RESULTS

This section discusses the qualitative and quantitative evaluation of radionuclide concentrations in fish. The evaluation consisted of two efforts. The initial task assessed trends from 1982 through 1992 in bass and whitefish. The second task focused on differences among sampling locations in the Hanford Reach and background locations from 1988 through 1992. This analysis also evaluated differences between sample concentrations by year. The screening analysis of fish tissue data identified numerous data sets of ^{90}Sr and ^{137}Cs among bass, carp, and whitefish that were statistically analyzed (Table 2).

Strontium-90 was present in nearly all carcass samples collected from the Hanford Reach and each species' respective background locations. Because there were very few negative values, there were no computational problems with statistical analysis of log-transformed data in carcass, or muscle samples.

Cesium-137 was quantitatively analyzed in F Slough bass muscle and whitefish muscle because of interest in this persistent man-made radionuclide in the environment. Because of a relatively large proportion of negative values, the application of parametric analyses was limited to ANOVA of carp muscle samples and regression analysis for trends of log-transformed median ^{137}Cs concentrations. Appendix B contains ANOVA tables for log-transformed ^{90}Sr and ^{137}Cs data comparisons. No other man-made radionuclide routinely measured by gamma spectroscopy, ^{99}Tc, or uranium isotopes, was present in measurable quantities, and a statistical analysis was not performed. Concentrations of ^{90}Sr and ^{137}Cs in salmon samples were predominantly less than detection limits, and statistical analyses were not done.

TREND ANALYSIS

Strontium-90 and ^{137}Cs trends were evaluated in bass samples collected from F Slough. Data from Priest Rapids and the 100-N to 100-D Areas were combined to establish median concentrations of ^{90}Sr and ^{137}Cs for trend analysis of whitefish samples [ANOVA for location effects demonstrated that tissue concentrations in whitefish from these two locations were not different (see Location Effects, p. 34)]. Data have been presented in box plots. Tissue concentrations were related to time and reported Site releases of radionuclides to the Columbia River.

Bass

Trend analysis was conducted for ^{90}Sr in muscle and carcass and for ^{137}Cs in muscle. Five bass samples were collected every year from 1983 through 1992 except 1991.

Muscle - Strontium-90

Strontium-90 was measured at very low levels in 29% of the 45 muscle samples collected from 1983 to 1992 at F Slough (Figure 5), and additional statistical analyses were not performed. These data suggest an increase from 1983 through 1986, followed by a decline over subsequent years; however, only 3 of 45 measurements were definitive (Table 2).

TABLE 2. Screening Evaluation of Ratios of Total Analytical Error/Concentration for Fish Results

Species[a]	Location	Radionuclide	Error/Concentration Ratio				N
			<0.00	0 to 0.50	>0.50 to 1.00	> 1.00	
Bass (M)	F Slough	^{60}Co	23 (51%)	0 (0%)	7 (16%)	15 (33%)	45
Bass (M)	F Slough	^{90}Sr	4 (9%)	3 (7%)	10 (22%)	28 (62%)	45
Bass (M)	F Slough	^{137}Cs	3 (7%)	16 (36%)	15 (33%)	11 (24%)	45
Bass (C)	F Slough	^{90}Sr	0 (0%)	44 (98%)	1 (2%)	0 (0%)	45
Bass (M)	Sunnyside	^{60}Co	5 (25%)	0 (0%)	2 (10%)	13 (65%)	20
Bass (M)	Sunnyside	^{90}Sr	4 (21%)	0 (0%)	2 (11%)	13 (68%)	19
Bass (M)	Sunnyside	^{137}Cs	7 (35%)	0 (0%)	1 (5%)	12 (60%)	20
Bass (C)	Sunnyside	^{90}Sr	1 (5%)	7 (35%)	11 (55%)	1 (5%)	20
Carp (M)	100-N & 100-D	^{60}Co	4 (36%)	0 (0%)	1 (9%)	6 (55%)	11
Carp (M)	100-N & 100-D	^{90}Sr	3 (27%)	3 (27%)	0 (0%)	5 (45%)	11
Carp (M)	100-N & 100-D	^{137}Cs	0 (0%)	3 (27%)	3 (27%)	5 (45%)	11
Carp (C)	100-N & 100-D	^{90}Sr	0 (0%)	9 (82%)	2 (18%)	0 (0%)	11
Carp (M)	300 Area	^{60}Co	5 (50%)	0 (0%)	1 (10%)	4 (40%)	10
Carp (M)	300 Area	^{90}Sr	4 (40%)	0 (0%)	0 (0%)	6 (60%)	10
Carp (M)	300 Area	^{137}Cs	1 (10%)	0 (0%)	2 (20%)	7 (70%)	10
Carp (C)	300 Area	^{90}Sr	0 (0%)	9 (90%)	1 (10%)	0 (0%)	10
Carp (M)	Vantage	^{60}Co	6 (46%)	0 (0%)	1 (8%)	4 (46%)	11
Carp (M)	Vantage	^{90}Sr	1 (8%)	0 (0%)	0 (0%)	12 (92%)	13
Carp (M)	Vantage	^{137}Cs	0 (0%)	0 (0%)	7 (54%)	6 (46%)	13
Carp (C)	Vantage	^{90}Sr	0 (0%)	13 (100%)	0 (0%)	0 (0%)	13
Salmon (M)	Priest Rapids	^{60}Co	3 (60%)	0 (0%)	0 (0%)	2 (40%)	5
Salmon (M)	Priest Rapids	^{90}Sr	0 (0%)	0 (0%)	0 (0%)	5 (100%)	5
Salmon (M)	Priest Rapids	^{137}Cs	0 (0%)	2 (40%)	1 (20%)	2 (40%)	5

TABLE 2. (contd)

Species[a]	Location	Radionuclide	Error/Concentration Ratio				N
			<0.00	0 to 0.50	>0.50 to 1.00	> 1.00	
Salmon (M)	100 F	^{60}Co	2 (40%)	0 (0%)	0 (0%)	3 (60%)	5
Salmon (M)	100 F	^{90}Sr	2 (40%)	0 (0%)	0 (0%)	3 (60%)	5
Salmon (M)	100 F	^{137}Cs	1 (20%)	0 (0%)	3 (60%)	1 (20%)	5
Whitefish (M)	100-N & 100-D	^{60}Co	28 (26%)	1 (0.9%)	25 (23%)	54 (50%)	108
Whitefish (M)	100-N & 100-D	^{90}Sr	15 (15%)	10 (10%)	31 (31%)	45 (45%)	101
Whitefish (M)	100-N & 100-D	^{137}Cs	13 (12%)	14 (13%)	32 (30%)	49 (45%)	108
Whitefish (C)	100-N & 100-D	^{90}Sr	1 (1%)	89 (92%)	5 (5%)	2 (2%)	97
Whitefish (M)	Priest Rapids	^{60}Co	13 (27%)	1 (2%)	6 (13%)	28 (58%)	48
Whitefish (M)	Priest Rapids	^{90}Sr	8 (19%)	5 (12%)	12 (28%)	18 (42%)	43
Whitefish (M)	Priest Rapids	^{137}Cs	14 (29%)	3 (6%)	11 (23%)	20 (42%)	48
Whitefish (C)	Priest Rapids	^{90}Sr	0 (0%)	37 (93%)	1 (3%)	2 (5%)	40
Whitefish (M)	300 Area	^{60}Co	6 (35%)	0 (0%)	1 (6%)	10 (59%)	17
Whitefish (M)	300 Area	^{90}Sr	4 (14%)	11 (29%)	6 (21%)	8 (28%)	29
Whitefish (M)	300 Area	^{137}Cs	3 (18%)	0 (0%)	3 (18%)	11 (65%)	17
Whitefish (C)	300 Area	^{90}Sr	0 (0%)	5 (100%)	0 (0%)	0 (0%)	5
Whitefish (M)	Kettle River	^{60}Co	7 (78%)	0 (0%)	2 (22%)	0 (0%)	9
Whitefish (M)	Kettle River	^{90}Sr	2 (22%)	0 (0%)	0 (0%)	7 (78%)	9
Whitefish (M)	Kettle River	^{137}Cs	3 (33%)	0 (0%)	1 (11%)	5 (56%)	9
Whitefish (C)	Kettle River	^{90}Sr	0 (0%)	7 (78%)	2 (22%)	0 (0%)	9

(a) M = muscle , C = carcass.

