Evaluation of Chum, Chinook and Coho Salmon Entrapment near Ives Island in the Columbia River

Annual Report
2002 - 2003

DOE/BP-00004287-2

September 2004

This Document should be cited as follows:

Duston, Reed, Jeremy Wilson, "Evaluation of Chum, Chinook and Coho Salmon Entrapment near Ives Island in the Columbia River", 2002-2003 Annual Report, Project No. 199900301, 71 electronic pages, (BPA Report DOE/BP-00004287-2)

Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

2003 EVALUATION OF CHUM, CHINOOK, AND COHO SALMON ENTRAPMENT NEAR IVES ISLAND IN THE COLUMBIA RIVER

Prepared by

Reed A. Duston

And

Jeremy Wilson

Pacific States Marine Fisheries Commission
2108 Grand Blvd
Vancouver, Washington 98661

Prepared for

Bonneville Power Administration
Environment Fish and Wildlife
P.O. Box 3621
Portland, Oregon 97208-3621

Project Number: 1999-003-01

Contract Numbers: BPA 00004287
PSMFC 528.03

ACKNOWLEDGEMENTS

EDITORIAL ASSISTANCE

Chris Murray	Pacific Northwest National Laboratory

FIELD SAMPLING

Rick Heitz	Pacific States Marine Fisheries Commission
Roy Clark	O.D.F.W.
Cameron Duff	O.D.F.W.
Robert Brooks	O.D.F.W.

CONTENTS

Tables continued…

Tables continued…

Tables

FIGURES

Figures continued…

Figures continued…

MAPS

From January to July of 2003, 42 entrapments and 25 stranding sites were examined on the Columbia River near Ives Island, downstream of Bonneville Dam. A total of 6,122 salmonids, consisting of three different species, were collected at these sites (Table 1). The fish sampled during this time were chinook salmon (69%), chum salmon (7%), and coho salmon (24%). The following analysis of the relationship between environmental factors and salmon placed at risk by river level fluctuations focuses on each of these three salmon species.

Table 1. Total number of fish observed during the late winter through early summer sampling period (January 24 – June 26) near Ives Island in 2003.

Common Name	Scientific Name	Entrapped		Stranded		Total Fish
		Mortality	Alive	Mortality	Alive	
Chinook Salmon	Oncorhynchus tshawytscha	38	4132	23	3	**4196**
Chum Salmon	Oncorhynchus keta	1	422	6	0	**429**
Coho Salmon	Oncorhynchus kisutch	30	1434	27	6	**1497**
Total		**69**	**5988**	**56**	**9**	**6122**

Methods and Definitions

An attempt was made to survey the entire Ives Island study area every one to three days. This of course does not mean that all stranded and entrapped salmon were sampled. Staff scheduling, timing of low water, predators and scavengers are just some of the factors making complete sampling all but impossible.

All numbers within this report are actual observations; there has been no attempt to estimate the number of entrapped or stranded fish that went unsampled. *Stranded* fish are those salmon found out of the water. *Entrapped* salmon were fish found within pools of water no longer connected to the river. *Mortalities* are fish that were dead at the time of discovery. It may be assumed that all live stranded fish would have become mortalities within a very short period of time and may, in fact, have died after being returned to the river. It is possible that entrapment mortalities were caused by dewatering at a time prior to sampling and would have been classified as stranding mortalities if the area had not re-flooded.

Each entrapment was measured for size, depth, distance to the river, height above river, and temperature. Visual estimates of dominant substrate size and vegetation densities were also recorded.

If an entrapment's waters were replenished by fluctuating river levels on a later date and the entrapment once again contained salmon, it was re-sampled. Subsequent samples are identified by the entrapment's identifying code followed by -2, -3, etc. In the interest of covering as much of the study area as possible within the shortest period of time, some of the entrapment characteristics considered to be stable (i.e., substrata, maximum size, height above river) were not re-measured during subsequent visits.

2. Seasonal Trends

Sampling began on January 24, 2003, and ended on June 26, 2003. The first and last sampling dates on which threatened chum salmon were observed were February 17, 2003, and May 13, 2003, respectively. The weekly sampling results of chum salmon are listed in Table B1 (Appndx. B) and plotted in Figure 1. Peak numbers of threatened chum were observed in late February and from late March through late April. There were 7 mortalities, approximately 1.6 % of the total number of observed threatened chum salmon.

The first and last sampling dates on which chinook salmon were observed were February 10, 2003 and June 25, 2003, respectively. The weekly sampling results of chinook salmon are listed in Table B2 and plotted in Figure 2. Peak numbers of chinook salmon were observed mid February through mid May. There were 61 mortalities, approximately 1.5% of the total number of observed chinook salmon.

The first and last sampling dates on which coho salmon were observed were February 10, 2003, and June 25, 2003, respectively. The weekly sampling results of coho salmon are listed in Table B3 and plotted in Figure 3. Peak numbers of coho salmon were observed in mid-February and from the end of March through mid May. Of the 1,497 sampled coho, 652 (43.6%) were coho smolts of which approximately 92% had clipped adipose fins. There were 57 mortalities, approximately 3.8% of the total number of observed coho salmon and 6.7% of observed coho with fork lengths less than 100mm.

Figure 1. Weekly sampling results of threatened chum salmon. No chum were sampled during the weeks ending 3/8 and 3/29.

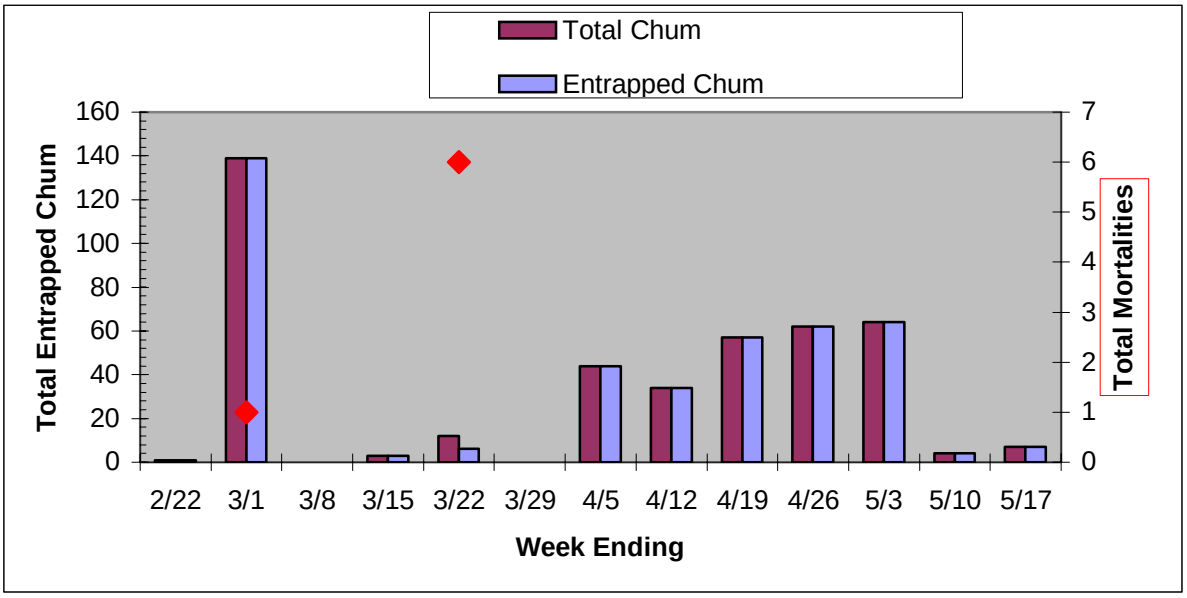


Figure 2. Weekly sampling results of chinook salmon. Four chinook salmon were sampled during the week ending 5/24. One chinook salmon was sampled during the week ending 5/31. No chinook were sampled during the weeks ending 6/7, 6/14, and 6/21

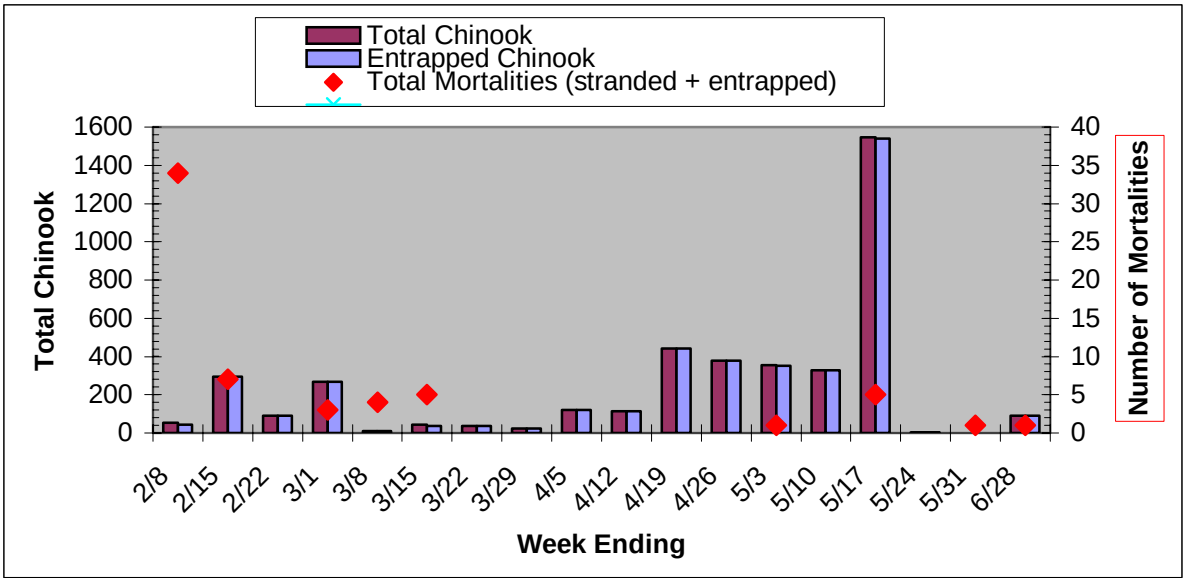
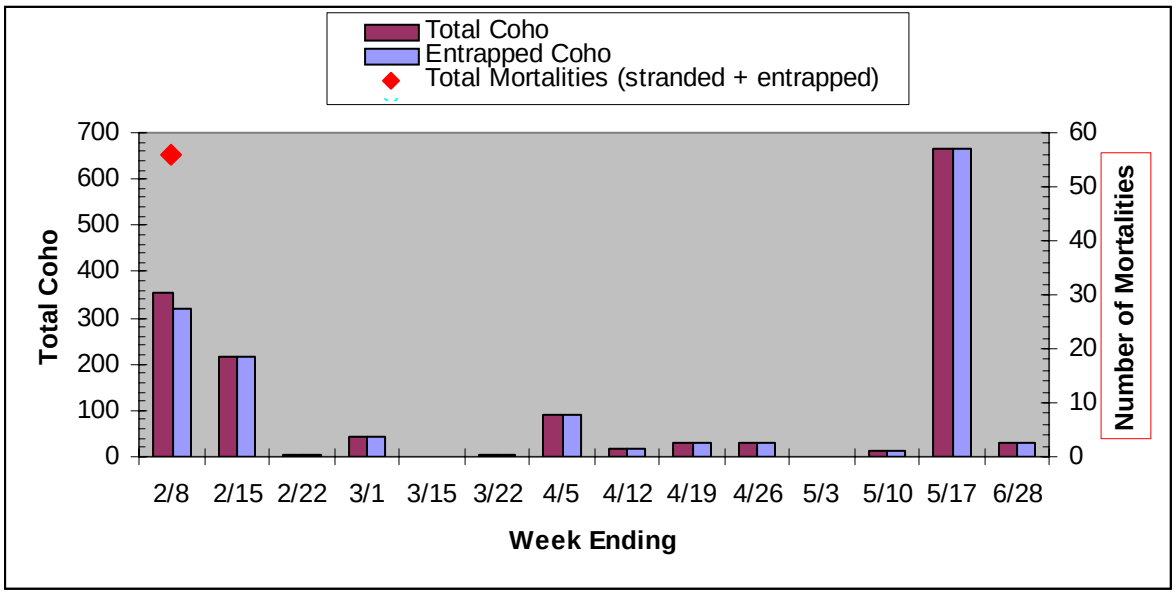


Figure 3. Weekly sampling results of coho salmon. One coho mortality was sampled during the week ending 2/15. One live entrapped coho was sampled during each of the weeks ending 3/15 and 5/3. No coho were sampled during the weeks ending 3/8 and 3/29, and between 5/17 and 6/21.



3. Distribution

Although an attempt was made to survey the entire study area every one to three days, all salmon sampled during 2003 were found within five major sampling areas, designated A, C, D, E, and F (Map 1, Table 2). These sampling areas were first identified during previous years and have consistently been responsible for the vast majority of stranded and entrapped salmonids in the study area. Several entrapments were sampled repeatedly as fluctuating water levels continued to replenish and then isolate their contents. Subsequent samples are identified in the tables as –2 (2nd sample), -3 (3rd sample), etc. Based on cumulative totals, 84.9%of all sampled fish were found within four entrapments (Map 2, Table 6). A brief description of each of the four major entrapments follows Map 2.

Entrapped chinook salmon comprised the largest numbers in Areas A, C, D, and E. Coho salmon comprised the largest numbers in Area F. Peak abundances of salmonids sampled were found in Areas A and C (Table 2, Figure 4).

Approximate river mile boundaries of the four major sampling areas are given in Table 3. Specific GPS coordinates and approximate river miles for the four entrapments containing the majority of the sampled fish are also found in Table 3. Coordinates for all other entrapment and stranding sites are listed in Appendix A.

Map 1: Sampling Areas: A through F

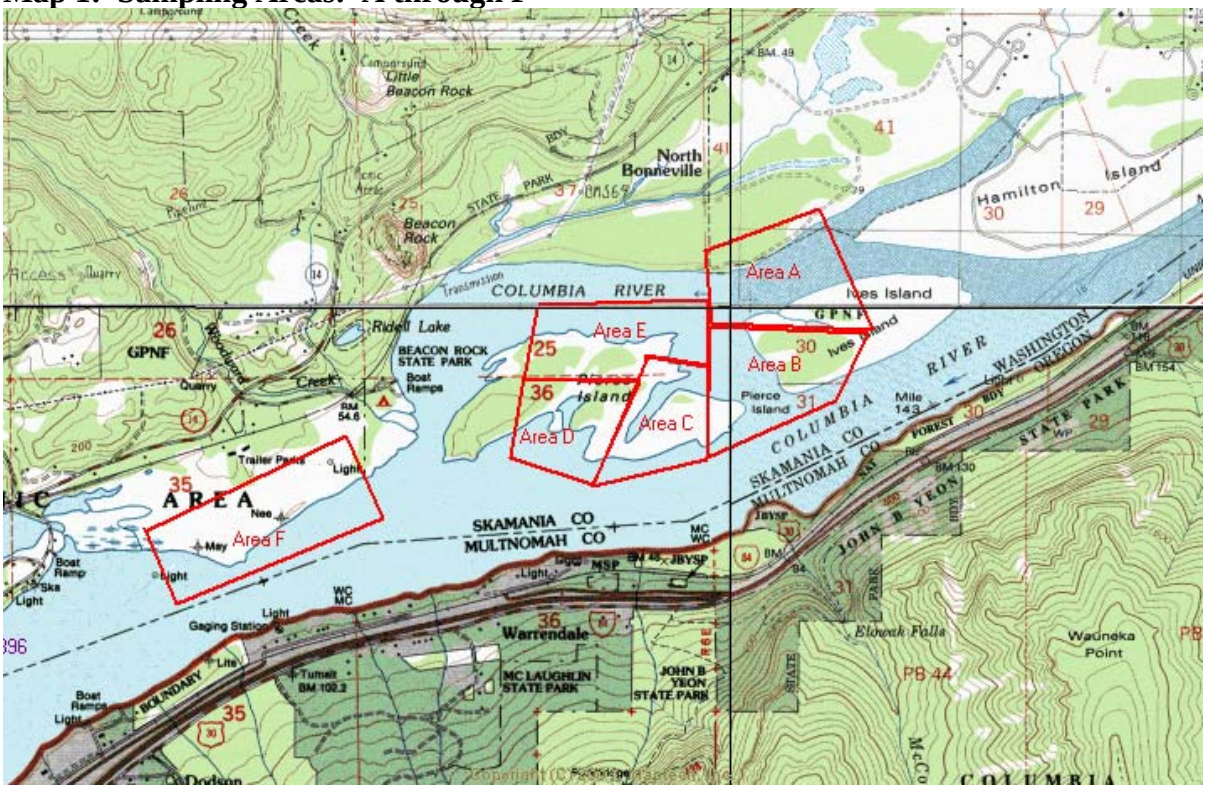


Table 2. Spatial distribution of chinook, coho, and threatened chum salmon

	Sampling Area					
	A	**B**	**C**	**D**	**E**	**F**
River Mile (statute miles)	142.35 to 142.75	142.15 to 142.48	141.9 to 142.25	141.77 to 142	141.8 to 142.2	140.7 to 141.7
Entrapped Chum	245(1)	0	168	9	1	0
Stranded Chum	1(1)	0	0	0	5(5)	0
Total Chum	246(2)	0	168	9	6(5)	0
% of all Chum sampled	57.3%	0.0%	39.2%	2.1%	1.4%	0.0%
Entrapped Chinook	1191(10)	0	1982	377	619(28)	1
Stranded Chinook	8(5)	0	9(9)	3(3)	6(6)	0
Total Chinook	1199(15)	0	1991(9)	380(3)	625(34)	1
% of all Chin. Sampled	28.6%	0.0%	47.4%	9.1%	14.9%	0.02%
Entrapped Coho	564(2)	0	698	133	44(28)	25
Stranded Coho	13(7)	0	10(10)	8(8)	1(1)	1(1)
Total Coho	577(9)	0	708(10)	141(8)	45(29)	26(1)
% of all Coho Sampled	38.5%	0.0%	47.3%	9.4%	3.0%	1.7%
Total Salmon	2022	0	2867(19)	530(11)	676(68)	27(1)
% of all Salmon Sampled	33.0%	0.0%	46.8%	8.7%	11.0%	0.4%

