Activity 13: Where Have All the Salmon Gone?
-Aquatic WILD-

Ages:
Grades 6 – 10

Time:
One or two 40 to 60-minute periods

State Essential Learning Requirements
Reading: 2.1, 2.2, 3.1, 3.2
Mathematics: 1.1, 1.4, All of 3, 4 and 5
Communications: 1.1, 1.2, 2.5, All of 3
Science: 1.2, 1.3, 2.2
History: All of 2 and 3
Geography: 1.1, 2.1, 2.2, all of 3
Civics: 2.2, 4.1
Economics: 1.1

Materials:
Aquatic WILD Activity provided: You need graph paper; copies of fish catch data; information about each fish species and historical information.

Overview:
Students graph and interpret actual fish population data in relation to historical events.

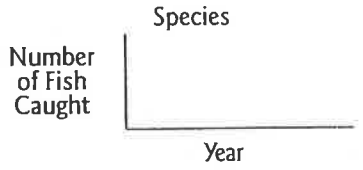
Washington data provided:
Use Washington state data for salmonids to determine trends in fish populations.

Objectives:
- To construct and interpret graphs of Washington data on salmon harvests.
- To formulate a theory to manage wild coho salmon populations based on research reports.

Critical Questions Addressed:
2. Endangered

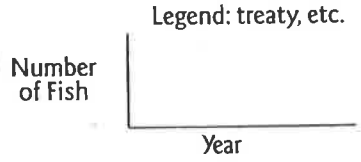
Resources:
- Puget Sound Commercial Salmon Landing by species in Numbers of Fish from 1913 to 1998.
- Puget Sound Salmon Catches by species 1989-1998

Directions:
Using Puget Sound Commercial Salmon Landings by Species
- Graph this data for each species



Activity: Analysis and Interpretation
What do you notice about each salmonid species. Write about:
- What years you find the lows and highs for each species.
- What is the difference in years between each low for each species.
- Which species has the greatest change in catch totals from 1913 to 1998
- What do you notice about the Pink salmon catch year by year. Can you explain this after studying the typical life cycle of the Pink.

Directions:
Using "Puget Sound Salmon Catches by Species 1989-1998
- Graph the Puget Sound salmon catch data for the last 10 years. Plot the catches for treaty, non-treaty and sport fishers.



Activity: Analysis and Interpretation
What do you notice about each salmonid species
- Describe the trends in catch for each species over the years.
- Describe the trends in catch by type of fisher over the years.

Extension: Resources
- Evaluating Salmonid Production in Bear Creek by Dave Seiler, Fish Management WDFW in Water Tenders, 1999,
- Wild Coho Forecasts by Dave Seiler, Fish Management WDFW

Guided Reading:
Read the two documents reporting research on Wild Salmon runs. Use the student worksheet attached to interpret the readings.

WHERE HAVE ALL THE SALMON GONE?

OBJECTIVES

Students will: 1) interpret and make inferences about fluctuations in fish populations from actual data; and 2) analyze the effects of human use and habitat changes on a fish population.

METHOD

Students graph and interpret actual fish population data in relation to historical events.

BACKGROUND

Data gathered about a wildlife population in a similar manner over a period of time may be useful in detecting trends in that population. The same data may be interpreted by those analyzing it in a variety of ways. Because a fish population is influenced by many factors, it may be difficult to measure the effect of a single factor. Thus, assumptions must often be made that factors other than the ones being measured are not significantly affecting the population.

In measuring populations of living creatures, biologists are seldom able to get a total count. Usually only a sample of the population can be obtained and inferences about the total population must be made from this sample. Errors or inconsistencies in gathering the data over time may greatly influence the accuracy of the data. Despite the influence of unknown factors and possible inconsistencies in data gathering, regularly conducted counts or inventories of a population may still be the best information available and decisions must be made from this information.

At times, biologists are simply unable to make any type of reasonably reliable count. How many fish are there in the sea, for example? How many of each species? There is simply no way to know. In these cases, some type of index to abundance may be used.

In this activity, actual data from fish catches from the Columbia River are provided for students to analyze. The fish species are all anadromous—that is, they migrate from the ocean to fresh water to spawn. Young fish live in the river from one to three years, return to the ocean and grow to adults in several more years. The data are in pounds of fish caught in the river rather than the ocean.

The major purpose of this activity is for students to make inferences about factors that affect some fish populations.

Age: Grades 6-12
Subjects: Science, Math
Skills: analysis, classification, comparing similarities and differences, computation, identification, inference, interpretation, listing, media construction, reading
Duration: one or two 40 to 60-minute periods
Group Size: any
Setting: indoors
Conceptual Framework Reference: IV.A., IV.A.1., IV.A.2., IV.A.3., IV.A.4., IV.B., IV.B.1., IV.B.2., IV.C., IV.C.1., IV.C.2., IV.C.3., IV.C.4., IV.D., IV.D.1., IV.D.2., IV.D.3., IV.D.4., IV.D.5., IV.D.6., IV.D.7., IV.E., IV.E.1., IV.E.2., IV.E.3., IV.E.4., IV.E.5., IV.E.6., IV.E.7., IV.E.8., IV.E.9., IV.E.10., IV.E.11., IV.F., IV.F.1., IV.F.2., IV.F.3., IV.F.4., IV.F.5., IV.F.6., IV.F.7., IV.F.8., IV.F.9., IV.F.10., IV.F.11.
Key Vocabulary: population, inventory, trend
Appendices: Local Resources

MATERIALS

graph paper; copies of fish catch data; information about each fish species and historical information

PROCEDURE

1. Provide students with the fish catch data and information about each fish species only. Have them graph levels of each species caught from 1870 to the present. There will be five lines on the graph with each a different color to represent a different species. Students should put a legend on their graphs. You may want to make an overhead for students to check against and for use in discussions.

Fish 1 (Chinook): Considered to be the most abundant and valued fish species for catching. They migrate the entire length of the river. Largest in individual size of all fish.

Fish 2 (Coho): These fish are second to Fish 1 in popularity and economic value. They migrate only up to the lower middle part of the river system.

Fish 3 (Chum): Never popular. Do not bite a hook well. Found only near the mouth of the river. Usually caught with nets.

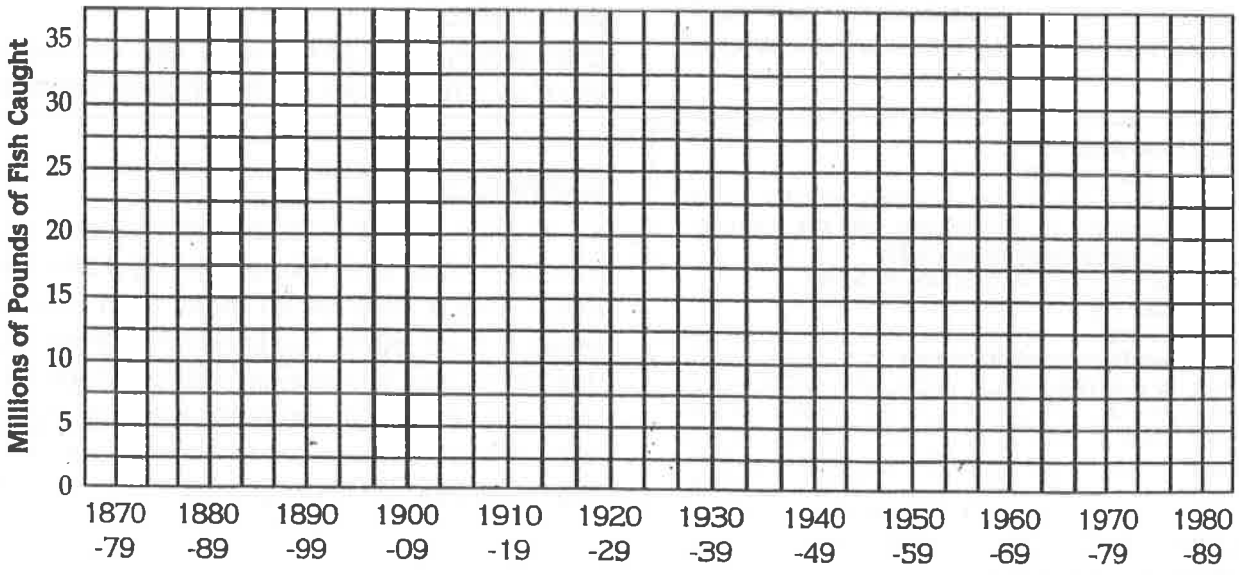
Fish 4 (Sockeye): Smallest-sized fish in the group. They migrate to the uppermost part of the river. They require lakes for successful spawning and rearing. Do not bite well. Taken mostly with nets.

Fish 5 (Steelhead): These fish migrate throughout the river system. Habitat requirements are more restrictive than others.

MILLIONS OF POUNDS OF FISH CAUGHT

YEARS	FISH 1	FISH 2	FISH 3	FISH 4	FISH 5
1870-79	22.7	—	—	—	—
1880-89	33.1	—	—	—	—
1890-99	24.1	3.2	0.8	2.4	3.0
1900-09	25.1	2.1	1.3	0.8	0.7
1910-19	28.1	4.3	3.6	0.9	1.9
1920-29	22.3	5.5	3.1	0.9	2.5
1930-39	17.2	3.2	1.2	0.3	1.9
1940-49	15.4	1.1	1.5	0.2	1.8
1950-59	7.4	0.6	0.2	0.3	1.1
1960-69	4.7	1.6	0.02	0.1	0.6
1970-79	5.9	1.9	0.01	0.2	0.4
1980-89*	5.4	1.9	0.01	0.06	0.3

*projected



Adapted from an activity by Patty Farthing in *Water, Water Everywhere,* Corvallis, OR; Oregon State University Extension Sea Grant Program, C 1985. Used with permission.

The data below are taken from actual fish catches. Figures are in millions of pounds. The accompanying historical data provides an overview of human activity in the river plus developing regulatory and management efforts over time.

2. Ask the students to list and explain whatever inferences they can draw from the data provided. Do the graphs show any long-term trends? Are there periods where the rates of fish caught change rapidly in a short time? What inferences about population abundance of each species can be made from the graphs and fish information? What other factors may be affecting the number of fish caught or population levels? Might the ways in which the fish are caught have changed? A new event or factor may take some time to have an effect on a population or to be detected. Do the graphs seem to show any of these situations in relation to historical events? Are there different interpretations that individual students make from the same information? Do each of the interpretations seem to explain or fit the information and data? If faced with making a management decision based on one of the interpretations, how would you decide which interpretation to use?

3. Provide the students with the historical background. Have them review this new information in relation to what their graphs show. It may be helpful for students to make notes on the graphs at the points where significant historical events occur. What new inferences can be made? Must some of the old inferences or explanations be changed to fit the new data? NOTE: This activity does not address ethical questions related to the appropriateness or inappropriateness of catching fish for human uses. This dimension may be added at the professional discretion of the educator conducting the activity.

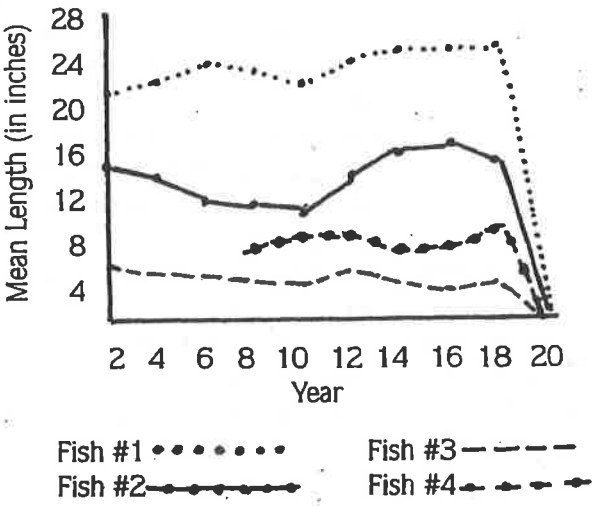
EXTENSIONS

1. Contact your local department of fish and wildlife. Invite a fisheries biologist to review the data with you and make his or her analysis. Does it differ significantly from your own?
2. Write a short "scientific" paper explaining the data, analysis and interpretations of the fish populations. Read your paper to the class, and defend your analysis.

EVALUATION

Study the graph to answer these questions:

AVERAGE LENGTH OF FISH SPECIES IN LAKE



- Which fish population appears to be the most stable?
- Fish #3 appears to be a prey species for which fish?
- What would you think is the primary diet of Fish #1? Fish #2? Fish #3? Why?
- What natural and human events may have accounted for the decrease in Fish #2's size between years two and four, and between years 16 and 18?
- What effect did the introduction of Fish #4 appear to have on the other fish species?
- What actions might the local (state) fish agency have taken to maintain the size of Fish #2?
- What natural and human events may have caused all the fish species to die in year 20?

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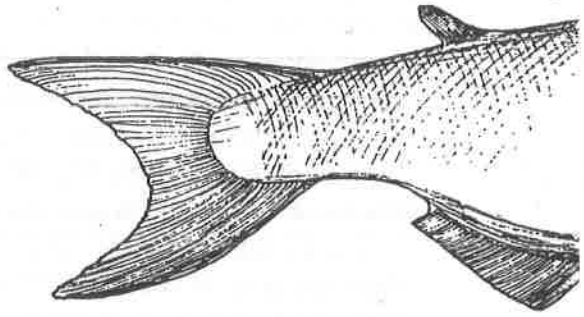
HISTORICAL DATA

1866	Opening of first fish cannery on the river.
1869-83	Canning of Fish 1 jumped from 100,000 cases to 630,000 cases.
1880-1889	43 million pounds of Fish 1 taken from river by commercial fishers.
After 1883	Canneries begin to use other species of fish (2, 3, 4, 5.)
1877-1878	First efforts to regulate fisheries by state. Enforcement was limited but control of amount and type of fishing gear helped.
1900-1909	30 million pounds of all fish taken.
1915-1920	40-44 million pounds of fish taken as World War I inspired intensive use.
1920	Approximately 1,000 commercial trollers operating in ocean. At least that many boats in the river with gill nets, seines and traps.
1933-1938	Construction of first dam on lower part of the river.
After 1935	Only gillnetters allowed on the river. All other commercial fishing techniques banned.
1941	Second dam built in upper river. No fish ladders installed.
1940-1950	Four new dams built on the river between existing dams.
1930-1950s	Extensive logging in lowest part of river systems.
1950s	Six dams built on the major tributary of the river.
	Government launches a massive hatchery program for Fish 1, 2 and 5.
1953	Another dam built on main river.
1957	Another dam built.
1950-1960s	Ocean harvest rather than river harvest of Fish 1 and 2 increases greatly.
1968	Another dam built.
1968-1973	Extreme nitrogen supersaturation in river from dam spill of runoff water. Many small fish killed.
1960-1980	Fish hatchery techniques greatly improved on Fish 1, 2 and 5.
1970s	Commercial use of Fish 5 is banned.
1980s	Intensive regulation of ocean fishing on Fish 1 and Fish 2.