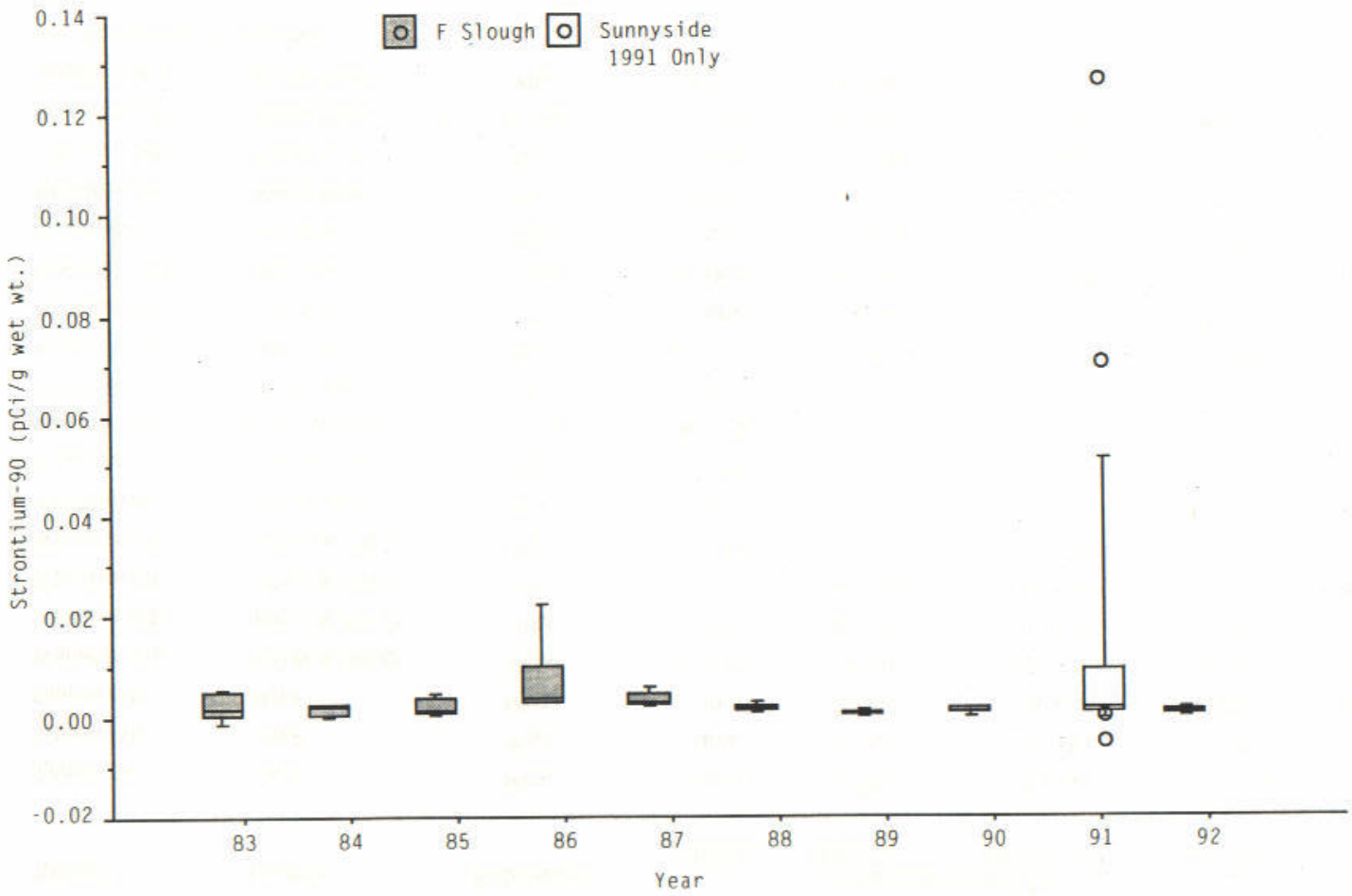

FIGURE 5. Box Plot of ^{90}Sr in Bass Muscle Collected from F Slough and Sunnyside

Muscle - Cesium-137

The median concentration of ^{137}Cs in bass muscle has generally decreased over the past 10 years (Figure 6). A small increase first noted in 1987 could be attributed to the Chernobyl accident in 1986; however, there is no way to trace the ^{137}Cs to this accident and it may reflect relatively elevated releases in 1984 and 1985 (see Figure 1).

Annual median ^{137}Cs muscle concentrations were log-transformed and analyzed by Model I regression analysis. The Model I regression analysis of log-transformed median ^{137}Cs concentrations was significant ($P = 0.010$, Appendix B, Table B.1), indicating a general reduction in ^{137}Cs in bass muscle over the past 10 years. The second-order polynomial regression of the log-transformed median was also significant ($P = 0.018$), but did not indicate an improvement in fit compared to the linear model (Figure 7). A Model II regression of reported Site releases of ^{137}Cs to the Columbia River and tissue concentrations in bass was not significant ($P = 0.185$; $R^2 = 0.236$, Table B.2). These regression analyses indicate that the amount of ^{137}Cs found in bass muscle was not highly related to Hanford Site releases to the Columbia River.

Carcass - Strontium-90

A similar pattern of ^{90}Sr was observed in bass carcass as seen in muscle; however, concentrations were one to two orders of magnitude greater in carcass samples and there were no negative concentrations (Figure 8). The Model I regression analysis for trends in the bass carcass data was inconclusive ($P = 0.683$, Table B.3) because of very low concentrations in 1983 and 1986 (see Figure 5). Generally,

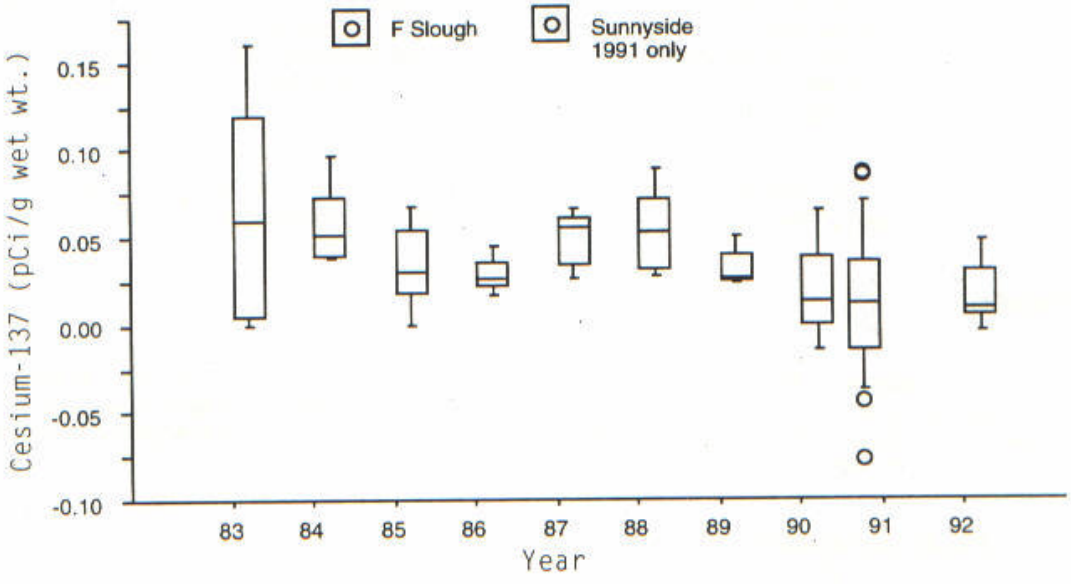

FIGURE 6. Box Plot of ^{137}Cs in Bass Muscle Collected from F Slough and Sunnyside