Figure 4. Spatial distribution of chum, chinook, and coho salmon

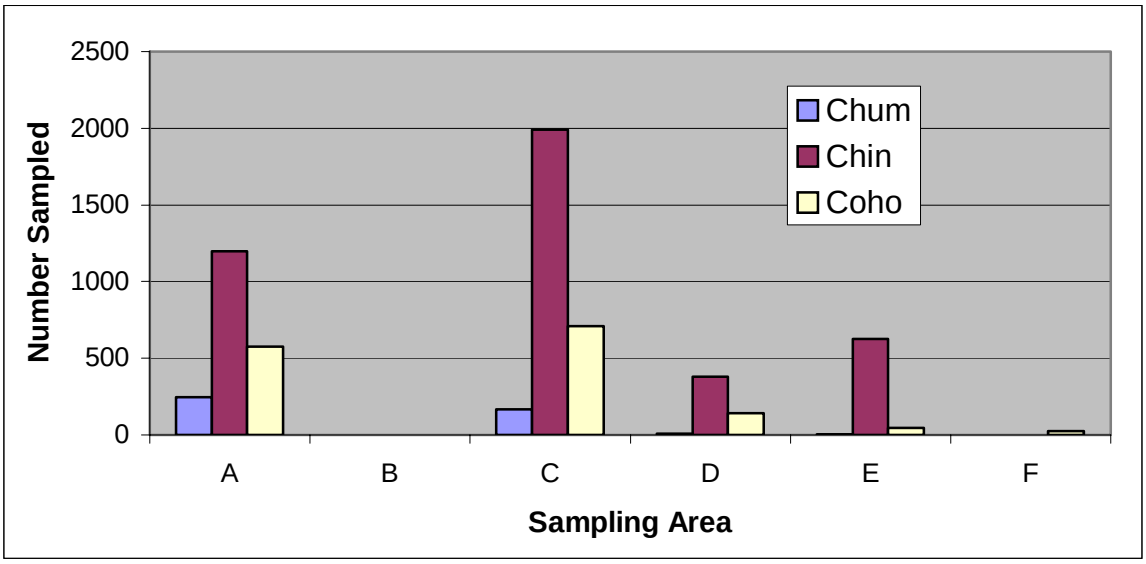
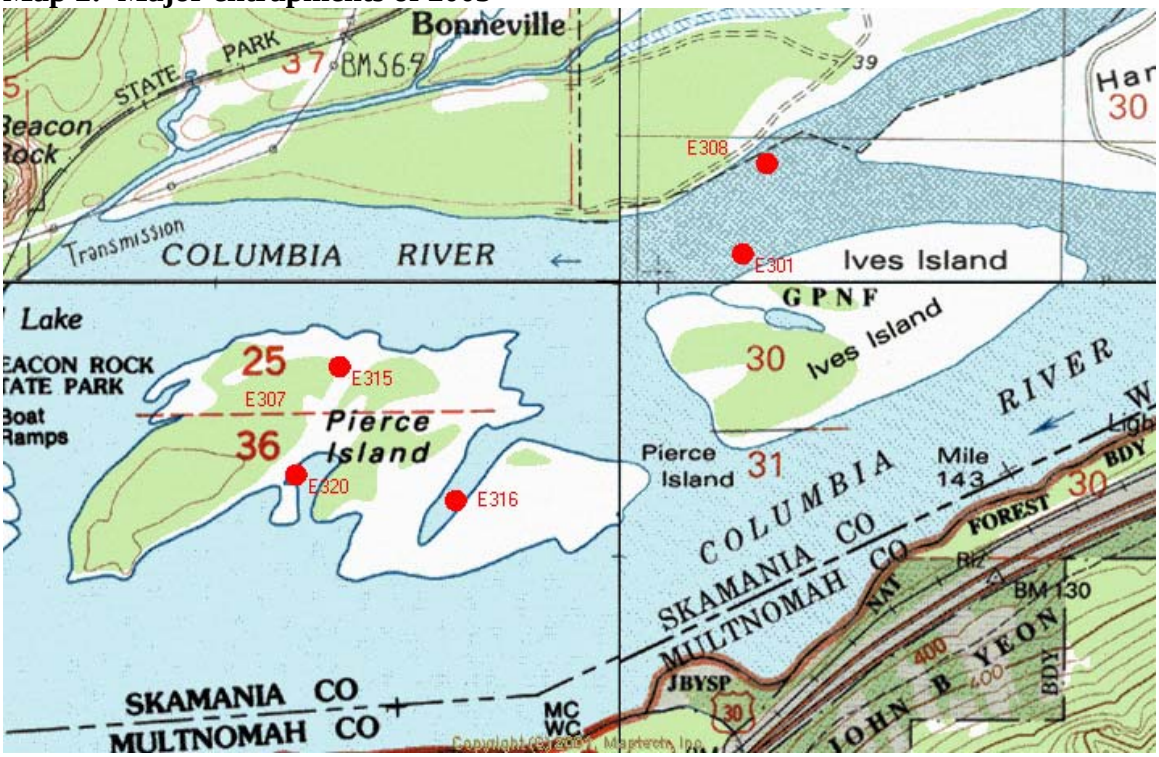


Table 3. Accumulated salmon counts and spatial distribution for entrapment sites containing the majority of sampled fish (includes fish found at stranding sites located within the perimeters of a dewatered entrapment). Numbers in parenthesis represent mortalities.

	Entrapment				
	E301	**E308**	**E315**	**E316**	**E320**
Chum salmon	134(1)	110	1	160	8
Chinook salmon	190(8)	945	541(24)	1933	373
Coho salmon	78(1)	446	34(28)	694	131
Total salmon	402	1434	576	2787	512
Percent of all sampled salmon	6.6%	23.4%	9.4%	45.5%	8.40%
River Mile	142.61	142.61	142	142.11	142
Latitude	N45.62577	N45.62754	N45.62317	N45.62028	N45.62085
Longitude	W121.99504	W121.99552	W122.00853	W122.00493	W122.00982
Sampling Area	**Area A**	**Area A**	**Area E**	**Area C**	**Area D**

Map 2: Major entrapments of 2003



The following are brief descriptions of each of the five major entrapments in 2003.

E301 (6.6% of all sampled salmon) was a long shallow depression in what was a dry channel along the northwest shore of Ives Island across from and just west of Hamilton Creek. Water flowing into the area comes from Hamilton Channel. The surface waters of Hamilton Channel were, at times, higher than E301 but blocked by a broad low-lying berm. In some cases, subsurface flow, probably coming from Hamilton Channel, replenished water within E301 without allowing entrapped salmon an opportunity to escape.

E308 (23.4% of all sampled salmon) was a deep depression on the Pierce Ranch N. W. R. immediately below the mouth of Hamilton Creek. It may be an old quarry pit resulting from the construction of the nearby Castle Rock Fishwheel and the Hamilton fishwheel scow (Donaldson).

E315 (9.4% of all sampled salmon) was a deep, straight channel cut through large cottonwoods in north central Pierce Island. Water flows into the entrapment from the north and, when high enough, exits to the south flowing through E307 and eventually into the lagoon in Pierce Island's south central shore. E315 has the appearance of a man made channel, possibly to provide increased flow for the Ladzick fishwheel near the center of Pierce Island (Donaldson).

E316 (45.5% of all sampled salmon) was the largest of all the entrapments. E316 occupies a portion of a broad floodplain that cuts through the eastern portion of Pierce Island. When tailwater levels are in excess of 17 feet, water flows from the channel between Ives and Pierce Islands southward through E316 to the main channel of the Columbia River.

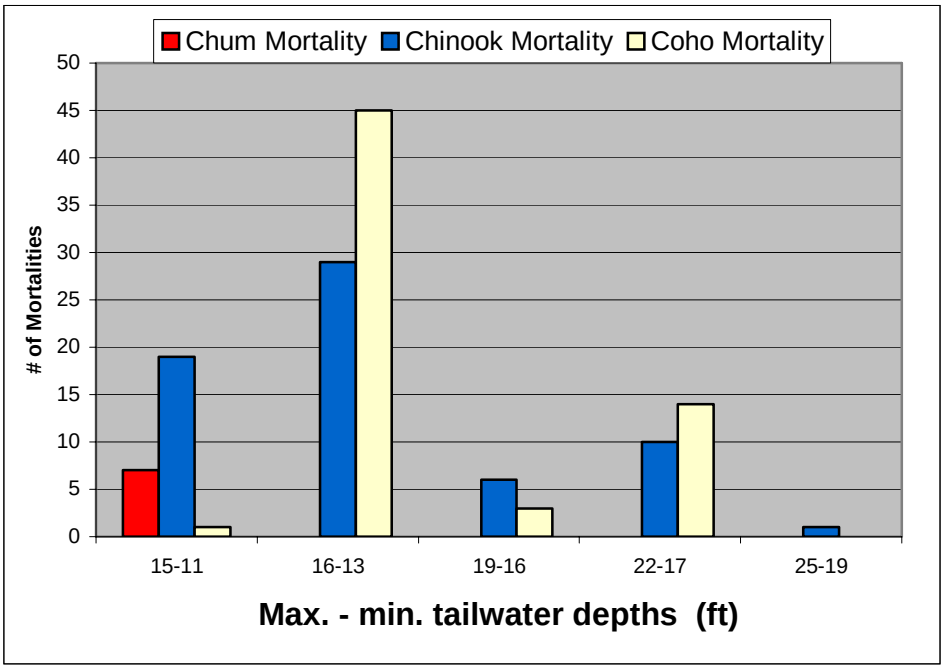
E320 (8.4% of all sampled salmon) is a bay along the south central shore of Pierce Island with a narrow entrance leading to the main channel of the Columbia River. The entry to E320 is lower than any of the other major entrapments and formation of E320 appears to require tailwater levels somewhere below 12 feet.

4. Tailwater Levels

Bonneville tailwater data was retrieved from the NWP Water Management: Data Query web site (http://www.nwd-wc.usace.army.mil//cgi-bin/DataQuery).

Ranges of tailwater declines during the twenty-four hour periods immediately preceding the sampling of salmon mortality, including all stranded salmon whether found living or dead, are shown in Figure 5 and Table B4. All known chum mortalities were preceded by continuous tailwater declines that began at levels no higher than 13 feet and ended at levels no lower than 11.7 feet (Table B4). The greatest numbers of chinook and coho mortalities (45.3% and 71.4%, respectively) were discovered following continuous tailwater declines that began at levels no higher than 15.9 feet and ended at levels no lower than 13.3 feet (Table B4). When taken as a whole, 55.2% of all known salmon mortalities were preceded by continuous tailwater declines beginning at levels no higher than 15.9 feet and ending at levels no lower than 13.3 feet (Table B4).

Figure 5: 2003 mortality frequencies related to tailwater declines during the 24 hours immediately prior to the time of sampling. The pairs of numbers along the x-axis identify a continuous decline in tailwater depth that began at a level equal to or lower than the figure on the left but ended at a level equal to or higher than the figure to the right. Some mortalities are represented more than once where ranges overlap.



Tailwater levels at the times each of the four major entrapments were sampled are listed in Table 4. Return visits to each entrapment are identified by the entrapment code followed by –2, -3, -4, etc. Some of the listed measurements are from 2002; they are included because it appeared that the formation requirements of the major entrapments were stable from one year to the next.

At the time of original sampling, each entrapment's height above the river was measured. An entrapment's height above the river refers to the difference in elevation between the surface of the river and what was perceived to be the low point in the crest of land between the river and the entrapment. In other words, the entrapment's height above the river identifies how much the river level would have to rise in order to reflood the entrapment. Theoretically, the height above the river could be used in conjunction with Bonneville tailwater measurements to determine critical tailwater levels for each entrapment. *Critical* tailwater levels refer to the Bonneville tailwater depths at which particular entrapments were formed. The unknown effects of river attenuation and channel hydrology within the study area prevented us from identifying specific critical tailwater levels. In some cases, an entrapment's height above the river was remeasured during subsequent visits. The heights above the river measurements for the four major entrapments are identified in Table 4.

Table 4. Tailwater levels associated with the sampling of the four major entrapments in 2002 and 2003

ENTRAPMENT	SAMPLE DATE	SAMPLE TIME	HEIGHT ABOVE RIVER (ft)	TAILWATER LEVEL AT TIME OF SAMPLING (ft)	TAILWATER DEPTHS DURING THE 3 HOURS PRIOR TO SAMPLING (ft)
E301	2/18/2002	1100	0.63	11.8	11.4-11.6
	3/25/2002	1200	1.4	11.4	11.5-11.6
	4/8/2002	800	0.67	12.8	11.7-12.3
	1/24/2003	1100	0.96	11.6	11.4
E308	5/6/2002	800	1.17	17.1	16.7-17.1
	2/5/2003	1000	1.54	15.5	15.8-15.9
	3/19/2003	900	0.87	17.1	16.9-17.0
	3/30/2003	1000	0.56	16.8	17.1-17.9
	4/2/2003	1200	0.29	18.1	17.3-18.0
	4/3/2003	1000	0.42	17.2	17.3-17.7
	4/10/2003	1200	1.00	17.5	16.6-17.3
	4/21/2003	1100	0.27	18.1	17.6-18.0
	4/23/2003	900	0.02	18.8	17.1-18.2
	5/4/2003	1000	0.54	17.3	17.2-17.3
E315	4/28/2002	1300	2.06	17.3	17.3-17.5
	5/7/2002	900	0.77	20.1	18.8-20.1
	2/5/2003	1300	2.71	15.8	15.5-15.9
	3/30/2003	1100	2.15	16.8	17.9-16.8
	4/20/2003	1000	1.48	17.9	17.7-18.0
	5/1/2003	900	0.85	18.7	18.7
	5/4/2003	1100	1.90	17.6	17.2-17.3
E316	2/1/2002	1100	0.23	16.3	15.4-16.2
	2/6/2003	1300	1.54	14.3	14.3
	4/13/2003	1100	0.48	16.2	15.5-16.2

Size Susceptibility

Mean, maximum, and minimum fork lengths for chum, chinook, and coho salmon are found in Tables B5, B6, and B7 respectively.

Minimum and maximum fork lengths of entrapped chum salmon were plotted as the two ends of the vertical bars for each sampling date in Figure 6, along with the median fork length (intersections). The median fork length for entrapped chum salmon ranged from 40 to 45 mm prior to May10th. The two chum sampled after May 10th had fork lengths of 57mm and 61mm.

Minimum and maximum fork length of entrapped Chinook salmon were plotted as the two ends of the vertical bars for each sampling date in Figure 7, along with the median fork length (intersections). The median fork length for entrapped chinook salmon ranged from 40-55mm prior to May 24th. Ninety chinook salmon were sampled after May 24th with a median fork length of 77mm.

Minimum and maximum fork length of entrapped coho salmon were plotted as the two ends of the vertical bars for each sampling date in Figure 8, along with the median fork length (intersections). The median fork lengths for entrapped coho salmon were 37.5- 40 mm through May 10th and 55-74mm after May 10th. Not included in the fork length data are 652 coho smolts entrapped between May 3rd and May 15th. Approximately 92% of the coho smolts had clipped adipose fins.

Figure 6. Minimum, maximum and median fork length of threatened chum salmon collected at entrapment sites near the Ives Island of the Columbia River in 2003. The lower and higher ends of the vertical lines represent the minimum and maximum fork length observed in the sample for the week, with the horizontal dashes as the median fork lengths.

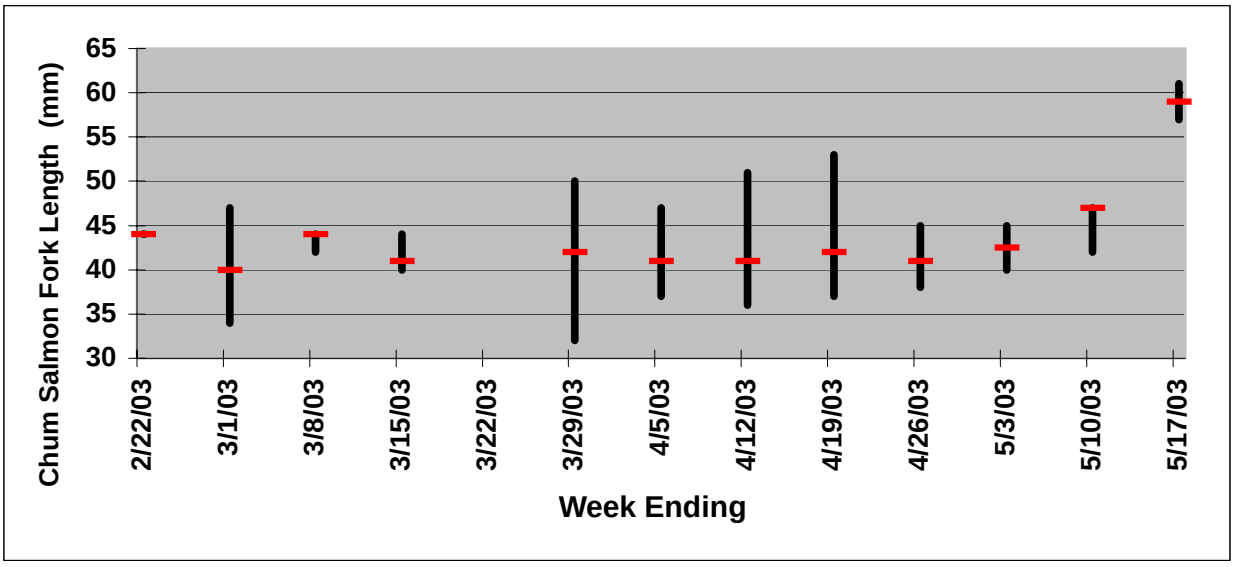


Figure 7. Minimum, maximum and median fork length of chinook salmon collected at entrapment sites near Ives Island of the Columbia River in 2003. The lower and higher ends of the lines represent the minimum and maximum fork length observed in the sample for the week, with the horizontal dashes as the median fork lengths.

