report provides length-weight regressions, length conversion regressions, and preliminary allozyme analyses for 15 protein-coding loci.

IDENTIFICATION

Atlantic salmon and the European and Eurasian trouts *(Salmo* spp.) are currently recognized as generically separate from the Pacific salmonids (Oncorhynchus spp.) (Smith and Stearley 1989; Robins et al. 1991a,b). Morphological and meristic characters useful for separating the two genera are not easily discerned in the field. Distinction between immature marine specimens of *Salmo* and Uncorhynchus is complicated because most species develop a predominately metallic blue to blue-green dorsal coloring, with silvery sides and belly. The distinctive parr marks, melanistic pigment spots, and areas of red, orange, or pink are often faded or absent. Distinguishing marine-caught Atlantic salmon from similar-appearing Pacific salmon and trout is possible by careful observation of the combined coloration, morphology, and fin ray counts, although no single characteristic is completely reliable. The large black pigment spots on the operculum are an easily observed field characteristic separating Atlantic salmon from most of the Pacific salmon. Atlantic salmon have fewer black pigment spots dorsally *than* chinook *(0. tshawytscha),* coho (0. *kisutch),* and pink salmon (0. *gorbuscha),* and these spots tend to be X-shaped, in contrast to the rounded or irregular spots of most Pacific salmon. The low anal fin ray count (8-12) separates Atlantic salmon from all of the anadromous *Oncorhynchus* species except steelhead (0. mykiss) and cutthroat trout (0. *clarki).* Also, Atlantic salmon have a narrow caudal peduncle (peduncle depth:standard length ratio of 12 to 15), which distinguishes Atlantic salmon from most of the Pacific salmon except chum salmon (0. *keta);* chum salmon, however, have higher anal fin ray counts (13 to 17) than Atlantic salmon and usually lack black pigmentation spots.

METHODS

Specimens of Atlantic salmon in gill-net, purse seine, and troll fishery catches delivered to fish processors in southeastern Alaska, 1991-95, were labeled and frozen by Alaska Department of Fish and Game port samplers. One specimen was received from the Shumagin Islands set-net fishery. The frozen salmon were shipped to the Auke Bay Laboratory and held frozen at -20°C until they were thawed for length and weight measurement, scale sampling, and tissue sampling for electrophoretic analysis of genetically variable enzymes. Following dissection, the thawed fish were air freighted to Seattle, Washington, where Andrew J. Thomson, Canadian Department of Fisheries and Oceans, sampled further for stomach contents, maturity stage, and relative fat condition.

Because various fishery agencies use different fish body measurements, multiple measurements were taken on each fish for comparisons and conversions (taxonomists, fishery managers, fish culturists, fish processors, commercial fishermen, and sports fishermen all use different sets of measurements, as well). Left-side body measurements (in millimeters) were obtained for the following:

Total Length (TL) = Tip of snout to end of tail.
Fork Length (FL) = Tip of snout to fork of tail.
Standard Length (SL) = Tip of snout to end of hypural plate.
Eye-Hypural (MEHP) = Mid-eye to end of hypural plate.
Eye-Fork (MEFT) = Mid-eye to fork of tail.
Eye Socket-Hypural (ESHP) = Posterior edge of eye socket to end of hypural plate.
Eye Socket-Fork (ESFT) = Posterior edge of eye socket to fork of tail.
Preanal length (PL) = Tip of snout to anus.
Head length (HL) = Tip of snout to posterior of opercle.
Head width (HW) = Widest dimension of the head.
Interorbital width (IOW) = Dorsal head width between orbits.
Orbit diameter (OD) = Horizontal diameter of the orbit.
Caudal peduncle depth (CD) = Narrowest depth of the caudal peduncle.
Body depth (BD) = Body depth at front of dorsal fin.
Girth (G) = Girth at front of dorsal fin.
Weight (WT) = Whole weight (undressed) recorded to 0.1 kg.
Also scales (two to five per fish) were taken from the fifth scale row above the lateral line and behind the dorsal fin on the left side.

Protein electrophoresis was also used to confirm the species identification using the diagnostic loci *PGDH** and *LDH** as described in Wing et al. (1992). Eye, heart, liver, and dorsal muscle tissues were extracted from 80 of the fish for electrophoretic isozyme analyses following the techniques of Aebersold et al. (1987). Genetic comparisons were made with standards from Atlantic salmon and six Pacific sahnonids (steelhead and sockeye [O. *nerkzz]*, pink, chum, chinook, and coho salmon).

RESULTS AND DISCUSSION

Eighty-nine Atlantic salmon were positively identified in Alaska fisheries from 1990 through 1995 (Table l), but only 82 were available for complete observation (three 1995 fish were not shipped from Ketchikan to Juneau, three 1995 fish were retained by the fishing vessels for personal consumption, and one 1991 fish was lost). All 82 examined fish had deformed or missing fins, indicative of net-pen rearing. Their lengths ranged from 319 to 752 mm (SL) and weights ranged from 0.5 to 6.0 kg.

Of the 82 fish examined, 52 fish were taken in purse seine fisheries, 24 in gill-net fisheries, 3 by commercial trollers, and 3 by unspecified commercial fishermen (Table 1). One fish, taken in 1994 in the set gill-net fishery at Nagai Island of the Shumagin Islands, was the westernmost occurrence of Atlantic salmon in the Pacific Ocean. Subsequently, in 1997 an Atlantic salmon was caught in the Pribilof Islands area in the eastern Bering Sea (Brodeur and Busby 1998). All the Atlantic salmon in this study were from southern southeastern Alaska, except the fish from the Shumagin Islands and two fish from the troll fisheries (Fig. 1). Verbal reports from charter boat operators, sports fishermen, and Alaska Department of Fish and Game personnel were received that Atlantic salmon occurred in sport catches near Ketchikan and Sitka, but not enough information was available to allow us to confirm these reports.

Length and Weight Relationships

The sample of fish sizes were collected over several years from fish caught in different fisheries with several types of gear. Sampled fish likely consisted of different ages. Gender information was not available for 15 of the fish; therefore, the sex composition could affect length-weight regressions. The data do not apply to a well-defined population, but a non-random sample can be useful in length-weight predictions if the central trend of the sample is similar to that of the intended population (Picker 1984), in this case West Coast Atlantic salmon. The central trend of a sample is reflected by a fitted geometric mean regression line, which can be used for prediction.

Sometimes the length but not weight of a fish is available. Weight information, however, may be desirable. All is not lost if good prior information about the length-weight relationship is available. Length-weight relationships are commonly described by regression equations. If such a regression equation exists, then the fitted equation can be used to predict a fish's unobserved weight, given its length. The observed length, for which a prediction of weight is desired, and the lengths used in the regression are assumed to come from the same population.

The geometric mean (GM) regression model (Picker 1973, 1984) was fit for prediction of fish weight (w) given length. GM regression was used instead of ordinary linear regression (OL) because GM regression is recommended for situations where both variables, weight and length, are subject to natural variability (Picker 1973). The GM regression line is close to the OL regression line in situations where the variates have high correlation. Weight was highly correlated ($r > 0.91$) with each of eight length measurements (TL, FL, SL, MEHP, MEFT, ESHP, ESFT, and PL). When both the GM regression and the OL regression lines were fit for In (W) on ln (TL), the estimated GM intercept and slope fell within the 90% confidence region for the estimated OL intercept and slope; that is, the coefficients estimated from the two methods were not significantly different at the 0.1 level of probability. Length and weight were log-transformed for all regressions. The log-log transformation improved the linearity between the two variables and is commonly used for positive variates. Assumptions of linearity, normality of data, and homogeneity of variance seem to be met for all regressions. Given the regression coefficients estimated from the GM regressions, prediction equations for fish weight (w) are provided for the above-mentioned length measurements that may be taken on a fish (Table 2, Fig. 2).