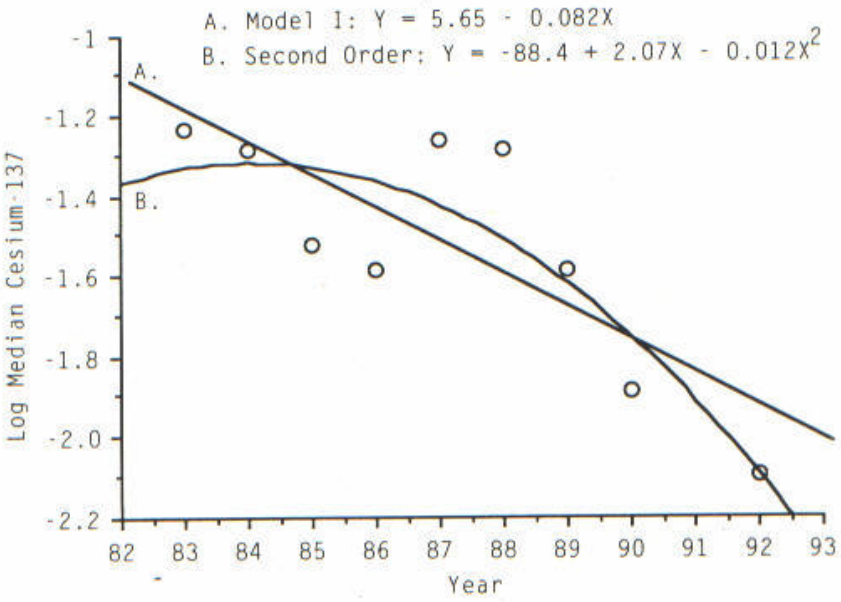

FIGURE 7. Model I and Second-Order Regression of Log-Transformed Median Concentrations of ^{137}Cs in Bass Muscle

concentrations of ^{90}Sr in bass carcass followed the pattern of releases to the Columbia River (see Figure 1); however, very low median carcass ^{90}Sr concentrations in 1983 and 1986 perturbed the log-linear relationship. The second-order polynomial regression of log-transformed median concentration versus year was also insignificant (P = 0.380, Table B.3), as was the regression of log-transformed median carcass concentration versus ^{90}Sr releases (P = 0.839, Table B.4).

Collectively, the regression analyses demonstrate that there was no consistent relationship between Site releases of ^{90}Sr to the Columbia River or time with concentrations of ^{90}Sr in bass carcass.

Whitefish

Trend analyses of whitefish samples include ^{137}Cs and ^{90}Sr from 1982 through 1992. In 1992, muscle samples were also analyzed for ^{99}Tc and uranium isotopes to quantify the effects of seepwater discharges from the Hanford Townsite and 300 Area. Technetium-99 and uranium isotope concentrations are summarized in Appendix A.

Muscle - Strontium-90

Most median ^{90}Sr muscle concentrations were at or below the MDC for ^{90}Sr of 0.005 pCi/g. Overall, the results were low and highly variable over the 11-year period (Figure 9). The data from Priest

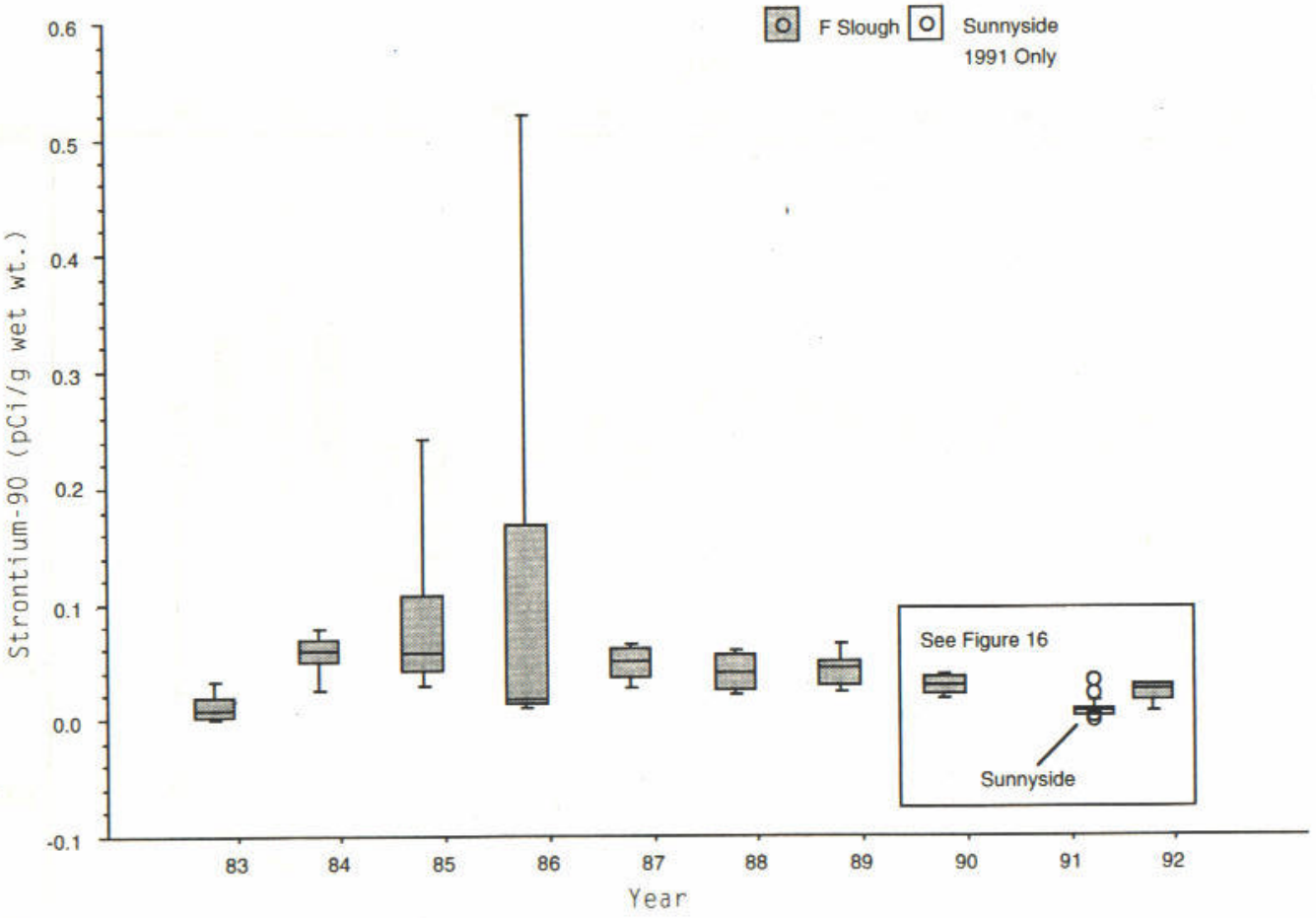

FIGURE 8. Box Plot of ^{90}Sr in Bass Carcasses Collected from F Slough and Sunnyside