PUGET SOUND COMMERCIAL SALMON LANDINGS BY SPECIES
IN NUMBERS OF FISH

1913 - PRESENT

YEAR	CHINOOK	CHUM	PINK	COHO	SOCKEYE	TOTALS
1913	290,044	604,857	15,907,710	1,225,115	21,598,964	39,626,690
1914	425,979	1,686,137	75,491	1,499,306	3,451,402	7,138,315
1915	301,192	1,884,144	7,368,713	1,106,896	804,385	11,467,330
1916	301,178	1,884,147	68,098	1,106,898	804,387	4,166,708
1917	440,864	1,095,015	13,345,280	936,242	4,961,933	20,779,334
1918	477,246	1,156,571	77,849	1,637,525	561,431	3,910,622
1919	347,766	1,475,091	4,667,820	1,363,153	746,694	8,600,524
1920	271,926	683,070	19,566	569,505	652,613	2,196,680
1921	268,962	270,193	4,401,516	762,221	1,135,473	6,838,385
1922	208,359	502,230	32,389	892,360	505,551	2,140,889
1923	224,624	637,882	5,534,086	867,471	482,387	7,766,450
1924	245,601	859,983	100,046	946,720	746,839	2,899,189
1925	284,496	534,812	6,665,345	669,013	1,242,820	9,596,486
1926	253,129	1,063,695	24,489	703,292	431,767	2,476,372
1927	287,762	526,868	6,526,034	1,028,815	987,749	9,357,228
1928	234,214	1,044,101	9,481	760,697	608,569	2,657,062
1929	311,642	1,466,434	7,432,802	806,971	1,247,717	11,265,566
1930	280,145	1,011,360	17,393	574,944	3,237,423	5,121,265
1931	207,898	682,495	8,131,922	512,867	723,275	10,258,457
1932	179,566	1,092,309	8,839	457,204	818,561	2,556,479
1933	210,602	504,139	6,039,870	535,978	1,575,236	8,865,825
1934	209,482	866,829	13,090	451,176	2,648,295	4,188,872
1935	76,043	718,647	4,993,613	577,401	535,385	6,901,089
1936	78,769	763,361	5,990	246,895	451,798	1,566,833
1937	93,060	774,195	4,167,791	347,858	870,275	6,253,179
1938	58,325	802,177	7,865	321,215	1,408,069	2,597,651
1939	61,003	331,350	3,945,844	358,619	547,587	5,244,403
1940	70,816	565,033	4,999	260,793	652,319	1,553,960
1941	72,166	672,715	1,451,640	275,514	1,548,130	4,020,165
1942	42,309	643,976	1,696	180,147	2,922,660	3,791,188
1943	56,583	396,191	757,176	217,745	196,587	1,624,282
1944	67,827	320,271	4,251	299,060	326,123	1,017,532
1945	87,501	421,096	5,768,811	378,946	718,414	7,374,768
1946	62,262	1,250,821	190	205,790	3,099,743	4,618,806
1947	37,380	595,014	9,273,596	468,642	76,153	10,450,785
1948	41,491	940,771	201	370,662	922,344	2,275,469
1949	51,913	439,933	6,754,592	425,733	908,753	8,580,924
1950	45,542	886,559	9,854	605,717	1,217,315	2,764,987
1951	51,797	796,283	5,392,848	423,324	1,128,829	7,793,091
1952	59,569	772,687	1,708	653,610	1,113,508	2,601,272
1953	58,659	346,293	5,359,585	341,518	1,981,005	8,087,060
1954	58,632	422,780	218	214,394	4,757,586	5,453,612
1955	57,244	212,360	3,837,862	300,048	933,725	5,341,239
1956	46,413	105,348	381	409,211	900,128	1,461,479
1957	48,623	103,495	2,966,258	293,949	1,698,945	5,121,270
1958	50,416	420,903	2,907	351,812	5,254,738	6,080,776
1959	55,323	361,095	2,427,036	347,620	1,807,862	4,999,136
1960	64,719	135,017	305	103,787	1,190,726	1,494,554
1961	81,084	133,243	668,213	384,177	1,377,712	2,664,429
1962	48,207	173,681	121	414,208	754,488	1,390,705
1963	94,007	295,362	5,671,717	232,822	1,314,725	7,608,633
1964	75,202	247,345	490	401,763	508,914	1,233,714
1965	96,297	191,664	624,177	405,060	1,022,984	2,340,202
1966	102,852	404,462	809	634,583	1,338,518	2,481,224
1967	98,752	271,632	3,696,857	287,763	2,094,774	6,449,578
1968	107,929	462,369	289	450,207	901,003	1,921,827
1969	104,076	145,385	942,178	360,185	1,628,361	3,180,185
1970	150,570	217,629	1,796	849,998	1,362,262	2,582,255
1971	156,949	151,382	2,478,439	553,661	3,062,775	6,406,206
1972	117,880	788,159	135	550,893	1,144,678	2,601,855
1973	136,387	535,032	2,363,299	801,793	2,674,989	6,511,500
1974	144,638	398,112	167	873,325	2,485,310	3,899,552
1975	230,388	175,542	1,330,171	961,526	1,616,570	4,314,197
1976	214,099	757,899	119	666,683	1,318,503	2,957,303
1977	246,560	453,233	2,033,959	998,009	1,839,135	5,570,896
1978	249,102	1,231,764	269	818,316	1,372,853	3,672,304
1979	192,750	124,534	4,146,924	757,952	1,796,943	7,019,103
1980	248,245	948,340	372	1,263,396	539,460	2,999,792
1981	214,369	498,903	3,898,606	743,769	1,304,864	6,658,501
1982	211,300	961,570	52	1,145,120	2,868,185	5,206,197
1983	179,000	480,000	1,846,000	921,000	401,000	3,827,000
1984	242,785	724,524	61	807,740	1,704,386	3,479,496
1985	244,675	1,098,853	4,171,823	1,142,005	2,917,249	9,574,605
1986	222,887	1,147,579	110	1,344,650	2,735,759	5,450,985
1987	213,055	1,301,611	2,089,760	1,782,184	1,948,056	7,312,665
1988	231,430	1,568,744	76	1,237,489	849,397	3,887,136
1989	253,880	686,512	3,427,694	965,444	2,251,728	7,785,258
1990	250,195	1,100,496	274	1,067,696	2,166,735	4,585,400
1991	143,259	1,021,186	3,268,471	596,747	1,628,087	6,679,772
1992	113,530	1,361,226	203	398,911	608,253	2,502,123
1993	82,441	1,128,200	2,085,181	189,886	2,698,620	6,184,308
1994	84,649	1,351,701	236	451,897	1,837,777	3,726,260
1995	78,467	740,949	2,702,319	296,582	406,003	4,224,320
1996	76,936	783,277	66	162,744	318,677	1,341,700
1997	76,446	418,814	1,880,712	144,607	1,361,992	3,880,571
1998	53,807	749,193	864	151,445	537,704	1,493,013
1999						0
2000						0
2001						0

1935-1982 Data from 1982 WDF Statistical Report
1983-1995 Data from 1995 WDFW Statistical Report
- Except, 1983-1998 Sockeye and Pink Catch & Weight from Puget Sound Value of Catch Reports

PUGET SOUND SALMON
CHINOOK CATCHES, 1989 - 1998

YEAR	TREATY CATCH	NON-TREATY NET CATCH	NON-TREATY SPORT CATCH*
1998	40,638	11,938	23,433
1997	55,193	21,883	63,937
1996	67,708	8,500	75,840
1995	71,269	6,099	76,701
1994	65,997	20,810	54,055
1993	64,716	18,107	89,677
1992	94,023	19,496	100,456
1991	121,620	21,629	93,895
1990	197,709	52,846	129,118
1989	200,070	54,112	140,090

PUGET SOUND SALMON
CHUM CATCHES, 1989 - 1998

YEAR	TREATY CATCH	NON-TREATY NET CATCH	NON-TREATY SPORT CATCH*
1998	218,671	509,041	8,318
1997	188,507	229,261	11,802
1996	253,269	528,231	24,957
1995	374,881	366,985	12,218
1994	791,260	581,223	19,343
1993	539,812	587,835	10,821
1992	763,643	617,592	15,459
1991	544,984	476,789	7,397
1990	573,607	526,891	4,260
1989	518,401	368,111	5,787

PUGET SOUND SALMON
COHO CATCHES, 1989 - 1998

YEAR	TREATY CATCH	NON-TREATY NET CATCH	NON-TREATY SPORT CATCH*
1998	113,205	12,473	87,667
1997	135,356	10,448	149,558
1996	141,935	17,276	102,395
1995	273,438	20,710	93,343
1994	435,367	23,905	45,328
1993	162,087	27,093	156,488
1992	299,961	98,920	202,008
1991	401,819	196,353	259,844
1990	676,819	390,879	321,205
1989	621,779	344,360	228,650

PUGET SOUND SALMON
SOCKEYE CATCHES, 1989 - 1998

YEAR	TREATY CATCH	NON-TREATY NET CATCH	NON-TREATY SPORT CATCH*
1998	293,262	229,166	90
1997	678,652	689,064	303
1996	283,100	32,874	70,319
1995	242,162	163,080	165
1994	956,407	880,356	64
1993	1,365,247	1,328,484	1,063
1992	292,140	316,113	213
1991	844,689	983,408	254
1990	1,184,374	982,361	585
1989	1,159,904	1,127,793	380

PUGET SOUND SALMON
PINK CATCHES, 1989 - 1998

YEAR	TREATY CATCH	NON-TREATY NET CATCH	NON-TREATY SPORT CATCH*
1998	263	279	198
1997	1,015,310	865,437	45,143
1996	47	0	49
1995	1,347,401	1,365,166	212,731
1994	1,691	29	5
1993	1,117,381	974,878	102,135
1992	121	82	390
1991	1,710,031	1,578,440	63,088
1990	264	10	243
1989	1,843,846	1,583,853	81,786

Commercial Catch Data From Puget Sound Summary (PSSUM) Annual Reports, WDFW.

Sport Catch Data From WDFW Annual Reports and Unpublished Data.

* = Note that catches do NOT include sport, net, and troll catches OUTSIDE Puget Sound (i.e., ocean sport and troll fisheries, etc.).

Note: 1998 Sport Catches DO NOT Include Freshwater Catch.

jda 991006

Where Have All the Salmon Gone?-Aquatic WILD-
Student Worksheet Page 3

Resources:

- Puget Sound Commercial Salmon Landing by species in Numbers of Fish from 1913 to 1998.
- Puget Sound Salmon Catches by species 1989-1998

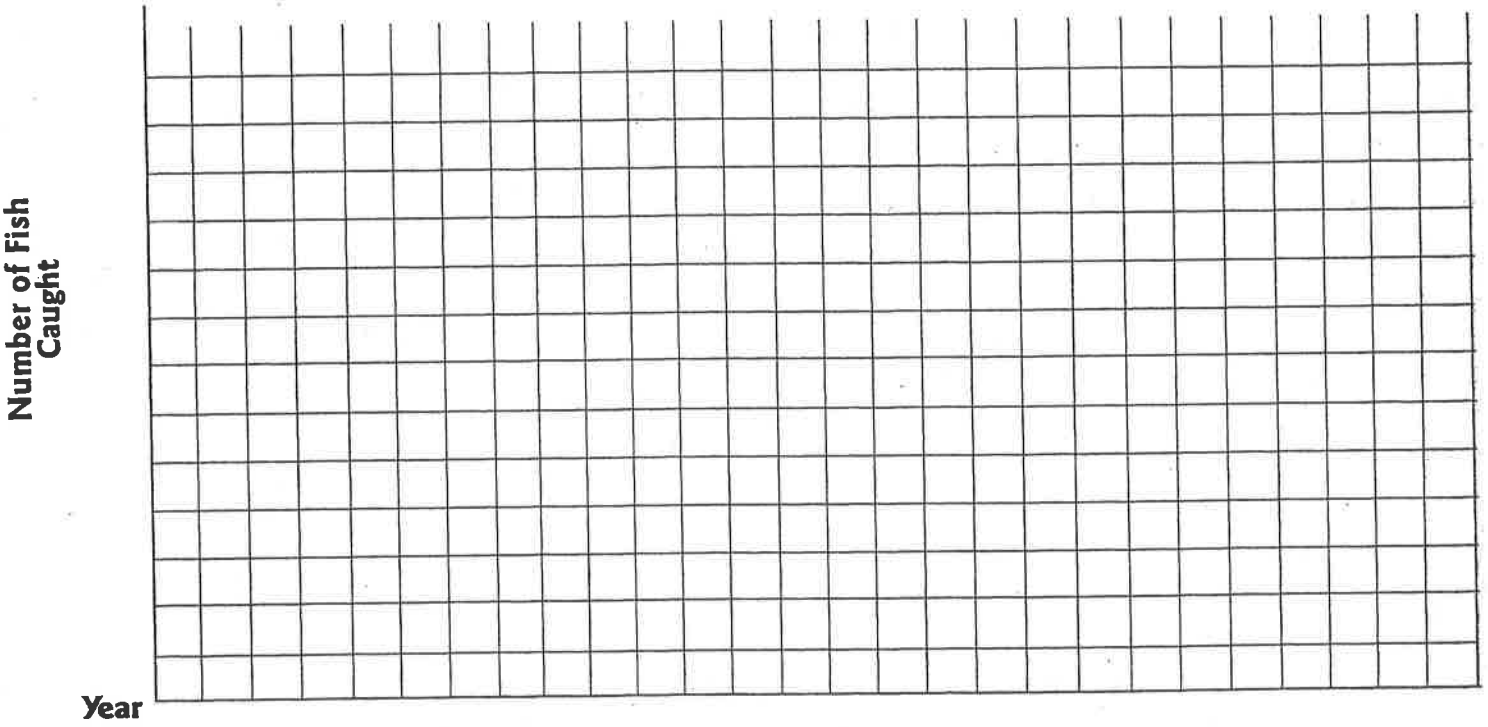
Directions:

Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Species

1. Chinook
2. Chum
3. Pink
4. Coho
5. Sockeye
6. Total



Reflections:

What do you notice about each salmonid species. Write about

- What years you find the lows and highs for each species.
- What is the difference in years between each low for each species.
- Which species has the greatest change in catch totals from 1913 to 1998
- What do you notice about the Pink salmon catch year by year. Can you explain this

Where Have All the Salmon Gone?-Aquatic WILD-

Student Worksheet Page 4

Resources:

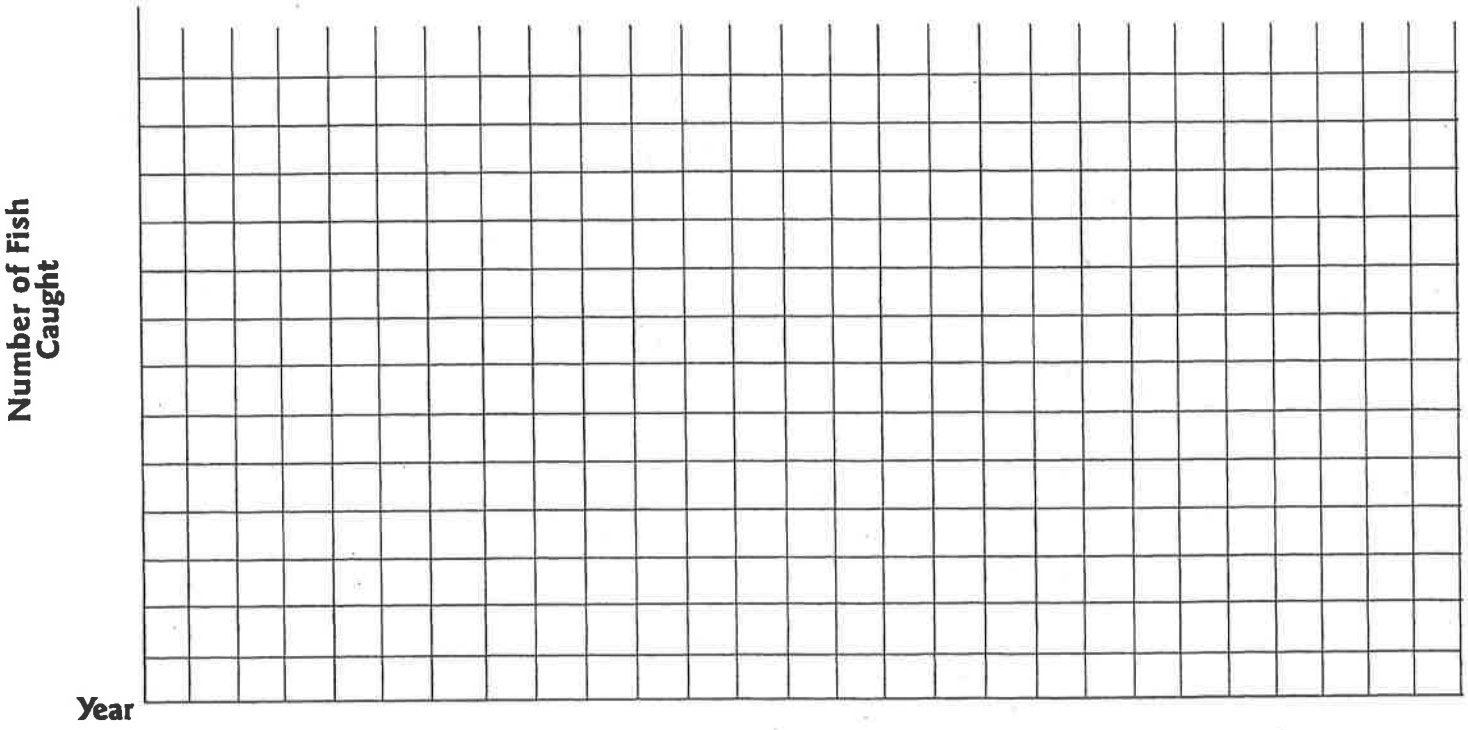
- Puget Sound Commercial Salmon Landing by species in Numbers of Fish from 1913 to 1998.
- Puget Sound Salmon Catches by species 1989-1998

Directions:

Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Fishers
1. Treaty
2. Non-treaty
3. Sport



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Where Have All the Salmon Gone?-Aquatic WILD-
Student Worksheet Page 4a

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- Puget Sound Salmon Catches by species 1989-1998

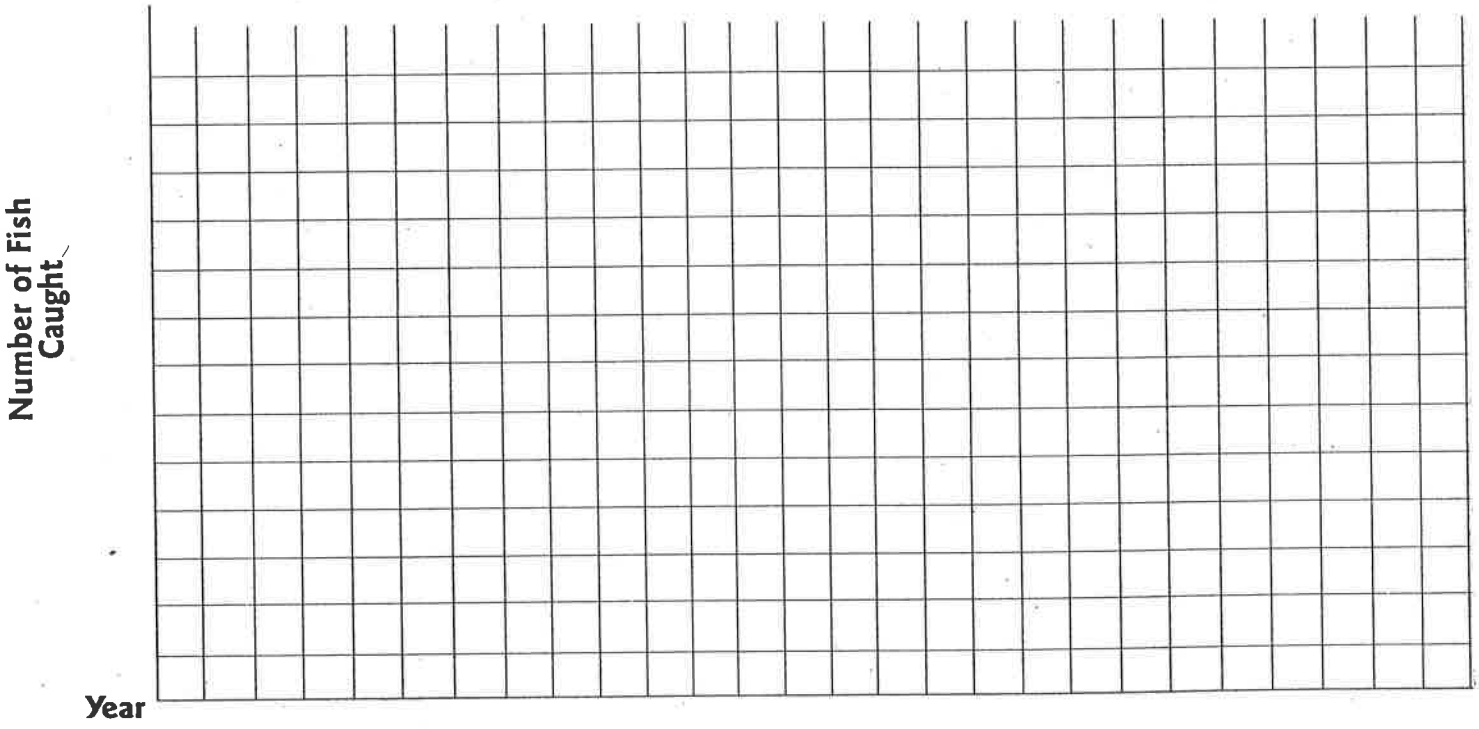
Directions:

Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Fishers
1. Treaty
2. Non-treaty
3. Sport

Chinook:



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Where Have All the Salmon Gone?-Aquatic WILD-
Student Worksheet Page 4b

Resources:

- Puget Sound Commercial Salmon Landing by species in Numbers of Fish from 1913 to 1998.
- Puget Sound Salmon Catches by species 1989-1998

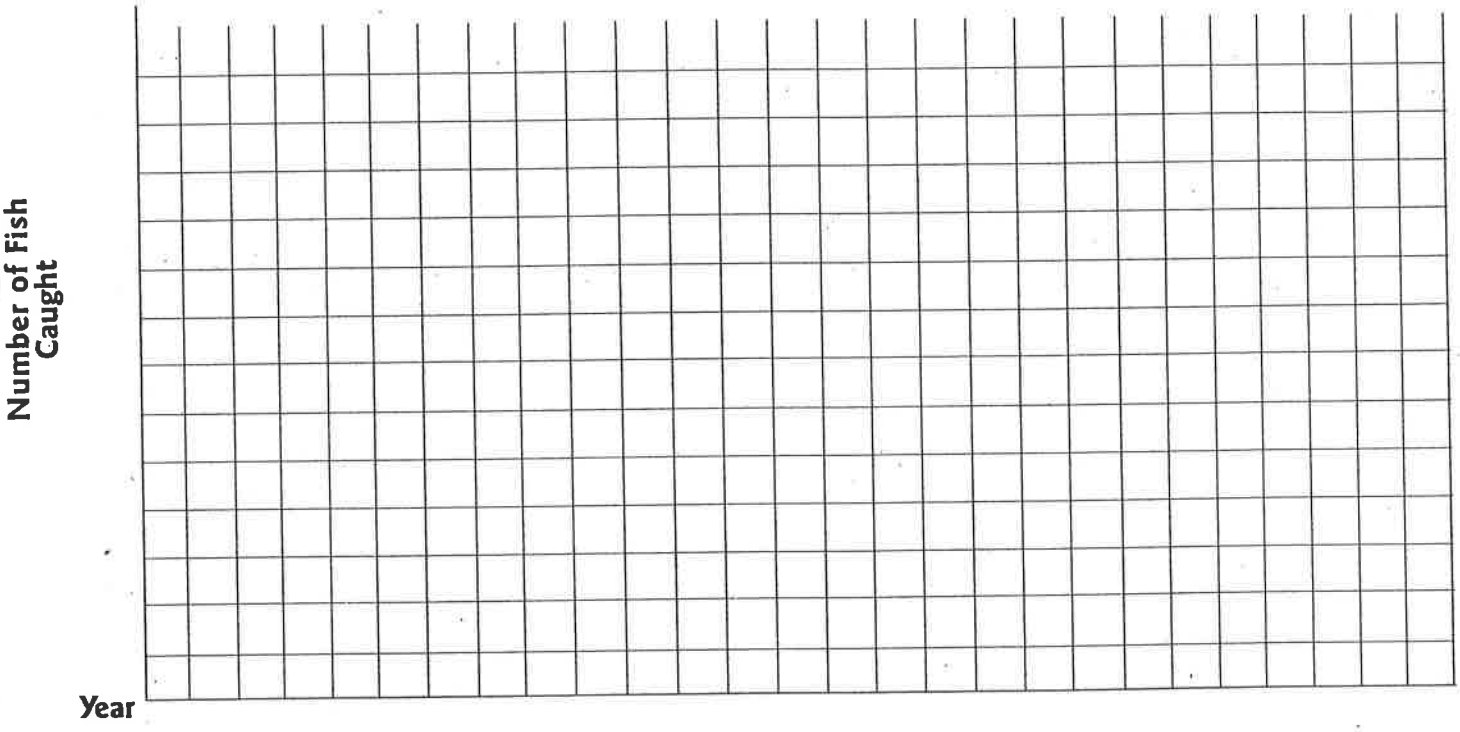
Directions:

Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Fishers
1. Treaty
2. Non-treaty
3. Sport

Chum



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Where Have All the Salmon Gone?-Aquatic WILD-
Student Worksheet Page 4c

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- Puget Sound Salmon Catches by species 1989-1998

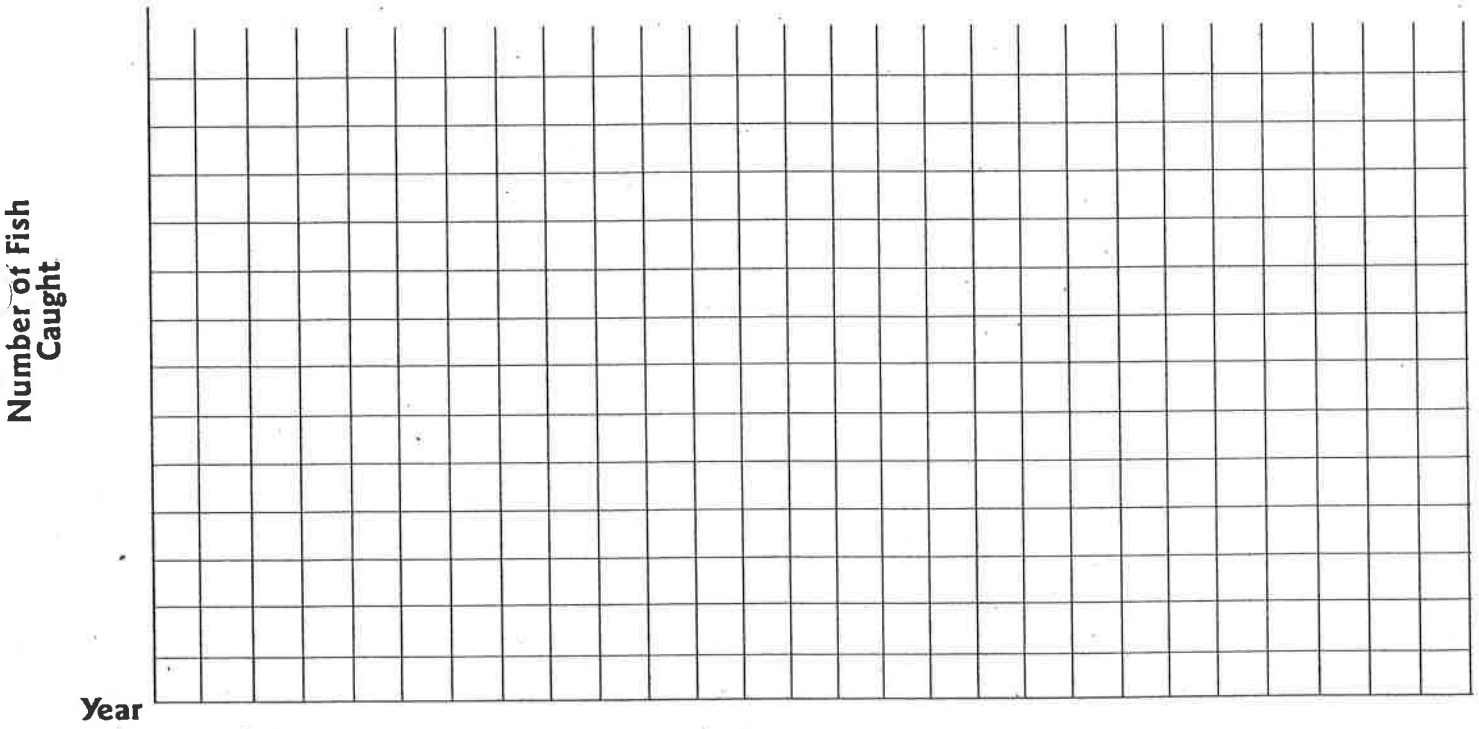
Directions:

Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Fishers
1. Treaty
2. Non-treaty
3. Sport

Pink



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Where Have All the Salmon Gone?-Aquatic WILD-
Student Worksheet Page 4d

Resources:

- Puget Sound Commercial Salmon Landing by species in Numbers of Fish from 1913 to 1998.
- Puget Sound Salmon Catches by species 1989-1998

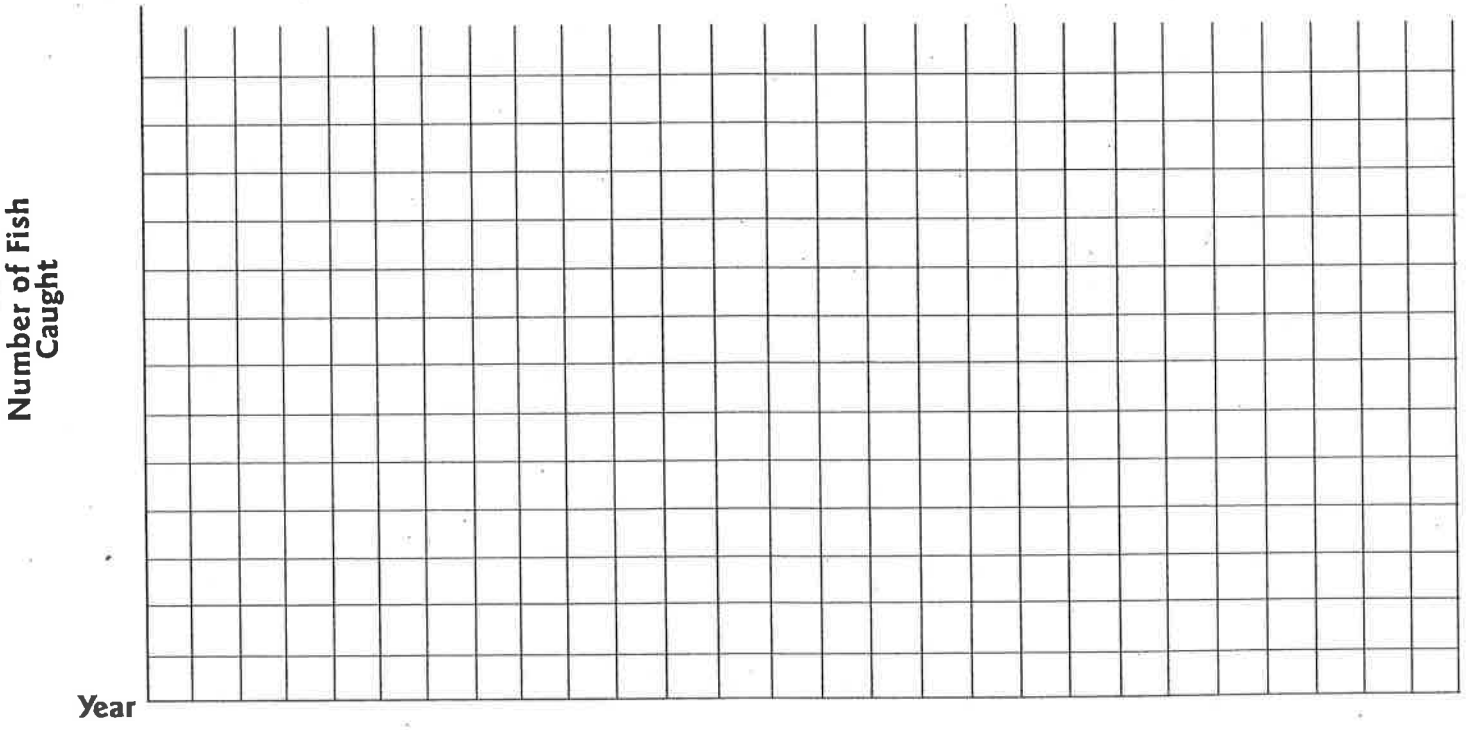
Directions:

Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Fishers
1. Treaty
2. Non-treaty
3. Sport

Coho:



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Where Have All the Salmon Gone?-Aquatic WILD-

Student Worksheet Page 4eP

Resources:

- Puget Sound Commercial Salmon Landing by species in Numbers of Fish from 1913 to 1998.
- Puget Sound Salmon Catches by species 1989-1998

Directions:

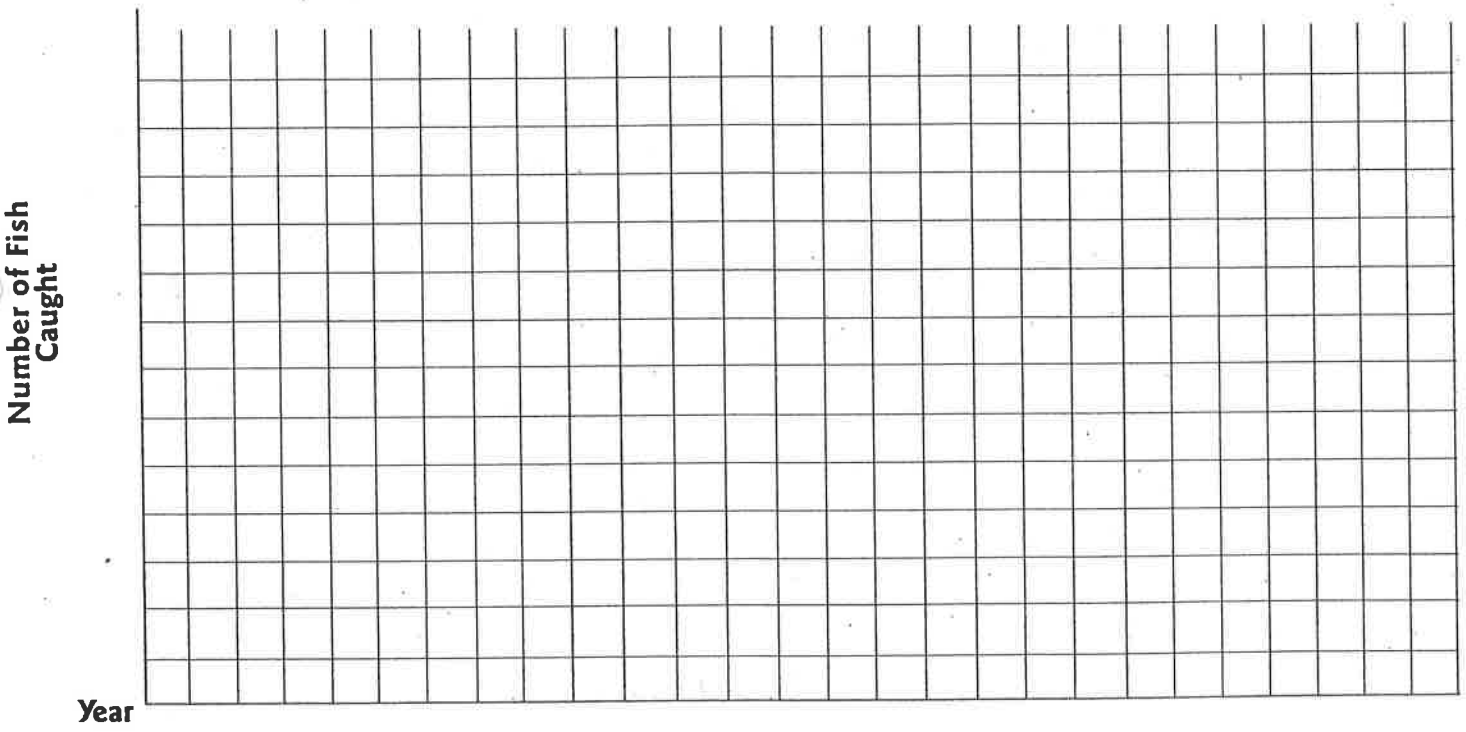
Using Puget Sound Commercial Salmon Landings by Species

- Graph this data for each species

Legend of Fishers

1. Treaty
2. Non-treaty
3. Sport

Sockeye



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Water Tenders
Spawning Ground
2nd Quarter 1999

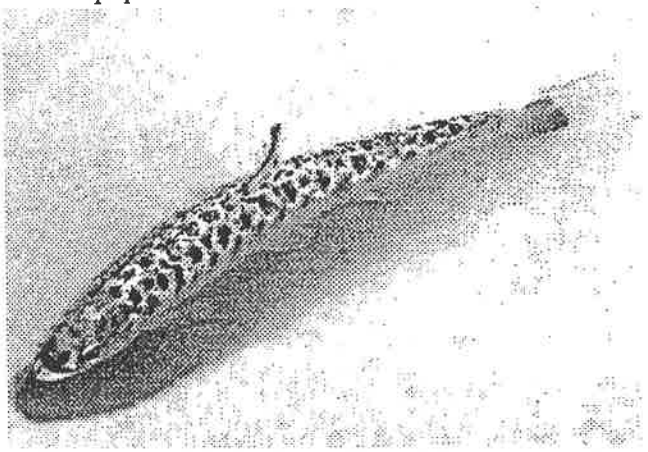
Evaluating Salmonid Production in Bear Creek

by Dave Seiler
Wild Salmon Production and Survival Evaluation Program,
Washington Department of Fish and Wildlife

To measure the status of various stocks of wild salmon, biologists routinely estimate the numbers of adult salmon returning to spawn. As the starting stock of the next generation, estimates of spawning populations are essential information for proper management. However, because the numbers of returning salmon reflect all of the conditions experienced by that brood, attributing the effects of any one factor, such as watershed health is difficult. In addition to the condition of the freshwater habitat, species interactions, year to year variation in factors such as temperatures and flows (before, during and after spawning, egg incubation and downstream migration), ocean conditions and harvest rates combine to obscure the relationship between the size of the parent spawning population and the numbers of adult salmon finally returning to the stream.