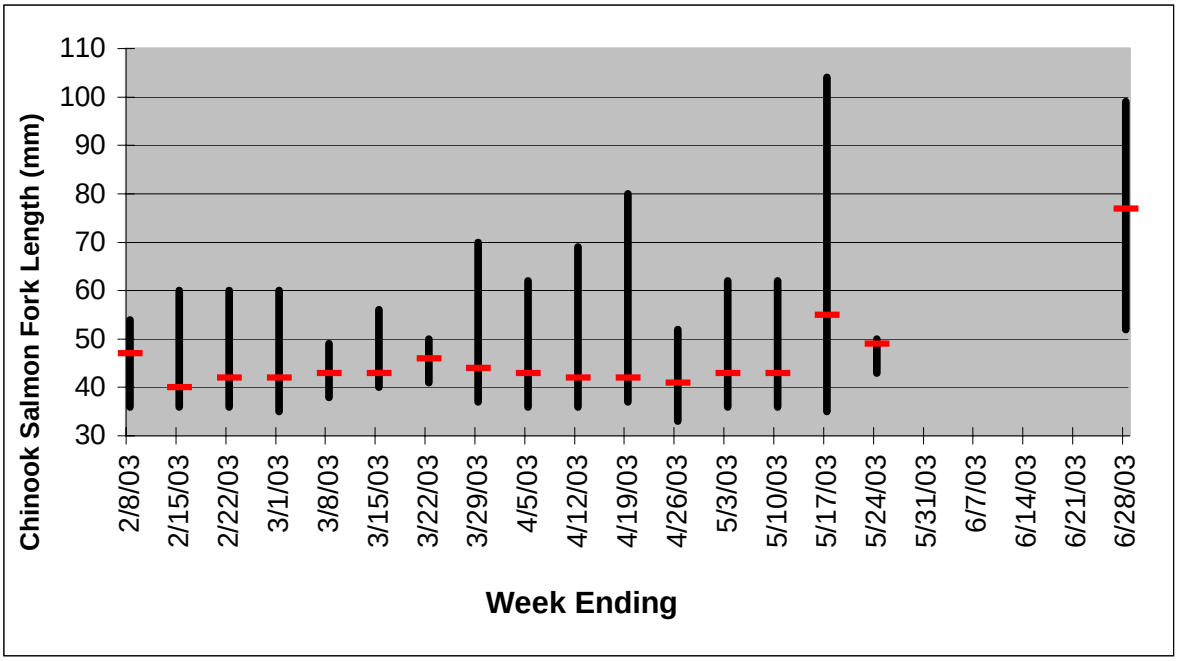
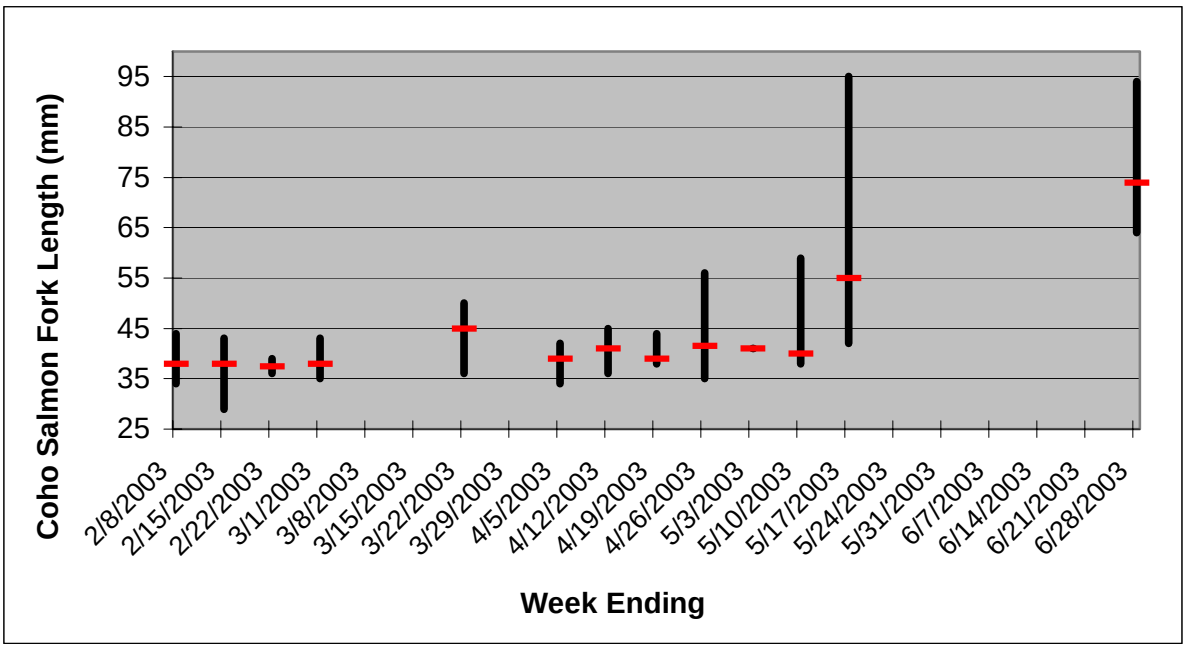


Figure 8. Minimum, maximum and median fork length of coho salmon collected at entrapment sites near the Ives Island of the Columbia River in 2003. The lower and higher ends of the lines represent the minimum and maximum fork length observed in the sample for the week, with the horizontal dashes as the median fork length.



Fork length summaries for stranded chum, chinook, and coho salmon are listed in Tables B8, B9, B10, respectively. Stranded salmonids appear to have a size distribution similar to those of entrapped salmonids sampled during the same time frame. The mean fork lengths for stranded chum, chinook, and coho salmon were 41.2mm, 45.2mm, and 35.9mm respectively. Stranded chinook were largest in early February (tule variety) and mid to late May (upriver brights).

6. Substrate Size

The most common substrate in a sampled area is defined as the dominant substrate, and the next most common substrate as the subdominant substrate. The codes of dominant and subdominant substrate at the sampling sites were defined using the following definitions (Nugent, et al., 2000):

Code	Substrate Class
1	Fines: clay to coarse sand (<1 mm)
2	Very coarse sand (1-2 mm)
3	Fine gravel (2-4 mm)
4	Medium gravel (4-8 mm)
5	Coarse gravel (8-16 mm)
6	Small pebble (16-32 mm)
7	Large pebble (32-64 mm)
8	Cobble or rubble (64-256 mm)
9	Boulder (>256 mm)

Entrapped chum salmon were observed for dominant substrate size of fines, coarse gravel, small and large pebble, and cobble (Codes 1, 5, 6, 7 and 8) (Table B11). The percentage of sites with a particular dominant substrate and the percentage of entrapped chum salmon found at sites with that substrate, are plotted in Figure 9. Coarse gravel (Code5) and cobble (Code 8) appear the most often (66.5% of the time, combined) and account for 65.7% of the all entrapped chum salmon. Sites with large pebbles (Code7) as the dominant substrate contained 26.7% of the entrapped chum.

The single chum entrapment mortality occurred at a site with a dominant substrate of large pebble.

Six of the seven stranded chum salmon (those found on dry land) were observed at sites with dominant substrate sizes of fine gravel, medium gravel, and coarse gravel (Codes 3, 4, and 5) (Table B12).

Figure 9. Percentage of entrapment sites with a particular dominant substrate, and the percentage of entrapped chum salmon found at those sites.

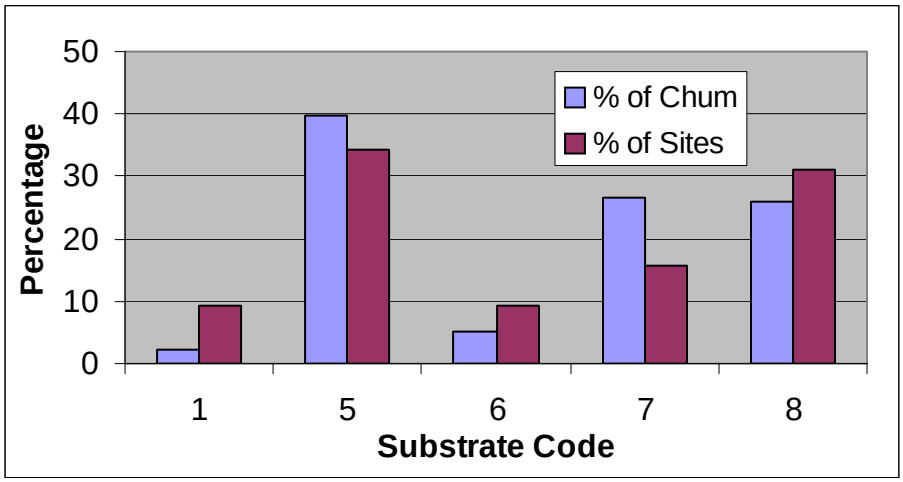
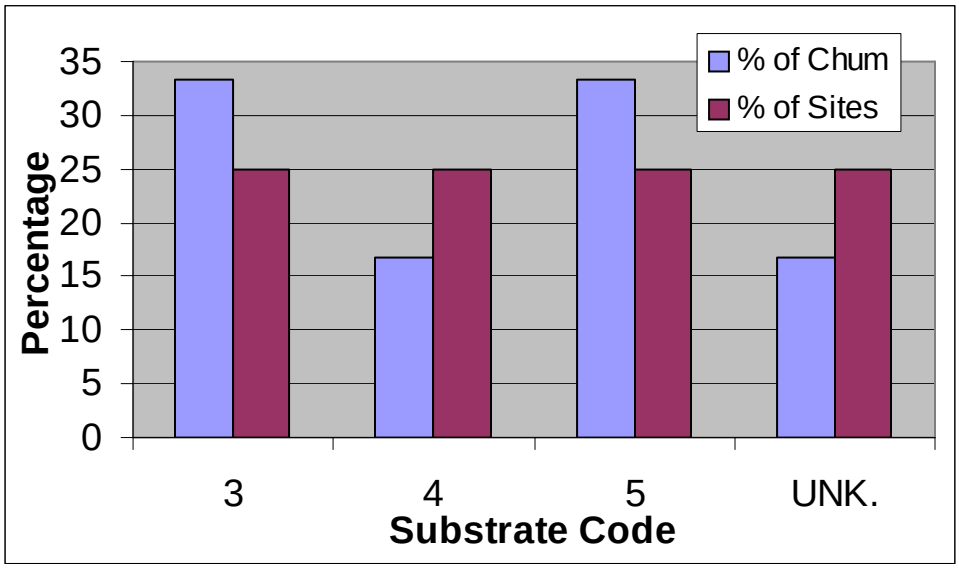


Figure 10. Percentage of stranding sites with a particular dominant substrate, and the percentage of stranded chum salmon found at those sites



Entrapped chinook salmon were observed for dominant substrates the size of fines, coarse gravel, small and large pebble, and cobble (Codes 1, 5, 6, 7, and 8). The percent of sites with a particular dominant substrate and the percentage of entrapped chinook salmon found on that substrate, are plotted in Figure 10. The dominant substrate coarse gravel (Code 5) appears most often accounting for 55% of the chinook salmon entrapment sites. The largest numbers of entrapped chinook (49.4%) were also observed at sites with dominant substrates of coarse gravel (Figure 11 and Table B13).

The numbers of mortalities of entrapped chinook salmon were greatest (64.9%) at sites where the substrate small pebble (Code 6) was dominant.

Stranded chinook salmon (those found dewatered) were observed at sites with dominant substrates of fines, fine gravel, medium gravel, coarse gravel, small pebble and large pebble

(Codes 1, 3, 4, 5, 6, and 7). Fines and coarse gravel were dominant at sites containing 65.4% of all sampled stranded chinook (Table B14).

Figure 11. Percentage of <u>entrapment</u> sites with a particular dominant substrate, and the percentage of chinook salmon found on those sites.

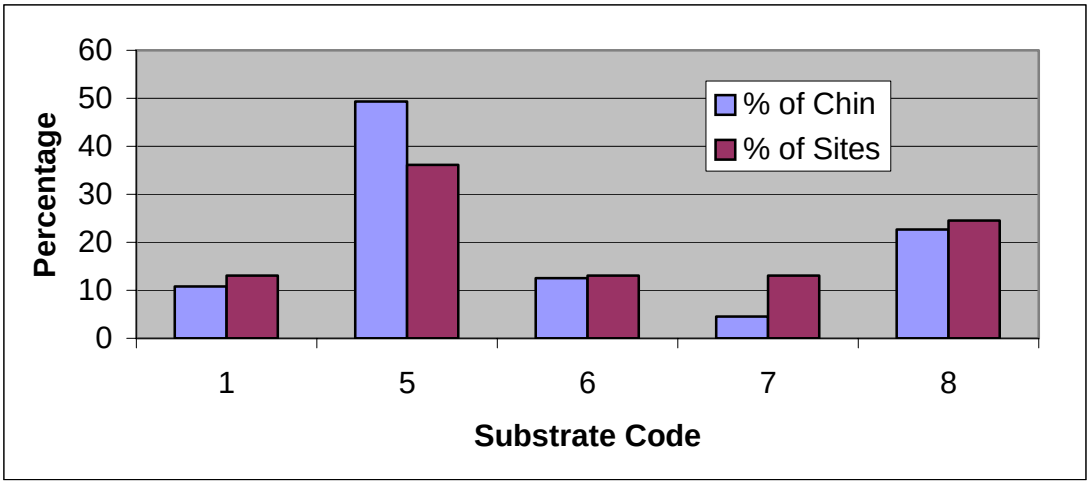
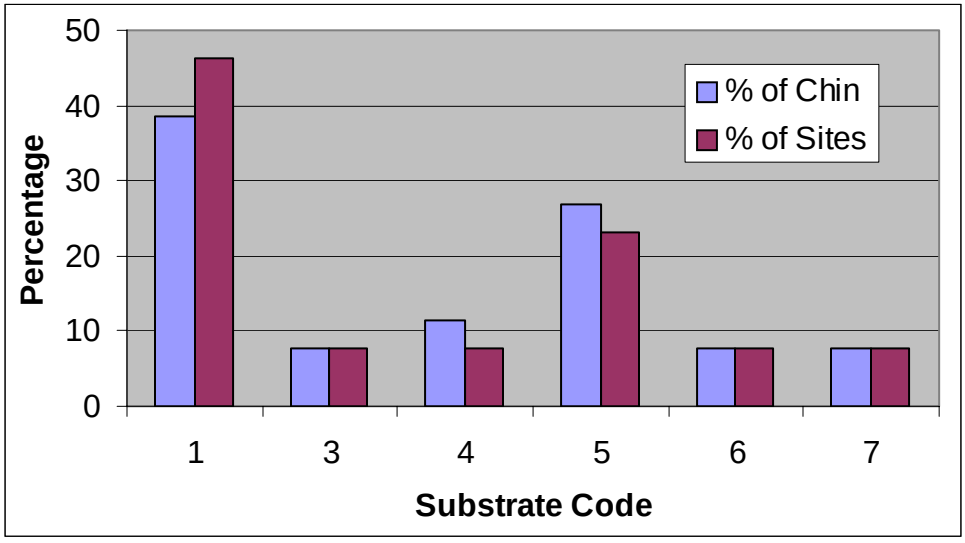


Figure 12. Percentage of <u>stranding</u> sites with a particular dominant substrate, and the percentage of chinook salmon found at those sites.



Entrapped coho salmon were observed for dominant substrate sizes of fines, coarse gravel, small pebble, large pebble, and cobble (Codes 1, 5, 6, 7, and 8). The percentage of sites with a particular dominant substrate and the percentage of entrapped coho salmon found at sites with that substrate, are plotted in Figure 12. The substrate coarse gravel (Code 5) and cobble (Code 8) appear most often, accounting for 32.6% and 30.4% of the sites, respectively. The substrate coarse gravel (Code 5) represents the dominant substrate for sites containing the greatest number of coho (48.7%). The substrate coarse gravel was the dominant substrate at sites containing the second greatest number of coho (30.5%) (Figure 12 and Table B15).

The numbers of mortalities of entrapped coho salmon were greatest (93.3%) at a single site where the substrate small pebble (Code 6) was dominant.

Stranded coho salmon (those found on dry land) were observed at sites with dominant substrates of fines, medium gravel, coarse gravel, small pebble, and large pebble (Codes 1, 4, 5, 6,and 7) Fines or small pebble were the dominant substrate at sites containing 69.7% of all sampled stranded coho (Table B16).

Figure 13. Percentage of entrapment sites with a particular dominant substrate, and the percentage of entrapped coho salmon found at those sites.