Sex ratios did not differ significantly from 1 :l over the 6-year period (Table 3). McKinnell et al. (1997) reported a predominance of males (13 males:0 females) in the 1995 Alaska catch. Their data did not include' an additional five Alaska fish: one was a female, and the sex of four was not determined (Table 3). The unsexed fish included specimens not sent to ABL and fish examined but whose sex could not be determined because the fish had been dressed before delivery. McKinnell and Thomson (1997) did not find an unbalanced sex ratio for either Alaska samples or combined Alaska-British Columbia samples from 1992 through 1996.

Length-Length Relationships

Choice of length measurement is not standardized among agencies, making comparison of length measurements taken from several agencies problematic. Similar to prediction of fish weight given fish length, prediction of a fish length can be made from a different length measurement.

GM regression models of fish lengths were fit to predict a fish length given a different length measurement. GM regression was used instead of OL regression because both independent and dependent variables are subject to natural variability. All length variables were highly correlated with each other ($r > 0.96$); therefore, GM regression lines are very close to OL regression lines. Assumptions of linearity, normality of data, and homogeneity of variance seem to be met for all length regressions. Given the regression coefficients estimated from the GM regressions, prediction equations for lengths given other lengths are provided (Tables 4-10, Fig. 3).

Age

Marine annuli were present on scales from 82 of the collected Atlantic salmon, and some showed considerable marine growth beyond the last annulus. Without a comparative baseline of scales from fish reared in marine pens, interpretation of the growth on the scales of these escapees would be highly speculative. Therefore, ageing of the fish was not attempted.

Genetic Variation

Seven enzyme-specific stains were used to assay tissues from 80 of the collected Atlantic salmon for 15 protein coding loci (Table 11). The isolocus *sMDHB-1,2** was polymorphic with the respective allelic frequencies. *l00 0.950, *fast 0.044, *slow 0.006. The variation was assigned to one locus, which is a conservative treatment for isoloci with relatively low allelic variability (Gharrett and Thomason 1987). The other 11 loci and 2 isoloci were monomorphic. This variation may prove useful for identifying sources of Atlantic salmon caught in Alaska fisheries.

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TABLES

Table 1.--Atlantic salmon recoveries in Alaska commercial fisheries by district and year, 1990-95.

	Atlantic Salmon Recovered						
District	1990	1991	1992	1993	1994	1995	Total
101		1		3	6	8	18
102		1		2	5	4	12
103		1			2	1	4
104				1	6	3	10
106		1		5	5	4	15
113	1					1	2
SSEAK[a]		3	2	17	2	3	27
Shumagin					1		1
TOTAL	1	7	2	28	27	24	89

[a] Southern southeastern Alaska, district not specified.

Table 2.--Statistics for prediction equations of fish weight (W) given an observed fish length. Coefficients were estimated from the functional regression model of In(W) given log-transformed fish length.

Point prediction, $\tilde{y}_*$, of y_* (weight associated with length x_*):

$$\tilde{y}_* = \exp(\hat{\beta}_0)\, x_*^{\hat{\beta}_1}, \text{ where}$$

$\hat{\beta}_0, \hat{\beta}_1$ = regression coefficients estimated from the functional regression and
x_* = observed length.

Standard error of prediction:

$$\text{sepred}(\tilde{y}_* | x_*) = \{[\exp(\hat{\sigma}^2) - 1] \exp(2\hat{\beta}_0 + \hat{\sigma}^2)\, x_*^{2\hat{\beta}_1}\}^{1/2},$$

where $\hat{\sigma}^2$ = prediction variance estimated from the functional regression.

Length (x_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Prediction Variance ($\hat{\sigma}^2$)
Total (TL)	-19.7810	3.2123	$0.0188 + 0.0206\,(\ln(x_*) - 6.4374)^2$
Fork (FL)	-19.3786	3.1599	$0.0173 + 0.0167\,(\ln(x_*) - 6.4168)^2$
Standard (SL)	-18.6170	3.0906	$0.0188 + 0.0191\,(\ln(x_*) - 6.3143)^2$
Eye-Hypural (MEHP)	-18.4391	3.1035	$0.0257 + 0.0364\,(\ln(x_*) - 6.2308)^2$
Eye-Fork (MEFT)	-19.7071	3.2466	$0.0184 + 0.0201\,(\ln(x_*) - 6.3467)^2$
Eye Socket-Hypural (ESHP)	-17.8354	3.0132	$0.0207 + 0.0220\,(\ln(x_*) - 6.2170)^2$
Eye Socket-Fork (ESFT)	-19.6602	3.2488	$0.0235 + 0.0334\,(\ln(x_*) - 6.3279)^2$
Preanal (PL)	-16.8320	2.9428	$0.0193 + 0.0182\,(\ln(x_*) - 6.0249)^2$

Table 3.--Sex composition of Atlantic salmon sampled in Alaska, 1990-95.

Year	Male	Female	unknown	Total
1990	0	1		1
1991	4	1	2	7
1992	1		1	2
1993	11	13	4	28
1994	10	13	4	27
1995	13	1	10	24

Table 4.--Statistics for prediction equations of nonstandard fish lengths (TL, FL, MEHP, MEFT, ESHP, ESFT), given an observed standard fish length (SL).

Point prediction, $\tilde{y}_*$, of y_* (nonstandard length associated with standard length x_*):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = regression coefficients estimated from the functional regression, and x_* = observed standard length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Total (TL)	29.2245	1.0776	$[175.0579 + 0.0002\ (x_* - 560.4756)^2]^{1/2}$
Fork (FL)	17.8261	1.0752	$[138.7955 + 0.0001\ (x_* - 560.4756)^2]^{1/2}$
Eye-Hypural (MEHP)	3.7250	0.9137	$[252.0051 + 0.0005\ (x_* - 559.6173)^2]^{1/2}$
Eye-Fork (MEFT)	31.0692	0.9768	$[164.4592 + 0.0002\ (x_* - 560.4756)^2]^{1/2}$
Eye Socket-Hypural (ESHP)	–11.6803	0.9288	$[226.6202 + 0.0004\ (x_* - 559.6173)^2]^{1/2}$
Eye Socket-Fork (ESFT)	29.5744	0.9605	$[270.3023 + 0.0005\ (x_* - 559.6173)^2]^{1/2}$

Table 5.--Statistics for prediction equations of fish lengths (ESHP, FL, MEFT, MEHP, SL, TL), given an observed eye socket-fork length (ESFT).

Point prediction, $\tilde{y}_*$, of y_* (length associated with x_* [ESFT]):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = coefficients estimated from the functional regression, and
x_* = observed eye socket-fork length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Eye Socket-Hypural (ESHP)	–40.2797	0.9670	$[457.0512 + 0.0017 (x_* - 567.0864)^2]^{1/2}$
Fork (FL)	–15.6297	1.1202	$[206.5907 + 0.0003 (x_* - 567.0864)^2]^{1/2}$
Eye-Fork (MEFT)	1.2498	1.0164	$[121.5835 + 0.0001 (x_* - 567.0864)^2]^{1/2}$
Eye-Hypural (MEHP)	–24.4093	0.9513	$[302.3791 + 0.0008 (x_* - 567.0864)^2]^{1/2}$
Standard (SL)	–30.7907	1.0411	$[292.9919 + 0.0006 (x_* - 567.0864)^2]^{1/2}$
Total (TL)	–4.4891	1.1231	$[243.3903 + 0.0004 (x_* - 567.0864)^2]^{1/2}$

Table 6.--Statistics for prediction equations of fish lengths (ESFT, FL, MEFT, MEHP, SL, TL), given an observed eye socket-hypural length (ESHP).