A first step in understanding the relative importance to salmon survival of these various factors involves quantifying populations as downstream migrants. Estimating the number of smolts produced from a given level of spawners determines the productivity of the watershed and stock. Over a number of broods, the factor(s) which cause variation in spawner to smolt survival rates are identified through correlation analysis. Estimating seaward migrants also enables estimating marine survival.

The Washington Department of Fish and Wildlife operates around thirty downstream migrant traps throughout the state to measure wild salmon populations as smolts. This work has been ongoing and generally increasing since the late 1970's. Through this program of annually monitoring smolt and adult populations for selected stocks in various habitats, we have made substantial progress on understanding the conditions critical for healthy salmon populations.



Young (about 3 inches long) Chinook Salmon Smolt *Oncorhynchus tshawytscha* from Bear Creek, digital photograph by Heather Poe

To address the decline of Lake Washington sockeye salmon, one of the actions that WDFW implemented in 1992 was devising a trapping operation in the lower Cedar River. Quantifying the numbers of hatchery and wild fry entering Lake Washington from the Cedar River provides the means to determine where the decline in sockeye survival is occurring and thereby direct appropriate remedial actions. Over the last nine years, operating this trap from January to June, we have measured in-river survival rates of the hatchery fry, fry production from wild spawners and estimated fry to smolt survival rates in Lake Washington. We

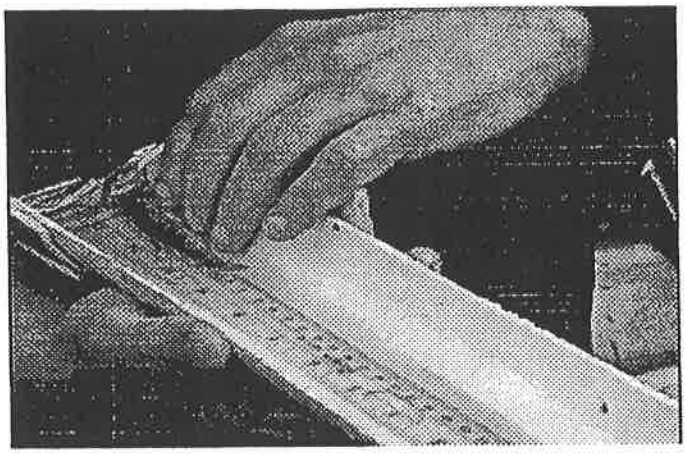
(Salmonoid Production continued on page 2)

(Salmonoid Production continued from page 1)

found that the severity of flood flows explains virtually all of the variation in the numbers of fry produced per natural spawner. In-river survival of the hatchery produced fry released at Landsburg is also a function of stream flows; survival increase with flow. While we are continuing this work, because survival in the lake is low, research is also being directed at understanding the species interactions taking place here while the fry are rearing to smolts.

Although the majority of the system's sockeye spawn in the Cedar River, on some recent broods, biologists have estimated that up to a third of the adults spawn in the tributaries to the Sammamish River Basin. As a basic goal of the sockeye research involves measuring lake survival, accomplishing this goal requires also estimating the numbers of fry entering Lake Washington from the Sammamish system.

In 1996, a large sockeye run returned to the lake, in excess of 500,000 fish. Biologists estimate that 60,000 spawned in tributaries to the Sammamish, the highest number on record. Unfortunately, this record run was followed by another record high. Recall the "Ice Storm" of January 1, 1997. This low elevation rain on snow event produced the highest flows recorded in the Slough. A month later, in February 1997, we began trapping sockeye fry in the Slough at Bothell. Over the season, we estimated only 900,000 sockeye fry survived the extreme high water. This production is a survival rate of just 1% of the 90 million eggs deposited.



Young Chinook Salmon *Oncorhynchus tshawytscha*, at Bear Creek, digital photograph by Heather Poe

In 1998 we again trapped in the Slough and estimated around 2 million fry from a much smaller spawning population. Flows were very moderate while the eggs were in the gravel and, as a result, survival was around 17%. These kinds of relationships indicate the importance of controlling storm runoff to prevent scouring of salmon eggs.

While this trapping operation yielded good estimates of sockeye fry production, the velocity in the Slough is too slow for capturing larger migrants; steelhead, coho, cutthroat, and Chinook. As the listing of fall Chinook loomed and the quantification of this species took on more importance, we elected to move the trapping effort to Bear Creek. This stream is by far the most important salmonid producer in the Sammamish system and also has sufficient flows to provide the requisite velocities to trap large migrants.

With funding from King County, we constructed and installed a floating "screw" trap in Bear Creek just downstream of Redmond Way. Supported in a thirty foot barge, this trap gently augers a portion of the downstream migrants into a holding tank. We have fished it continuously since February and

(Salmonoid Production continued on page 3)

Important Numbers

The Metropolitan King County Council
King County Courthouse
516 Third Avenue
Seattle, WA 98104
296-0100
Councilmember Louise Miller 296-1003
Dana Chapman (aide to Louise Miller) 296-0308

Ray Heller, Bear Creek Basin Steward 296-8391

Water Tenders
P. O. Box 402
Woodinville, WA 98072
Terry Lavender 788-2304
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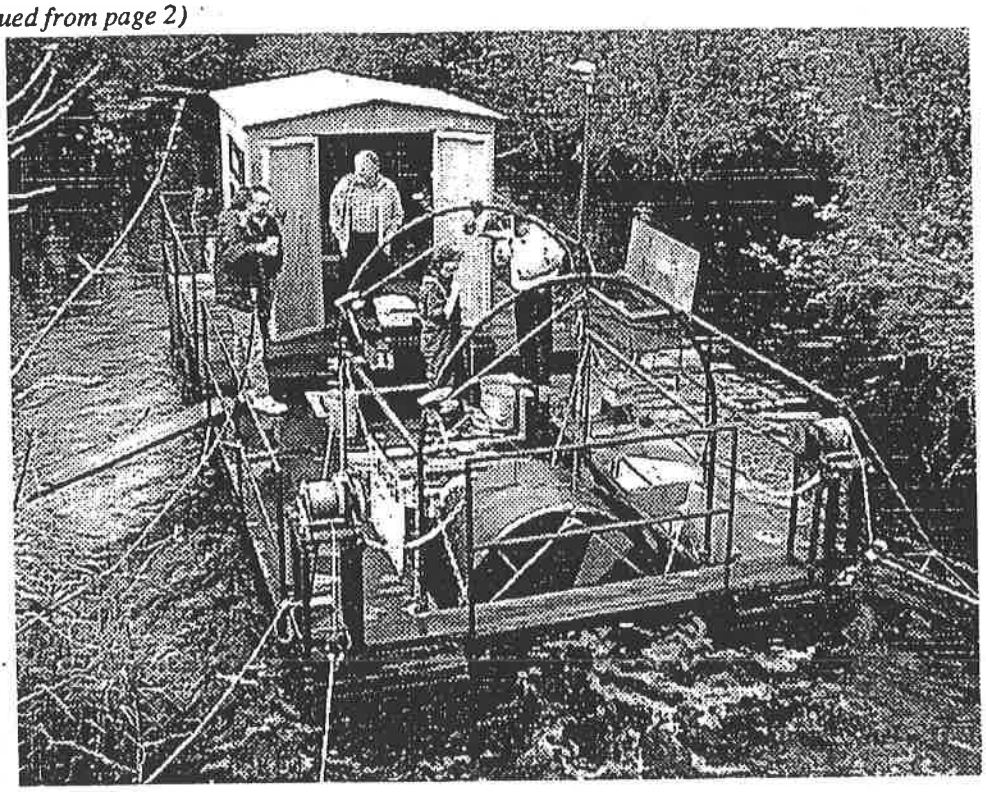
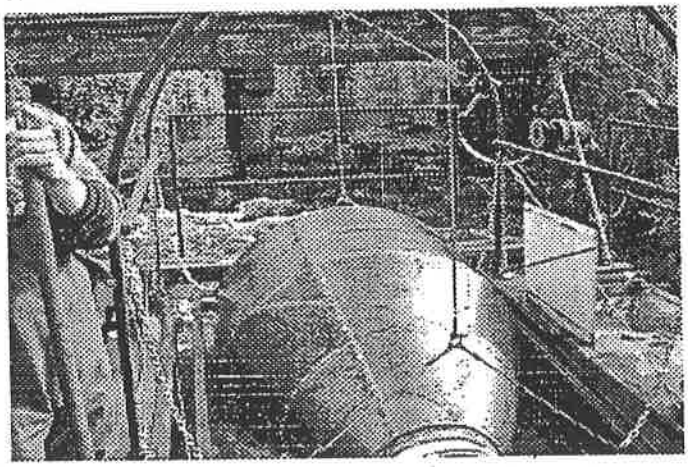
Heather Poe 788-9092 (editor, fax 788-9093)
Nancy Stafford 788-5841
Wendy Walsh 788-4434
Judy Westall 788-9372
(Annual dues are $15.00, please mail to the P. O. Box)

(Salmonoid Production continued from page 2)

plan to continue until the Chinook migration is completed. At least twice a day, a WDFW Scientific Technician checks the trap and enumerates the catches before release. During periods of high flows/debris and or intense fish migrations a worker stays onboard to insure that captured fish are safe. Each day, numbers permitting, we release a group or two of marked fish above the trap to calibrate its capture rate. Trap efficiency varies between species and also as a function of flow but over the season, thus far it has ranged from 10% to 40%.



Above, input end of trap. Main body of trap funnel, bottom left. Bottom right, output end of trap funnel.
Digital photographs by Heather Poc



After we compile and analyze all the data we will produce a report that documents the numbers of Chinook, coho and sockeye salmon and steelhead and cutthroat trout produced from Bear Creek. In addition to these salmonid we also count and record all other fishes captured. Also noteworthy is the evaluation of the hatchery produced steelhead which were stocked into Bear Creek in 1997 as fingerlings. All 13,000 of these fish were marked with excision of the adipose fin. Over the season we have examined each steelhead smolt captured for this mark and recorded the numbers of marked and unmarked.

It has been a pleasure working in Bear Creek. City officials have been supportive, residents very interested and positive, several high school classes have come out on field trips, and not one instance of vandalism or theft has occurred. We appreciate the Redmond Police keeping an eye on the project. Blockbuster Video has graciously provided electricity throughout the season greatly improving our safety and comfort through many long nights in the trap house. Anyone is welcome to come and check out the trap and see the wild salmon that Bear Creek is producing.

STATE OF WASHINGTON
DEPARTMENT OF FISH & WILDLIFE
FISH MANAGEMENT PROGRAM
RESOURCE ASSESSMENT DIVISION

January 22, 1999

TO: Bill Tweit

FROM: Dave Seiler

SUBJECT: **WILD COHO FORECASTS**

Attached for your information and consideration are my 1999 wild coho run forecasts for all Washington state production areas outside the Columbia River. These estimates are based primarily on the results of the *Wild Salmon Production & Survival Evaluation Unit*'s long-term research and monitoring program. I welcome any additional data, comments, and questions.

DS:lek

Attachments

cc: Bruce Crawford
Lew Atkins
Rich Lincoln
Ross Fuller
Pat Pattillo
Chuck Phillips
Tim Flint
Dan Rawding
Phil Anderson
Larrie Lavoy
Doug Milward
Jim Packer
Dick Geist
Teresa Scott
Jim Ames
Bruce Sanford
Lee Blankenship
Tony Floor

1999 WILD COHO FORECASTS
FOR PUGET SOUND & WASHINGTON COASTAL SYSTEMS

Washington Department of Fish & Wildlife
Dave Seiler

Run size forecasts for wild coho stocks are an important element of the joint state-tribal pre-season planning process for Washington State salmon fisheries. Accurate forecasts on a stock basis are required to ensure adequate spawning escapements, while realizing harvest benefits and achieving allocation goals.

Various approaches have been used across this state's coho producing systems to predict ocean recruits. Most of these methods rely on the relationship between adult escapement estimates and resultant run sizes. Reconstructing coho run sizes, however, is notably difficult due to the problems of accurately estimating escapements and the inability to allocate catches in intercepting fisheries, by stock. Even if the run size data bases were reasonably accurate however, in systems that are adequately seeded, coho forecasts based solely on estimated escapement have no predictive value. Such forecasts do not account for the two primary and independent components of interannual variation in run size, freshwater and marine survival. Moreover, because adult to adult forecasts combine these two parameters, understanding the components of error in such forecasts post-season are precluded. Improving our ability to manage wild coho runs depends on learning which factors cause significant variation in abundance for each major system.

Smolts are the measure of freshwater production. In recognition of this, natural coho escapement goals throughout this state are based on the projected smolt carrying capacity of each system. To assess these goals and to improve run forecasts, WDFW and tribes have made substantial investments in monitoring smolt populations in a number of basins. These data have been incorporated into some forecasts, but, until recently, have not been used on a consistent basis or in all systems.

Marine survival rates for wild coho stocks have also been measured over many years at several stations in Puget Sound and at one station in the Grays Harbor system. These data describe the patterns of interannual and inter-system variation in survival within broods. Given the extreme difficulty in estimating coho escapements with survey-based approaches, only those tag groups returning to trapping structures with 100% capture capability throughout all flows estimate marine survival without bias.

Adult recruits are the product of smolt production and marine survival. Therefore, any estimate of adult recruits can be expressed in a simple matrix as combinations of these two components. Through a process of comparing the outcomes for each term relative to measured and or likely values, the veracity of forecasts derived from methodologies not employing smolt and marine survival estimates can be assessed. Understanding variation in hatchery runs, for example, is reduced to analyzing the components of post-release survival because the number of smolts released, the starting population, is known.

Fisheries are managed to achieve escapement goals for natural/wild coho stocks returning to eight production areas. These systems include; Skagit, Stillaguamish/Snohomish, Hood Canal, Straits, Quillayute, Hoh, Queets, and Grays Harbor. While the forecasts to these systems, which are considered the "primary" wild coho management units, will be used to determine the extent and shape of fisheries, production from all the other freshwater habitat units can also be approximated by extrapolating measured rates. Expressing natural coho production in the common terms of smolts will enable useful interannual comparisons within systems and annual comparisons across systems. This also should promote better understanding by stakeholders as it more directly connects coho production with habitat.

Presented in Tables 1a-b are the forecasts of coho run size derived by combining estimates of natural smolt production and predictions of marine survival for all Puget Sound and Coastal production areas. The resultant estimates of three year old ocean recruits were "backed up" to estimate the population in terms of December Age 2 recruits. The following sections detail each estimate of smolt production and marine survival.

Table 1a. Wild coho run forecasts for Puget Sound in 1999, based on estimates of smolt production and marine survival.

Production Unit	FRESHWATER PRODUCTION Projected Smolt Prod. (Zillges)	Est. Actual Smolt Prod. Spr. 1998	Ratio Actual/ Projected	X MARINE SURVIVAL Adults (Age 3)	Dec. (Age 2)	= RECRUITS Adults (Age 3)	Dec. (Age 2)
Primary Units							
Skagit River	1,371,058	1,760,000	**128%**	6.9%	9.2%	120,971	161,859
Stillaguamish River	864,094	529,000	61%	6.9%	9.0%	36,360	47,595
Snohomish River	2,027,497	1,470,000	73%	9.8%	12.8%	144,174	188,724
Hood Canal	1,006,577	551,000	**55%**	9.9%	13.2%	54,806	72,618
HCJTC estimate	561,631	422,000	**75%**				
Straits of Juan de Fuca	443,098	161,000	**36%**	5.0%	6.7%	8,007	10,761
Secondary Units							
Nooksack River	451,275	226,000	50%	6.9%	9.2%	15,534	20,706
Strait of Georgia	51,821	26,000	50%	6.9%	9.2%	1,787	2,382
Samish River	169,489	100,000	59%	6.9%	9.2%	6,873	9,162
Lake Washington	842,253	42,000	5%	3.8%	4.8%	1,583	2,025
Green River	541,239	162,000	30%	3.8%	4.8%	6,107	7,811
Puyallup River	575,536	173,000	30%	3.8%	4.8%	6,522	8,342
Nisqually River	200,314	20,000	10%	3.8%	4.8%	754	964
Deschutes River	219,574	6,000	**3%**	3.8%	4.8%	226	289
South Sound	573,770	86,000	15%	3.8%	4.8%	3,242	4,147
East Kitsap	154,973	46,000	30%	3.8%	4.8%	1,734	2,218
Puget Sound Total	10,054,199	5,780,000	57%			408,681	539,605

Note: Ratios in bold indicate "actual" estimates based on smolt trapping in Spring 1998.

Table 1b. Wild coho run forecasts for Washington Coastal Systems in 1999, based on estimates of smolt production and marine survival.