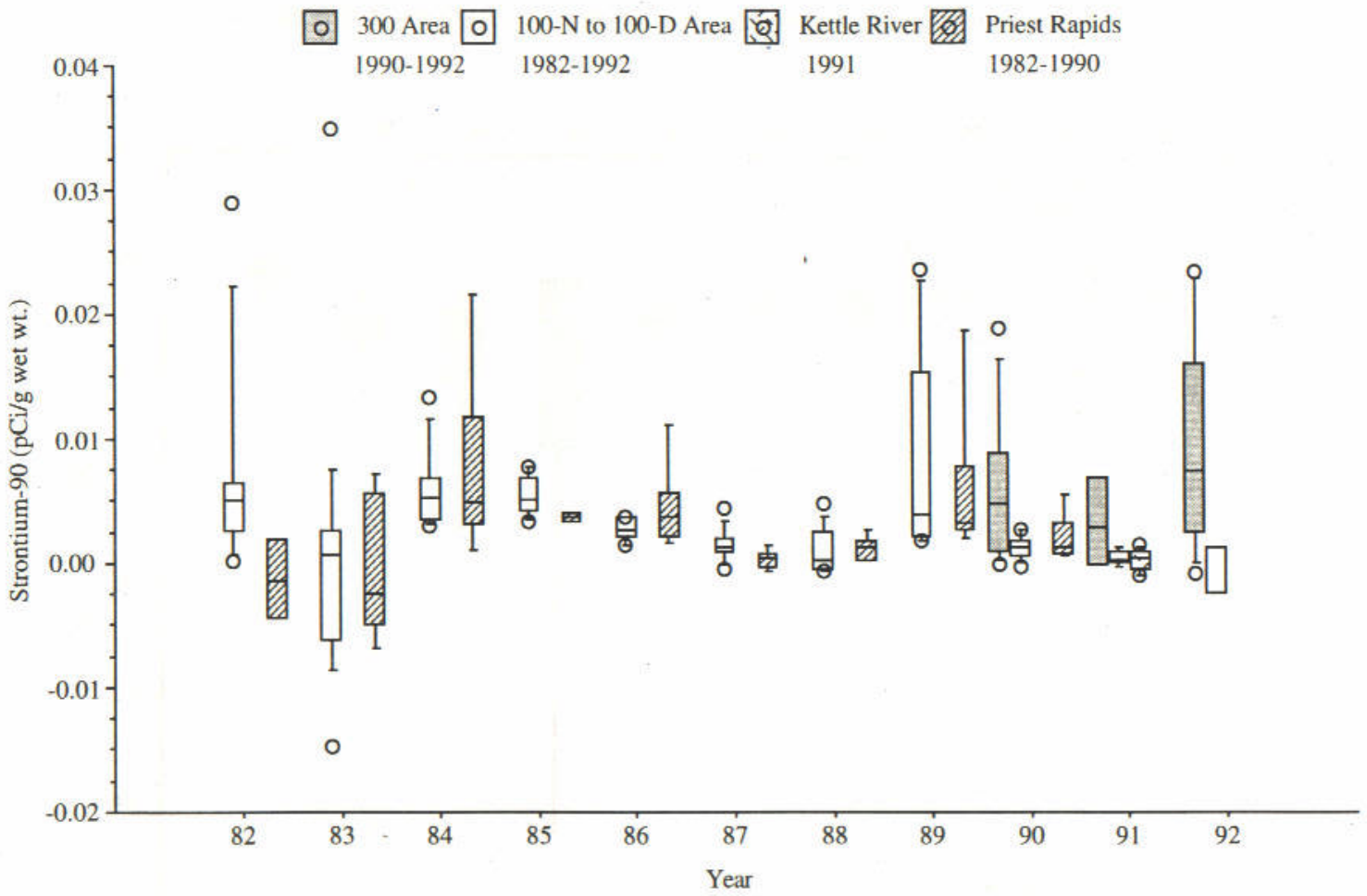

FIGURE 9. Box Plot of ^{90}Sr in Whitefish Muscle

Rapids and 100-N to 100-D Areas were combined, and the median concentrations for each year were determined. The Model I regression analysis of log-transformed median ^{90}Sr concentrations in whitefish muscle versus year was significant (P = 0.024, Table B.5), indicating a general reduction in ^{90}Sr in whitefish muscle over the past 11 years. The second-order polynomial regression of log-transformed median concentration versus year was insignificant (P = 0.089), suggesting that concentrations in whitefish muscle did not reflect reported releases (Figure 10). The Model II regression of log-transformed median carcass concentration versus ^{90}Sr releases (Figure 11), however, was significant (P = 0.048, Table B.6).

Collectively, the regression analyses suggest that there was a log-linear decrease in ^{90}Sr in whitefish muscle over time which corresponded with Site releases of ^{90}Sr to the Columbia River. Median ^{90}Sr concentrations in 1983 and 1992 were excluded from the analysis because they were negative. Consequently, the relationships discussed here are marginal. Strontium-90 measured in muscle is probably associated with small bones, and analysis of carcass samples for ^{90}Sr is more indicative of accumulation patterns of ^{90}Sr in whitefish.

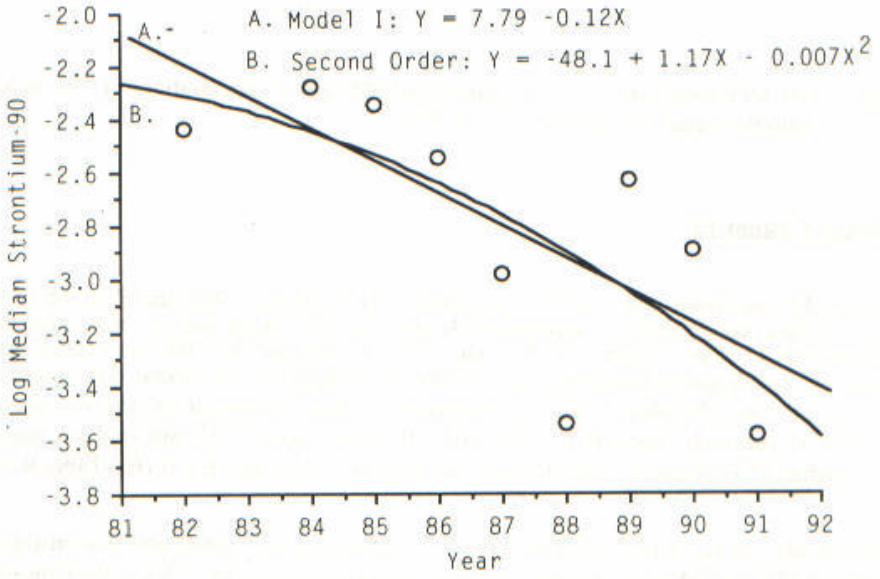

FIGURE 10. Model I and Second-Order Regression of Log-Transformed Median Concentrations of ^{90}Sr in Whitefish Muscle

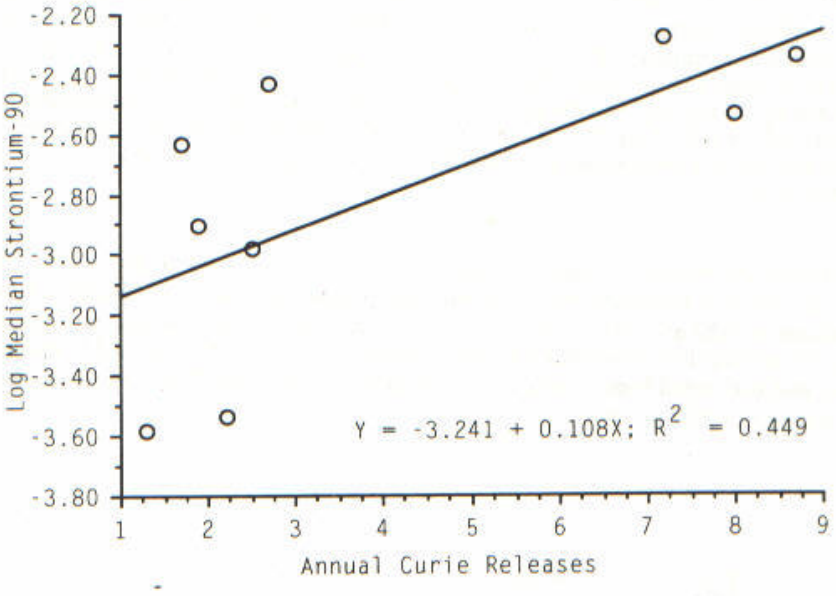

FIGURE 11. Model II Regression of Log-Transformed Median Concentrations of ^{90}Sr in Whitefish Muscle versus Annual Releases of ^{90}Sr

Muscle -Cesium-137

Cesium-137 was measured in 43% of whitefish muscle samples collected from the 100-N and 100-D Areas. Median concentrations were generally less than 0.03 pCi/g and showed no indication of any change over the past 11 years (Figure 12). The data from Priest Rapids and 100-N to 100-D Areas were combined and regressed against sampling year. Neither the simple nor the second-order regression analysis of log-transformed median ^{137}Cs concentrations in whitefish muscle by year was significant (P = 0.485 and 0.640, respectively, Table B.7). The Model II regression of ^{137}Cs Site releases versus log-transformed median ^{137}Cs muscle concentration also was not significant (P = 0.163, Table B.8).

Collectively, the regression analyses failed to demonstrate any significant relationship between concentrations of ^{137}Cs in whitefish muscle over time and with releases of ^{137}Cs to the Columbia River.