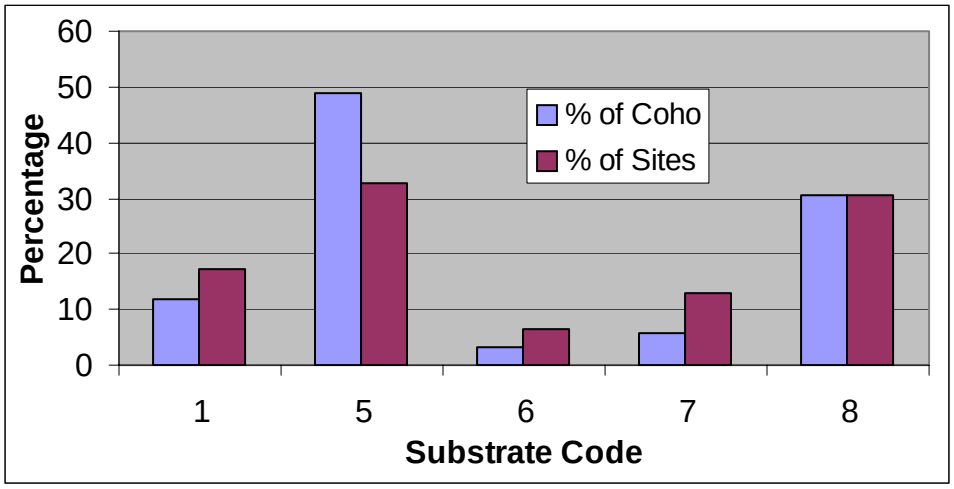
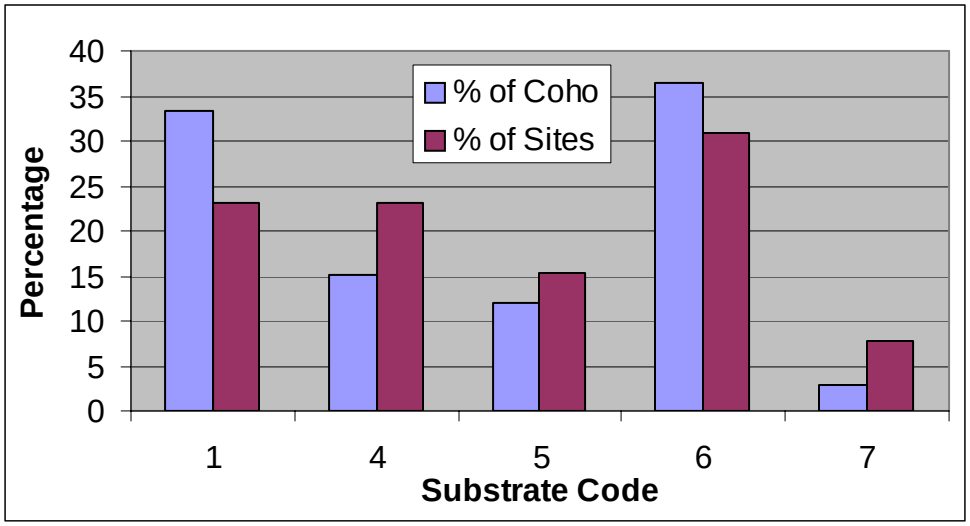


Figure 14. Percentage of stranding sites with a particular dominant substrate, and the percentage of stranded coho salmon found at those sites.



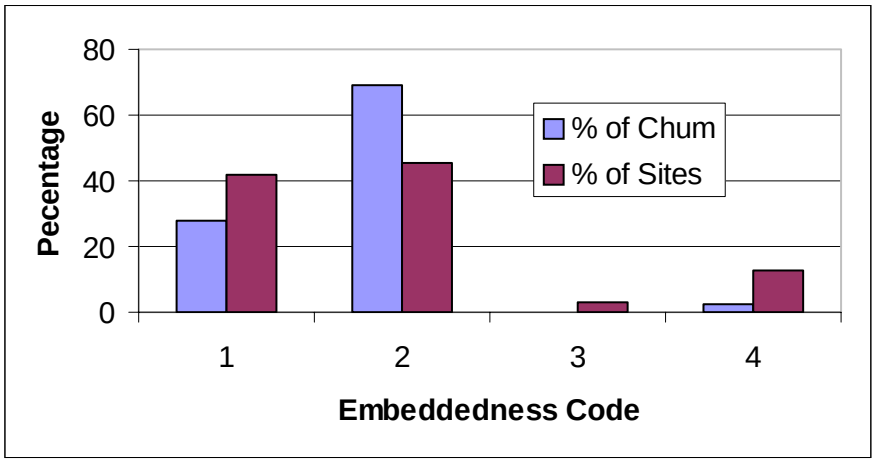
7. Substrate Embeddedness

The substrate embeddedness refers to the degree that the interstices between the larger particles are filled by sand, silt or clay. The substrate embeddedness was estimated visually and coded as follows (Nugent et al., 2000):

Code	% Fines	Description
1	0-25	Openings between dominant sized particles are 1/3 to 1/2 the size of the particles. Few fines in between. Edges are clearly discernible.
2	25-50	Openings are apparent, but <1/4 the size of the particles. Edges are discernible, but up to half obscured.
3	50-75	Openings are completely filled, but half of edges are still discernible.
4	75-100	All openings are obscured. Only one or two edges discernible and size cannot be determined without removal.

The mean and median numbers of threatened chum salmon per survey site found in entrapment sites with various degrees of substrate embeddedness are listed in the last two rows of Table B17. The majority of entrapped chum salmon (69.3%) were found at sites with substrate embeddedness of 25 to 50% fines (code 2, Figure 15). The single chum mortality was found at an entrapment site with a substrate embeddedness of 25 to 50% (code 2).

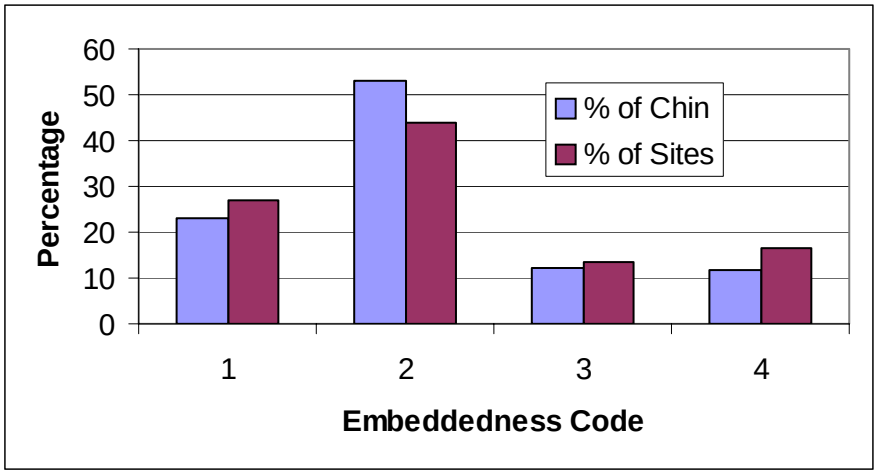
Figure 15: Degrees of substrate embeddedness at chum entrapment sites



The mean and median numbers of threatened chum salmon per survey site found at stranding sites with various degrees of substrate embeddedness are listed in the last two rows of Table B18. The majority of stranded chum salmon (83.3%) were found at sites with substrate embeddedness of 25 to 50% fines (code 2). All stranded chum salmon were mortalities.

The mean and median number of chinook salmon per survey site found in entrapment sites with various degrees of substrate embeddedness are listed in the last two rows of Table B19. The majority of entrapped chinook (53.2%) occurred in sites with substrate embeddedness of 25 to 50% (code 2) (Figure 16). The majority of entrapment mortalities (63.2%) were found in a single site with a substrate embeddedness of 50 to 75% (code 3).

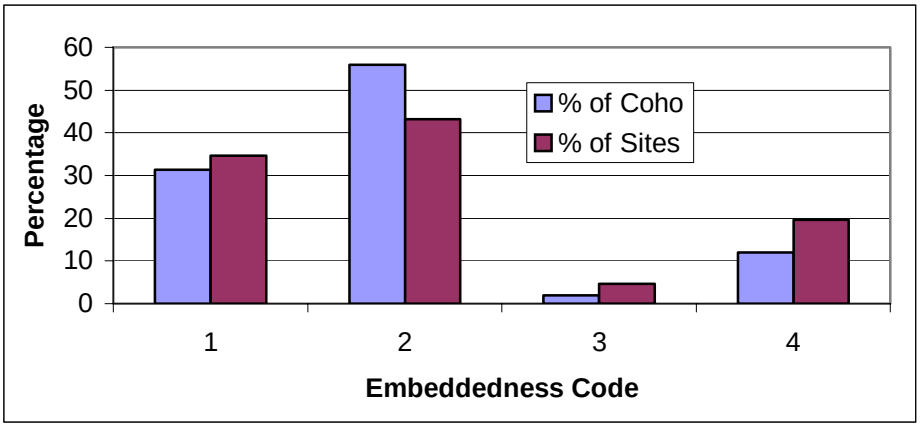
Figure 16: Degrees of substrate embeddedness at chinook entrapment sites



The mean and median number of chinook salmon per survey site found at stranding sites with various degrees of substrate embeddedness are listed in the last two rows of Table B20. The majority of stranded chinook (65.4%) occurred in sites with substrate embeddedness' of either 0 to 25% or 75 to 100% (codes 1 and 4).

The mean and median numbers of coho salmon per survey site found in entrapment sites with various degrees of substrate embeddedness are listed in the last two rows of Table B21. The majority of entrapped coho (54.7%) occurred at sites with a substrate embeddedness of 25 to 50% (code 2) (Figure 17). The majority of coho mortalities (93.3%) occurred at an entrapment site with a substrate embeddedness of 50 to 75%.

Figure 17: Degrees of substrate embeddedness at coho entrapment sites



The mean and median numbers of coho salmon per survey site found in stranding sites with various degrees of substrate embeddedness are listed in the last two rows of Table B22. The majority of stranded coho sampled (69.7%) were nearly evenly split between sites with substrate embeddedness of 0 to 25% (Code 1) and 75 to 100% (Code 4).

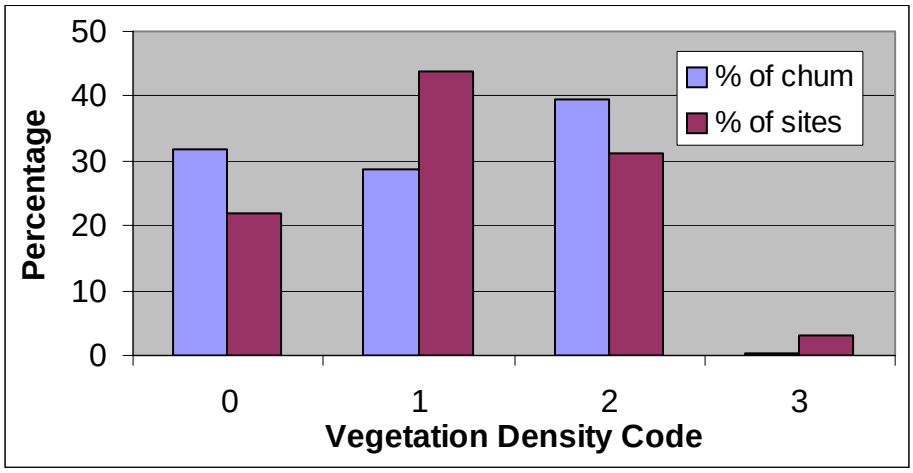
8. Vegetation Density

The amount of substrate concealed by vegetation was estimated visually. The codes are defined as follows (modified from Nugent et al., 2000):

Code	Description
0	No vegetation present
1	Sparse vegetation, substrate is completely evident.
2	Medium vegetation, substrate is only partially obscured.
3	Dense vegetation, substrate is nearly or completely obscured.

During the year 2003, entrapments with medium and dense vegetation contained primarily aquatic plants, including algae.
Chum salmon were found in areas of all four vegetation densities although only one chum salmon was found in an entrapment with dense vegetation (Code 3). Chinook and coho salmon were both found in areas with vegetation densities ranging from zero vegetation to vegetation of medium density (Codes 0-2).The greatest numbers of entrapped chum salmon (41.9%) were found at sites with medium vegetation (code 2, Table B23). The majority of chum entrapment sites had sparse vegetation (Figure 18). The single chum entrapment mortality was found at a site void of vegetation.

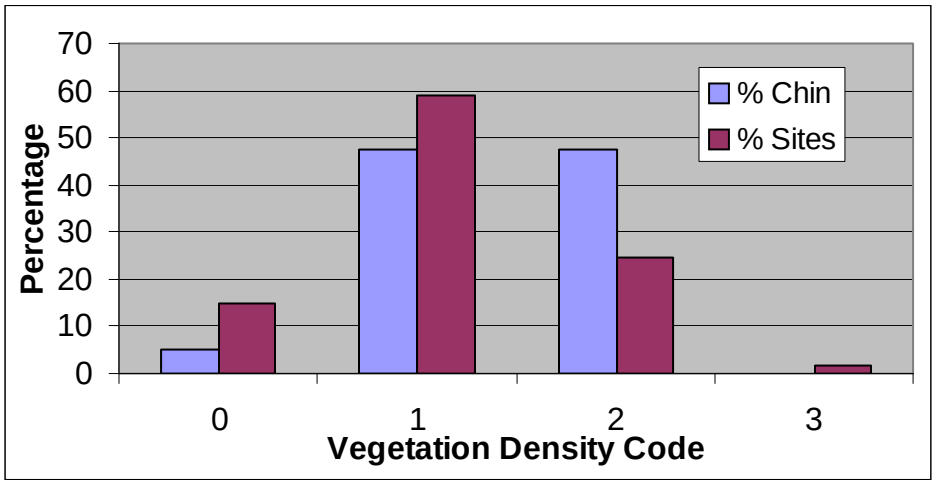
Figure 18: Degrees of vegetation density within chum entrapments



The greatest numbers of stranded (those found out of water) chum salmon (83.3%) were found in sites with either sparse or medium vegetation (codes 1 and 2, Table B24).

The greatest numbers of entrapped chinook salmon were found at sites with either sparse (47.5%) or medium (47.4%) vegetation densities (codes 1 and 2, Table B25). The majority of chinook entrapment sites were in areas of sparse vegetation (code 1, Figure 19).

Figure 19: Degrees of vegetation density within chinook entrapments

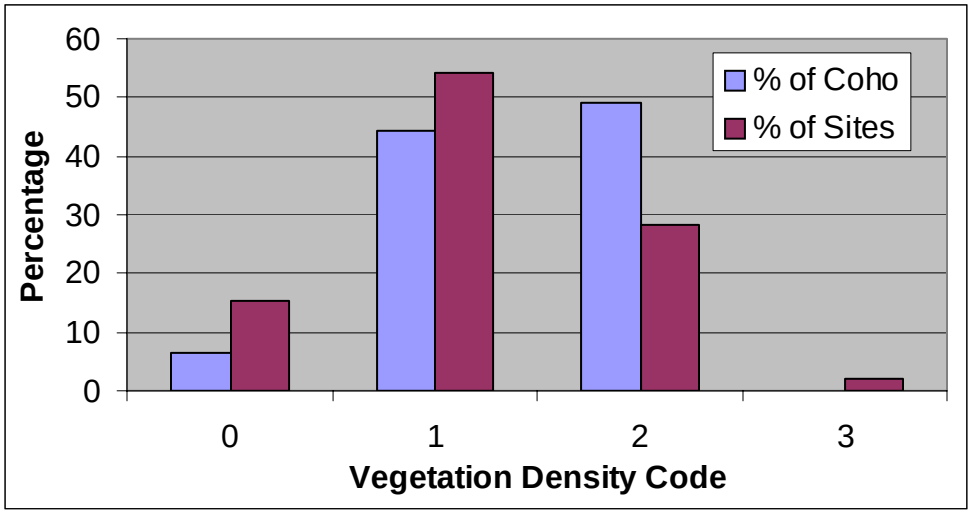


The greatest number of chinook entrapment mortalities (75.7%) occurred at sites with sparse vegetation (Table B25).

The greatest numbers of stranded chinook (73.1%) were also found at sites with sparse vegetation (code 1, Table B26).

The greatest numbers of entrapped coho were found at sites with either sparse or medium vegetation (codes 1 and 2 Table B27). The greatest numbers of stranded coho (93.9%) were found at sites with sparse vegetation (code 1, Table B28).

Figure 20: Degrees of vegetation density within coho entrapments



Ninety-three percent of coho entrapment mortalities were discovered in a single entrapment containing sparse vegetation.

9. Temperature

Two entrapment temperatures were taken, one at the beginning of the sample and one at the end. The temperatures were taken at the same location within the entrapment. River temperatures were taken once a day and air temperatures were taken once or twice a day depending on the weather and length of time spent sampling on a particular day.

Water temperatures of 78ºF and above are considered lethal to juvenile chum and coho salmon (Bell 1973). Water temperatures of 77ºF and above are considered lethal to juvenile chinook salmon (Brett 1952). The highest water temperature found for any entrapment containing juvenile salmon was 74ºF. It is possible that water temperatures exceeded the lethal thresholds at a time when samplers were not present but probably not in a situation that led to the death of a significant number of juvenile salmon. Of the 6057 sampled juvenile salmon found in entrapments, 69 (1.1%) were found dead, and of those, none were found in water exceeding 54ºF. It is more likely that dewatering at a time prior to the samplers arrival caused the majority of the entrapment mortalities. Over 75% of the salmon mortalities found in entrapments were found in a single, small, well shaded entrapment void of any living salmon and with a water temperature of 50ºF, well within the range of safety.

The temperatures of entrapments known to contain any of the three species of juvenile salmon ranged from 42ºF to 74ºF (Table 7). The temperature of the entrapment known to contain the chum mortality was 46ºF. The temperature range of entrapments known to contain chinook mortalities was 42ºF to 69ºF. The temperature range of the entrapments known to contain coho mortalities was 48ºF to 50ºF.

Table 5. Temperature ranges of entrapments with and without salmon mortality

Month	Temp range of entrapments with salmon mortality	Temp range of entrapments with salmon but without mortality
Jan	NA	NA
Feb	45F-54F	44F-60F
March	42F	44F-74F
April	NA	50F-62F
May	NA	54F-70F
June	69F	60F
July	NA	NA

Temperature data related to the lone chum entrapment mortality is found in Figure 21 and Table B29. The air temperature was not recorded.

Mortality of chinook salmon at the entrapment sites was plotted against three temperature measurements (Figure 22). Air and entrapment temperatures had a correlation coefficient of .4202. River and entrapment temperatures had a correlation coefficient of 0. The number of chinook mortalities and entrapment temperature had a correlation coefficient of negative .1284. Peak mortality was observed on February 7 in an entrapment having a temperature of 50ºF (Table B30).