Point prediction, $\tilde{y}_*$, of y_* (length associated with x_* [ESHP]):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = coefficients estimated from the functional regression, and
x_* = observed eye socket-hypural length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Eye Socket-Fork (ESFT)	41.6529	1.0341	$[488.7457 + 0.0020 (x_* - 508.1111)^2]^{1/2}$
Fork (FL)	31.0279	1.1583	$[256.0412 + 0.0004 (x_* - 508.1111)^2]^{1/2}$
Eye-Fork (MEFT)	43.5872	1.0511	$[171.2293 + 0.0002 (x_* - 508.1111)^2]^{1/2}$
Eye-Hypural (MEHP)	15.2153	0.9837	$[256.9903 + 0.0006 (x_* - 508.1111)^2]^{1/2}$
Standard (SL)	12.5752	1.0766	$[262.6774 + 0.0005 (x_* - 508.1111)^2]^{1/2}$
Total (TL)	42.2896	1.1613	$[303.9126 + 0.0006 (x_* - 508.1111)^2]^{1/2}$

Table 7.--Statistics for prediction equations of fish lengths (ESFT, ESHP, MEFT, MEW, SL, TL), given an observed fork length (FL).

Point prediction, $\tilde{y}_*$, of y_* (length associated with x_* [FL]):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = coefficients estimated from the functional regression, and x_* = observed fork length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Eye Socket-Fork (ESFT)	13.9532	0.8927	$[164.6485 + 0.0002\ (x_* - 619.5926)^2]^{1/2}$
Eye Socket-Hypural (ESHP)	–26.7865	0.8633	$[190.8265 + 0.0002\ (x_* - 619.5926)^2]^{1/2}$
Eye-Fork (MEFT)	14.8747	0.9085	$[47.7201 + 1.3115E{-5}\ (x_* - 620.4512)^2]^{1/2}$
Eye-Hypural (MEHP)	–11.1356	0.8493	$[235.5971 + 0.0004\ (x_* - 619.5926)^2]^{1/2}$
Standard (SL)	–16.5793	0.9301	$[120.0589 + 7.9651E{-5}\ (x_* - 620.4512)^2]^{1/2}$
Total (TL)	11.3583	1.0023	$[37.7917 + 6.7486E{-6}\ (x_* - 620.4512)^2]^{1/2}$

Table 8.--Statistics for prediction equations of fish lengths (ESFT, ESHP, FL, MEHP, SL, TL), given an observed eye-fork length (MEFT).

Point prediction, $\tilde{y}_*$, of y_* (length associated with x_* [MEFT]):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = coefficients estimated from the functional regression, and x_* = observed eye-fork length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Eye Socket-Fork (ESFT)	–1.2296	0.9838	$[117.6842 + 0.0001\ (x_* - 577.6543)^2]^{1/2}$
Eye Socket-Hypural (ESHP)	–41.4688	0.9514	$[154.9899 + 0.0002\ (x_* - 577.6543)^2]^{1/2}$
Fork (FL)	–16.3734	1.1008	$[57.8202 + 1.9254E{-5}\ (x_* - 578.5366)^2]^{1/2}$
Eye-Hypural (MEHP)	–25.5790	0.9359	$[202.2174 + 0.0003\ (x_* - 577.6543)^2]^{1/2}$
Standard (SL)	–31.8075	1.0238	$[172.3674 + 0.0002\ (x_* - 578.5366)^2]^{1/2}$
Total (TL)	–5.0520	1.1032	$[104.7047 + 6.3057E{-5}\ (x_* - 578.5366)^2]^{1/2}$

Table 9.--Statistics for prediction equations of fish lengths (ESFT, ESHP, FL, MEFT, SL, TL), given an observed eye-hypural length (MEHP).

Point prediction, $\tilde{y}_*$, of y_* (length associated with x_* [MEHP]):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = coefficients estimated from the functional regression, and
x_* = observed eye-hypural length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Eye Socket-Fork (ESFT)	25.6588	1.0512	$[334.1288 + 0.0009\ (x_* - 515.0617)^2]^{½}$
Eye Socket-Hypural (ESHP)	–15.4669	1.0165	$[265.5590 + 0.0006\ (x_* - 515.0617)^2]^{½}$
Fork (FL)	13.1120	1.1775	$[326.6519 + 0.0007\ (x_* - 515.0617)^2]^{½}$
Eye-Fork (MEFT)	27.3302	1.0685	$[230.8539 + 0.0004\ (x_* - 515.0617)^2]^{½}$
Standard (SL)	–4.0767	1.0944	$[301.8405 + 0.0007\ (x_* - 515.0617)^2]^{½}$
Total (TL)	24.3272	1.1805	$[354.2628 + 0.0008\ (x_* - 515.0617)^2]^{½}$

Table 10.--Statistics for prediction equations of fish lengths (ESFT, ESHP, FL, MEFT, MEHP, SL), given an observed total fish length (TL).

Point prediction, $\tilde{y}_*$, of y_* (length associated with x_* [TL]):

$$\tilde{y}_* = \hat{\beta}_0 + \hat{\beta}_1 x_*,$$

where $\hat{\beta}_0$, $\hat{\beta}_1$ = coefficients estimated from the functional regression, and
x_* = observed total length.

Length (y_*)	Intercept ($\hat{\beta}_0$)	Slope ($\hat{\beta}_1$)	Standard Error of Prediction (sepred($\tilde{y}_* \mid x_*$))
Eye Socket-Fork (ESFT)	3.9972	0.8904	$[192.9735 + 0.0002\ (x_* - 632.3827)^2]^{½}$
Eye Socket-Hypural (ESHP)	–36.4143	0.8611	$[225.3331 + 0.0003\ (x_* - 632.3827)^2]^{½}$
Fork (FL)	–11.3328	0.9978	$[37.6220 + 6.688\text{E–}6\ (x_* - 633.2073)^2]^{½}$
Eye-Fork (MEFT)	4.5793	0.9064	$[86.0267 + 4.257\text{E–}5\ (x_* - 633.2073)^2]^{½}$
Eye-Hypural (MEHP)	–20.6067	0.8471	$[254.1895 + 0.0004\ (x_* - 632.3827)^2]^{½}$
Standard (SL)	–27.1194	0.9280	$[150.7461 + 0.0001\ (x_* - 633.2073)^2]^{½}$

Table 11 .--Variability of protein coding loci (Shaklee et al. 1990) for enzymes and the buffers in which they were resolved. EC numbers are in accordance with NC-IUBMB (1992). L = liver, H = heart, M = muscle, E = eye.

Enzyme	EC Number	Locus	Tissue	Buffer[a]	Variability Level[b]
Aspartate aminotransferase	2.6.1.1	*mAAT-1**	M,H	A	1
		*sAAT-1,2**	M,H	A	1
Creatine kinase	2.7.3.2	*CK-A1**	M	B	1
		*CK-A2**	M	B	1
Glucose-6-phosphate isomerase	5.3.1.9	*GPI-B1**	M	B	1
		*GPI-B2**	M	B	1
Isocitrate dehydrogenase	1.1.1.42	*mIDHP-1**	M,H	A	1
Lactate dehydrogenase	1.1.1.27	*LDH-A1**	M	B	1
		*LDH-A2**	M	B	1
		*LDH-B1**	M,E	B	1
		*LDH-B2**	M,H,L,E	B	1
Malate dehydrogenase	1.1.1.37	*sMDH-B1,2**	H,M	A	2
6-Phosphogluconate dehydrogenase	1.1.1.44	*PGDH**	M,H,E,L	A	1

[a] A = CAME 7.2 (Aebersold et al. 1987), B = R (Ridgway et al. 1970).