Carcass - Strontium-90

Strontium-90 was measured in nearly all whitefish carcass samples analyzed from 1982 through 1992 (see Table 2), and these measurements provide the most rigorous data base for evaluating trends of ^{90}Sr in Hanford Reach fish. Generally, there appears to be an increase in concentrations of ^{90}Sr in carcass followed by a gradual decrease after peaking in 1985-1986 (Figure 13).

Strontium concentrations were evaluated by combining the Priest Rapids and 100-N to 100-D Area data and regressing the log-transformed median concentration by year. The Model I regression was

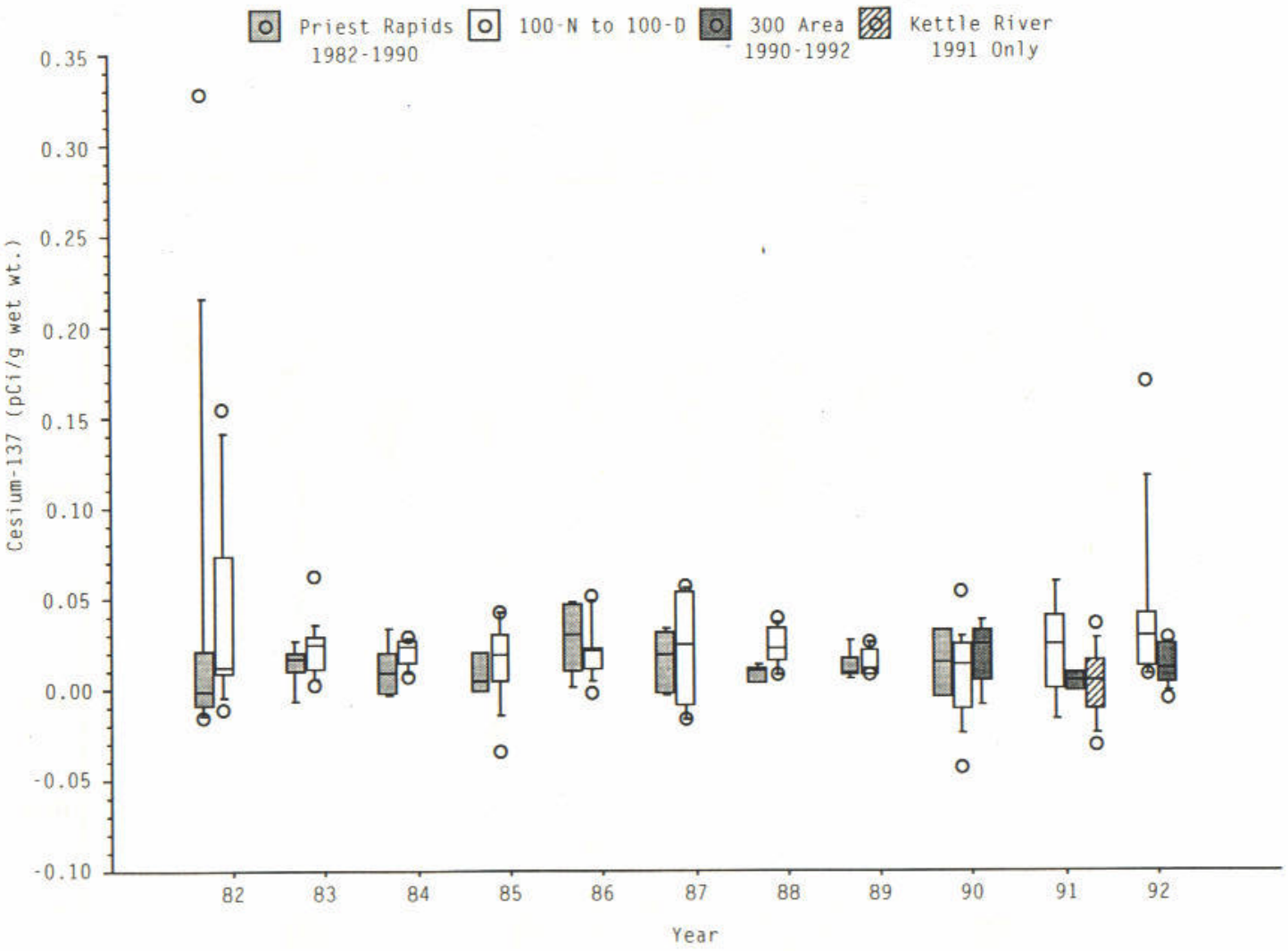

FIGURE 12. Box Plot of ^{137}Cs in Whitefish Muscle

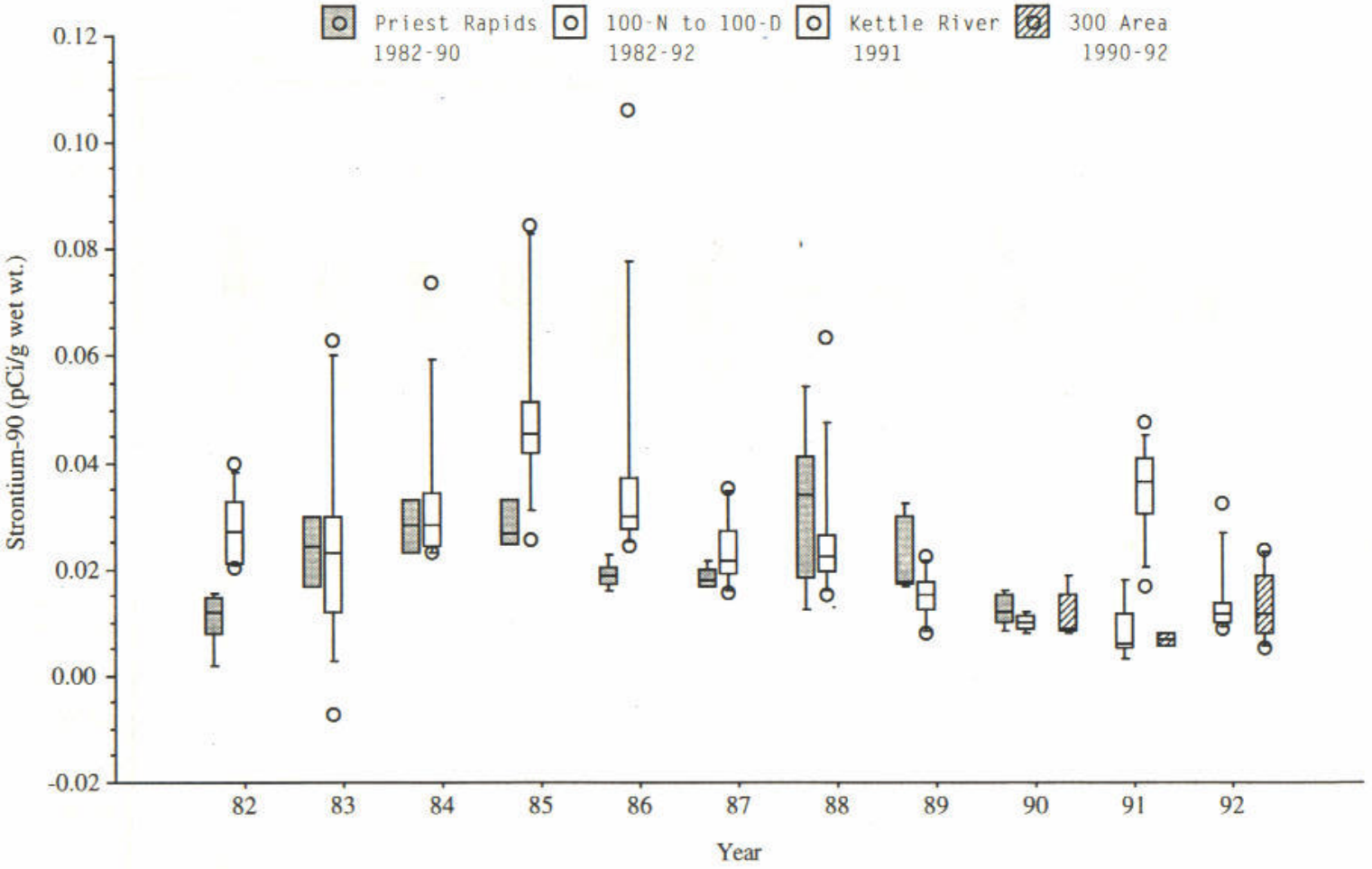

Figure 13. Box Plot of ^{90}Sr in Whitefish Carcass

significant (P = 0.007, Table B.9). A second-order regression indicated that a parabolic model was a better fit (P = 0.003) for the log-transformed median concentrations (Figure 14). Strontium-90 concentrations in whitefish carcass followed the pattern of Site releases to the Columbia River (see Figure 1). There was a strong correlation and significant regression (P = 0.006, Table B.10) for log-transformed median ^{90}Sr in whitefish carcass versus amount of ^{90}Sr (Ci) released from the Site per year (Figure 15).