Mortality of coho salmon at the entrapment sites was plotted against the same three temperature measurements as for chinook salmon (Figure 23). Air and entrapment temperatures had a correlation coefficient of -.3974. River and entrapment temperatures had a correlation coefficient of -1. The number of coho mortalities and entrapment temperature had a correlation coefficient of .8030. Even though coho mortalities and entrapment temperatures had a high correlation, the temperatures of all entrapments containing dead coho were well within the range of safety. Peak coho mortality was observed on February 7 in the same entrapment as the peak chinook mortality and had an entrapment temperature of 50ºF (Table B31).

Figure 21. Mortality of threatened chum salmon and temperature measurements at entrapment sites near the Ives Island of the Columbia River in 2003.

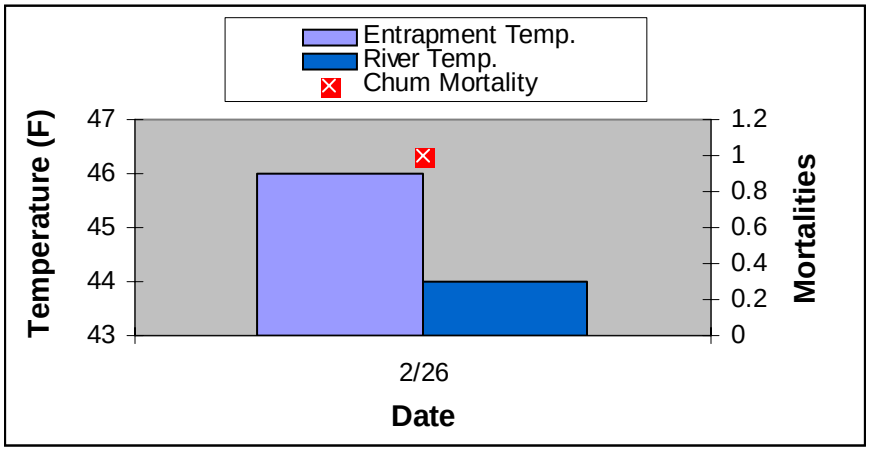


Figure 22. Mortality of chinook salmon and temperatures measurements at entrapment sites near Ives Island of the Columbia River in 2003

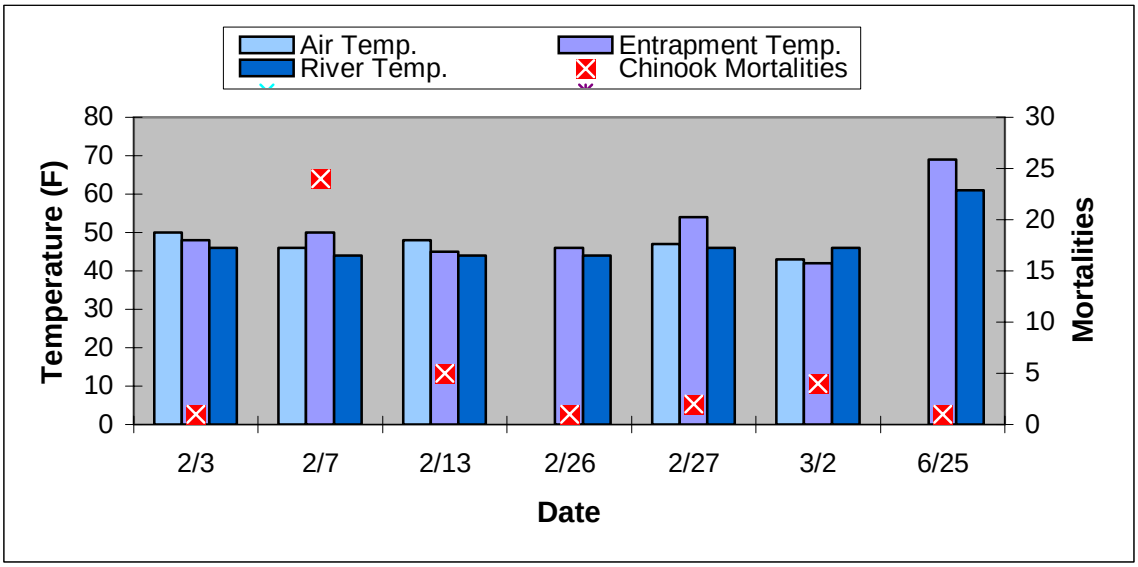
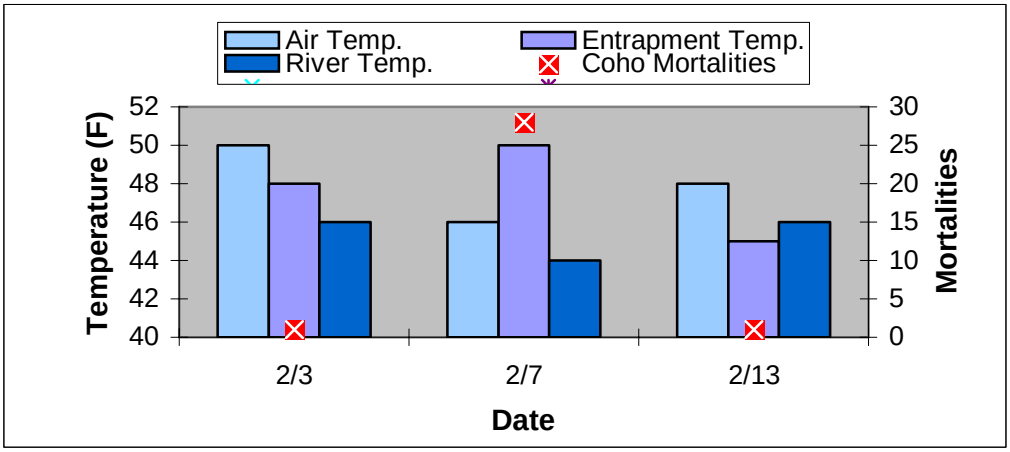


Figure 23. Mortality of coho salmon and temperatures measurements at entrapment sites near Ives Island of the Columbia River in 2003



10. Year-to-Year Comparison

The following is a comparison of the number of fish sampled during each of the four study years followed by a discussion of each of eight major entrapments and possible reasons for the increase in the number of entrapped chinook and coho in 2003.

Table 6. Sampling totals by study year

Study Year	Live Chinook	Live Chum	Live Coho	Dead Chinook	Dead Chum	Dead Coho	Total
2000 (Mar. 2 - June 27)	1258	3	0	53	5	0	1319
2001 (Jan. 29 - June 26)	783	404	349	47	37	1	1621
2002 (Jan. 25 - July 10)	1061	597	415	53	61	85	2272
2003 (Jan. 24 - June 25)	4135	422	1440	61	7	57	6122

MAP 3: Major entrapments of 2000, 2001, 2002 and 2003.

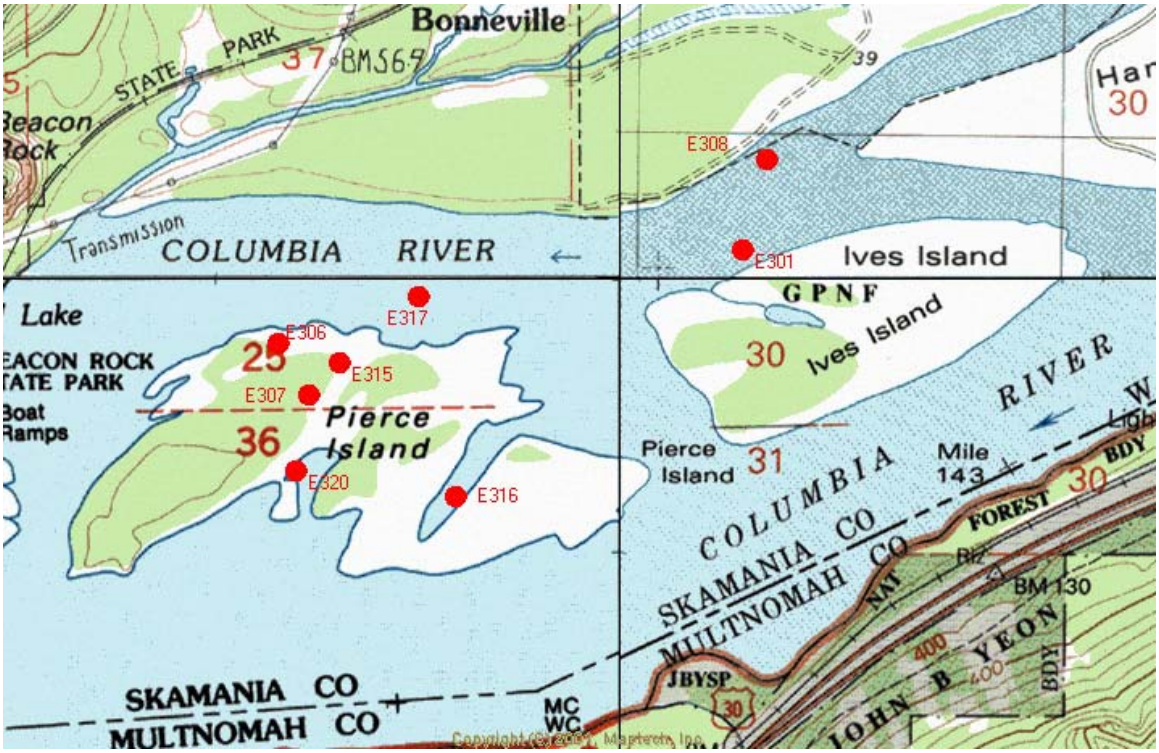


Table 7. Yearly sampling totals per major entrapment

Entrapment and Year	Total Chinook (% of yearly chin)	Total Chum (% of yearly chum)	Total Coho (% of yearly coho)	Dead Chin	Dead Chum	Dead Coho
E315, formally E274 ('02), PIN46 ('00) - (Pierce Island)						
2000	721 (55%)	0	0	6	0	0
2001	Dry all season.	NA	NA	NA	NA	NA
2002	229 (20.6%)	52 (7.9%)	0	0	0	0
2003	541 (12.9%)	1 (0.2%)	34 (2.3%)	24	0	28
E316, formally E208 ('02), PIE31 ('00) - (Pierce Island)						
2000	86	0	0	0	0	0
2001	Dry all season.	NA	NA	NA	NA	NA
2002	0	0	0	0	0	0
2003	1933 (31.6%)	160 (37.3%)	694 (46.4%)	0	0	0
E317, formally E210 ('02), PIN112 ('01) - (Pierce Island)						
2000	Flooded all season?	NA	NA	NA	NA	NA
2001	250 (30.1%)	136 (30.9%)	89 (25.4%)	0	0	0
2002	291 (26.1%)	401 (60.9%)	176 (35.2%)	0	0	1
2003	41 (1.0%)	0	9 (0.6%)	4	0	0
E306, formally E269 ('02), PIN61 ('00) - (Pierce Island)						
2000	205 (15.6%)	0	0	0	0	0
2001	Dry all season.	NA	NA	NA	NA	NA
2002	124 (11.1%)	0	0	2	0	0
2003	0	0	0	0	0	0
E307, formally E264 ('02), PIM48 ('00) - (Pierce Island)						
2000	188 (14.3%)	0	0	0	0	0
2001	Dry all season.	NA	NA	NA	NA	NA
2002	28 (2.5%)	0	0	0	0	0
2003	4 (0.1%)	0	1 (0.07%)	0	0	0
E320, formally PIM103 ('01) - (Pierce Island)						
2000	Flooded all season?	NA	NA	NA	NA	NA
2001	225 (27%)	166 (37.6%)	203 (58%)	0	0	1
2002	Flooded all season.	NA	NA	NA	NA	NA
2003	373 (8.9%)	8 (1.9%)	131 (8.8%)	0	0	0
E301, formally E234 ('02), IIN113 ('01) - (Ives Island)						
2000	Flooded all season.	NA	NA	NA	NA	NA
2001	41 (4.9%)	72 (16.4%)	36 (10.3%)	0	0	0
2002	38 (3.4%)	92 (14%)	43 (8.6%)	0	0	0
2003	190 (4.5%)	113 (26.3%)	78 (5.2%)	8	1	1
E308, formally E279 ('02) - (Pierce Ranch N. W.R.)						
2000	Too deep to sample.	NA	NA	NA	NA	NA
2001	Never connected to river.	NA	NA	NA	NA	NA
*2002	241 (21.6%)	6 (0.9%)	65 (13%)	0	0	0
2003	945 (22.5%)	110 (25.6%)	446 (29.8%)	0	0	0

*****In 2002,the sampling crew switched from a 30ft stick sein net to a 100ft beach sein net when sampling E308.

E301contained 6.3% of all sampled juvenile salmon and 18.1% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E301 is a long shallow depression in what was a dry channel along the northwest shore of Ives Island across from and just west of Hamilton Creek. Water flowing into the area comes from Hamilton Channel. The surface waters of Hamilton Channel were, at times, higher than E301 but blocked by a broad low-lying berm. In some cases, subsurface flow, probably coming from Hamilton Channel, replenished water within E301 without allowing entrapped salmon an opportunity to escape.

E306 contained 2.9% of all sampled juvenile salmon and 0% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E306 is an isolated clearing west of E315 on the northwest shore of Pierce Island. It is one of the most densely vegetated of all the entrapments and is surrounded by large trees. Relatively high flows are required for surface water to enter it. When flooded, it becomes an enclosed bay. A sandy berm covered by canary grass has formed at its mouth.

E307 contained 1.9% of all sampled juvenile salmon and 0% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E307is near the middle of Pierce Island just southwest of E315. It receives water from the north via E315 and expels water to the south. The southern border of E307 is formed by what appears to be the remnants of the old Ladzick fishwheel guide (Donaldson). If the remnants were removed, most of E307's water would drain into another entrapment to the south.

E308 contained 16% of all sampled juvenile salmon and 7.6% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E308 is a deep depression on the Pierce Ranch N. W. R. immediately below the mouth of Hamilton Creek. It may be an old quarry pit resulting from the construction of the nearby Castle Rock Fishwheel and the Hamilton fishwheel scow (Donaldson).

E315 contained 14.4% of all sampled juvenile salmon and 3.5% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E315 is a deep, straight channel cut through large cottonwoods in north central Pierce Island. Water flows into the entrapment from the north and, when high enough, exits to the south flowing through E307 and eventually into the lagoon in Pierce Island's south central shore. E315 has the appearance of a man made channel, possibly to provide increased flow for the Ladzick fishwheel near the center of Pierce Island (Donaldson). A berm of natural deposits has formed at its' north entrance. Cutting off water flow through E315 would reduce the likelihood of E307 becoming an entrapment.

E316 contained 25.3% of all sampled salmon and 10.4% of all sampled chum during the 2000, 2001,2002, and 2003 sampling periods.

E316 has the largest maximum surface area of any of the entrapments, its' length and maximum width dimensions are in excess of 675 feet and 102 feet, respectively. E316 occupies a portion of a broad floodplain that cuts through the eastern portion of Pierce Island. When tailwater levels are in excess of 17 feet, water flows from the channel between Ives and Pierce Islands southward through E316 to the main channel of the Columbia River.

E317 contained 12.3% of all sampled salmon and 35% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E317 is a broad shallow pond forming N.E. of E315 along the north central shore of Pierce Island. Water backs into it via a larger and deeper pond to the west and, when high enough, flows into it from the channel separating Ives and Pierce Islands to the east. Although only small numbers of dead salmon have been documented within this entrapment, the possibility of high water temperatures due to E317's shallowness poses a serious threat to entrapped salmon on sunny days. E317 is part of a large area of undulating topography, which includes many other lesser entrapments.

E317 has trapped more threatened chum than any other entrapment during the 4 years of sampling.

E320 contained 9.8% of all sampled salmon and 11.3% of all sampled chum during the 2000, 2001, 2002, and 2003 sampling periods.

E320 is a bay on the south central shore of Pierce Island with a narrow entrance leading to the main channel of the Columbia River. The entry to E320 is lower than any of the other major entrapments and formation of E320 appears to require tailwater levels somewhere below 12 feet.

The year 2003 saw a 169.5% (3,850) increase in known stranded or entrapped juvenile salmon over what was discovered in 2002. Nine hundred ten (17.5%) more juvenile salmon were discovered stranded or entrapped in 2003 than during the three previous study years combined. All of the increase can be attributed to larger numbers of sampled chinook (4196) and coho (1497) salmon. The total number of sampled chum salmon (431) actually declined by 34.8% between 2002 and 2003 and was 2.7% lower than in 2001 (Table 6).

The largest number of salmon sampled in a single day was recorded on May 12, 2003 when 1,449 juvenile salmon (856 chinook and 593 coho) were retrieved from entrapment E316. The largest number of salmon sampled during a two day period was recorded on May 12 and 13, 2003 when a total of 2,184 juvenile salmon were sampled of which 2,049 (1,385 chinook, 662 coho, and 2 chum) were recovered from entrapment E316.

It is likely that a large number of the chinook and nearly all of the coho sampled from E316 were part of a hatchery release. Of the 1,385-sampled chinook, 11 were missing adipose fins and of the 662 coho 500 (75.5%) were missing adipose fins. The chinook can easily be divided into two size groups, those with fork lengths of 40-65mm and those with fork lengths of 75-105mm. Approximately 475 of the juvenile chinook including all of the clipped chinook were in the 75-105mm range and are thought likely to have been a part of Spring

Creek Hatchery's release of 3,370,867 fall chinook on May 8 (Fish Passage Center). Of the coho salmon, 544, including all clipped coho were smolts and were also thought likely to be hatchery fish. When combined, the 1,019 suspected hatchery fish represent 16.6% of 2003's total sampling and are equal to nearly 45% of 2002's total sampling.

Even without the presence of a large number of hatchery fish during a critical drop in tailwater depth, the number of salmon sampled in 2003 would still have been more than double that of 2002. It is thought that the increase in numbers of entrapped or stranded fish was probably due to increased tailwater fluctuations involving levels related to the formation of what are referred to as major entrapments, i.e., those entrapments traditionally known to contain the large majority of sampled juvenile salmon.