[b] 1 = monomorphic.
2 = highly variable; most abundant allele ≤ 0.95.

FIGURES

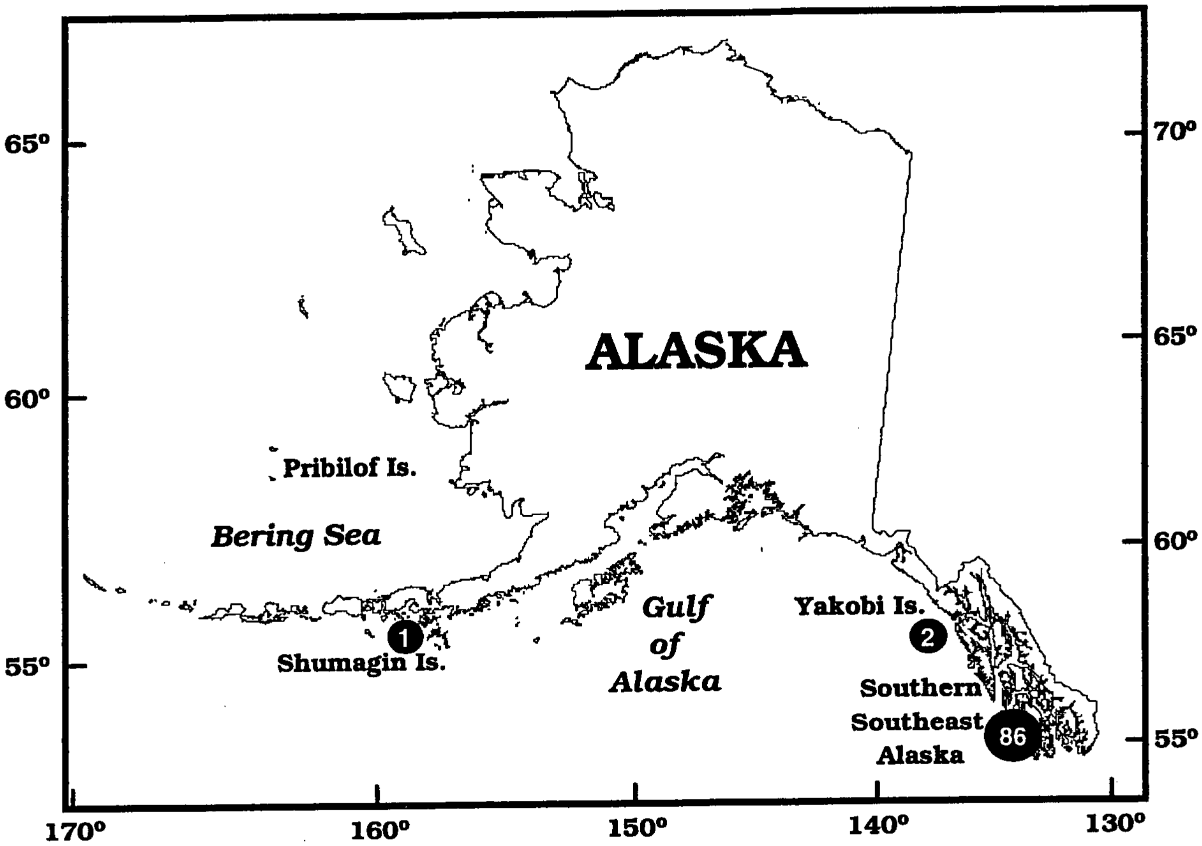


Figure 1 .--Distribution of Atlantic salmon in commercial fisheries of Alaska, 1990-95. Numbers in black circles represent the number of fish caught.

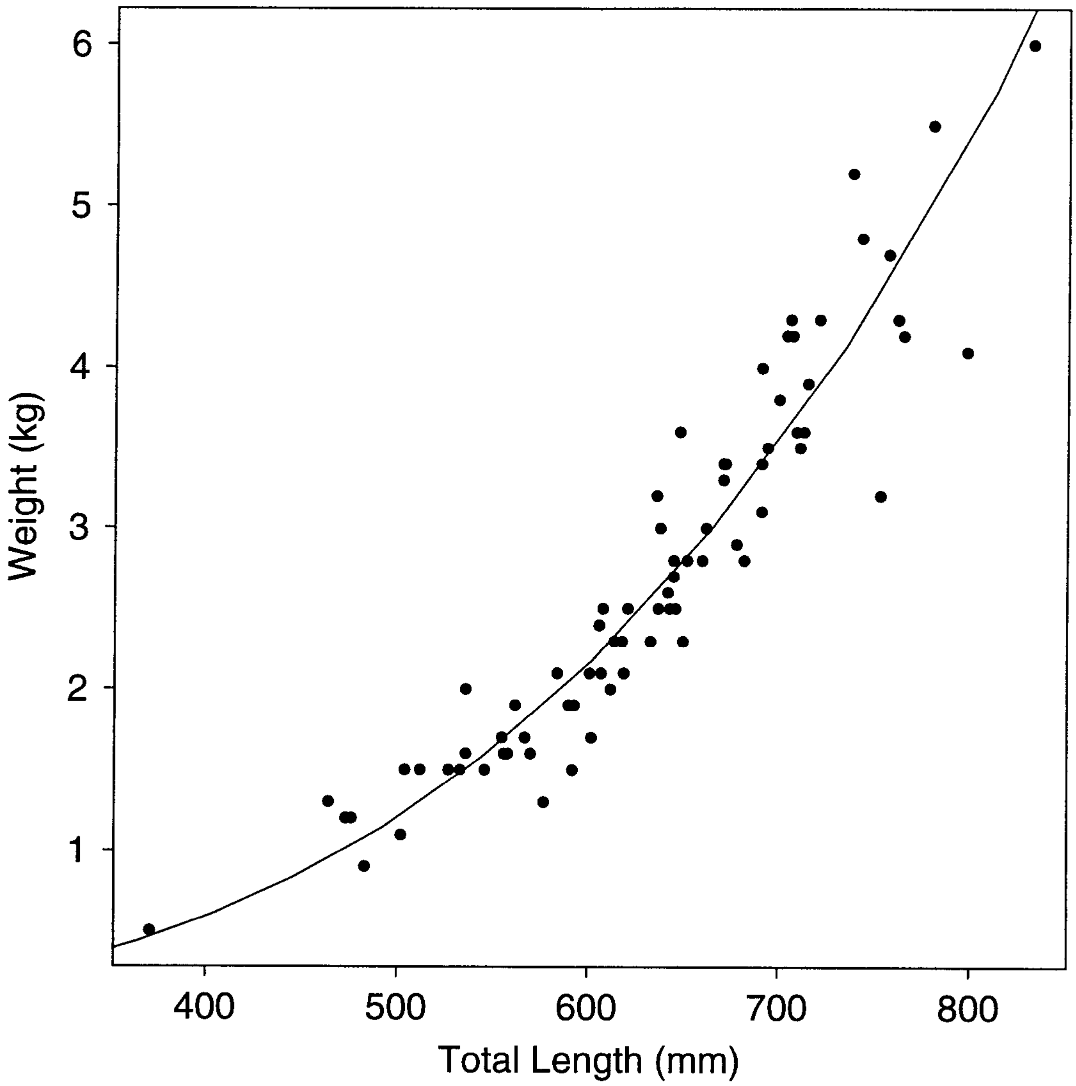


Figure 2.--Weight versus total length (TL) of Atlantic salmon recovered in Alaska commercial fisheries, 1990-95.