Collectively, the regression analyses indicate that concentrations of ^{90}Sr measured in Hanford Reach whitefish carcass accurately reflect reported releases to the Columbia River over the 1982-through-1992 time frame. The second-order regression equation provides the best fit of the data over time.

LOCATION EFFECTS

This section evaluates differences in concentrations of ^{90}Sr and ^{137}Cs in fish collected from the Hanford Reach and background locations from 1988 through 1992. Differences among discrete years were also evaluated.

Bass

Bass were collected from two locations: F Slough and a background pond in Sunnyside, Washington.

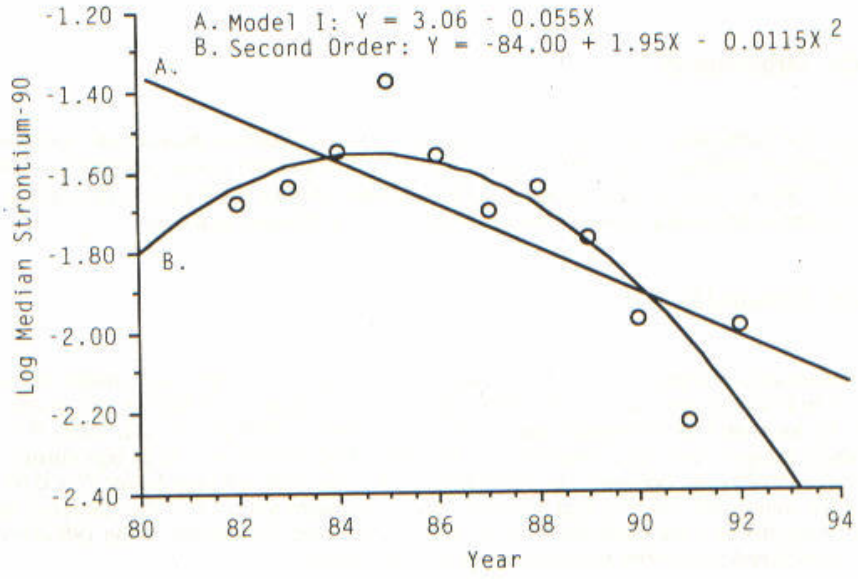

FIGURE 14. Model I and Second-Order Regression of Log-Transformed Median Concentrations of ^{90}Sr in Whitefish Carcass

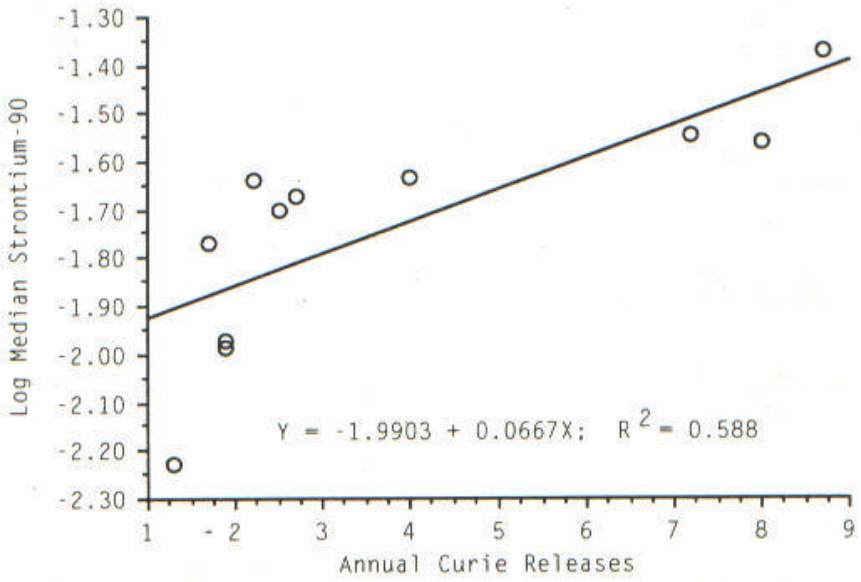

FIGURE 15. Model II Regression of Log-Transformed Median Concentrations of ^{90}Sr in Whitefish Carcass and Annual Releases of ^{90}Sr

Muscle - Strontium-90

The data for Sunnyside bass muscle were highly variable, with two measurable concentrations reported of 19 samples analyzed (see Table 2 and Figure 5). The median concentrations for Sunnyside bass muscle and F Slough bass muscle samples collected from 1990 to 1992 were both 0.001 pCi $^{90}Sr/g$, indicating no apparent difference between the background and F Slough locations.

Muscle - Cesium-137

The median concentration of ^{137}Cs in Sunnyside bass muscle in 1991 was similar to median levels measured in F Slough bass muscle in 1990 and 1992 (see Figure 6). ANOVA of log-transformed concentrations by location was not significant for the years 1990 to 1992 ($P = 0.423$, Table B.11). Most of the bass muscle samples had concentrations less than the MDC (0.015 to 0.02 pCi/g) during these years, and Fisher's PLSD tests between any combination of years were not significant ($P \leq 0.05$). Thirty-five percent of the Sunnyside samples had negative values that were not used in the statistical analysis. No additional comparisons were made for location effects; however, inspection of the 1990-through-1992 data suggests no difference between locations for that time period.

Carcass - Strontium-90

The median concentration of ^{90}Sr in bass carcass collected from Sunnyside was 0.005 pCi/g, compared with 0.027 pCi/g in bass carcass in the 10 fish collected in 1990 and 1992 from F Slough (Figure 16). An ANOVA of log-transformed carcass concentrations of ^{90}Sr from 1990 to 1992 for F Slough and Sunnyside was significant ($P < 0.0001$, Table B.12). The log-transformed mean for ^{90}Sr in Sunnyside bass carcass was significantly less than the log-transformed mean for ^{90}Sr in F Slough bass collected in 1990 and 1992 (Table B.13). This difference, while highly significant, does not necessarily indicate a Hanford effect on bass at F Slough, because the concentration of ^{90}Sr in the Sunnyside pond water and sediment is unknown and may be different than conditions upstream of Hanford in the Columbia River.

ANOVA of the log-transformed F Slough data (1983 through 1992) by year was significant ($P = 0.0064$, Table B.14). Fisher's PLSD test was applied to determine differences between log-transformed means. There were nine statistically significant differences among yearly pairs of means (Table 3). Strontium-90 concentrations in bass carcasses in 1983 were lower than all 8 years sampled subsequent to 1983, and ^{90}Sr concentrations in 1985 were lower than 1992 concentrations.

Carp

Carp was first sampled in 1990, and the time frame was too short to evaluate any potential trends that may exist; however, comparisons were made with log-transformed data to determine differences among years and whether there was a Hanford effect.