Since major entrapments are well known to the samplers, their existence or non-existence is carefully watched. Whenever a major entrapment is believed to have reformed, samplers check to see if additional fish have been entrapped. It is believed that major entrapments rarely reformed without being resampled. With that in mind, one can look at how often the major entrapments were sampled in a year and get a fairly accurate idea of how often tailwater levels fluctuated to the degree necessary to create them.

In 2003, the eight major entrapments listed in Table 7 were sampled 51 times and in 2002, they were sampled 29 times. If one compares the differences in per entrapment averages to the differences in yearly totals, the increases in entrapment averages are smaller. In 2002, the formation of any of the major entrapments is thought to have caused, on average, the entrapment of approximately 70 salmon. In 2003, the formation of any of the major entrapments is thought to have represented, on average, the entrapment of approximately 114 juvenile salmon, an increase of 62% per entrapment compared to the 169.5% increase in yearly total. If one disregards the suspected hatchery salmon from E316 (an event that was not known to have occurred in 2002), the increase per major entrapment becomes 34.2%. If one completely omits the two site visits to E316 during May 12-13, 2003, the increase in average number of salmon per major entrapment is reduced to 9.9% (from 69.9 fish to 76.8 salmon per entrapment). It may therefore be reasonable to say that the 169.5% increase of entrapped or stranded salmon during 2003 can be primarily attributed to two factors, the more frequent fluctuations in tailwater levels critical to the formation of the seven major entrapments and, a particularly timely critical drop in tailwater during a two-day period in May.

Whereas the total salmon count more than doubled in 2003, the total number of known salmon mortalities declined (Table 7). One hundred twenty five juvenile salmon were found dead in 2003 compared to 199 in 2002, a drop of 37.2%. The decrease in known mortalities can be attributed primarily to an 88.5% (54 fish) decline in known chum mortalities and, to a lesser extent, a 32.9% (28 fish) decline in known coho mortalities. Known chinook mortalities increased in number by 15.1% (8 fish) but declined in rate from 5% to 1.5%.

During the 2003 study year, sixty-nine (55.2%) of the sampled mortalities were found in entrapments. Of the entrapment mortalities, fifty-four (75.4%) were found in a single entrapment that had approximately 18 square feet of surface area and an average depth of 1.9 inches. It is possible that these salmon died from thermal poisoning but unlikely since it was early February and the air and entrapment temperatures were 46ºF and 49ºF, respectively. It is more likely the salmon had died from being stranded (dewatered) at a time prior to the

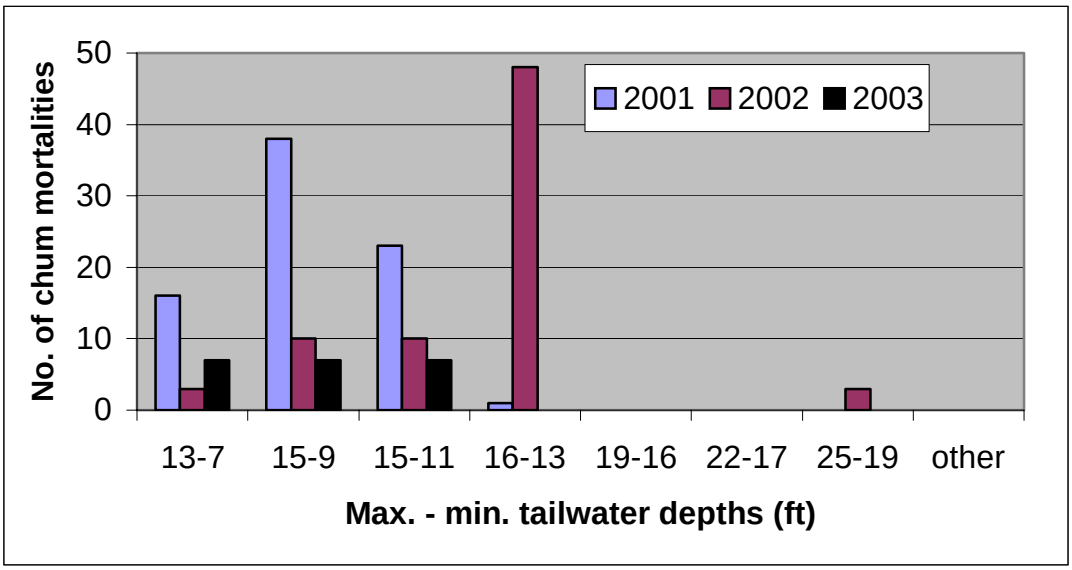
arrival of the samplers. Bonneville Dam records show that the tailwater depth had been as much as 1.7 feet lower during the previous 24 hours (Army Corps of Engineers), a difference that would easily have been enough to drain the 1.9 inches of water existing at the time of sampling.

If the fifty-four entrapment mortalities suspected of stranding are combined with the fifty-six known stranding mortalities, it can be said that at least 110 (88%) of the salmon mortalities can be attributed to dewatering which in turn is directly related to tailwater fluctuation. It is believed that dewatering was also the main cause of death in all previous study years (2000, 2001, and 2002).

A search of Bonneville Dam tailwater records was conducted to determine if there were any similarities in tailwater declines during the twenty-four hour periods immediately preceding the discovery of salmon mortality in the years 2001, 2002, and 2003.

Ranges of tailwater declines during the twenty-four hour periods immediately preceding the sampling of chum salmon mortality, including all stranded chum whether found living or dead, in 2001, 2002, and 2003 are shown in Figure 24. During this three-year period, 50% of all known chum mortalities were preceded by continuous tailwater declines that began at levels no higher than 15 feet and ended at levels no lower than 9 feet. Forty four and one half percent of all known chum mortalities were preceded by declines that began at levels no greater than 16 feet and ended at levels no less than 13 feet. Only a small number of the known chum mortalities (16 of 105) were discovered following 24-hour periods with continuous tailwater declines of less than one foot. Of those sixteen mortalities, 13 were discovered in 2001.

Figure 24: Tailwater declines during the 24 hours immediately prior to the time of sampling of chum salmon mortality in 2001, 2002, and 2003. The pairs of numbers along the x-axis identify a continuous decline in tailwater depth that began at a level less than or equal to the figure on the left but ended at a level higher than or equal to the figure to the right. Some mortalities are represented more than once where ranges overlap.



During 2001, 2002, and 2003, 51.7% of all known salmon mortalities (chum, chinook, and coho together) were preceded by continuous tailwater declines that began at levels no greater than 16 feet and ended at levels no less than 13 feet (Figure 25). The 16ft to 13ft tailwater range becomes even more noteworthy when it is recognized that, during 2001, tailwater levels exceeded 15 feet on just 16 dates, nearly all of which were after the peak numbers of sampled salmon had passed (Army Corps of Engineers).

Since tailwater declines within the 16ft to13ft range preceded over half the known salmon mortalities, a second search was conducted to determine the yearly frequency of such declines. The search was limited to declines of at least 1ft that occurred during February, March, April, and May, the months of peak local salmon activity. In 2003, such declines occurred on 7 separate dates, in 2002 the declines occurred on 10 separate dates, and in 2001 the declines occurred on 3 separate dates (Figure 26).

Listing sample years in order of the 16-13ft tailwater decline frequency produces the same sequence (2002, 2003, 2001) as listing them in order of known mortalities. However, it should be noted that even in 2001, when the possibility of fluctuating in the 16ft to 13ft range was very small due to low river levels, 54% of known mortalities were still associated with tailwater declines of more than 1 ft. So, even though fluctuations in the 16-13ft range appear to be most hazardous to juvenile salmon, large fluctuations at any water level tend to be associated with juvenile salmon mortality.

Figure 25: Tailwater declines during the 24 hours immediately prior to the time of sampling of chum, chinook, or coho salmon mortality in 2001, 2002, and 2003. The pairs of numbers along the x-axis identify a continuous decline in tailwater depth that began at a level less than or equal to the figure on the left but ended at a level higher than or equal to figure on the right. Some mortalities are represented more than once where ranges overlap.

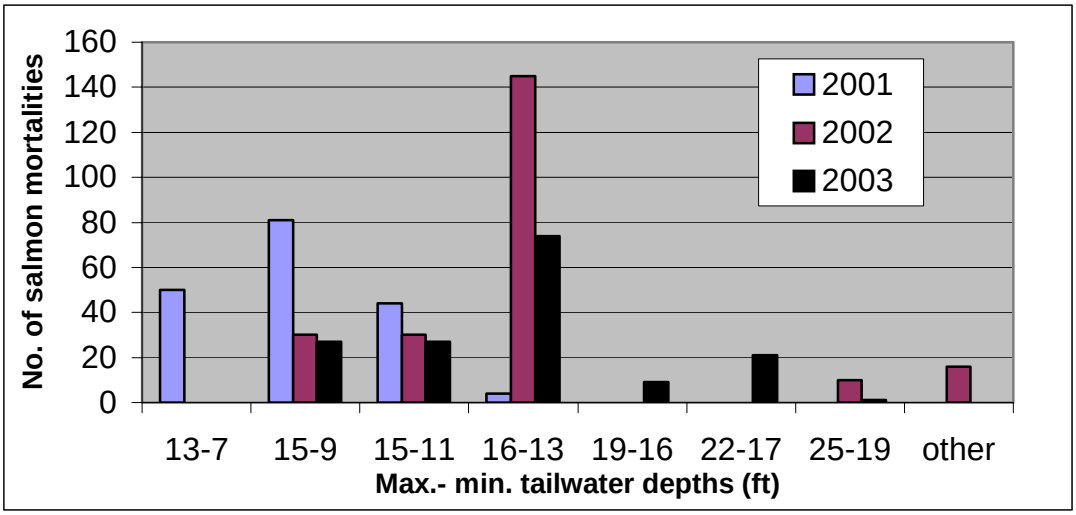
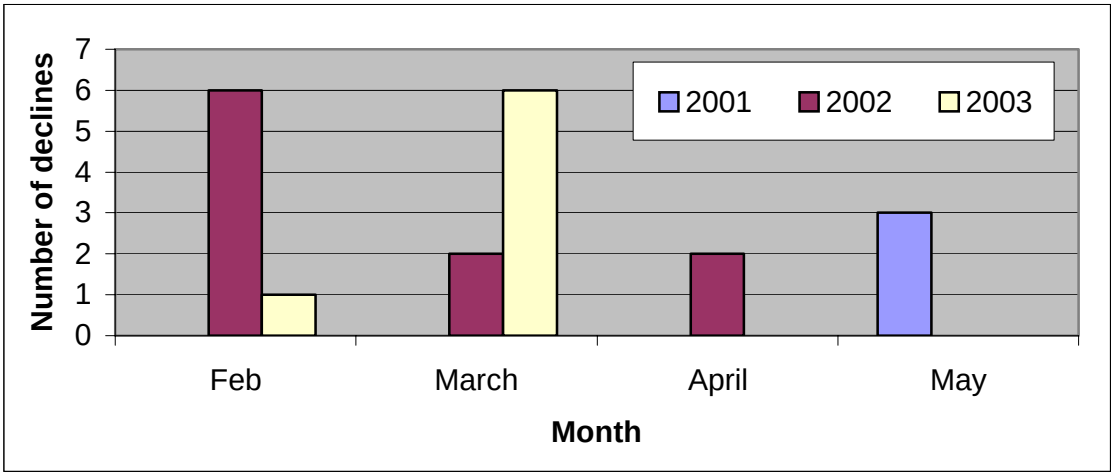


Figure 26: Frequency of tailwater declines of at least 1 foot that began at levels less than or equal to 16ft and ended at levels greater than or equal to 13 ft



11. Summary

During the 2003 sampling period near Ives Island on the Columbia River, 69% of the 6122 sampled fish were chinook salmon, 7% were threatened chum salmon, and 24% were coho salmon. Sixty-five salmon were observed stranded (dewatered) of which 26 were chinook, 6 were chum, and 33 were coho.

When compared to the 2002 study year, mortality and stranding rates declined for all three species. Mortality and stranding rates were once again highest for coho salmon, but declined from 17% and 16.8% to 3.8% and 2.2%, respectively. Mortality and stranding rates for sampled chum salmon declined from 9.3% and 7.9% to 1.6% and 1.4%, respectively. Mortality and stranding rates for chinook salmon declined from 4.8% and 3.1%, in 2002, to 1.4% and 0.6%, respectively. Nine of the stranded salmon, 3 chinook and 6 coho, were still alive when sampled.

Peak numbers of threatened chum salmon were observed the week of February 23 to March 1 and between March 30 and May 3, primarily between Ives Island and the Pierce Ranch N. W. R. below Hamilton Creek and on a wide flood plain cutting through the eastern third of Pierce Island (Areas A and C, Map 1). The greatest numbers of chum salmon mortalities (71.4%) were observed along the northern shore of Pierce Island (Area E, Map 1).

Peak numbers of threatened tule chinook salmon were observed between February 9 and March 1. Peak numbers of upriver bright chinooks were observed between April 13 and May 17. The majority of sampled chinook salmon were observed on the wide flood plain cutting through the eastern third of Pierce Island and between Ives Island and Pierce Ranch N. W. R. (Areas C and A, Map 1). The greatest numbers of chinook salmon mortalities (55.7%) were observed along the northern shore of Pierce Island (Area E, Map 1).

Peak numbers of coho salmon were observed February 2 to 15 and between March 30 and April 26. A group of 677, primarily hatchery smolts, were entrapped on May 12. The majority of sampled coho salmon were observed along the shores between Ives Island and the Pierce Island N. W. R. (Area A, Map 1). The hatchery smolts were entrapped on the

wide flood plain in Area C. The greatest numbers of coho salmon mortalities (55.7%) were observed along the northern shore of Pierce Island (Area E, Map 1).

The year 2003 saw a 169.5% increase in known stranded or entrapped juvenile salmon over what was discovered in 2002. Nine hundred ten more juvenile salmon were discovered stranded or entrapped in 2003 than during the three previous study years combined. All of the increase can be attributed to larger numbers of sampled chinook and coho salmon. The total number of sampled chum salmon actually declined by 34.8% between 2002 and 2003 and was 2.7% lower than in 2001.

Some of the increased numbers of entrapped fish are due to entrapment of salmon released from Spring Creek Hatchery in May of 2003. However, even without the presence of a large number of hatchery fish during a critical drop in tailwater depth in May of 2003, the number of salmon sampled in 2003 would still have been more than double that of 2002. It is thought that the increase in numbers of entrapped or stranded fish was probably due to increased tailwater fluctuations involving levels related to the formation of what are referred to as major entrapments, i.e., those entrapments traditionally known to contain the large majority of sampled juvenile salmon.

If the fifty-four entrapment mortalities suspected of stranding are combined with the fifty-six known stranding mortalities, then at least 110 (88%) of the salmon mortalities can be attributed to dewatering which in turn is directly related to tailwater fluctuation. It is believed that dewatering was also the main cause of death in all previous study years (2000,2001, and 2002).

All known chum mortalities were preceded by continuous tailwater declines that began at levels no higher than 13 feet and ended at levels no lower than 11.7 feet during the 24 hours prior to sampling (Table B31). The greatest numbers of chinook and coho mortalities (45.3% and 71.4%, respectively) were discovered following continuous tailwater declines that began at levels no higher than 15.9 feet and ended at levels no lower than 13.3 feet (Table B31). When taken as a whole, 55.2% of all known salmon mortalities were preceded by continuous tailwater declines beginning at levels no higher than 15.9 feet and ending at levels no lower than 13.3 feet (Table B31).

During 2001, 2002, and 2003, 51.7% of all known salmon mortalities were preceded by continuous tailwater declines that began at levels no greater than 16 feet and ended at levels no less than 13 feet (Figure 25). Listing sample years in order of the 16-13ft tailwater decline frequency produces the same sequence (2002, 2003, 2001) as listing them in order of known mortalities. Although the 16-13ft range appears to be most hazardous to juvenile salmon, overall, 87.3% of all known juvenile salmon mortality followed 24-hour periods with continuous tailwater declines of more than 1 ft., so tailwater declines at any elevation are likely to be hazardous.

Tailwater levels ranged between 15.5ft and 18.8ft (Army Corps of Engineers) during the sampling of the four major entrapments. The unknown affects of river attenuation and channeling within the study area prevent the identification of specific critical tailwater levels. Tailwater levels associated with each of the major entrapments are list in Table 4.

The fork length data indicate that the majority of the entrapped and stranded salmon are in the 40-50 mm range. Fork lengths of all three species averaged above 50mm after May 10. Ninety-nine and one half percent of all sampled chum and 82.2% of all salmon mortalities were less than 50mm. This appears to agree with the conclusions of Nugent et al. that show that salmonids are most likely to be impacted by river level fluctuations when they are small, however, approximately 39% of all sample chinook, and more than 45% of all sampled coho had fork lengths greater than 60mm. Nearly all of the larger salmon were found on just two survey dates, May 12 and 13, in two very large entrapments (E316-9 and E342).

The most common substrates for entrapments containing juvenile salmon were coarse gravel and cobble, while stranded salmon were found at sites with a wide variety of dominant substrates, ranging from fines to coarse gravel. The largest numbers of juvenile salmon mortalities were found at stranding sites with sparse vegetation.

Temperature did not appear to be a major control on juvenile salmon mortality. The temperatures of entrapments known to contain juvenile salmon ranged from 42ºF to 74ºF. The temperature of the entrapment known to contain the single chum mortality was 46ºF. The temperature range of entrapments known to contain chinook mortalities was 42ºF to 69ºF. The temperature of the entrapments known to contain coho mortalities was 48ºF to 50ºF. All of the temperatures cited above should be well within the tolerance of juvenile salmon. Two thousand six hundred ninety-six juvenile salmon were found in entrapments with water temperatures in excess of 60º F. Of those fish, only 1 (00.04%) was a mortality.

All live sampled salmon were released into the Columbia River, it is not known how many would have died if they had been returned to the entrapments.

Several factors create the likelihood that salmon mortalities were higher than recorded. Because of the size of the survey area, some juvenile salmon are likely to have been overlooked. Rising water levels may have swept away dead salmon prior to the arrival of samplers. Predators taking advantage of the confined waters or scavengers may have eaten some of the entrapped or stranded salmon.