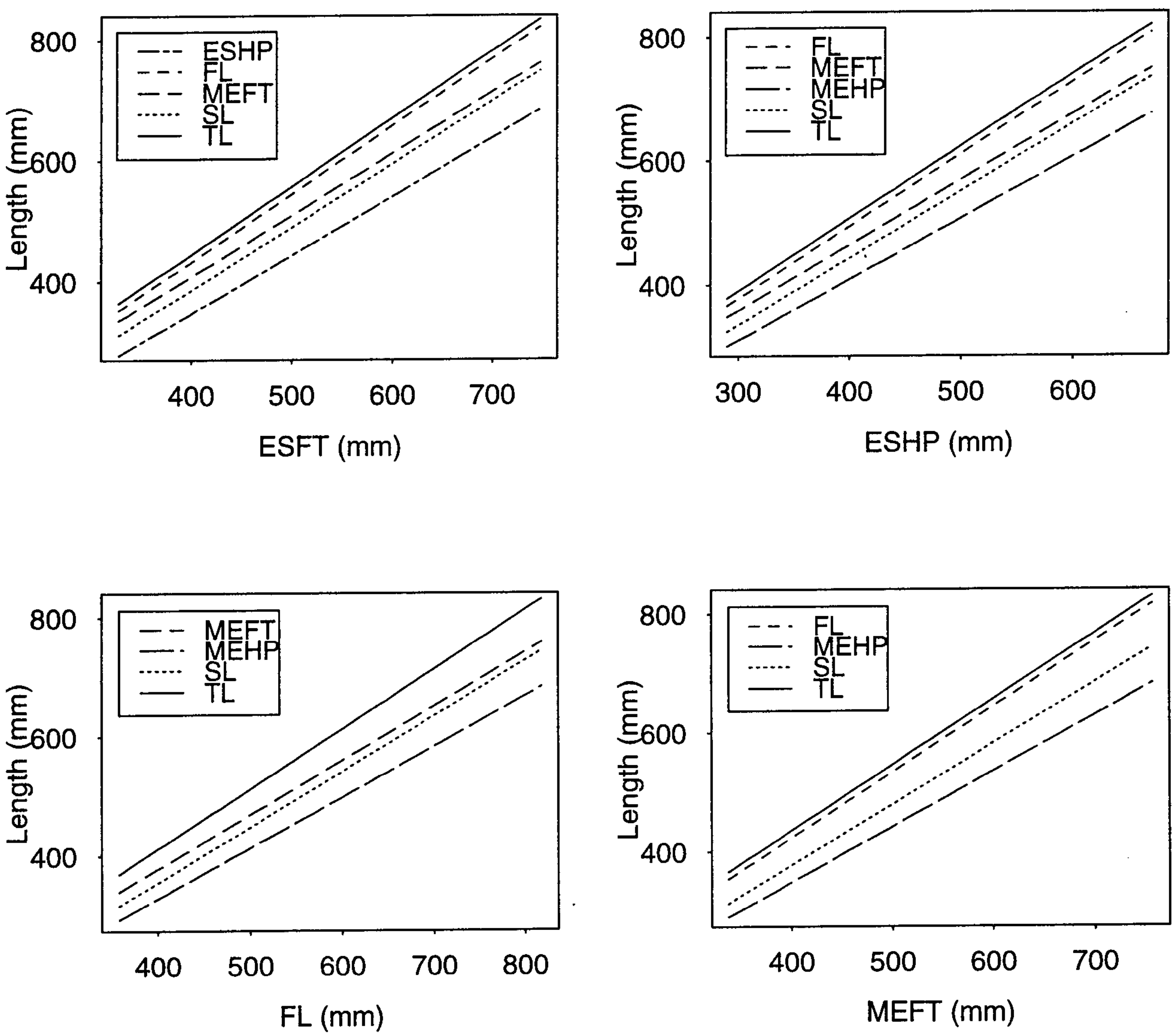


Figure 3.--Length regressions of Atlantic salmon recovered in Alaska commercial fisheries, 1990-95. Lengths: ESFT = eye socket-fork, ESHP = eye socket-hypural, FL = fork length, MEFT = eye-fork, MFNP = eye-hypural, SL = standard length, TL = total length.

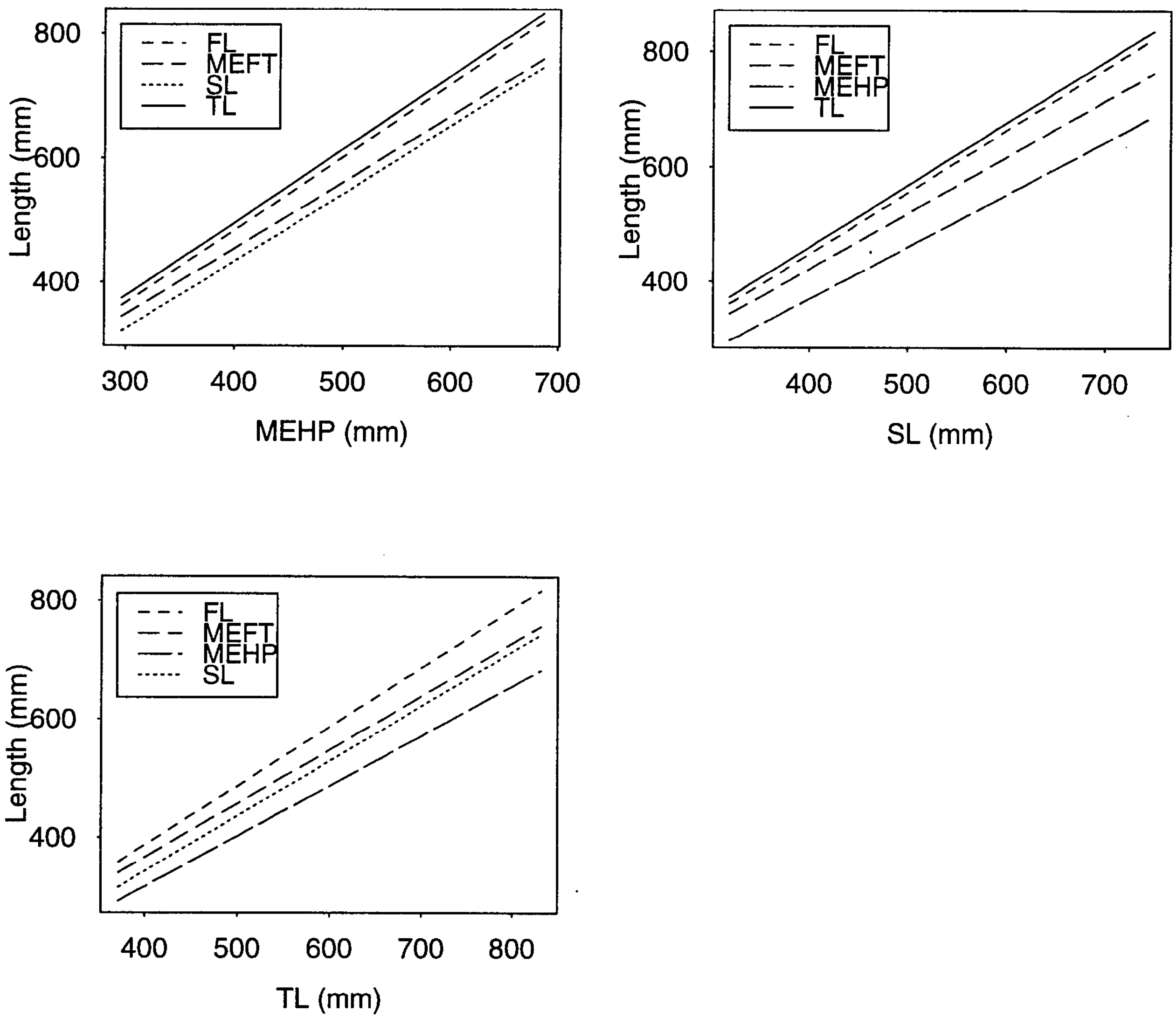


Figure 3.--Continued.