Production Unit	Drainage Area mi^2	SMOLTS Freshwater Production Spr. 1998	x MARINE SURVIVAL Adults (Age 3)	Dec. (Age 2)	= RECRUITS Adults (Age 3)	Dec. (Age 2)
Coast						
Quillayute River	629	236,000	2%	2.6%	4,720	6,136
Queets River	450	154,000	2%	2.6%	3,080	4,004
Hoh River	299	102,000	2%	2.6%	2,040	2,652
Quinault River	434	87,000	2%	2.6%	1,740	2,262
Independent Tributaries	424	170,000	2%	2.6%	3,400	4,420
Grays Harbor						
Chehalis River	2,300	2,857,000	2%	2.6%	57,140	74,282
Humptulips River	250	311,000	2%	2.6%	6,220	8,086
Willapa Bay	850	425,000	2%	2.6%	8,500	11,050
Coastal Systems Total	5,636	4,342,000			86,840	112,892

Independent Tribs =

Stream Name	Drainage Area
Waatch River	13
Sooes River	41
Ozette River	88
Goodman Creek	32
Mosquito Creek	17
Cedar Creek	10
Kalaloch Creek	17
Raft River	77
Camp Creek	8
Duck Creek	8
Moclips River	37
Joe Creek	23
Copalis River	41
Conner Creek	12
	424

SMOLT PRODUCTION

A substantial level of coho smolt production evaluation work has been conducted in each of the eight major natural production systems except the Hoh. In the Skagit River, total smolt production has been estimated annually since 1990. We have also estimated total system smolt production from the Chehalis Basin, the largest watershed in the state accessible to anadromous fish outside of the Columbia River, annually since 1986. Smolt production has also been measured from significant portions of the Snohomish, Stillaguamish, Hood Canal, Quillayute, and Queets systems. In aggregate, this work has produced a body of information that describes wild coho carrying capacity among these systems, largely as a function of habitat quality and quantity. Seeding levels, environmental effects (flows), and human-caused habitat degradation explain much of the interannual variations in smolt production that we have measured (Table 2).

While annual smolt monitoring in each major system (as presently conducted on the Skagit River) would be optimal, sufficient information exists to approximate production in systems currently unmeasured. The method of extrapolating annual measured results to estimate production from other systems varies, as it depends on the data available. Within Puget Sound, **WDF Technical Report 28** Zillges 1977 (T.R.28), provides the means of transferring smolt production monitoring results to other basins. This document, which is the basis for most Puget Sound wild coho escapement goals, contains estimates of the wetted habitat at summer low flow, and projections of potential coho smolt production for each stream in Puget Sound (east of Cape Flattery). For coastal systems, smolt production in unstudied watersheds can be approximated by extrapolating the smolt production per square mile of drainage basin rates measured in the study streams.

Puget Sound Primary Units: Managed for Natural Escapement

Skagit River. Spring 1998 was the ninth year of estimating total smolt production from this system. This estimate is based on trapping and marking wild coho in tributaries and sampling emigrants in the lower mainstem river with floating scoop and screw traps. In the first eight years, production ranged from 618,000 to 1,174,000 coho smolts. Prior to 1997, all of the high productions occurred on even years, while production during odd years was approximately half. We explained this pattern with the hypothesis that adult pink salmon, which spawn only on odd years, provided a positive interaction. While this relationship may still be valid for most years, for the 1995 brood, which produced the highest number of smolts since 1990, it was apparently overridden by beneficial flows during freshwater rearing. This contention is supported by the record high smolt production we also measured in two other systems in 1997.

In 1998, we estimated 1,760,000 coho smolts emigrated from the Skagit River (Table 3). This is the highest coho smolt production we have yet measured in this system. As with the previous brood, we attribute this record high production in 1998 to beneficial flow effects. From spring through summer 1997, the Skagit system had record high flows. Apparently, this abundance of water, provided by a heavy winter snow pack, reduced the constraint of summer low flows, enabling a higher population to survive into the fall. Throughout the fall and winter, peak flows

were relatively benign, which contributed to the high smolt production from the 1996 brood by not displacing juveniles downstream. This was evident from the high smolt counts from the upper tributaries trapped, relative to those lower in the system. Conversely, on broods which experience high winter flows, fewer smolts emigrate from the upper tributaries in the Spring, relative to lower tributaries.

Stillaguamish River. We estimated smolt production from the Stillaguamish River upstream of R.M. 16 in three years (1981-1983). Production from these broods, which we deemed were fully-seeded, ranged from 203,000 to 379,000, and averaged 276,000 coho smolts. Expanding for the portion of projected smolt production (T.R.28) downstream of this point (23%), mean system production was estimated at 360,000 smolts. Given the record high production we measured in the Skagit River in 1998, we expect Stillaguamish coho smolt production was also well above average. Applying the Skagit factor of 1.94 (the ratio of the 1998 production to its previous eight-year average of 907,367 smolts) to the average Stillaguamish production, estimates 698,000 smolts. This estimate may be high, so we selected the value of 529,000 smolts, which is midway between average production (360,000 smolts) and that estimated with the Skagit factor. This adjustment accounts for the lower average elevation of the headwaters of the Stillaguamish, relative to the Skagit River, and it therefore retains less snow for water supply during the summer.

Snohomish River. We measured smolt production from known numbers of spawners in the South Fork Skykomish River over nine brood years (1976-1984) (Figure 1). This basin comprises 20.7% of the Snohomish River system's drainage area. Excluding the three years in which we reduced escapement, production averaged 276,000 smolts. These estimates were generated using "back-calculation"; determining mark ratios upon adult return. Consequently, they include production which reared downstream of Sunset Falls. Trapping-based estimates for these six broods indicate that around 75% of these estimated productions emigrated as smolts from above Sunset Falls. Adjusting the estimates by this rate yields an average production of 207,000 smolts that remained above Sunset Falls until spring. Expansion of this estimate to the entire system calculates an average total production of 1,000,000 coho smolts. This estimate may be biased high because 450 mi^2, 26% of the 1,714 mi^2 Snohomish Basin, is inaccessible to anadromous fish. This area includes the Snoqualmie River, above Snoqualmie Falls (375 mi^2), and the Sultan River above the dam (75 mi^2). Countering this bias, however, is the fact that much of the rest of the basin is lower gradient than the watershed above Sunset Falls, and therefore, more productive. Based on the record high production we measured from the Skagit River, we expect Snohomish Basin smolt production was also above average in 1998, but not to the same extent. As with the Stillaguamish, the Snohomish Basin has a lower mean elevation than the Skagit system. In addition, two other factors combine to reduce Snohomish Basin coho smolt production from former levels: development has impacted lower basin tributaries; and the "ice storm" on January 1, 1997, produced high flows in low elevation tributaries, which resulted in high egg mortality. Using the Skagit expansion factor (1.94) estimates Snohomish coho production at 1,940,000 smolts. Because this appears too high, we selected the median value between the average and that estimated with the Skagit factor, to estimate 1,470,000 smolts.

Hood Canal. In previous years we trapped four independent tributaries to Area 12. In 1998 we could not trap one of these streams, Little Anderson Creek, because extreme habitat degradation

(sedimentation) resulting from development, obliterated the stream channel. We trapped Big Beef, Stavis, and Seabeck Creeks, which produced 22,222, 5,979, and 1,393 coho smolts, respectively. Production in both Big Beef and Seabeck Creeks were slightly below average, while Stavis Creek was above average. In Big Beef Creek, production from the relatively high spawning escapement of 698 females upstream in 1996 was negated by the record high flow produced by the "ice storm" on January 1, 1997. This storm produced a peak discharge, estimated at 1,600 cfs, over double the previous record high flow. Relatively high flows during Summer 1997 (almost double the average of the last seven years) provided some compensation through above-average rearing survival. The 22,000 smolts produced represent an average production rate of 31.8 smolts/female.

The coho production potential of tributaries to Hood Canal was originally estimated at 1,006,577 smolts (T.R.28). A more recent review by the Hood Canal Joint Technical Committee (HCJTC) has revised this estimate downward to 561,631 smolts. Both of these estimates were predicated upon adequate seeding and average environmental conditions. Assuming our three study streams represent coho smolt production in tributaries to Hood Canal, system production in 1998 is estimated at 550,520 and 422,000 smolts, based on T.R.28 and HCJTC, respectively. Wild coho escapements in Hood Canal in both 1997 and 1998 have been around 100,000 spawners. The run sizes which produced these escapements resulted from higher smolt production levels than projected by the HCJTC. Consequently, for 1999, we selected the higher T.R.28-based projection, of 550,520 coho smolts (Table 4). Even this smolt projection is likely conservative, however, because the three streams we trapped have suffered more development-caused habitat degradation than the major coho-producing systems (Dewatto, Union, and Tahuya Rivers) located further south.

Straits of Juan de Fuca. In Spring 1998, WDFW and the Lower Elwah S'Klallam Tribe initiated smolt trapping in nine Straits' tributaries, from (east to west) the Dungeness River to Little Hoko Creek (Tables 5a-b). In the Dungeness, we operated a screw trap in the mainstem, and a fence trap in Mattriotti Creek, a lower-river tributary to this system. Our preliminary estimate, based on this work, is 50,000 coho smolts for this 198 mi^2 watershed, a production rate of 253 smolts/mi^2. We used this rate to project smolt production for the other six systems with mainstem habitat (Table 5a). T.R.28 computes smolt production potential on the basis of wetted habitat area in streams with widths less than 6 yds, and uses a linear rate for mainstem areas ≥6 yds. To approximate production in the smaller independent streams, we applied the average production rate (5.9 smolts/100 yd^2) measured in the six independent small streams trapped to the total wetted habitat area (Table 5b). This approach estimates 42,000 smolts were produced from the small independent tributaries to the Straits in 1998. We excluded the production information collected from Mattriotti and Little Hoko Creeks from this estimate because these two streams are tributaries to larger systems, and therefore, do not represent independent streams. Summing the large stream and small stream estimates project a total production of 161,049 coho smolts. Continued smolt monitoring in this region will determine what portion of carrying capacity this production level represents. The production estimated in 1998 lies between the 222,000 smolts we projected in 1997 and the 133,000 smolts in 1995 and 1996.

Puget Sound Secondary Units; Managed for Hatchery Harvest Rates

Nooksack River. Considering the extent of habitat degradation and underseeding due to high harvest rates, we expect natural smolt production from the Nooksack River system was well below projected potential in 1998. We used a value of 50% of the production projected by T.R.28 to estimate 226,000 smolts in 1998. This rate is an increase from the 30% we used last year, based on the higher production we measured in the Skagit River.

Strait of Georgia. We also selected the value of 50% of the projected production (T.R.28), to estimate 26,000 smolts in 1998.

Samish River. Assuming that virtually all of the returning adult coho enumerated at the Samish Hatchery are wild fish (which scale sampling/analysis in 1996 confirmed), production is typically well in excess of the 58,000 smolts projected in (T.R.28). In some recent years, 10,000 adult coho have returned. Even at a relatively low harvest rate of 50% and a high marine survival of 20%, production would be estimated at 100,000 smolts, almost double the projected production. If harvest rates were higher and/or marine survival lower, then even more smolts were produced. We used 100,000 smolts as our best approximation of production.

Lake Washington, Green River, Puyallup River, and Nisqually River. Coho production in each of these systems are impacted by habitat degradation through development, diking, water withdrawals, and underescapement due to high, hatchery-directed harvest rates. Each of these systems also contains a dam on the mainstem, which blocks access to the upper watershed. Hatchery fry are outplanted in an attempt to mitigate for the presumed underseeding by natural spawners. While these outplants may contribute to production, it is likely that resultant smolt production is lower than would be achieved with adequate numbers of natural spawners.

For the Lake Washington system, we used the very low rate of 5% of the projected production (T.R.28) to reflect our belief that in this most urbanized watershed, the estimated 842,253 smolt potential is unrealistically high. Not only has development continued to reduce production potential, but the T.R.28 projection includes 192,500 smolts estimated as the production component occurring in the lake. Recent investigations of its fish populations have found virtually no coho rearing in the littoral or pelagic zones of Lake Washington. In addition, a comprehensive electro-shocking survey of Lake Washington Basin tributaries found very low densities of juvenile coho in late-summer (Kurt Fresh, pers.comm.). In this low-elevation watershed, the 1996 brood was devastated by the January 1, 1997 "ice storm". This rain-on-snow event produced record-high flows in the Sammamish River. One measure of the impact of this storm was the 99% mortality that we measured on naturally-produced sockeye fry in the Sammamish system in 1997. The potential egg deposition (P.E.D.) of 90 million eggs from a spawning escapement of 60,000 sockeye in 1996 produced only 900,000 fry in 1997. Recent, very low coho escapement estimates also indicate natural smolt production is very low in this system. For example, in 1998, the natural spawning escapement estimate will likely be <1,000 coho. At a survival-to-return rate of 3%, this equates to a production of only 30,000-40,000 smolts.

We selected a value of 30% of the production projected by T.R.28 for the Green and Puyallup Rivers.

For the Nisqually River, we discounted projected production even more, with a rate of 10%. We used this lower rate based on the very low smolt production we have measured from the nearby Deschutes River. Natural coho production in the Nisqually has also suffered from very low escapement as a result of habitat degradation, poor marine survival, and overfishing.

Deschutes River. A number of factors have combined to severely depress production in this system: habitat degradation, particularly in the upper watershed; low reproductive potential due to small fish size; and low escapement. Escapements have declined as a result of poor smolt production due to habitat degradation, extreme high flows during egg incubation, and poor marine survival. In the 1990s, marine survival for Deschutes coho is even lower than other Puget Sound stocks. This may indicate a reduction in the productive potential of the South Sound marine environment.

Based on trapping in 1998, we estimated only around 6,000 smolts emigrated from this system. As in 1997, this level of production is the lowest we have measured in 20 years of continuous monitoring. In 1996, the spawning escapement, comprised of 188 females and 276 males, was followed in late-December by the "ice storm", which produced a peak flow of 4,350 cfs. While not the highest flow on record, it was certainly destructive to incubating eggs. Relating smolt production to this escapement yields only 32 smolts/female, the same rate we measured at Big Beef Creek on this brood. Typically, coho populations compensate for very low seeding rates through density-dependent survival, producing over 100 smolts/female, as we measured at the South Fork Skykomish (Figure 2). The ice storm caused such high egg mortality, that the surviving fry population was simply too low for compensatory mechanisms to offset this loss. Consequently, the 1998 smolt production represents only one third of the 18,000 smolts that this system should have produced.

South Sound. This production area includes all of the independent tributaries to Puget Sound, south of Area 10 (Seattle), excluding Lake Washington, and the Green, Puyallup, Nisqually, and Deschutes Rivers. We applied 15% to the production projected by T.R.28. This rate — which is lower than that measured in Hood Canal (55%), but much higher than the 3% estimated for the Deschutes — reflects our belief that production from these streams has not only suffered many of the same problems that have impacted Deschutes River coho, but even more habitat degradation due to development and, for this brood, the ice storm.

East Kitsap. The streams in this region are small and similar in character to those we trap in Hood Canal. However, habitat degradation, largely from development, has probably had a greater impact in the East Kitsap region than in our study streams. Therefore, we discounted the reduction factor from the 55% estimated in Hood Canal to 30% of the production projected by T.R.28.

Coastal Units

Quillayute River. We have measured smolt production in two sub-basins of the Quillayute River — the Bogachiel and Dickey Rivers. Over three years, production from the Bogachiel River averaged 53,751 smolts. Relating this production to the 129 mi^2 upstream of the trap estimates an average of 417 smolts/mi^2. This work also included evaluating fry plants, and as a result, we concluded that the system was already seeded to capacity by natural spawners.

Over three years, production from the Dickey River averaged 71,189 smolts from the 87 mi^2 upstream of the trap. Production/area in this system averaged 818 smolts/mi^2. We attributed this production rate, higher than that measured in the Bogachiel, to this system's low gradient and resultant abundant summer and winter rearing habitat. Results also indicate this system was probably seeded to capacity.

To estimate average system smolt production, we applied these average production/area values to the Quillayute system (629 mi^2). Based on stream character, we assumed the Bogachiel average production/area value (417 smolts/mi^2) best represents production in the majority (521 mi^2) of the Quillayute watershed (excluding the Dickey River Basin), which is relatively high gradient. Including the average estimated production from the Dickey River's 108 mi^2 drainage area (88,344 smolts) calculates an average system production of 306,000 smolts.

To estimate production in 1998, we adjusted this average production estimate by the ratio of 1998 Clearwater production to its long-term average. QFiD biologists estimated that the Clearwater River produced 47,800 smolts in 1998, 77% of its 18 year average (61,700 smolts). Application of this rate to the average Quillayute production estimates 236,000 coho smolts were produced in 1998.

Queets River. Smolt production has been measured from the Clearwater River each Spring since 1981. Over the first 15 broods, coho production ranged two-fold between extremes, from around 43,000 to 95,000 smolts. Estimates of parent spawners have ranged six-fold, from around 300 to over 1,900 females but explained none of the variation in smolt production prior to brood year 1994. Instead, we found, through an analysis of flows during the entire freshwater life, that the severity of flow on one day during egg incubation explains over half the variation in smolt production (Figure 3).

In brood years 1983 and 1994, however, it appears that low escapements did reduce smolt production. In 1996, QFiD biologists estimated only 35,000 coho smolts were produced from the Clearwater River. Not only is this estimate the lowest on record, but it falls well below the value predicted by the flow relationship (Figure 3). Relating this estimate to the 260 females estimated in the 1994 escapement, yields an average of 135 smolts/female, which is a high value (Figure 2). These outcomes indicate that the low escapement in 1994 was probably inadequate to seed the system, and as a result, smolt production was limited in 1996.

In 1998, QFiD estimated that the Clearwater River produced 47,800 coho smolts (pers.comm. Dan Eastman). This value is considerably lower than the 63,000 smolts the flow relationship

predicts, even though spawning escapement in 1996 was more than sufficient to seed the system. We attribute this discrepancy to the effects of the extreme high flows measured in the Queets River (91,000 cfs), which occurred on March 19, 1997. High flows at this time displaced downstream 1996 brood coho fry already emerged from the gravel, leaving upper reaches of the Clearwater underseeded, and caused high mortality on any eggs still incubating.

We estimated coho smolt production for the entire Queets system at 154,000 smolts by applying the production rate measured in the Clearwater (341 smolts/mi^2) to the 450 mi^2 Queets Basin. QFiD biologists may refine this projection through their seining project at the mouth of the Queets River.

Hoh River. Due to the similarity and proximity of the Hoh watershed to that of the Clearwater River, we used the Clearwater rate to approximate Hoh River coho smolt production in 1998. The rate of 341 smolts/mi^2 applied to the 299 mi^2 drainage area of the Hoh system estimates 102,000 coho smolts were produced.