References

Army Corps of Engineers. Bonneville Dam tailwater tables, 2000, 2001, 2002, 2003. *http://www.nwdwc.usace.army.mil/cgibin/dataquery.pl?k=Bonneville+dam+Tailwater*

Bell, Milo C. 1973. Temperature- effects of fish, Fisheries Handbook of Engineering Requirements and Biological Criteria. Fisheries-Engineering Research Program, Corps Of Engineers, North Pacific Division, Portland, Oregon.

Brett, J. R. 1952. Temperature tolerance in young Pacific salmon, Genus *Oncorhynchus.* Fisheries Research Board of Canada, Journal, 9(6): 265-323

Chien, Yi-Ju and Murray, C. 2001. Evaluation of Chinook Salmon Entrapment near Ives Island in the Columbia River in 2000. Pacific Northwest National Laboratory.

Duston, R., and Jackman, B. 2002. 2001 Evaluation of Chum, Chinook, and Coho Entrapment near Ives Island in the Columbia River. Pacific States Marine Fisheries Commission, 2108 Grand Blvd., Vancouver, WA 98661

Duston, R., and Wilson, J. 2003. 2002 Evaluation of Chum, Chinook, and Coho Entrapment near Ives Island in the Columbia River. Pacific States Marine Fisheries Commission, 2108 Grand Blvd., Vancouver, WA 98661

Donaldson and Cramer. 1971. Fishwheels of the Columbia. Binford and Mort, Publishers, Portland, Oregon, 97242.

Fish Passage Center. Hatchery Data, 2003. *http://www.fpc.org/Hatchery/Hatchery.htm*

Nugent, et al. 2001. 1998 Evaluation of Juvenile Fall Chinook Stranding on the Hanford Reach of the Columbia River. Washington Department of Fish and Wildlife.

O.D.F.W./ P.S.M.F.C. 2003. Ives Island cumulative juvenile chum and chinook catch, 1999-2003. *http://www.fpc.org/ives_island/Graphs_of_cum_catch.htm*

van der Nald, Spellman, and Clark. 2000. 1999-2000 Evaluation of Fall Chinook and Chum Salmon Spawning Below Bonneville, The Dalles, John Day and McNary Dams. O.D.F.W. 2501 S.W. First Avenue, Box 59, Portland, OR 97207.

van der Nald, Clark, and Spellman. Clark. 2001. 2000-2001 Evaluation of Fall Chinook and Chum Salmon Spawning Below Bonneville, The Dalles, John Day and McNary Dams. O.D.F.W. 2501 S.W. First Avenue, Box 59, Portland, OR 97207.

Appendix A: Site Coordinates

TABLE A. Year 2003 entrapment locations found near Ives Island on the Columbia River.

Entrapment Locations				Sampling Area
Entrapment Code	Species Sampled	Latitude	Longitude	
E301	chum, chin, coho	N45.62577	W121.99504	A
E302		N45.62595	W121.99468	A
E303	chum, chin, coho	N45.62951	W121.99445	A
E304	chinook, coho	N45.62737	W121.99645	A
E305		N45.62768	W121.99615	A
E306		N45.62327	W122.01086	E
E307	chinook, coho	N45.62224	W122.00949	D
E308	chum, chin, coho	N45.62754	W121.99552	A
E309		N45.62866	W121.99480	A
E310		N45.62637	W121.99547	A
E311		N45.62637	W121.99572	A
E312		N45.62627	W121.99577	A
E313		N45.62083	W121.99920	B
E314	chinook, coho	N45.62197	W122.00390	C
E315	chum, chin, coho	N45.62317	W122.00853	E
E316	chum, chin, coho	N45.62028	W122.00493	C
E317	chinook, coho	N45.43666	W122.00755	E
E318	chinook, coho	N45.61506	W122.02788	F
E319	coho	N45.61488	W122.02771	F
E320	chum, chin, coho	N45.62085	W122.00982	D
E321	chum, coho	N45.62105	W122.00917	D
E322	chinook, coho	N45.62458	W122 00868	E
E323		N45.62073	W121.99851	C
E324		N45.62125	W121.99920	C
E325		N45.62171	W122.00280	C
E326		N45.62605	W121.99489	A
E327		N45.62714	W121.99318	A
E328		N45.62455	W122.00539	E
E329		N45.62457	W122.00512	E
E330		N45.62196	W122.00347	C
E331		N45.62191	W122.00380	C
E332	chum, chinook	N45.62169	W122.00423	C
E333		N45.62122	W121.99959	C
E334		N45.6244	W122.00396	E
E335	chum	N45.62128	W122.01540	W. PIERCE
E336	chum, chin, coho	N45.61929	W122.00609	C
E337		N45.62213	W122.00376	C
E338		N45.62149	W122.00485	C
E339		N45.62159	W122.00475	C
E340		N45.61533	W122.02803	F
E341		N45.61478	W122.02854	F
E342	chinook, coho	N45.62415	W121.99491	A

TABLE B. Year 2003 stranding locations found near Ives Island on the Columbia River.

Stranding Locations				Sampling Area
Entrapment Code	Species Sampled	Latitude	Longitude	
S301	chinook, coho	N45.62771	W121.99503	A
S302	coho	N45.62799	W121.99533	A
S303	chinook, coho	N45.62758	W121.99606	A
S304	chinook, coho	N45.62728	W121.99681	A
S305	chum, chinook	N45.62719	W121.99685	A
S306	chinook	N45.62142	W122.00975	D
S307	chinook, coho	N45.62173	W122.00956	D
S308	coho	N45.62172	W122.00870	D
S309	chinook	N45.62184	W122.00372	C
S310	coho	N45.62163	W122.00421	C
S311	chinook, coho	N45.61931	W122.00616	C
S312	coho	N45.61485	W122.02856	F
S313	coho	N45.61845	W122.00858	D
S314	coho	N45.61847	W122.00844	D
S315	coho	N45.62418	W122.00916	E
S316	chinook	N45.62552	W121.99529	A
S317	chum	N45.62441	W122.00398	E
S318	chum	N45.62459	W122.00475	E
S319	chum	N45.62457	W122.00512	E
S320	chinook	N45.62396	W122.00977	E
S321	chinook	N45.62455	W122.00539	E
S322	chum	Missing	Missing	?
S323	chinook	N45.62384	W122.00806	E
S324	chinook	N45.62197	W122.00390	C
S325	chinook	N45.62202	W122.00838	D

Appendix B: Tables

Table B1: Weekly sampling results of threatened chum salmon, 2003

Week	Stranded		Entrapped	Total Mortalities (Stranded + Entrapped)	Total Chum
	Mortality	Alive			
February 16-22	0	0	1	0	1
February 23-March 1	0	0	139	1	139
March 9-15	0	0	3	0	3
March 16-22	6	0	6	6	12
March 23-29	0	0	0	0	0
March 30-April 5	0	0	44	0	44
April 6-12	0	0	34	0	34
April 13-19	0	0	57	0	57
April 20-26	0	0	62	0	62
April 27-May 3	0	0	64	0	64
May 4-10	0	0	4	0	4
May 11-17	0	0	7	0	7
March 9-15	0	0	2	0	2
Total	**6**	**0**	**423**	**7**	**429**

Table B2. Results of weekly sampling of chinook salmon, 2003

Week	Stranded		Entrapped		Total Mortalities (Stranded + Entrapped)	Total Chinook
	Mortality	Live	Mortality	Live		
February 2-8	9	3	25	17	34	54
February 9-15	2	0	5	288	7	295
February 16-22	0	0	0	89	0	89
February 23-March 1	0	0	3	265	3	268
March 2-8	0	0	4	6	4	10
March 9-15	5	0	0	38	5	43
March 16-22	0	0	0	38	0	38
March 23-29	0	0	0	23	0	23
March 30-April 5	0	0	0	120	0	120
April 6-12	0	0	0	113	0	113
April 13-19	0	0	0	443	0	443
April 20-26	0	0	0	377	0	377
April 27-May 3	1	0	0	353	1	354
May 4-10	0	0	0	329	0	329
May 11-17	5	0	0	1540	5	1545
May 18-24	0	0	0	4	0	4
May 25-31	1	0	0	0	1	1
June 1-7	0	0	0	0	0	0
June 8-14	0	0	0	0	0	0
June 15-21	0	0	0	0	0	0
June 22-28	0	0	1	89	1	90
Total	**23**	**3**	**38**	**4132**	**61**	**4196**

Table B3. Results of weekly sampling of coho salmon, 2003

Week	Stranded		Entrapped		Total Mortalities (Stranded + Entrapped)	Total Coho
	Mortality	Live	Mortality	Live		
February 2-8	27	6	29	291	56	353
February 9-15	0	0	1	213	1	214
February 16-22	0	0	0	4	0	4
February 23-March 1	0	0	0	44	0	44
March 2-8	0	0	0	0	0	0
March 9-15	0	0	0	1	0	1
March 16-22	0	0	0	3	0	3
March 23-29	0	0	0	0	0	0
March 30-April 5	0	0	0	91	0	91
April 6-12	0	0	0	17	0	17
April 13-19	0	0	0	31	0	31
April 20-26	0	0	0	30	0	30
April 27-May 3	0	0	0	1	0	1
May 4-10	0	0	0	12	0	12
May 11-17	0	0	0	667	0	667
May 18-24	0	0	0	0	0	0
May 25-31	0	0	0	0	0	0
June 1-7	0	0	0	0	0	0
June 8-14	0	0	0	0	0	0
June 15-21	0	0	0	0	0	0
June 22-28	0	0	0	29	0	29
Total	**27**	**6**	**30**	**1434**	**57**	**1497**

Table B4. Maximum continuous tailwater declines during the 24-hour periods immediately preceding the sampling of juvenile salmon mortality including all stranded salmon whether found living or dead. Site codes beginning with E are entrapments, those beginning with S are strandings.

Tailwater Range (ft)	Date	Site Code	Live Chum	Live Chin.	Live Coho	Chum Morts.	Chin. Morts.	Coho Morts.
12.3-11.7	02/13/03	E301-3	Does not apply			0	5	1
12.3-11.7	02/13/03	S316	0	0	0	0	2	0
12.5-11.7	02/26/03	E301-6	Does not apply			1	1	0
13.0-11.7	03/02/03	E317-4	Does not apply			0	4	0
13.0-11.8	03/13/03	S317	0	0	0	1	0	0
13.0-11.8	03/13/03	S318	0	0	0	2	0	0
13.0-11.8	03/13/03	S319	0	0	0	2	0	0
13.0-11.8	03/13/03	S320	0	0	0	0	3	0
13.0-11.8	03/13/03	S321	0	0	0	0	2	0
13.0-11.8	03/13/03	S322	0	0	0	1	0	0
13.7-12.3	02/27/03	E301-7	Does not apply			0	2	0
14.3-13.3	02/07/03	E315-2	Does not apply			0	24	28
14.3-13.3	02/07/03	S312	0	0	0	0	0	1

14.3-13.3	02/07/03	S313	0	0	0	0	0	3
14.3-13.3	02/07/03	S314	0	0	0	0	0	2
14.3-13.3	02/07/03	S315	0	0	0	0	0	1
15.8-13.6	06/25/03	E342	Does not apply			0	1	0
15.9-13.3	02/06/03	S309	0	0	0	0	2	0
15.9-13.3	02/06/03	S310	0	0	0	0	0	5
15.9-13.3	02/06/03	S311	0	0	0	0	2	5
18.6-16.5	05/11/03	S324	0	0	0	0	5	0
19.9-18.4	02/04/03	S307	0	0	0	0	1	2
19.9-18.4	02/04/03	S308	0	0	0	0	0	1
20.5-18.5	05/01/03	S323	0	0	0	0	1	0
21.2-17.3	02/03/03	E304	Does not apply			0	1	1
21.2-17.3	02/03/03	S301	0	2	4	0	0	0
21.2-17.3	02/03/03	S302	0	0	0	0	0	1
21.2-17.3	02/03/03	S303	0	1	2	0	0	0
21.2-17.3	02/03/03	S304	0	0	0	0	3	3
21.2-17.3	02/03/03	S305	0	0	0	0	0	3
21.2-17.3	02/03/03	S306	0	0	0	0	1	0
24.6-19.6	05/29/03	S325	0	0	0	0	1	0

Table B5. Fork length summary of entrapped chum salmon, 2003

Week Ending	Number of Chum	Fork Length			
		Median	Mean	Minimum	Maximum
2/22/2003	1	44	44	44	44
3/1/2003	139	40	39.8	34	47
3/8/2003	3	44	43.3	42	44
3/15/2003	6	41	41.5	40	44
3/22/2003	0				
3/29/2003	44	42	41.4	32	50
4/5/2003	34	41	40.8	37	47
4/12/2003	57	41	42	36	51
4/19/2003	62	42	43.1	37	53
4/26/2003	64	41	40.9	38	45
5/3/2003	4	42.5	42.5	40	45
5/10/2003	7	45	45.3	42	47
5/17/2003	2	59	59	57	61

Table B6. Fork Length summary of entrapped chinook salmon, 2003

Week Ending	Number of Chinook		Fork Length		
		Median	Mean	Minimum	Maximum
2/8/2003	42	47	51.4	36	54
2/15/2003	293	40	41.5	36	60
2/22/2003	89	42	44.4	36	60
3/1/2003	268	42	43.4	35	60
3/8/2003	10	43	43.2	38	49
3/15/2003	38	43	45.2	40	56
3/22/2003	38	46	45.1	41	50
3/29/2003	23	44	47.8	37	70
4/5/2003	120	43	46.2	36	62
4/12/2003	113	42	43	36	69
4/19/2003	443	42	39.4	37	80
4/26/2003	377	41	40.5	33	52
5/3/2003	353	43	43	36	62
5/10/2003	329	43	43.5	36	62
5/17/2003	1540	55	61.8	35	104
5/24/2003	4 (1)	49	47	43	50
5/31/2003	0				
6/7/2003	0				
6/14/2003	0				
6/21/2003	0				
6/28/2003	90	77	77	52	99

( )- indicates # of smolts, excluded in F.L. calculations

Table B7. Fork Length summary of entrapped coho salmon, 2003

Week Ending	Number of Coho		Fork Length		
		Median	Mean	Minimum	Maximum
2/8/2003	320	38	38.3	34	44
2/15/2003	214	38	37.9	29	43
2/22/2003	4	37.5	37.5	36	39
3/1/2003	44	38	38.3	35	43
3/8/2003	0				
3/15/2003	1[no measurement]				
3/22/2003	3	45	44	36	50
3/29/2003	0				
4/5/2003	91	39	38.7	34	42
4/12/2003	17	41	40.4	36	45
4/19/2003	31	39	39.7	38	44
4/26/2003	30	41.5	43.1	35	56
5/3/2003	1	41	41	41	41
5/10/2003	12 (9)	40	45.7	38	59
5/17/2003	667 (643)	55	63.9	42	95
5/24/2003	0				
5/31/2003	0				
6/7/2003	0				

6/14/2003	0				
6/21/2003	0				
6/28/2003	29	74	74.9	64	94

( )- indicates # of smolts, excluded in F.L. calculations

Table B8. Observed fork length summary of threatened chum salmon at stranding sites near Ives Island in 2003.

Date	Number of Chum	Fork Length (mm)			
		Median	Mean	Minimum	Maximum
3/13/2003	6	42	41.2	37	43

Table B9. Observed fork length summary of chinook salmon at stranding sites near Ives Island in 2003.

Date	Number of Chinook	Fork Length (mm)			
		Median	Mean	Minimum	Maximum
2/3/2003	7		41.1	38	49
2/4/2003	1		38	38	38
2/6/2003	4		50.5	50	51
2/13/2003	2		36	35	37
3/13/2003	5		42.2	39	50
5/1/2003	1		40	40	40
5/11/2003	5		53.4	47	58
5/29/2003	1		58	58	58

Table B10. Observed fork length summary of coho salmon at stranding sites near Ives Island in 2003

Date	Number of Coho	Fork Length (mm)			
		Median	Mean	Minimum	Maximum
2/3/2003	13		37	34	39
2/4/2003	3		35.7	35	36
2/6/2003	10		35	33	37
2/7/2003	7		35.2	32	39

Key to dominant substrate codes

Code	Substrate Class
1	Fines: clay to coarse sand (<1 mm)
2	Very coarse sand (1-2 mm)
3	Fine gravel (2-4 mm)
4	Medium gravel (4-8 mm)
5	Coarse gravel (8-16 mm)
6	Small pebble (16-32 mm)
7	Large pebble (32-64 mm)
8	Cobble or rubble (64-256 mm)
9	Boulder (>256 mm)

Table B11. Number of chum salmon found on entrapment sites marked by a particular dominant substrate near Ives Island in 2003. Numbers in ( ) represent mortalities.