APPENDICES

Appendix l.--Collection data of Atlantic salmon recovered in Alaska commercial fisheries, 1990-95.

No.	Date”	Gear Type	District[b]	Sex[c]	Total Length (mm)	Whole Weight (kg)	Gonad Weight (g)	Fat Code[d]	Feed”
1	7/20/90	power troll	113-11	F	575				
2	8/06/91	seine	102	M	601	2.1			
3	8/07/91	seine	103-11	M	636	3.2			
4	8/xx/91	seine	SSEAK	M	643	2.5	1.1	2	E
5	8/xx/91	seine	106	U	659				D
6	x/xx/91	seine	SSEAK	M	660	2.8			
7	x/xx/91	seine	101/102/104	F	691	3.1	9.6	3	GM
8	x/xx/91	gill net	101-11	U	700				
9	7/21/92	seine	101/102/104	M	711	3.5	1.0	2	GM/FS
10	7/31/92	seine	101/102	U	464	1.3			
11	8/06/93	seine	101	M	709	3.6	1.0	3	GM
12	8/10/93	seine	101/102	F	590	1.9	7.3	2	E
13	8/10/93	seine	102	M	645	2.7	1.0	3	GM
14	8/10/93	seine	104-20	F	533	1.5	4.4	2	FS
15	8/13/93	gill net	101	F	645	2.8	8.9	2	E
16	8/15/93	seine	101-29, 102-50	M	476	1.2	1.0	2	GM
17	8/18/93	seine	101/102	M	473	1.2	1.0	3	E
18	8/19/93	seine	101/102	F	562	1.9	4.8	3	IP
19	8/20/93	seine	104/105	F	536	2.0	8.2	3	E
20	8/20/93	seine	104/105	M	502	1.1	1.0	2	E
21	8/20/93	seine	104/105	F	527	1.5	3.0	2	E
22	8/22/93	seine	101/102/103/104	F	546	1.5	7.1	2	E
23	8/24/93	gill net	106	M	694	3.5	1.0	2	H/FS
24	8/26/93	gill net	106	M	721	4.3	1.0	2	E
25	8/27/93	seine	101	M	652	2.8	1.0	2	IP
26	8/27/93	seine	102	M	584	2.1	1.0	2	E
27	8/27/93	seine	101/102	M	638	3.0	1.0		E
28	8/27/93	seine	SSEAK	F	555	1.7	3.9	2	E
29	8/27/93	seine	SSEAK	U	612	2.0			
30	8/28/93	seine	SSEAK	F	504	1.5	4.0	3	E
31	8/31/93	seine	101/102/103/104	F	648	3.6	7.5	3	E
32	8/31/93	seine	101/102/103/104	F	608	2.5	5.4	2	GM
33	8/31/93	seine	101/102	F	606	2.4	6.0	2	E
34	8/31/93	seine	101/102	M	536	1.6	1.0	3	E
35	6/29/94	gill net	101-11	M	614	2.3			
36	7/20/94	gill net	106	F	621	2.5			

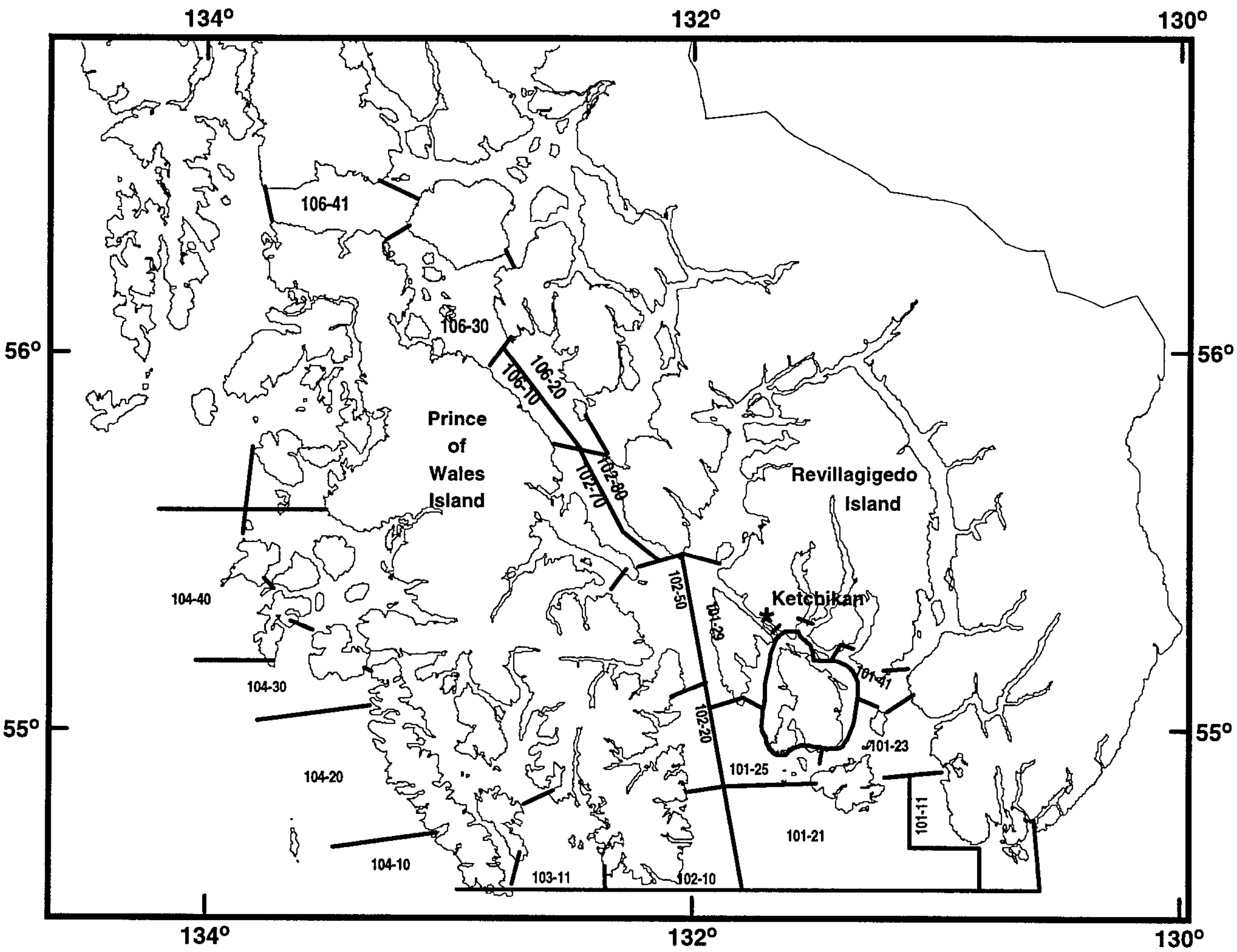
Appendix 1 .--Continued.