Quinault River. Low escapement due to high hatchery harvest rates and degraded habitat likely combined to limit natural smolt production from this system. To reflect these effects, we used the relatively low rate of 200 smolts/mi^2. This rate, applied to the total area in this basin (434 mi^2), estimates total production at around 87,000 smolts.

Independent Tributaries. Smolt production has not been directly measured from any of the independent coastal tributaries. Application of an average production rate of 400 smolts/mi^2 to the total watershed area (424 mi^2) estimates 170,000 coho smolts were produced from these systems (Table 1b). The value of 400 smolts/mi^2 was selected, higher than the rate measured in the Clearwater River in 1998, for two reasons: drainage area values were not available for some of the minor tributaries, thus the total area estimate is low; and many of these systems have lower gradients than the Clearwater River and, therefore, production/area should be higher.

Grays Harbor. We have estimated coho smolt production from the Chehalis River system each year since the 1980 brood. This estimate relies upon annually trapping/tagging wild smolts, and CWT sampling adults caught in the Quinault Tribe's terminal net fishery in the lower Chehalis River. Resultant estimates have ranged seven-fold, from around 0.5 million to 3.5 million (Table 6). Analysis to understand the components of variation has determined that only one variable, flow during spawning, explains a significant portion (59%) of the interannual variation in estimated smolt production (Figure 4).

We excluded two brood years from this analysis (1990 and 1994). Tagging on the 1990 brood was limited, and therefore, also likely not representative. As a result, only six wild tagged adult coho were recovered in an estimated 2,104 wild fish sampled, a very low incidence of 0.29%. This value estimated an unreasonably high wild production of almost six million smolts. The minimum spawning flow in 1990, however, was quite high (1,130 cfs), so although it is likely that smolt production was high on this brood, we have little confidence in this estimate. We also excluded the 1994 brood because escapement was extremely low: less than 10,000 spawners. Upon adult return in 1997, we estimated only around 500,000 smolts were produced from this

brood. This brood experienced the highest minimum flows during spawning, however, which helped compensate for the low escapement.

The flow/production relationship is even stronger than indicated by the correlation coefficient. For the three broods with production below the regression line, other important brood-specific factors were in effect.

- The 1989 brood was impacted by the severe storm which produced extremely high flows on January 10, 1990. On this date, the Chehalis River flooded, closing Interstate-5. This storm scoured spawning gravels in higher-gradient stream reaches, which reduced egg survival and triggered mass wasting events.
- The 1986 brood was reduced by the effects of the devastating drought of summer 1987 which resulted in the lowest production on record from Bingham Creek (Figure 5).
- The 1982 brood may have been constrained by low escapement.

Apparently, in the low gradient, rain-fed, over-appropriated-for-water-withdrawals Chehalis River system, the level and timing of significant flow increases during spawning (November and December) is an important determinant of natural coho production. The most plausible hypothesis we have to explain this finding is that access to the upper portions of streams throughout this watershed is a function of flow. In such very dry fall seasons as the 1987 drought, adult spawners simply cannot ascend as high in tributaries as they can in wetter years. Because fry emerge from redds and distribute generally downstream, despite favorable flow conditions following spawning, the proportion of the watershed available for rearing juveniles is largely determined by the upstream extent of the spawning population.

Correlation of estimated escapement with the estimates of smolt production explained only 11% of the interannual variation. Analyzing flow effects during other periods — winter (incubation), spring (fry distribution), and summer (fry rearing) — also yielded insignificant correlations.

For the fourteen broods analyzed, this flow correlation indicates that natural seeding rates have been adequate, perhaps with the exception of the 1982 brood. It also appears that the fry planting program has not produced enough smolts to obscure this effect of flow on natural production.

This relationship provides a means to predict freshwater production, for broods with adequate spawning escapements. Escapement in 1996 was very high, in excess of 100,000 spawners. This estimate is the product of our relatively low smolt estimate in 1995 (1.2 million) and a record high survival-to-return rate (9.0%) we measured at Bingham Creek in 1996. The record high return to the Elk Creek fishway/trap in 1996 (over 1,700 wild adult coho) corroborates this estimate.

In Fall 1996, the minimum spawning flow during November and December, recorded at Grand Mound, was 1,080 cfs. This flow predicts a production of 2,857,000 smolts in Spring 1998. Relating this estimate to the Chehalis Basin drainage area of 2,300 mi^2 (including the Wishkah, Hoquiam, Johns, and Elk Rivers, and other southside tributaries) yields an average production/area of 1,242 smolts/mi^2. Assuming this rate is also correct for the 250 mi^2 Humptulips River system, we estimate 311,000 smolts from this system.

Willapa Bay. The Willapa Basin, with a total area of 850 mi^2, is drained by four main river systems and a number of smaller tributaries. Little empirical smolt production evaluation work has been conducted in this system. Given the presumed high harvest rates in Willapa Bay, and the generally degraded condition of its freshwater habitat, it is likely that coho production/area was considerably lower than that measured in the Chehalis Basin. To approximate production of the 1996 brood, we selected a value of 500 smolts/mi^2. This rate, applied to the total basin area, estimates 425,000 coho smolts were naturally-produced in 1998.

While this production level may be approximately correct for the entire Willapa system in 1998, we believe that production/area was not uniform. Recent adult mark-and-recapture studies in the North River system (240 mi^2 drainage area) have found relatively high natural spawning populations (2,000 to 12,000 adults) over three years (1995-1997). Applying the survival-to-return rates measured at Bingham Creek to these respective estimates indicate natural production levels of 130,000 to 200,000 smolts from the North River system. These estimates translate to production/area rates of 540 and 833 smolts/mi^2, which are considerably higher than the production rates we believe are occurring in most other tributaries to Willapa Bay.

MARINE SURVIVAL

Puget Sound

Marine survival rates for Puget Sound wild coho stocks have been measured for many years at Big Beef Creek, Deschutes River, South Fork Skykomish, and (as of the 1989 brood) Baker River. Marine survival, in terms of age 3 recruits, has varied from 9% to 32% at Big Beef Creek, and averaged 17.9% over brood years 1975-1993. Over the same period, marine survival of Deschutes River coho has averaged 17%, ranging nearly ten-fold from 3% to 29%. Over the first nine broods (1977-1985), survival of this stock averaged 24%, similar to that of Big Beef Creek smolts. Beginning with the 1986 brood, however, survival of Puget Sound coho declined, particularly the Deschutes River population (Figure 6). Although fishery recoveries are not yet available for the 1995 brood, only 1% of the smolts tagged in 1997 returned to the trap in 1998. Given the low harvest rate in 1998, we expect marine survival for this brood will be less than 2%.

Although marine survival measured at Big Beef Creek in Hood Canal has averaged higher than the other three systems outside of Hood Canal, we believe even this represents an underestimate of actual marine survival. Since at least 1991, a significant but unknown portion of the terminal net fishery catch has not been reported and/or sampled. In 1997, for example, WDFW biologists conducted limited on-the-water catch sampling on the mornings of September 24 and 25, in Area 12, near Seabeck. Of the total 225 adult coho they sampled, 75 ad-marks were present, of which 64 contained tags we had implanted in Big Beef Creek wild coho in Spring 1996. However, because catch for the entire season, as recorded on fish tickets (156 coho), was less than even this small sample, the tags observed could not be expanded. Excluding any Puget Sound mixed net and seine recoveries, contribution to other fisheries and escapement was estimated at 14.1%. These data, along with observations of the terminal net fishery, indicate total survival would be

considerably higher, perhaps near 20%, if this fishery had reported catch and had sampling occurred.

Marine survival measured at Sunset Falls (SF Skykomish) ranged three-fold (8% to 24%), and averaged 15% over the nine broods that we tagged wild smolts, somewhat lower than the rates estimated for Big Beef Creek and Deschutes River coho. We attribute this lower survival to the smaller size of smolts produced from this colder, higher-elevation system. Although we no longer trap and CWT wild coho smolts in this system, we approximate marine survival at Sunset Falls through applying projected harvest rates to adult returns. Relating these estimates of run size to the average smolt production we measured with full seeding (276,000 smolts), approximates marine survival.

Survival of Baker River coho (beginning with the 1989 brood), has varied from 6-14%, and appears to track the other stocks we have measured (Figure 6). Over these first six broods, Baker River survival alternates, with odd-numbered broods experiencing higher survival than even-numbered broods.

In addition to within-brood survival, ocean exploitation rates are also correlated among these stocks (Figure 7). This suggests that while differences in survival may exist among Puget Sound wild coho stocks, survival for all stocks tends to rise and fall in response to ocean conditions. The importance of this observation is that rates measured for selected stocks can be extrapolated to estimate survival of smolts produced in nearby systems.

Presently, no correlation with ocean environmental conditions has explained the observed inter-annual variation in marine survival. Clearly, the ocean has been less productive beginning around Spring 1990 (brood year 1988). Prior to this period, we had not measured any consecutive years in which marine survival at our Puget Sound study streams averaged less than 17%; whereas in only one of the succeeding seven brood years did survival average higher than 17% for all four stocks (Figure 6, Table 7).

Correlating jack returns with same-brood survival-to-adults at the only stations where jacks are reliably enumerated (Big Beef Creek and Deschutes River) has not indicated any relationship. In 1998, however, only one jack returned to the Deschutes fishway, and less than 100 jacks returned to Big Beef Creek. Both of these counts are extremely low, relative to all previous data and therefore, may indicate poor brood survival.

Lacking any other indicator of marine survival for Puget Sound stocks, forecasts must rely on the selection of survival rates which are deemed to reflect brood-specific marine environmental conditions. For predicting 1996 brood marine survival, we selected rates that incorporated the averages, by station, for brood years 1988 through 1994 (Table 7). This decision reflects our belief that the recent survival rates are more likely to predict this brood's marine survival than the long-term average rates.

- For the north Sound systems (Nooksack through the Stillaguamish River), we selected the average marine survival rate (6.9%) for the three even-numbered brood years measured thus far at the Baker River.
- For the Snohomish River, we used the average of the four even-numbered brood years (1988-1994) estimated at Sunset Falls, on the SF Skykomish River (9.8%)
- Due to the extreme low survival of Deschutes coho, we used the average marine survival of the last three broods (1993-1995) to predict South Sound stocks (Lake Washington and south) at 3.8%.
- For Hood Canal, we used the average marine survival (9.9%) measured at Big Beef Creek for the three even-numbered brood years, 1988, 1990, and 1992. We elected to use this rate, lower than the recent all-brood average (1988-1993) of 12.6% to reflect the low marine survival that may be indicated by the very low jack return rate in 1998.

Straits of Juan de Fuca

We currently lack any direct measurement of marine survival in tributaries to the Straits of Juan de Fuca. Observations at Snow Creek and spawning ground information from other systems, however, indicate marine survival in this region is considerably lower than that of inner Puget Sound coho. Given the consistently lower survival of coastal stocks relative to Puget Sound stocks, it is logical that coho emigrating from Straits tributaries experience intermediate survival. We selected a value of 5.0%, half of the rate we used for Hood Canal.

Coast

The wild coho trapping and tagging conducted annually at Bingham Creek (Grays Harbor) since the 1980 brood represents the only direct measurement of marine survival for jacks and adults on the Washington Coast. Marine survival (age 3) of wild Bingham Creek coho has ranged nineteen-fold, from 0.6% to 11.5%, and averaged 4.3% over 16 years (Figure 8). Although highly variable, marine survival is also somewhat predictable. Tagged jack returns correlated with same brood adult survival explain some of the inter-annual variation in marine survival. Over all broods measured, however, the relationship is poor (Figure 9). When the data set is split into early- and later-years, however, the correlation improves, especially if the two El Niño broods are excluded (Figure 10). In these broods (1980 and 1990), adult survival was low relative to the high jack returns. This phenomenon was also observed elsewhere on the coast, notably in the Oregon Production Index. Because we are unable to predict the ocean conditions which produce this response, we should discount marine survival on broods with high jack return rates to avoid overestimating run size.

Based on the relationship developed for the recent years (Figure 10), the wild jack return rate to Bingham Creek in 1998 of only 0.04% predicts an adult marine survival to the ocean (age 3) of 1.4%. This rate may underestimate the marine survival of other, non-Chehalis Basin, coastal stocks if the differential survival problem, which has long impacted Chehalis Basin coho, has not been resolved. Presently this remains uncertain, although the high survival of some recent returns

(notably in 1991 and 1996) indicate that substantial progress on reducing this problem may have been achieved. Although we expect that near-shore marine environmental conditions and/or predator populations varied somewhat along the coast, both of which would influence survival rates, because of the low jack return rate in 1998, we expect marine survival will be low coastwide.

While marine survival for the 1996 brood will probably be low, we have underestimated marine survival in two of the last three broods (Table).

Return Year	ADULT MARINE SURVIVAL		Error
	Predicted	Actual	
1996	5.4%	11.6%	-115%
1997	3.0%	1.4%	53%
1998	1.0%	3.1%	-210%

The predicted values in this table were the rates we forecasted, based on the correlations developed pre-season. For this reason, they vary relative to the present regression line (later brood years 1987 through 1995). The direction of this error may indicate that the relationship between jacks and adults is trending toward that represented by the steeper line, which fit the early broods' data (1981 through 1986) better (Figure 10).

Another possibility is that, in recent years, a higher proportion of the jacks were caught in the river sport fishery. This likely happened in Fall 1998, because stream flows remained at summer low flows until November 14. As a result, the smaller, earlier-migrating jacks would not only have been more susceptible to capture in the low, clear water but, in the absence of adults, fishermen may have been more likely to retain them. Moreover, because the wild tagged jacks were not outwardly identifiable with an adipose fin-clip, none of the tags would have been voluntarily submitted.

Given these factors, and the empirical results, we elected to increase the survival estimate to 2%. This rate is midway between the two values predicted by the regression lines, but still less than half of average survival (4.3%). Caution in this upward adjustment is supported by the low jack return to the Elk Creek trap in the Upper Chehalis Basin in Fall 1998. Only 20 jacks returned to this trap, the third lowest count in 15 years (average = 45, range 2 to 108).

Table 2. Summary of coho smolt production evaluations in ten Western Washington streams, and sources of interannual variation.

Stream	Number of Years	Watershed Area (sq. mi.)	SMOLT PRODUCTION Range Low	Range High	Ratio Hi/Lo	Average Production	Avg. Prod./ (sq.mi.)	Identified Sources of Variation (see key)
Big Beef Creek	21	14	11,510	45,634	4.0	24,614	1,758	1, 2, 4, 5
Bingham Creek	17	35	15,280	71,708	4.7	29,259	836	2, 3
Deschutes River	19	130	7,060	133,198	18.9	66,022	508	1, 2, 4, 5
SF Skykomish River	9	362	181,877	353,981	1.9	249,442	689	7
Dickey River	3	87	61,717	77,554	1.3	71,189	818	6
Bogachiel River	3	129	48,962	61,580	1.3	53,751	417	6
Clearwater River	18	140	35,000	95,000	2.7	61,712	441	1, 4, 5
Stillaguamish River	3	540	203,072	379,022	1.9	275,940	511	6
Skagit River	9	1,918	617,600	1,759,600	2.8	1,002,056	522	1, 2, 3, 8
Chehalis River	16	2,114	502,918	3,592,275	7.1	1,940,814	918	1, 2, 3, 4
Total		5,469						
Mean							742	
Wt'd Mean							690	

Notes: Skagit River total drainage area = 3,093 mi^2; 1,175 mi^2 are inaccessible above dams.
Deschutes River total drainage area = 160 mi^2; 30 mi^2 are inaccessible above Deschutes Falls.
Watersheds for Dickey and Bogachiel Rivers are estimated areas above trap locations.
Weighted mean by watershed area.

Key:
1. Winter flows - gravel scour/egg survival
2. Summer flows - rearing habitat
3. Fall flows - spawner distribution
4. Seeding
5. Habitat damage
6. No factors identified
7. Experimental escapement reduction.
8. Species interactions

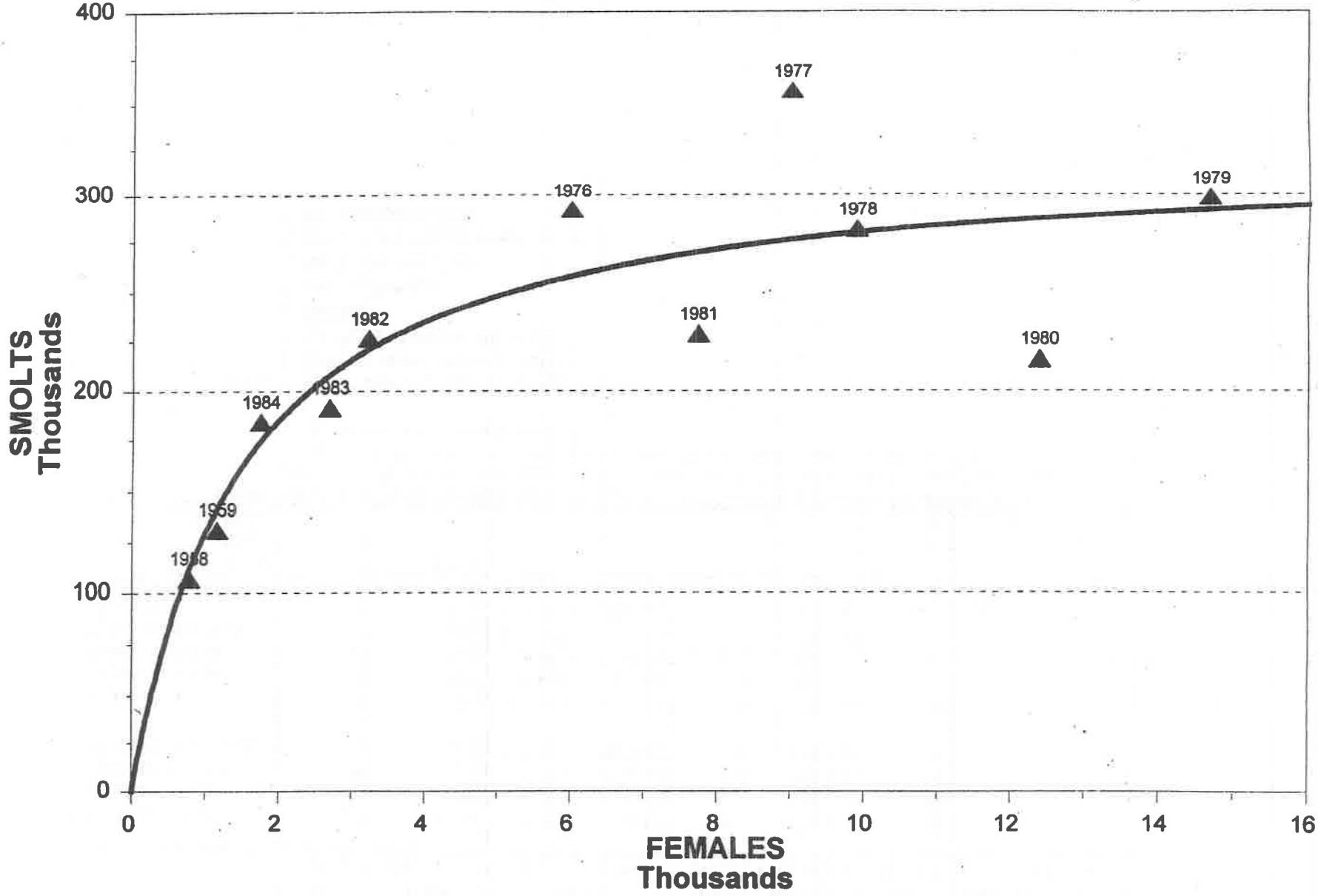


Figure 1. SF Skykomish River wild coho spawners & recruits, by brood year.