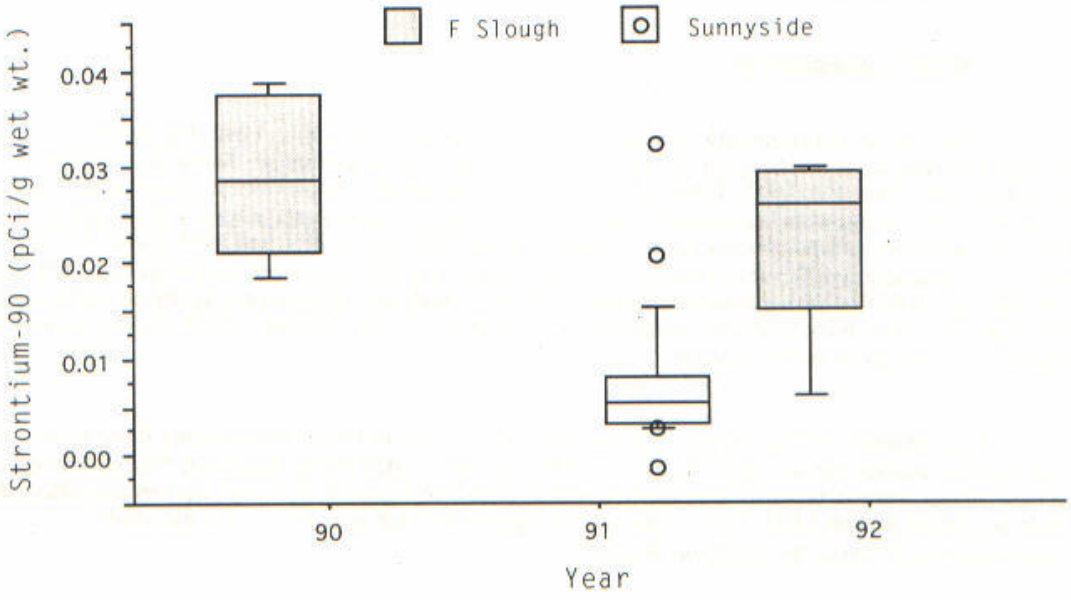

FIGURE 16. Box Plot of ^{90}Sr in Bass Carcasses Collected from F Slough and Sunnyside

TABLE 3. Yearly Comparison of Statistically Significant Differences by Fisher's PLSD Comparisons of Log-Transformed Means of ^{90}Sr in Bass Carcass Collected from F Slough (other yearly comparisons not listed were not significant)

	Mean			Mean		PLSD	
Year	(pCi/g)	Log-Mean	Year	(pCi/g)	Log-Mean	Difference.	P-Value
83	0.012	-2.248	84	0.057	-1.274	-0.974	0.0004
83	0.012	-2.248	85	0.088	-1.183	-1.065	0.0001
83	0.012	-2.248	86	0.122	-1.433	-0.815	0.0023
83	0.012	-2.248	87	0.049	-1.332	-0.916	0.0007
83	0.012	-2.248	88	0.040	-1.427	-0.820	0.0021
83	0.012	-2.248	89	0.042	-1.404	-0.843	0.0017
83	0.012	-2.248	90	0.029	-1.557	-0.691	0.0085
83	0.012	-2.248	92	0.022	-1.721	-0.527	0.0406
85	0.088	-1.135	92	0.022	-1.721	0.538	0.0367

Muscle - Cesium-137

Cesium-137 was measured in 54% of the carp muscle samples collected from 1990 through 1992 at Vantage and between the 100-N and 100-D Areas (see Table 2). The MDC for ^{137}Cs was 0.015 pCi/g in 1990 samples and 0.02 pCi/g in 1991 and 1992 samples; however, many of the measured concentrations were below the MDCs (Figure 17). The ANOVA of ^{137}Cs by location was significant ($P = 0.044$, Table B.15). Scheffé's multiple comparison test was used because of the addition of sample collection locations in different years. Scheffé's multiple comparison was significant for the 100-N to 100-D Areas comparison with Vantage, suggesting a potential Hanford effect (Table 4). Other combinations of locations were not significant. There was no difference in ^{137}Cs concentrations between years at any location ($P > 0.40$, Table B.16).

Carcass - Strontium-90

Strontium-90 was routinely monitored in carp carcasses from 1990 to 1992 (Figure 18). Background samples were collected in 1990 and 1991 at Vantage, Washington. Based on ANOVA of log-transformed data ($P = 0.035$, Table B.17) and Scheffé's multiple comparisons test, log-transformed mean ^{90}Sr concentrations in background carp carcasses collected from Vantage were significantly greater than log-transformed mean concentrations measured at the 300 Area in 1991 and 1992 (Table 5). There were no statistically significant differences between ^{90}Sr in carp carcasses from the 100-N to 100-D Areas and Vantage. ANOVA of log-transformed data by location and year indicated no significant differences between years at the three locations sampled ($P > 0.060$, Table B.18). Collectively, these data suggest no Hanford Site impact from ^{90}Sr in carp.

Median levels of ^{90}Sr in carp collected from the 100-N and 100-D Areas during these years were similar to the median carcass concentrations in F Slough bass (0.027 pCi/g); however, ^{90}Sr concentrations in bass carcass were an order of magnitude higher in 1986 (see Figure 8) and in a carp carcass collected from the 100-N Area in 1990. These observations suggest that fish were exposed to elevated concentrations of ^{90}Sr in the Columbia River.

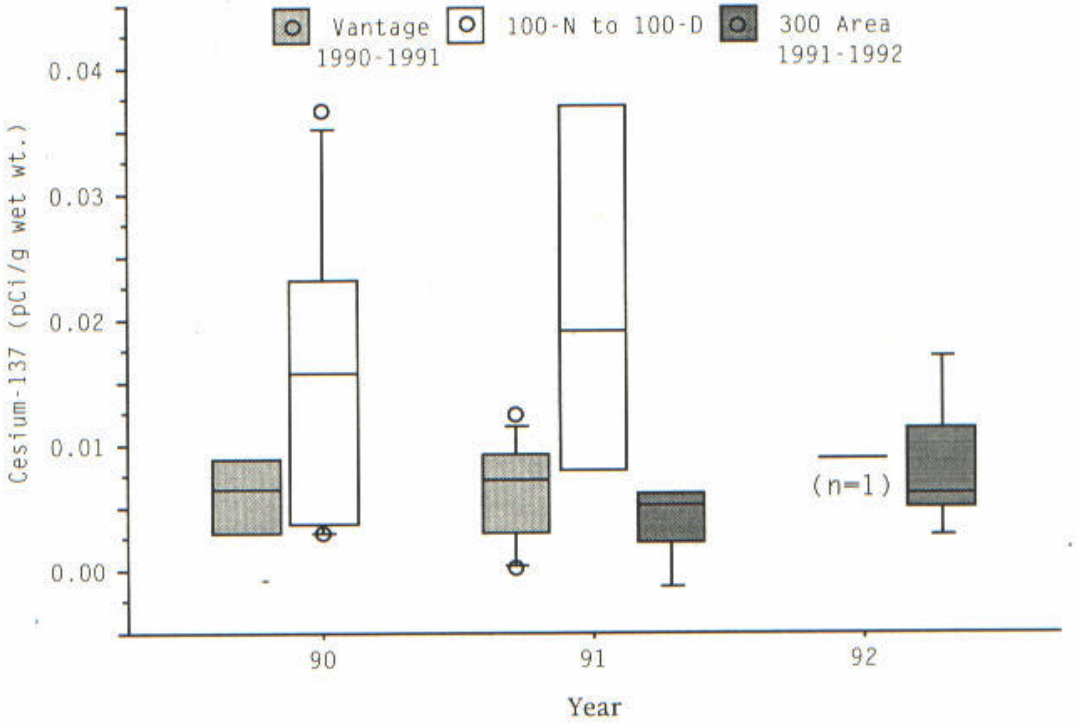

FIGURE 17. Box Plot of ^{137}Cs in Carp Muscle

TABLE 4. Scheffé's Comparisons of Log-Transformed Means of ^{137}Cs in Carp Muscle by Location, 1990 Through 1992

Location	N	Mean pCi/g	Log-Mean	Location Comparison	Log-Mean Difference	Scheffé's P-Value
100-N to 100-D	11	0.018	-1.890	300 Area (-2.225)[(a)]	0.335	0.2289
100-N to 100-D	11	0.018	-1.890	Vantage (-2.337)	0.446	0.0505
300 Area	9	0.006	-2.225	Vantage (-2.337)	0.112	0.8328
Vantage	13	0.007	-2.337	--	--	--

(a) Value in () is the log-mean ^{137}Cs concentration for the comparison.