Site Code	Substrate Code				
	1	5	6	7	8
E301-4				1	
E301-5				2	
E301-6				24(1)	
E301-7				83	
E301-8				3	
E303-3			13		
E303-4			8		
E308-3					1
E308-4					28
E308-5					5
E308-6					1
E308-7					1
E308-8					63
E308-9					1
E308-10					3
E308-11					6
E308-12					1
E315-6			1		
E316-2		6			
E316-3		28			
E316-4		15			
E316-5		21			
E316-6		34			
E316-7		49			
E316-8		5			
E316-10		2			
E320-2	8				
E321-2	1				
E325-2	1				
E332-2		1			
E332-3		6			
E336-2		1			
Total Number	**10**	**168**	**22**	**113**	**110**
Mean Number per Site	**3.3**	**15.3**	**7.3**	**22.6**	**11**
Median Number per Site	**1**	**6**	**8**	**3**	**2**

Table B12. Number of <u>stranded</u> chum salmon found on sites marked by a particular dominant substrate near Ives Island in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B10)

Site Code	Substrate Code			
	3	4	5	UNK.
S317		1(1)		
S318			2(2)	
S319	2(2)			
S322				1(1)
Total Number	**2**	**1**	**2**	**1**
Mean Number per Site	**2**	**1**	**2**	**1**
Median Number per Site	**2**	**1**	**2**	**1**

Table B13. Number of <u>entrapped</u> chinook salmon found on sites marked by a particular dominant substrate near Ives Island in 2003. Numbers in ( ) represent mortalities (key precedes Table B10)

Site Code	Substrate Code				
	1	5	6	7	8
E301-2				8	
E301-3				25(5)	
E301-4				58	
E301-5				2	
E301-6				20(1)	
E301-7				74(2)	
E301-8				3	
E303-3			11		
E303-4			7		
E304				1(1)	
E307	4				
E308					11
E308-2					38
E308-3					53
E308-4					45
E308-5					16
E308-6					14
E308-7					10
E308-8					300
E308-9					45
E308-10					71
E308-11					169
E308-12					94
E308-13					23

E308-14					3
E308-15					53
E314		1			
E314-2		2			
E315-2			24(24)		
E315-3		4			
E315-4		5			
E315-5		27			
E315-6			264		
E315-7			18		
E315-8			66		
E315-9			132		
E315-10			1		
E316		1			
E316-2		38			
E316-3		11			
E316-4		6			
E316-5		26			
E316-6		73			
E316-7		362			
E316-8		31			
E316-9		856			
E316-10		529			
E317-1		10			
E317-2		11			
E317-3		13			
E317-4		7(4)			
E318	1				
E320	249				
E320-2	124				
E322	31				
E322-2	1				
E322-3	5				
E332-3		8			
E336		6			
E336-2		32			
E342	37(1)				
Total Number	**452**	**2059**	**523**	**191**	**945**
Mean Number per Site	**56.5**	**93.6**	**65.4**	**23.9**	**63**
Median Number per Site	**18**	**11**	**21**	**14**	**45**

Table B14. Number of <u>stranded</u> chinook salmon found on sites marked by a particular dominant substrate near Ives Island in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B10).

Site Code	Substrate Codes					
	1	3	4	5	6	7
S301	2					
S303				1		
S304			3(3)			
S306	1(1)					
S307	1(1)					
S309	2(1)					
S311					2(1)	
S316						2(1)
S320	3(3)					
S321		2(1)				
S323	1(1)					
S324				5(5)		
S325				1(1)		
Total Number	**10**	**2**	**3**	**7**	**2**	**2**
Mean Number per Site	**1.7**	**2**	**3**	**2.3**	**2**	**2**
Median Number per Site	**1.5**	**2**	**3**	**1**	**2**	**2**

Table B15. Number of <u>entrapped</u> coho salmon found on entrapment sites marked by a particular dominant substrate near Ives Island in 2003. Numbers in ( ) represent mortalities (key precedes Table B10).

Site Code	Substrate Codes				
	1	5	6	7	8
E301-2				55	
E301-3				4(1)	
E301-4				3	
E301-6				6	
E301-7				10	
E303-2			10		
E303-3			7		
E304				8(1)	
E307	1				
E308					282
E308-2					3
E308-3					21
E308-4					49
E308-5					20
E308-6					9

E308-7					5
E308-8					27
E308-9					1
E308-10					1
E308-11					2
E308-12					10
E308-13					2
E308-15					14
E314		1			
E315-2			28(28)		
E315-3		1			
E315-4		1			
E315-5		1			
E315-9		3			
E316-2		1			
E316-5		5			
E316-6		3			
E316-7		20			
E316-8		3			
E316-9		593			
E316-10		69			
E317-1		6			
E317-2		3			
E318	8				
E319	17				
E320	113				
E320-2	18				
E321	1				
E322	1				
E336-2		3			
E342	15				
Total Number	**174**	**713**	**45**	**86**	**446**
Mean Number per Site	**21.75**	**47.5**	**15**	**14.4**	**31.9**
Median Number per Site	**11.5**	**3**	**10**	**7**	**9.5**

Table B16. Number of <u>stranded</u> coho salmon found on sites marked by a particular dominant substrate near Ives Island in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B10).

Site Code	Substrate Codes				
	1	4	5	6	7
S301	4				
S302				1(1)	
S303			2		
S304		3(3)			
S305				3(3)	
S307	2(2)				
S308		1(1)			
S310	5(5)				
S311				5(5)	
S312					1(1)
S313				3(3)	
S314			2(2)		
S315		1(1)			
Total Number	**11**	**5**	**4**	**12**	**1**
Mean Number per Site	**3.7**	**1.7**	**2**	**3**	**1**
Median Number per Site	**4**	**1**	**2**	**3**	**1**

Key to embeddedness codes

Code	% Fines	Description
1	0-25	Openings between dominant sized particles are 1/3 to 1/2 the size of the particles. Few fines in between. Edges are clearly discernible.
2	25-50	Openings are apparent, but <1/4 the size of the particles. Edges are discernible, but up to half obscured.
3	50-75	Openings are completely filled, but half of edges are still discernible.
4	75-100	All openings are obscured. Only one or two edges discernible and size cannot be determined without removal.

Table B17. Number of threatened chum salmon found at entrapment sites with a given substrate embeddedness near Ives Island of the Columbia River in 2003. Numbers in ( ) represent mortalities.

Site Code	Embeddedness Code			
	1	2	3	4
E301-4	1			
E301-5		2		
E301-6		24(1)		
E301-7		83		
E301-8		3		
E303-3		13		
E303-4		8		
E308-3	1			
E308-4	28			
E308-5	5			
E308-6	1			
E308-7	1			
E308-8	63			
E308-9	1			
E308-10	3			
E308-11	6			
E308-12	1			
E315-6			1	
E316-2		6		
E316-3		28		
E316-4		15		
E316-5		21		
E316-6		34		
E316-7		49		
E316-8		5		
E316-10		2		
E320-2				8
E321-2				1
E335-2				1
E332-2	1			
E332-3	6			
E336-2				1
Total Number	**118**	**293**	**1**	**11**
Mean Number per Site	**9.1**	**20.9**	**1**	**2.75**
Median Number per Site	**1**	**14**	**1**	**1**

Table B18. Number of threatened chum salmon found at stranding sites with a given substrate embeddedness near Ives Island of the Columbia River in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B16).

Site Code	Embeddedness Code				
	1	2	3	4	UNK
S317		1(1)			
S318		2(2)			
S319		2(2)			
S322					1(1)
Total number	**0**	**5**	**0**	**0**	**1**
Mean number per site	**0**	**1.7**	**0**	**0**	**1**
Median number per site	**0**	**2**	**0**	**0**	**1**

Table B19. Number of chinook salmon found at entrapment sites with given substrate embeddedness near Ives Island of the Columbia River in 2003. Numbers in ( ) represent mortalities (key precedes Table B16).

Site Code	Embeddedness Code			
	1	2	3	4
E301-2				
E301-3		25(5)		
E301-4		58		
E301-5		2		
E301-6		20(1)		
E301-7		74(2)		
E301-8		3		
E303-3		11		
E303-4		7		
E304	1(1)			
E307				4
E308	11			
E308-2	38			
E308-3	53			
E308-4	45			
E308-5	16			
E308-6	14			
E308-7	10			
E308-8	300			
E308-9	45			
E308-10	71			

E308-11	169			
E308-12	94			
E308-13	23			
E308-14	3			
E308-15	53			
E314			1	
E314-2			2	
E315-2			24(24)	
E315-3		4		
E315-4		5		
E315-5		27		
E315-6			264	
E315-7			18	
E315-8			66	
E315-9			132	
E315-10			1	
E316		1		
E316-2		38		
E316-3		11		
E316-4		6		
E316-5		26		
E316-6		73		
E316-7		362		
E316-8		31		
E316-9		856		
E316-10		529		
E317-1		10		
E317-2		11		
E317-3		13		
E317-4		7(4)		
E318				1
E320				249
E320-2				124
E322				31
E322-2				1
E322-3				5
E332-3	8			
E336				6
E336-2				32
E341				37(1)
Total number	**954**	**2218**	**508**	**490**
Mean number per site	**56.1**	**85.3**	**63.5**	**49**
Median number per site	**38**	**12**	**21**	**18.5**

Table B20. Number of chinook salmon found at stranding sites with given substrate embeddedness near Ives Island of the Columbia River in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B16).

Site Code	Embeddedness Code			
	1	2	3	4
S301				2
S303		1		
S304	3(3)			
S306				1(1)
S307				1(1)
S309				2(2)
S311	2(2)			
S316	2(2)			
S320				3(3)
S321		2(2)		
S323				1(1)
S324			5(5)	
S325		1(1)		
Total number	**7**	**4**	**5**	**10**
Mean number per site	**2.3**	**1.3**	**5**	**1.7**
Median number per site	**2**	**1**	**5**	**1.5**

Table B21. Number of coho salmon found at entrapment sites with given substrate embeddedness near Ives Island of the Columbia River in 2003. Numbers in ( ) represent mortalities (key precedes Table B16).

Site Code	Embeddedness Code			
	1	2	3	4
E301-2		55		
E301-3		4(1)		
E301-4	3			
E301-6		6		
E301-7		10		
E303-2		10		
E303-3		7		
E304	8(1)			
E307				1
E308	282			
E308-2	3			
E308-3	21			
E308-4	49			
E308-5	20			
E308-6	9			

E308-7	5			
E308-8	27			
E308-9	1			
E308-10	1			
E308-11	2			
E308-12	10			
E308-13	2			
E308-15	14			
E314			1	
E315-2			28(28)	
E315-3		1		
E315-4		1		
E315-5		1		
E315-9		3		
E316-2		1		
E316-5		5		
E316-6		3		
E316-7		20		
E316-8		3		
E316-9		593		
E316-10		69		
E317-1		6		
E317-2		3		
E318				8
E319				17
E320				113
E320-2				18
E321				1
E322				1
E336-2				3
E341				15
Total Number	**457**	**801**	**29**	**177**
Mean Number per Site	**28.6**	**42.2**	**14.5**	**19.7**
Median Number per Site	**8.5**	**5**	**14.5**	**8**

Table B22. Number of coho salmon found at stranding sites with given substrate embeddedness near Ives Island of the Columbia River in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B16).

Site Code	Embeddedness Code			
	1	2	3	4
S301				4
S302		1(1)		
S303		2		
S304	3(3)			
S305	3(3)			
S307				2(2)
S308		1(1)		
S310				5(5)
S311	5(5)			
S312		1(1)		
S313		3(3)		
S314			2(2)	
S315				1(1)
Total number	**11**	**8**	**2**	**12**
Mean number per site	**3.7**	**1.6**	**2**	**3**
Median number per site	**3**	**1**	**2**	**3**

Key to vegetation density codes

Code	Description
0	No vegetation present
1	Sparse vegetation, substrate is completely evident.
2	Medium vegetation, substrate is only partially obscured.
3	Dense vegetation, substrate is nearly or completely obscured.

Table B23. Number of threatened chum salmon observed at entrapment sites with given vegetation densities near Ives Island of the Columbia River in 2003. Numbers in ( ) represent mortalities.

Site Code	Vegetation Density Code			
	0	**1**	**2**	**3**
E301-4	1			
E301-5	2			
E301-6	24(1)			
E301-7	83			
E301-8	3			
E303-3	13			
E303-4	8			
E308-3		1		
E308-4		28		
E308-5		5		
E308-6		1		
E308-7		1		
E308-8		63		
E308-9		1		
E308-10		3		
E308-11		6		
E308-12		1		
E315-6		1		
E316-2			6	
E316-3			28	
E316-4			15	
E316-5			21	
E316-6			34	
E316-7			49	
E316-8			5	
E316-10			2	
E320-2		8		
E321-2		1		
E325-2				1
E332-2			1	
E332-3			6	
E336-2		1		
Total Number	**110**	**121**	**167**	**1**
Mean Number per Site	**18.3333**	**8.64286**	**16.7**	**1**
Median Number per Site	**5.5**	**1**	**10.5**	**1**

Table B24. Number of threatened chum salmon observed at stranding sites with given vegetation densities near Ives Island of the Columbia River in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment (key precedes Table B22). Numbers in ( ) represent mortalities.

Site Code	Vegetation Density Code				
	0	1	2	3	UNK.
S317		1(1)			
S318		2(2)			
S319			2(2)		
S322					1(1)
Total Number	**0**	**3**	**2**	**0**	**1**
Mean Number per Site	**0**	**1.5**	**2**	**0**	**1**
Median Number per Site	**0**	**1.5**	**2**	**0**	**1**

Table B25. Number of chinook salmon observed at <u>entrapment</u> sites with given vegetation densities near Ives Island of the Columbia River in 2003. Numbers in ( ) represent mortalities (key precedes Table B22).

Site Code	Vegetation Density Code			
	0	1	2	3
E301-2	8			
E301-3	25(5)			
E301-4	58			
E301-5	2			
E301-6	20(1)			
E301-7	74(2)			
E301-8	3			
E303-3	11			
E303-4	7			
E304			1(1)	
E307				4
E308		11		
E308-2		38		
E308-3		53		
E308-4		45		
E308-5		16		
E308-6		14		
E308-7		10		
E308-8		300		
E308-9		45		
E308-10		71		
E308-11		169		
E308-12		94		
E308-13		23		
E308-14		3		
E308-15		53		
E314		1		
E314-2		2		
E315-2		24(24)		

E315-3			4	
E315-4			5	
E315-5			27	
E315-6		264		
E315-7		18		
E315-8		66		
E315-9		132		
E315-10		1		
E316			1	
E316-2			38	
E316-3			11	
E316-4			6	
E316-5			26	
E316-6			73	
E316-7			362	
E316-8			31	
E316-9			856	
E316-10			529	
E317-1		10		
E317-2		11		
E317-3		13		
E317-4		7(4)		
E318		1		
E320		249		
E320-2		124		
E322		31		
E322-2		1		
E322-3		5		
E332-3			8	
E336		6		
E336-2		32		
E342		37		
Total Number	**208**	**1980**	**1978**	**4**
Mean Number per Site	**23.1**	**55**	**131.9**	**4**
Median Number per Site	**11**	**23.5**	**26**	**4**

Table B26. Number of chinook salmon observed at stranding sites with given vegetation densities near Ives Island of the Columbia River in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment (key precedes Table B22). Numbers in ( ) represent mortalities (key, p. 57).

Site Code	Vegetation Density Code			
	0	1	2	3
S301		2		
S303		1		
S304		3(3)		
S306		1(1)		
S307			1(1)	
S309		2(2)		
S311		2(2)		
S316	2(2)			
S320		3(3)		
S321			2(2)	
S323				1(1)
S324		5(5)		
S325			1(1)	
Total Number	**2**	**19**	**4**	**1**
Mean Number per Site	**2**	**2.4**	**1.3**	**1**
Median Number per Site	**2**	**2**	**1**	**1**

Table B27. Number of coho salmon observed at entrapment sites with given vegetation densities near the Ives Island of the Columbia River in 2003. Numbers in ( ) represent mortalities (key precedes Table B22).

Site Code	Vegetation Density Code			
	0	1	2	3
E301-2	55			
E301-3	4(1)			
E301-4	3			
E301-6	6			
E301-7	10			
E303-2	10			
E303-3	7			
E304			8(1)	
E307				1
E308		282		
E308-2		3		
E308-3		21		
E308-4		49		
E308-5		20		
E308-6		9		
E308-7		5		
E308-8		27		

E308-9		1		
E308-10		1		
E308-11		2		
E308-12		10		
E308-13		2		
E308-15		14		
E314		1		
E315-2		28(28)		
E315-3			1	
E315-4			1	
E315-5			1	
E315-9		3		
E316-2			1	
E316-5			5	
E316-6			3	
E316-7			20	
E316-8			3	
E316-9			593	
E316-10			69	
E317-1		6		
E317-2		3		
E318		8		
E319		17		
E320		113		
E320-2		18		
E321			1	
E322		1		
E336-2		3		
E342			15	
Total Number	**95**	**647**	**721**	**1**
Mean Number per Site	**13.6**	**25.9**	**55.5**	**1**
Median Number per Site	**7**	**8**	**3**	**1**

Table B28. Number of coho salmon observed at stranding sites with given vegetation densities near the Ives Island of the Columbia River in 2003. Accompanying entrapment codes identify the stranding site as a dewatered entrapment. Numbers in ( ) represent mortalities (key precedes Table B22).

Site Code	Vegetation Density Code			
	0	1	2	3
S301		4		
S302		1		
S303		2(2)		
S304		3(3)		
S305		3(3)		
S307			2(2)	
S308		1(1)		
S310		5(5)		
S311		5(5)		
S312		1(1)		
S313		3(3)		
S314		2(2)		
S315		1(1)		
Total Number	**0**	**31**	**2**	**0**
Mean Number per Site	**0**	**2.6**	**2**	**0**
Median Number per Site	**0**	**2.5**	**2**	**0**

Table B29. Chum mortalities and temperature measurements

Sampling Date	Entrapment Code	Mortalities	Air Temp. (F)	River Temp. (F)	Entrapment Temp. (F)
2/26/2003	E301-6	1	missing	44	46

Table B30. Chinook mortalities and temperature measurements

Sampling Date	Entrapment Code	Mortalities	Air Temp. (F)	River Temp. (F)	Entrapment Temp. (F)
2/03/2003	E304	1	50	46	48
2/07/2003	E315-2	24	46	44	50
2/13/2003	E301-3	5	48	45	45
2/26/2003	E301-6	1	missing	44	46
2/27/2003	E301-7	2	47	46	54
3/02/2003	E317-4	4	43	46	42
6/25/2003	E342	1	missing	60	69

Table B31. Coho mortalities and temperature measurements

Sampling Date	Entrapment Code	Mortality	Air Temp. (F)	River Temp. (F)	Entrapment Temp. (F)
2/03/2003	304	1	50	46	48
2/07/2003	315-2	1	46	44	50
2/13/2003	301-3	28	48	45	45