Table 3. Estimation of wild coho smolt production, Skagit River, 1998.

	Number	Formula
Total mainstem trap catches	24,546	
Baker River	[a]-603	
Skagit Hatchery/Lake Shannon	[b]-1,651	
Subtotal	-2,254	
Wild coho captured (c)	**22,292**	$N = \frac{(m+1)(c+1)}{(r+1)}$
LVs recaptured (r)	720	
LVs released (m)	55,227	
Total production (N)	**1,707,625**	
Variance (Var)	3.86e+09	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+1)}$
Standard deviation (sd)	62,149	
Coefficient of Var (CV)	3.64%	CV = sd ÷ N
Confidence interval (CI)	±121,812	CI = ± 1.96(sd)
Estimated coho production Skagit River	1,707,625	
Baker River	51,972	
Total Production	1,759,597	
Upper CI (95%)	1,829,437	
Lower CI (95%)	1,585,813	

[a] Estimated Baker recoveries: visually identified ad-marks (298) times the tag expansion factor (2.0229) = 603 total tagged and unmarked Baker River smolts in the catch.

[b] Hatchery ad-marked and unmarked smolt total from counts obtained by visual identification at trapping (1,638 Skagit hatchery + 13 brands from Baker Lake = 1,651).

Table 4. Actual and projected wild coho smolt productions in Hood Canal 1998.

Stream	PROJECTED SMOLTS		Actual Production (1998)	RATIO ACTUAL/PROJECTED	
	Zillges	HCJTC		Zillges	HCJTC
Big Beef Creek	38,586	29,638	22,222	58%	75%
Little Anderson	5,100	3,190	n/a	n/a	n/a
Seabeck Creek	10,497	6,564	1,393	13%	21%
Stavis Creek	5,027	3,144	5,979	119%	190%
Subtotal (w/o Little Anderson)	54,110	39,346	29,594	55%	75%
Total Hood Canal	1,006,577	[a]561,631	Est. 1998 Production	550,520	422,429
Projected proportion (Subtotal/Total)	5.4%	7.0%			

[a]Includes catch area 9A tributaries (7,027 smolts).

Table 5a. Estimated and projected wild coho smolt production in larger Straits of Juan de Fuca systems (mainstem widths ≥6 yards), 1998.

Large Systems	Watershed Area (mi^2)	Coho Smolt Production	Average Production (mi^2)	Projected Smolt Production
Dungeness River	198.0	50,000	253	50,000
Morse Creek	46.6		253	11,790
Lyre River	66.0		253	16,698
Pysht River	44.4		253	11,233
Clallam River	31.6		253	7,995
Hoko River	51.2		253	12,954
Sekiu River	33.0		253	8,349
Total	470.8			119,018

Table 5b. Measured and projected wild coho smolt production in small Straits of Juan de Fuca systems (mainstem widths <6 yards), 1998.

Small Streams	Wetted Habitat (yds^2)	Coho Smolt Production	Prod. Rate (Smolts/100 yd^2)	Projected Smolt/yd^2
Mattriotti Creek	10,560	3,885	36.8	
Little Hoko Creek	37,664	3,695	9.8	
Seibert Creek	51,040	358	0.7	
Ennis Creek	18,304	972	5.3	
Valley Creek	8,800	3	0.03	
Tumwater Creek	4,576	119	2.6	
Salt Creek	83,072	7,357	8.9	
Deep Creek	52,976	4,022	7.6	
Subtotal	218,768	12,831	5.9	
Total Independent Tribs	716,628		5.9	42,031

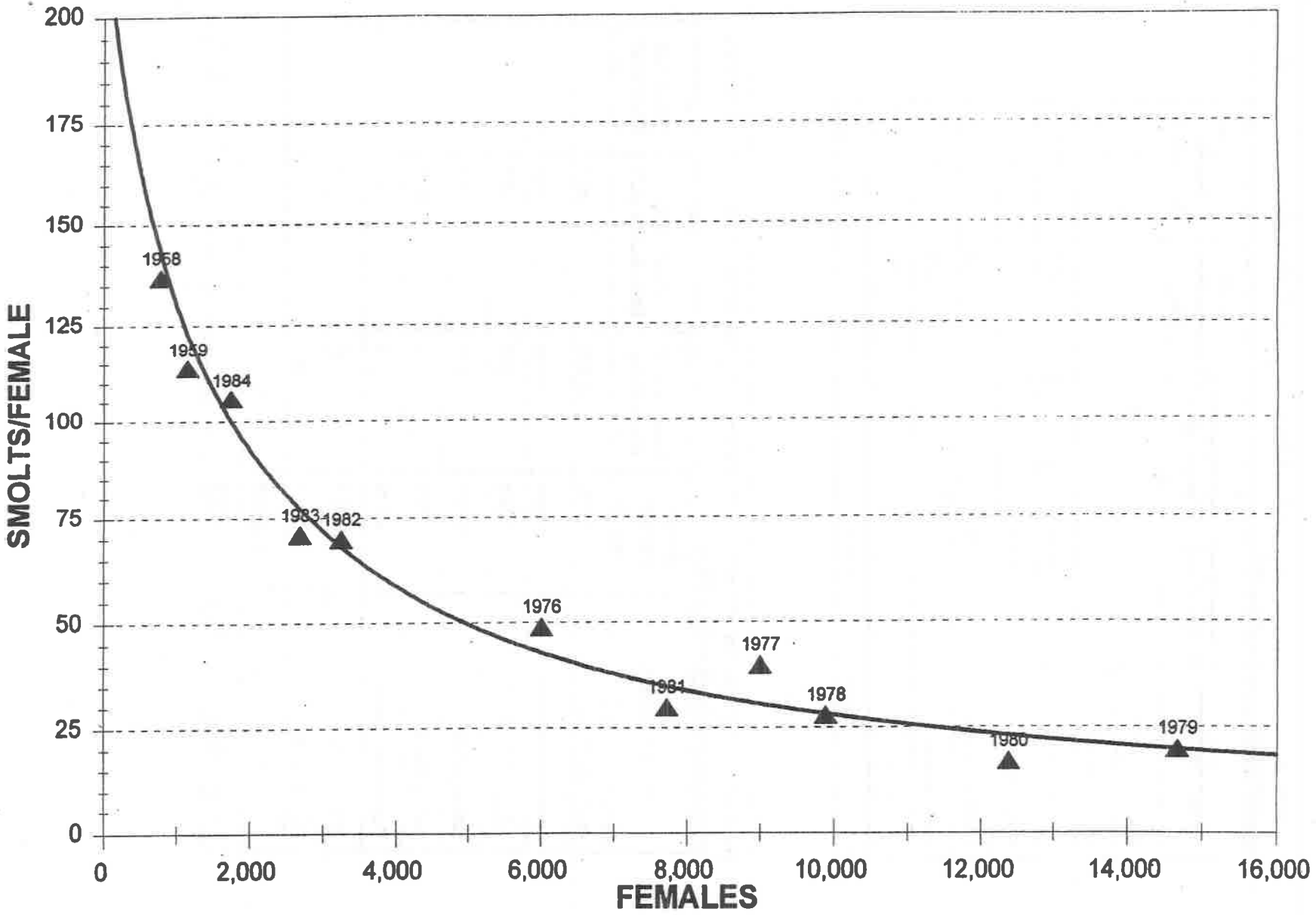


Figure 2. Productivity as a function of spawner abundance, SF Skykomish River wild coho.

Figure 3. Clearwater River wild coho smolt production & Queets River flow during egg incubation.

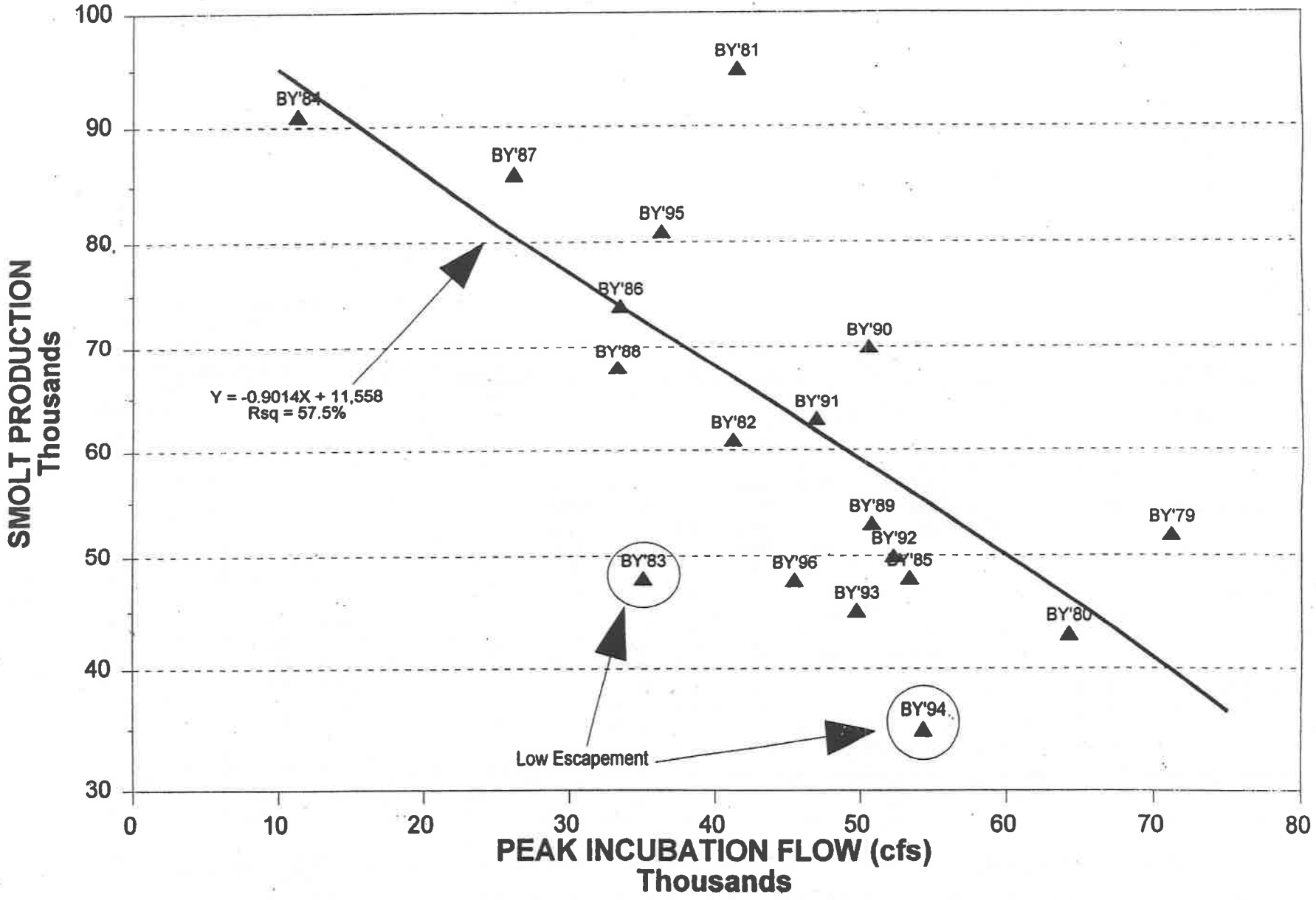


Table 6. Estimation of wild coho smolt production from the Chehalis Basin, via back-calculation. These estimates assume expanded tag recoveries accurately reflect the numbers of hatchery and wild tags caught.

				ESTIMATION OF WILD TAG RATE					WILD SMOLT TAGGING				ESTIMATED SMOLT PRODUCTION				
				A	B	C	D	E	F	G	H	I	J	K			
Br. Yr.	Tag Yr.	Rtn. Yr.		Total Catch	Est. Hatch.	Wild Catch (A-B)	# Est. W-tags	Tag Inc. (D/C)	Number Tagged	Mort Adj.	Tag Rtnt'n	Adj. Tag Grp (FGH)	Total Smolts (I/E)	SE (Var.)^2	95% Conf. Interval Low (J-(1.96*K))	95% Conf. Interval High (J+(1.96*K))	CV (K/J)
1980	1982	1983		10,115	3,669	6,446	104	1.61%	47,711	0.84	0.96	38,474	2,384,657	207,638	1,977,688	2,791,627	8.71
1981	1983	1984		5,196	1,432	3,764	93	2.47%	78,839	0.84	0.96	63,576	2,573,110	250,223	2,082,672	3,063,547	9.72
1982	1984	1985		6,991	4,025	2,966	164	5.53%	110,020	0.84	0.96	88,720	1,604,536	118,303	1,372,662	1,836,410	7.37
1983	1985	1986		19,600	6,548	13,052	481	3.69%	96,687	0.84	0.96	77,968	2,115,683	86,032	1,947,061	2,284,305	4.07
1984	1986	1987		23,129	4,810	18,319	272	1.48%	74,847	0.84	0.85	53,338	3,592,275	173,901	3,251,429	3,933,121	4.84
1985	1987	1988		3,856	1,490	2,366	39	1.65%	59,860	0.84	0.96	48,271	2,928,447	431,344	2,083,012	3,773,882	14.73
1986	1988	1989		13,824	10,367	3,457	112	3.24%	54,285	0.84	0.96	43,775	1,351,175	118,427	1,119,058	1,583,293	8.76
1987	1989	1990		27,251	17,824	9,427	210	2.23%	44,889	0.84	0.96	36,198	1,624,967	94,459	1,439,829	1,810,106	5.81
1988	1990	1991		45,211	22,073	23,138	690	2.98%	69,701	0.84	0.96	56,207	1,884,804	54,055	1,778,856	1,990,753	2.87
1989	1991	1992	A	12,111	7,745	4,366	213	4.88%	71,457	0.84	0.96	57,623	1,181,135	75,185	1,033,773	1,328,497	6.37
			B	12,111	10,197	1,914	213	11.13%	71,457	0.84	0.96	57,623	517,795	32,589	453,921	581,669	6.29
			C	12,111	8,971	3,140	213	6.78%	71,457	0.84	0.96	57,623	849,465	54,143	743,344	955,585	6.37
1990	**1992**	**1993**	**B**	**10,153**	**4,702**	**5,451**	**16**	**0.29%**	**21,125**	**0.84**	**0.96**	**17,035**	**5,803,680**	**1,060,259**	**3,725,572**	**7,881,787**	**18.27**
1991	1993	1994	S	5,375	3,666	1,709	30	1.76%	32,027	0.84	0.96	25,827	1,471,254	241,154	998,591	1,943,917	16.39
1992	1994	1995		23,903	11,755	12,148	263	2.16%	64,035	0.84	0.96	51,638	2,385,157	126,262	2,137,683	2,632,631	5.29
1993	1995	1996		26,824	8,898	17,926	527	2.94%	42,812	0.84	0.96	34,524	1,174,326	34,813	1,106,093	1,242,560	2.96
1994	1996	1997		700	607	93	7	7.53%	46,942	0.84	0.96	37,854	502,918	141,640	225,304	780,532	28.16
1995	1997	1998		7,819	2,129	5,690	154	2.71%	78,462	0.84	0.96	63,272	2,337,768	175,004	1,994,759	2,680,777	7.49

Estimate A: Assumes Simpson (late) and Satsop Springs fish survived and contributed 1/2 the rate as Simpson (normal) hatchery stock.

Estimate B: Assumes Simpson (late) and Satsop Springs fish survived and contributed at the same rate as Simpson (normal) hatchery stock.

Estimate C: Average of Estimates A&B.