No.	Date"	Gear Type	District[b]	Sex[c]	Total Length (mm)	Whole Weight (kg)	Gonad Weight (g)	Fat Code[d]	Feed
37	8/09/94	seine	104-40	M	619	2.1			
38	8/09/94	seine	104-40	F	567	1.7			
39	8/09/94	seine	104	F	602	1.7			
40	8/09/94	seine	104	F	646	2.5			
41	8/17/94	seine	104	F	682	2.8			
42	8/18/94	gill net	101-11	M	738	5.2			
43	8/20/94	seine	102	F	590	1.9			
44	8/20/94	seine	103	M	650	2.3			
45	8/20/94	seine	103	M	593	1.9			
46	8/24/94	gill net	106	M	606				
47	8/25/94	seine	104-10	F	713	3.6			
48	8/28/94	seine	102-50	M	633	2.3			
49	8/28/94	seine	102-50	F	637	2.5			
50	9/01/94	unknown	unknown	F	592	1.5			
51	9/02/94	gill net	106	U	707	4.2			
52	9/02/94	unknown	unknown	U	743	4.8			
53	9/06/94	set gill net	Shumagin Is.	U	762	4.3			
54	9/15/94	gill net	101-11	M	662	3.0			
55	9/15/94	gill net	101-11	F	691	3.4			
56	9/19/94	seine	102-50	U	765	4.2			
57	9/20/94	gill net	106	F	753	3.2			
58	9/21/94	seine	102-50	M	671	3.4			
59	9/22/94	gill net	101-11	F	691	4.0			
60	9/22/94	gill net	101	U	700	3.8			
61	9/22/94	gill net	101	U	704	4.2			
62	9/22/94	gill net	101	U	715	3.9			
63	9/26/94	gill net	101-11	M	757	4.7			
64	9/xx/94	gill net	106	F	512	1.5			
65	6/28/95	gill net	111	U	708			0	D
66	7/14/95	seine	102-15	M	780	5.5	1.0	3	E
67	7/16/95	seine	102-10	M	483	0.9	>1.0	1	E
68	7/16/95	seine	102-10	M	706	4.3	5.3	2	E
69	7/25/95	gill net	106	M	671	3.3	2.0	3	E
70	7/26/95	seine	101	M	570	1.6	1.5	2	E
71	7/31/95	seine	101	M	556	1.6	1.0	2	E
72	8/01/95	gill net	106-41	M	642	2.6	1.0	1	E
73	8/1195	seine	101-40	M	672	3.4	1.0	3	E
74	8/13/95	seine	101,102,104	F	558	1.6	2.4	2	E

Appendix 1 .--Continued.

No.	Date"	Gear Type	District[b]	Sex"	Total Length (mm)	Whole Weight (kg)	Gonad Weight (g)	Fat Code[d]	Feed"
75	8/15/95	seine	101-29	M	618	2.3	1.0	2	
76	8/15/95	seine	104-20	M	607	2.1	1.0	2	E
77	8/28/95	seine	101	M	798	4.1	7.2	1	E
78	8/29/95	power troll	113-94	U	371	0.5	>1.0	2	K
79	9/18/95	power troll	106-41	U	678	2.9		0	D
80	9/26/95	gill net	101-11	M	832	6.0	2.6	3	E
81	9/xx/95	unknown	unknown	M	577	1.3	1.0	1	H
82	9/xx/95	gill net	106	U	718			0	D

[a] xx = Delivery date not recorded.
[b] Deliveries may be mixed catches from 2 to 4 districts. SSEAK = southern southeastern Alaska.
[c] F = female, M = male, U = sex not recorded.
[d] Fat codes are as described in Thomson and McKinnell (1994). 0 = dressed or greatly decomposed, 1 = little or no fat globs on organs, 2 = larger fat globs on major organs, 3 = extensive fat throughout pyloric caeca, 4 = organs encased in fat.
[e] D = fish delivered dressed, E = stomach empty, FS = fish scales, GM = unidentified gray matter, H = herring, IP = larval fish, K = krill (euphausiids).



Appendix 2.--Alaska Department of Fish and Game commercial salmon fishery districts of southern southeastern Alaska (SSEAK) from which most Atlantic salmon were recovered, 1990-95.

Appendix 3.--Left side measurements (mm) of Atlantic salmon recovered in Alaska commercial fisheries, 1990-95. Column headings defined on p. 2.

No.	Date[a]	Sex	TL	FL	SL	MEFT	MEHP	ESFT	ESHP	PL	HL	G	BD	CD	OD	IOW	HW	WT	SL/CD
1	7/20/90	F	575	540	490	504	455	500	442	360	107	260	98	33	18	35	48		14.85
2	8/06/91	M	601	595	540	563	563	553	497	452	111	298	115	41	18	45	67	2.1	
3	8/07/91	M	636	635	581	596	530	588	524	454	124	348	130	42	18	49	77	3.2	13.83
4	8/xx/91	M	643	631	548	590	507	579	498	415	123	300	116	43	18	44	64	2.5	12.74
5	8/xx/91	U	659	657	596	610	543	600	531	459	133	338	129	47	18	50	64		12.68
6	x/xx/91	M	660	658	598	619	555	607	544	452	124	324	126	41	18	48	68	2.8	14.59
7	x/xx/91	F	691	668	597	633	560	621	550	442	127	312	121	48	19	50	73	3.1	12.44
8	x/xx/91	U	700	690	630	650								43					
9	7/21/92	M	711	694	614	639	559	632	548	474	148	329	128	48	20	54	73	3.5	12.79
10	7/31/92	U	464	457	478	428	380	422	374	309	85	237	91	32	16	33	57	1.3	14.94
11	8/06/93	M	709	696	624	649	571	639	567	478	142	338	130	48	22	50	72	3.6	13.00
12	8/10/93	F	590	570	501	529	462	522	453	377	124	271	103	40	20	42	60	1.9	12.53
13	8/10/93	M	645	638	572	599	533	593	527	428	128	323	123	42	18	45	61	2.7	13.62
14	8/10/93	F	533	518	462	483	424	476	418	349	103	242	95	36	15	36	55	1.5	12.83
15	8/13/93	F	645	633	564	591	521	583	512	420	128	343	140	44	21	49	69	2.8	12.82
16	8/15/93	M	476	467	417	435	380	430	375	307	105	227	84	31	17	33	44	1.2	13.45
17	8/18/93	M	473	463	407	435	382	427	371	310	93	235	90	32	17	28	45	1.2	12.72
18	8/19/93	F	562	558	494	521	459	513	450	369	113	282	105	42	18	40	63	1.9	11.76
19	8/20/93	F	536	519	465	482	430	478	425	355	107	287	110	38	17.4	36.5	52.5	2.0	12.24
20	8/20/93	M	502	487	432	457	400	450	393	318	101	222	83	31	16.8	31	44	1.1	13.94
21	8/20/93	F	527	515	462	482	428	469	400	344	109	250	91	34	16.5	34	49	1.5	13.59
22	8/22/93	F	546	530	473	498	441	489	432	348	107	245	99	35	17	39	53	1.5	13.51
23	8/24/93	M	694	683	598	628	547	622	537	445	134	330	132	49	20	57	69	3.5	12.20
24	8/26/93	M	721	706	644	658	594	584	647	483	155	383	148	53	20	58	81	4.3	12.15

Appendix 3.--Continued.