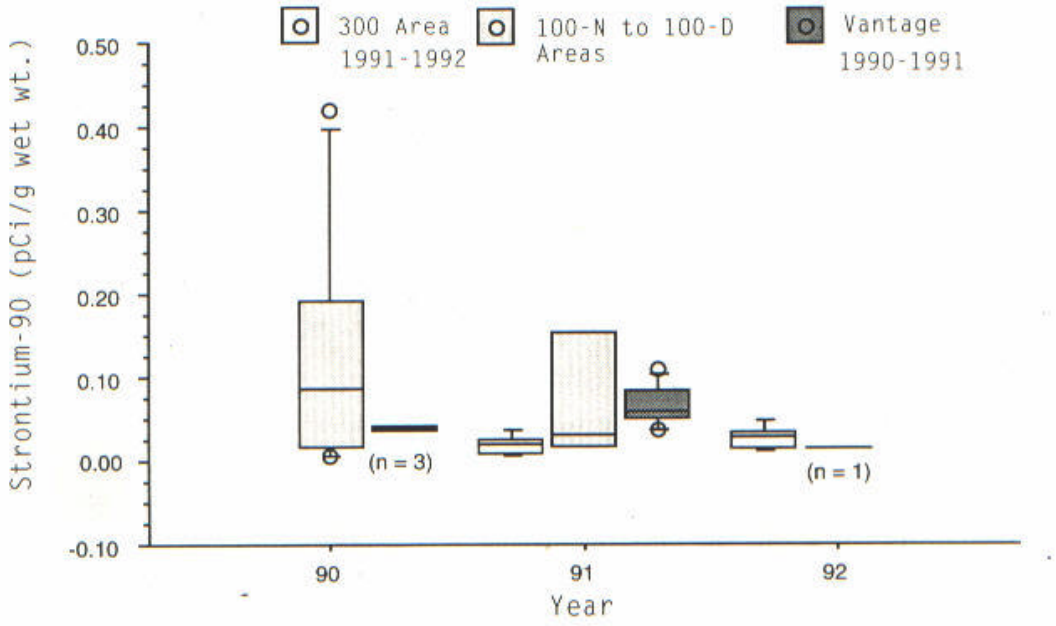

FIGURE 18. Box Plot of ^{90}Sr in Carp Carcass

TABLE 5. Scheffé's Comparisons of Log-Transformed Means of ^{90}Sr in Carp Carcass by Location, 1990 Through 1992

Location	N	Mean pCi/g	Log Mean	Location Comparison	Log-Mean Difference	Scheffé's P-Value
100-N to 100-D	11	0.105	-1.384	300 Area (-1.730)[(a)]	0.345	0.1806
100-N to 100-D	11	0.105	-1.384	Vantage (-1.261)	-0.123	0.7712
300 Area	10	0.022	-1.730	Vantage (-1.261)	-0.469	0.0395
Vantage	13	0.059	-1.261	--	--	--

(a) Value in () is the log-mean ^{90}Sr concentration.

Salmon

Fall chinook salmon were collected around the 100-F Area and Priest Rapids Dam in 1988 to address concerns about concentrations in sport fish harvest. The maximum concentration of ^{137}Cs was 0.05 ± 0.02 pCi/g in a Priest Rapids fish; all other measurements of ^{137}Cs were not definitive. There was no apparent difference among locations. Strontium-90 was not detected in salmon muscle from either location. Carcass samples were not analyzed. The data are summarized in Appendix A.

Whitefish

Whitefish were most frequently collected from the Priest Rapids Hatchery and 100-D Area. In 1990, the 100-N Area was added for routine monitoring. For this analysis, the 100-N and 100-D Areas were considered one sampling location. A small number of samples collected from Ringold and the Hanford Townsite in 1982 and 1983 were not used in the evaluations.

Muscle - Strontium-90

Strontium-90 was detected in 50% of the whitefish muscle samples collected from the 300 Area from 1990 through 1992, and comparisons were made with all other locations for the period of 1988 through 1992. The ANOVA of log-transformed data indicated significant differences by location ($P = 0.0003$, Table B.19). The concentration of ^{90}Sr in Kettle River whitefish muscle was significantly lower than concentrations found in fish collected the 300 Area for the time period of 1988 through 1992 (Table 6), but differences were not significant for other Hanford Reach locations. These observations point to the problems inherent in evaluating concentrations of radionuclides in mobile populations of fish.

TABLE 6. Scheffé's Comparisons of Log-Transformed Means of ^{90}Sr in Whitefish Muscle by Location, 1988 Through 1992

Location	N	Mean pCi/g	Log Mean	Location Comparison	Log-Mean Difference	Scheffé's P-Value
100-N to 100-D	31	0.002	-2.921	Kettle River (-3.398)[a]	0.477	0.397
100-N to 100-D	31	0.002	-2.921	Priest Rapids (-2.784)	-0.137	0.918
100-N to 100-D	31	0.002	-2.921	300 Area (-2.324)	-0.598	0.007
300 Area	25	0.008	-2.324	Kettle River (-3.398)	1.074	0.004
300 Area	25	0.008	-2.324	Priest Rapids (-2.784)	0.460	0.165
Priest Rapids	15	0.003	-2.784	Kettle River (-3.398)	0.614	0.244
Kettle River	6	0.0002	-3.398	--	--	--

(a) Value in () is the log-mean ^{90}Sr concentration.

Comparisons among years by location indicated significant differences at Priest Rapids and 100-N to 100-D Areas for log-transformed ^{90}Sr in whitefish muscle for the period of 1982 through 1992 (Table B.20). Comparisons between years within locations at Priest Rapids and at the 100-N to 100-D Areas on log-transformed means by Fisher's PLSD tests was not done because of negative values found in certain years that introduced a bias in the analysis.

Muscle - Cesium-137

Cesium-137 was measured in 43% of whitefish muscle samples collected from the 100-N and 100-D Areas. While the median concentration of ^{137}Cs in Kettle River whitefish collected in 1991 (0.005 pCi/g) was less than the 5-year median concentrations in Hanford Reach whitefish (0.009), all median concentrations were close to or less than the MDC for ^{137}Cs by gamma spectroscopy. ANOVA of log-transformed concentrations of ^{137}Cs in muscle by location for 1988 through 1992 ($P = 0.061$, Table B.21) and by year within locations ($P > 0.31$, Table B.22) were not significant. While some data were lost from log-transformation of negative concentrations, this did not affect the conclusion of either ANOVA for ^{137}Cs in whitefish muscle.

Carcass - Strontium-90

ANOVA of log-transformed concentrations by locations was significant for data collected from 1988 through 1992 ($P = 0..0003$, Table B.23). Scheffé's multiple comparison of log-transformed means indicated that the Kettle River whitefish had more ^{90}Sr in carcass samples than the 100-N to 100-D Area and the 300 Area fish (Table 7). Additionally, the 300 Area ^{90}Sr concentrations in whitefish carcass were lower than those for the Priest Rapids whitefish.

The Priest Rapids and 100-N to 100-D Area data were analyzed separately for differences by year, and the ANOVA was significant for both locations ($P = 0.0017$ and 0.0001, respectively, Table B.24). Year-by-year comparisons at Priest Rapids and 100-N to 100-D Areas (Table B.25) suggest an increase in ^{90}Sr concentrations through the early 1980s, followed by a decrease into the early 1990s, corroborating previously reported trend analyses in this report.

The median concentration of ^{90}Sr measured in Kettle River whitefish carcass (0.035 pCi/g) was distinctly greater than median values measured at the combined 100-N to 100-D Areas since 1988 and the 300 Area in 1992. Elevated concentrations in Kettle River whitefish may reflect elevated exposure to ^{90}Sr resulting from historical fallout from atmospheric weapons testing.

TABLE 7. Scheffé's Comparisons of Log-Transformed Means of ^{90}Sr in Whitefish Carcass by Location, 1988 Through 1992

Location	N	Log Mean	Location Comparison	Log-Mean Difference	Scheffé's P-Value
100-N to 100-D	35	-1.863	Kettle River (-1.476)[a]	-0.386	0.0004
100-N to 100-D	35	-1.863	Priest Rapids (-1.715)	-0.148	0.2213
100-N to 100-D	35	-1.863	300 Area (-1.960)	0.096	0.5628
300 Area	17	-1.960	Kettle River (-1.476)	-0.483	<0.0001
300 Area	17	-1.960	Priest Rapids (-1.715)	0.245	0.0321
Priest Rapids	15	-1.715	Kettle River (-1.476)	-0.238	0.1123
Kettle River	9	-1.476	--	--	--

(a) Value in () is the log-mean ^{90}Sr concentration.