No.	Date	SEX	TL	FL	SL	MEFT	MEHP	ESFT	ESHP	PL	HL	G	BD	CD	OD	IOW	HW	WT	SL/CD
25	8/27/93	M	652	644	588	598	541	587	532	434	141	297	117	44	19	45	68	2.8	13.36
26	8/27/93	M	584	568	510	528	474	520	465	384	115	278	110	36	18	41	61	2.1	14.17
27	8/27/93	M	638	627	565	588	523	581	517	434	124	331	130	46	19	49	70	3.0	12.28
28	8/27/93	F	555	543	492	510	458	502	448	363	113	263	102	33	18	37	58	1.7	14.91
29	8/27/93	U	478	464	457	428	380	422	374	309	85	237	91	32	16	33	57	1.3	14.94
30	8/28/93	F	504	492	437	458	397	453	397	323	111	260	102	33	18	34	56	1.5	13.24
31	8/31/93	F	648	633	570	591	525	583	518	430	126	370	145	49	20	52	76	3.6	11.63
32	8/31/93	F	608	601	540	563	498	555	487	398	125	303	118	45	20	43	68	2.5	12.00
33	8/31/93	F	606	601	539	562	499	551	490	411	133	294	113	40	16.5	41.1	57	2.4	13.48
34	8/31/93	M	536	524	468	488	434	482	424	349	111	259	96	37	18	46	59	1.6	12.65
35	6/29/94	M	614	603	537	567	503	556	492	405	112	301	117	42	18	49	62	2.3	12.79
36	7/20/94	F	621	603	541	568	506	555	496	402	111	312	121	40	19	44	64	2.5	13.53
37	8/09/94	M	619	603	574	561	504	556	498	410	113	296	109	39	19	47	62	2.1	14.72
38	8/09/94	F	567	554	504	525	475	513	465	378	101	278	102	36	20	44	55	1.7	14.00
39	8/09/94	F	602	576	525	543	484	536	477	403	110	281	105	40	18	45	60	1.7	13.13
40	8/09/94	F	646	629	570	591	528	582	522	426	119	285	112	46	19	52	63	2.5	12.39
41	8/17/94	F	682	665	596	624	555	614	546	437	122	345	133	48	21	57	67	2.8	12.42
42	8/18/94	M	738	720	654	671	602	659	592	477	142	437	164	52	22	60	82	5.2	12.58
43	8/20/94	F	590	581	523	543	488	535	480	384	105	275	102	40	18	47	60	1.9	13.08
44	8/20/94	M	650	638	579	597	537	586	527	436	120	292	110	42	20	48	67	2.3	13.79
45	8/20/94	M	593	585	523	545	484	533	472	395	109	287	114	40	20	44	63	1.9	13.08
46	8/24/94	M	606	595	530	562	492	552	487	405	116	305	115	39	18	48	62		13.59
47	8/25/94	F	713	703	632	648	578	642	573	482	133	335	127	46	20	58	76	3.6	13.74
48	8/28/94	M	633	623	565	576	516	564	507	425	124	280	104	40	19	51	63	2.3	14.13

Appendix 3.--Continued.

No.	Date	Sex	TL	FL	SL	MEFT	MEHP	ESFT	ESHP	PL	HL	G	BD	CD	OD	IOW	HW	WT	SL/CD
49	8/28/94	F	637	623	560	583	521	580	515	414	113	308	118	44	17	55	70	2.5	12.73
50	9/01/94	F	592	575	515	539	477	527	467	372	109	281	102	36	20	41	52	1.5	14.31
51	9/02/94	U	707	694	633	647	588	641	578	473	141	377	145	51	22	56	74	4.2	12.41
52	9/2/94	U	743	730	666	676	609	666	600	510	143	388	148	51	23	58	85	4.8	13.06
53	9/06/94	U	762	745	699	686	610	674	600	483	153	360	139	51	20	53	73	4.3	13.71
54	9/15/94	M	662	655	589	615	457	605	538	452	125	366	143	44	20	53	66	3.0	13.39
55	9/15/94	F	691	680	610	640	570	629	560	460	124	384	149	48	20	53	75	3.4	12.71
56	9/19/94	U	765	745	677	690	617	675	608	523	153	390	153	50	23	61	87	4.2	13.54
57	9/20/94	F	753	743	673	702	628	701	625	496	134	375	144	52	21	56	74	3.2	12.94
58	9/21/94	M	671	666	593	617	543	537	608	445	132	361	136	44	20	45	69	3.4	13.48
59	9/22/94	F	691	682	607	630	562	621	554	471	133	376	142	47	22	60	83	4.0	12.91
60	9/22/94	U	700	695	638	643	580	630	573	490	138	375	147	43	17	52	73	3.8	14.84
61	9/22/94	U	704	697	633	647	583	635	571	476	142	390	143	53	19	54	80	4.2	11.94
62	9/22/94	U	715	703	634	647	571	639	558	488	151	379	143	47	18	55	79	3.9	13.49
63	9/26/94	M	757	746	673	692	620	684	614	492	146	400	157	49	21	66	81	4.7	13.73
64	9/xx/94	F	512	508	453	474	421	465	410	337	97	260	99	35	19	38	60	1.5	12.94
65	6/28/95	U	708	688	636	651	598	638	583	474	123	306	139	48	21	51	70		13.25
66	7/14/95	M	780	753	701	703	658	692	647	541	143	332	157	49	19	62	81	5.5	14.31
67	7/16/95	M	483	468	423	440	395	432	389	313	87	202	90	33	13	34	48	0.9	12.82
68	7/16/95	M	706	688	632	634	581	625	576	487	143	330	148	49	18	52	77	4.3	12.90
69	7/25/95	M	671	661	603	608	553	596	542	437	132	372	137	47	19	50	73	3.3	12.83
70	7/26/95	M	570	554	498	512	462	512	453	374	108	260	103	37	15	40	54	1.6	13.46
71	7/31/95	M	556	541	485	507	450	497	442	358	104	232	97	34	16	38	53	1.6	14.26
72	8/01/95	M	642	617	552	569	502	557	492	424	127	276	114	44	18	47	58	2.6	12.55

Appendix 3.--Continued.

No.	Date	SEX	TL	FL	SL	MEFT	MEHP	ESFT	ESHP	PL	HL	G	BD	CD	OD	IOW	HW	WT	SL/CD
73	8/1195	M	672	653	591	611	546	600	531	445	131	302	130	47	18	54	67	3.4	12.57
74	8/13/95	F	558	552	501	518	467	510	460	373	99	242	99	36	15	38	56	1.6	13.92
75	8/15/95	M	618	603	547	569	517	555	503	399	107	268	116	39	17	44	61	2.3	14.03
76	8/15/95	M	607	598	533	559	497	552	488	403	113	298	115	40	16	45	54	2.1	13.33
77	8/28/95	M	798	780	712	678	619	667	605	551	193	321	129	51	24	71	75	4.1	13.96
78	8/29/95	U	371	358	319	337	296	328	290	239	72	142	73	25	13	28	40	0.5	12.76
79	9/18/95	U	678	675	612	628	568	620	558	460	124	298	137	47	20	53	66	2.9	13.02
80	9/26/95	M	832	823	752	760	688	750	678	562	167	380	153	53	20	63	87	6	14.19
81	9/xx/95	M	577	559	505	520	467	513	460	372	103	230	95	37	15	38	50	1.3	13.65
82	9/xx/95	U	718	712	640	676	600	672	588	491	127	330	144	50	20	55	78		12.80

[a] x = Date not recorded.

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