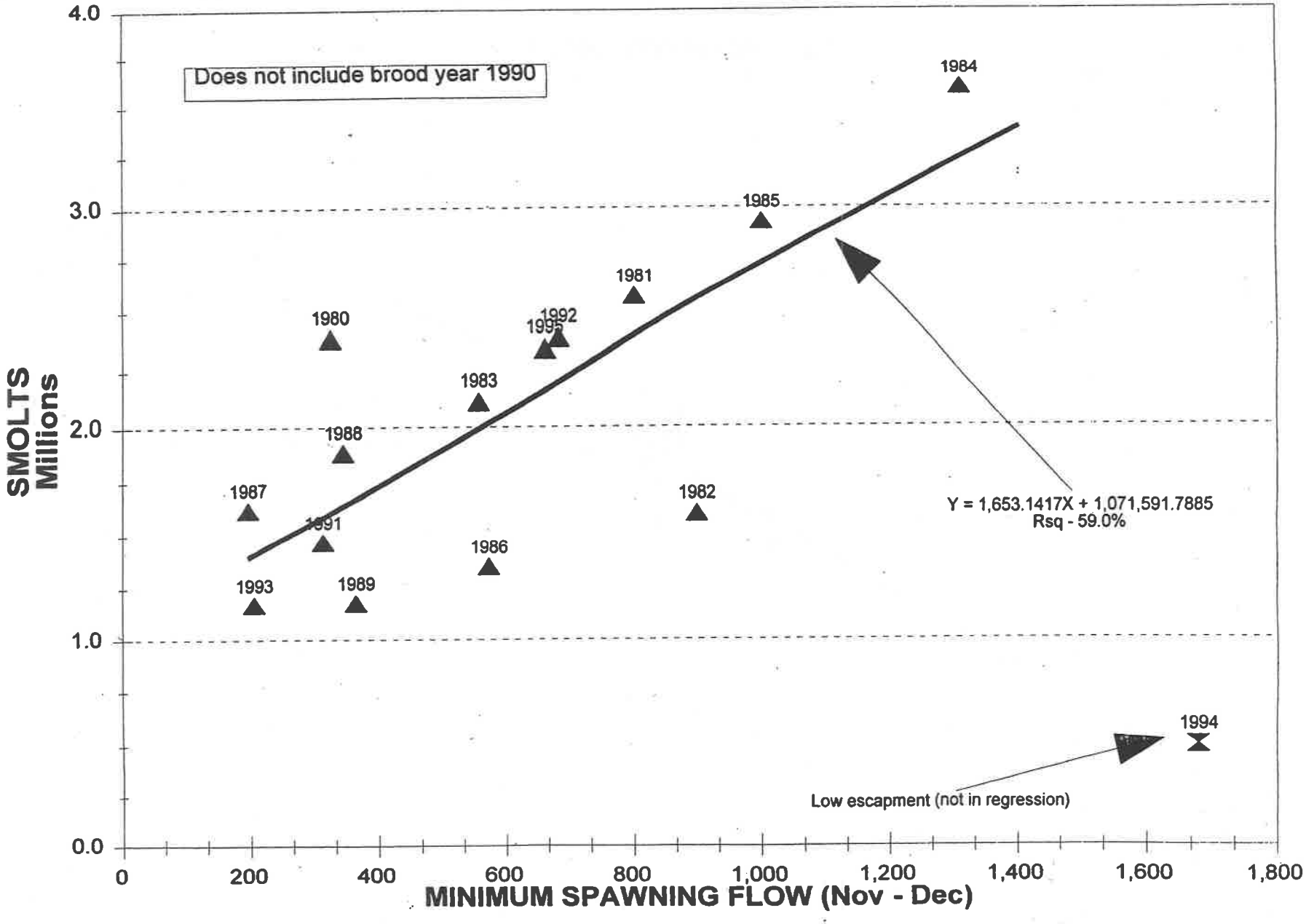
Estimate S: Hatchery/ Wild Catch estimates based on scale analysis

Shaded years are preliminary.

Excludes BY 1990	
1,940,814	avg
502,918	min
3,592,275	max
15	count

Figure 4.

COHO SMOLT PRODUCTION & FLOW (cfs)
CHEHALIS RIVER, BROOD YEARS 1980-1995



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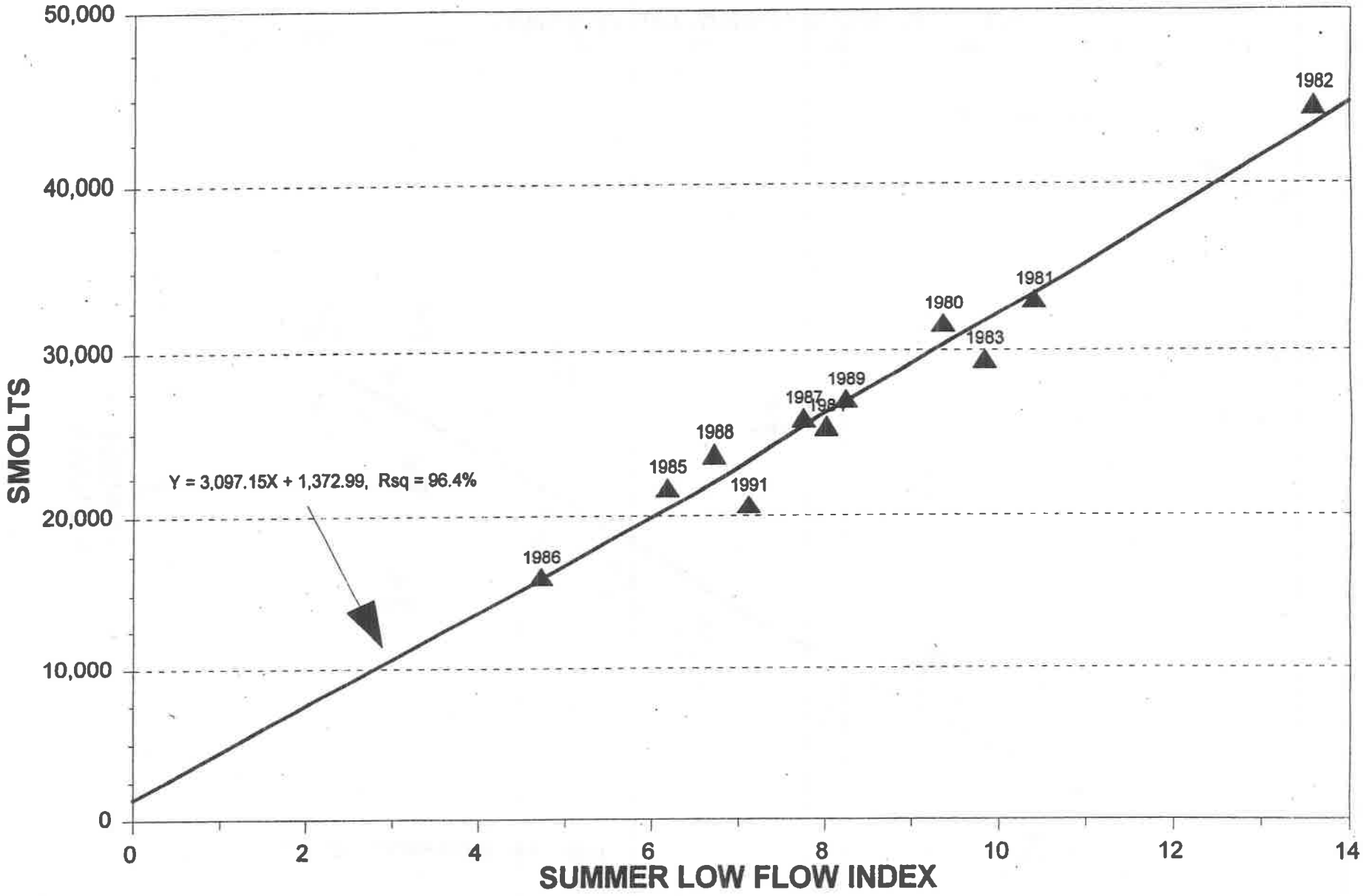
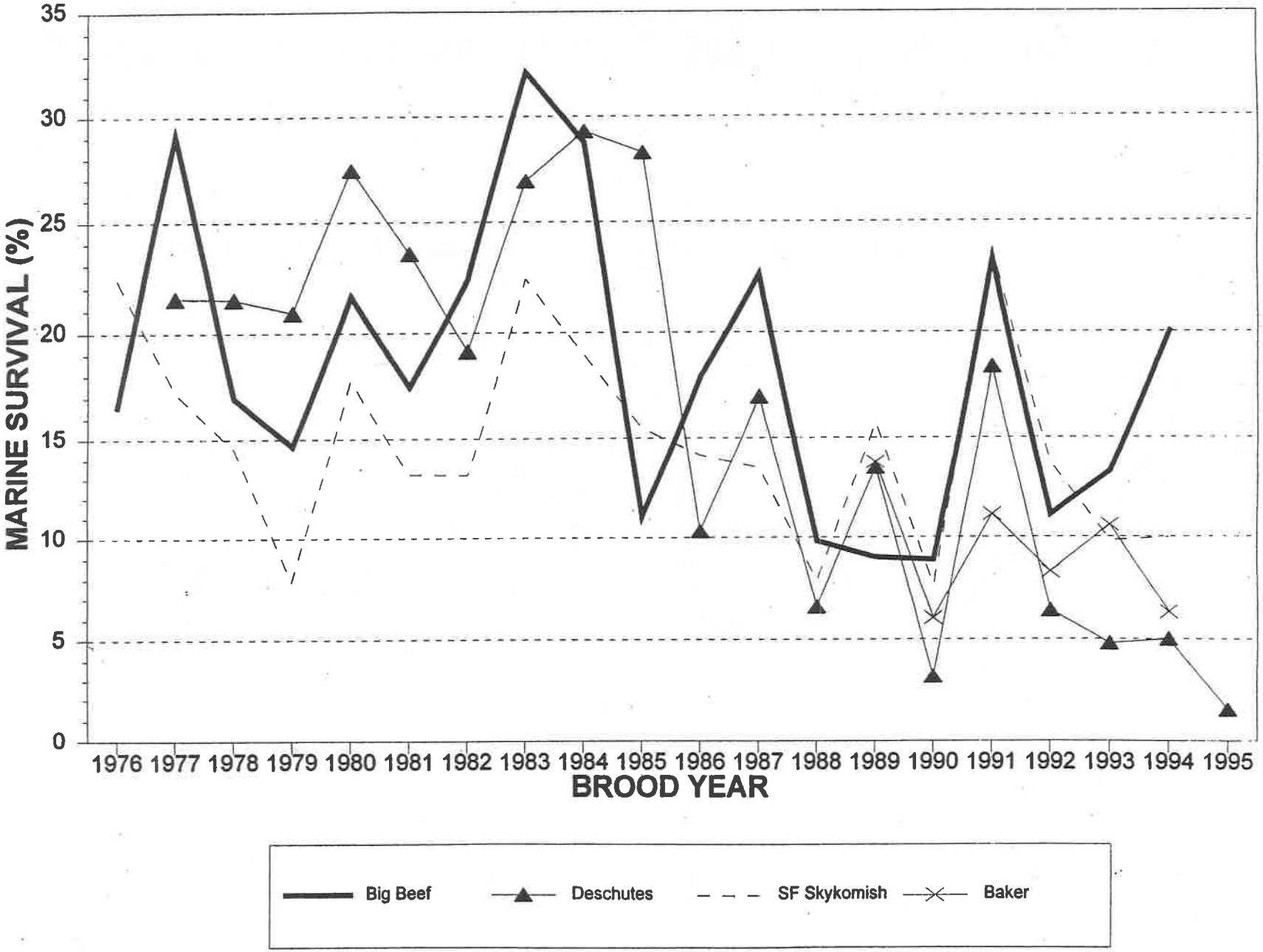


Figure 5. Wild coho smolt production vs. summer low flow, Bingham Creek, brood years 1980-1991 (broods 1990, & 1992-1995 omitted).

Figure 6. MARINE SURVIVAL: PUGET SOUND WILD COHO (age 3)



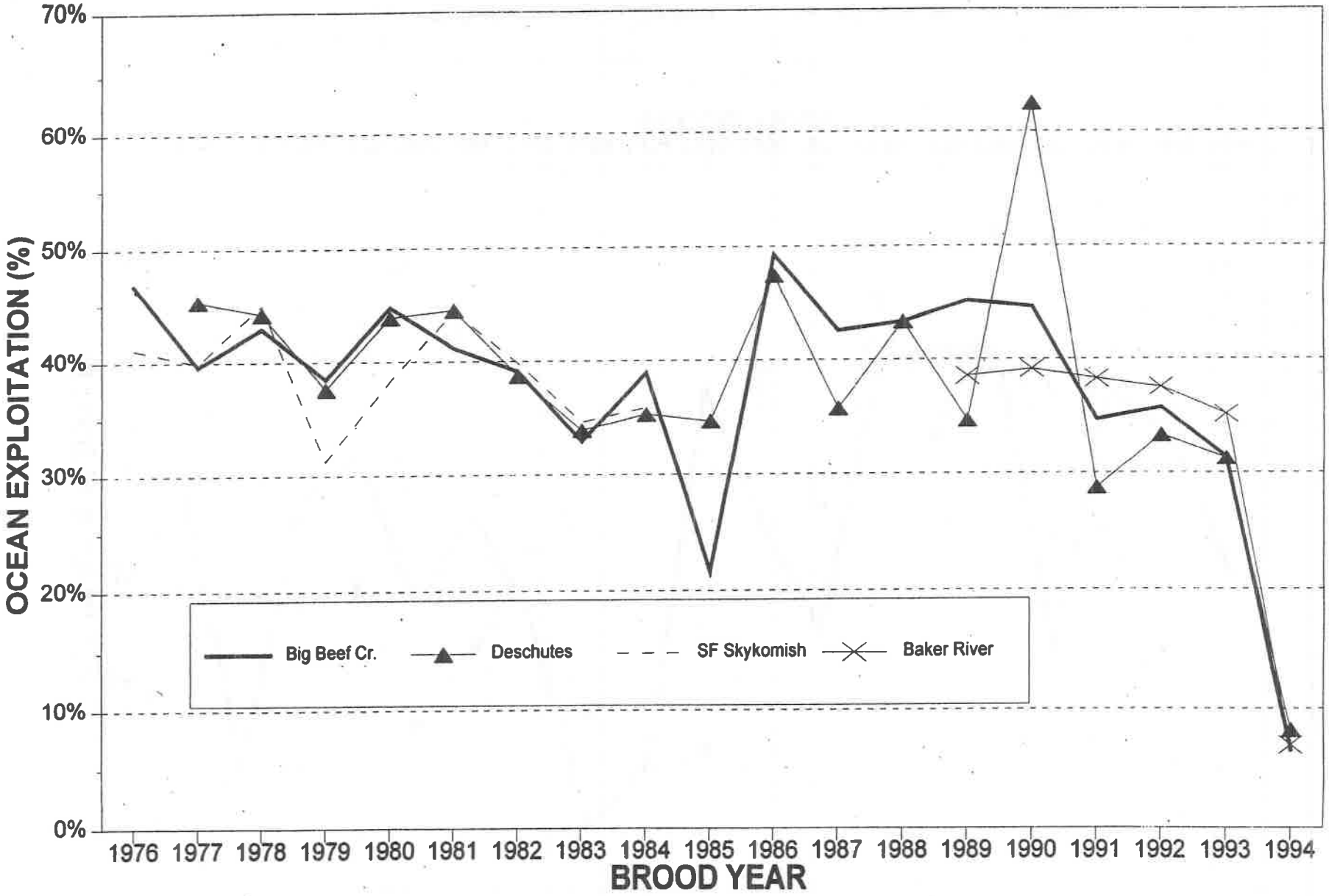


Figure 7. Wild coho ocean exploitation rates from four Puget Sound streams.

Table 7. Comparison of marine survival (age 3), Big Beef Creek, Deschutes River, SF Skykomish River, and Baker River wild tagged coho.

YEAR		Big	Desch.	SF	Big	Desch.	SF	Baker	AVERAGE		
Br.	Rtn	Beef	River	Sky	Beef	River	Sky	River	Early	Late	Count
1975	1978	13.24							---		
1976	1979	16.58		22.32					19.45		2
1977	1980	29.07	21.55	17.25					22.62		3
1978	1981	16.97	21.49	14.54					17.67		3
1979	1982	14.66	20.90	7.87					14.48		3
1980	1983	21.61	27.44	17.79					22.28		3
1981	1984	17.47	23.52	13.22					18.07		3
1982	1985	22.32	19.12	13.15					18.20		3
1983	1986	32.16	26.90	22.34					27.13		3
1984	1987	28.76	29.28	18.97					25.67		3
1985	1988	11.06	28.27	15.47					18.27		3
1986	1989	17.93	10.31	14.14					14.13		3
1987	1990	22.54	16.98	13.51					17.68		3
1988	1991				9.83	6.58	7.86			8.09	3
1989	1992				9.01	13.50	15.76	13.80		13.02	4
1990	1993				8.90	3.18	7.67	6.02		6.44	4
1991	1994				23.23	18.39	23.64	11.12		19.10	4
1992	1995				11.11	6.39	13.71	8.30		9.88	4
1993	1996				13.30	4.80	9.83	10.60		9.63	4
1994	1997				20.00	5.01	9.98	6.30		10.32	4
1995	1998					1.50					
Average		20.34	22.34	15.88	13.63	8.26	12.64	9.36	18.13	10.93	
	Min	11.06	10.31	7.87	8.90	3.18	7.67	6.02	14.13	6.44	
	Max	32.16	29.28	22.34	23.23	18.39	23.64	13.80	27.13	19.10	
	Count	13	11	12	7	7	7	6	13	7	

Notes: Marine survival for the SF Skykomish 1981 brood is estimated ([mean ratio of the average BBC + Deschutes survival]/[SF Sky survival, by year]); because a portion of the adult return would not enter the fishway.

SF Skykomish marine survival for the 1985 brood and later is estimated ([adult returns/ escapement rate]/276,000 smolts).

Marine survival for the Big Beef Creek 1994 brood could not be directly estimated due to large unreported/unsampled catch in the terminal area. Without Puget Sound mixed net and seine recoveries, 14.1% of tagged smolts were estimated captured in fisheries and escapement. These data, along with observations of the terminal net fishery, indicate total survival would be considerably higher, perhaps around 20% if this fishery had reported catch and had sampling occurred.

Figure 8. MARINE SURVIVAL
BINGHAM CREEK TAGGED WILD COHO

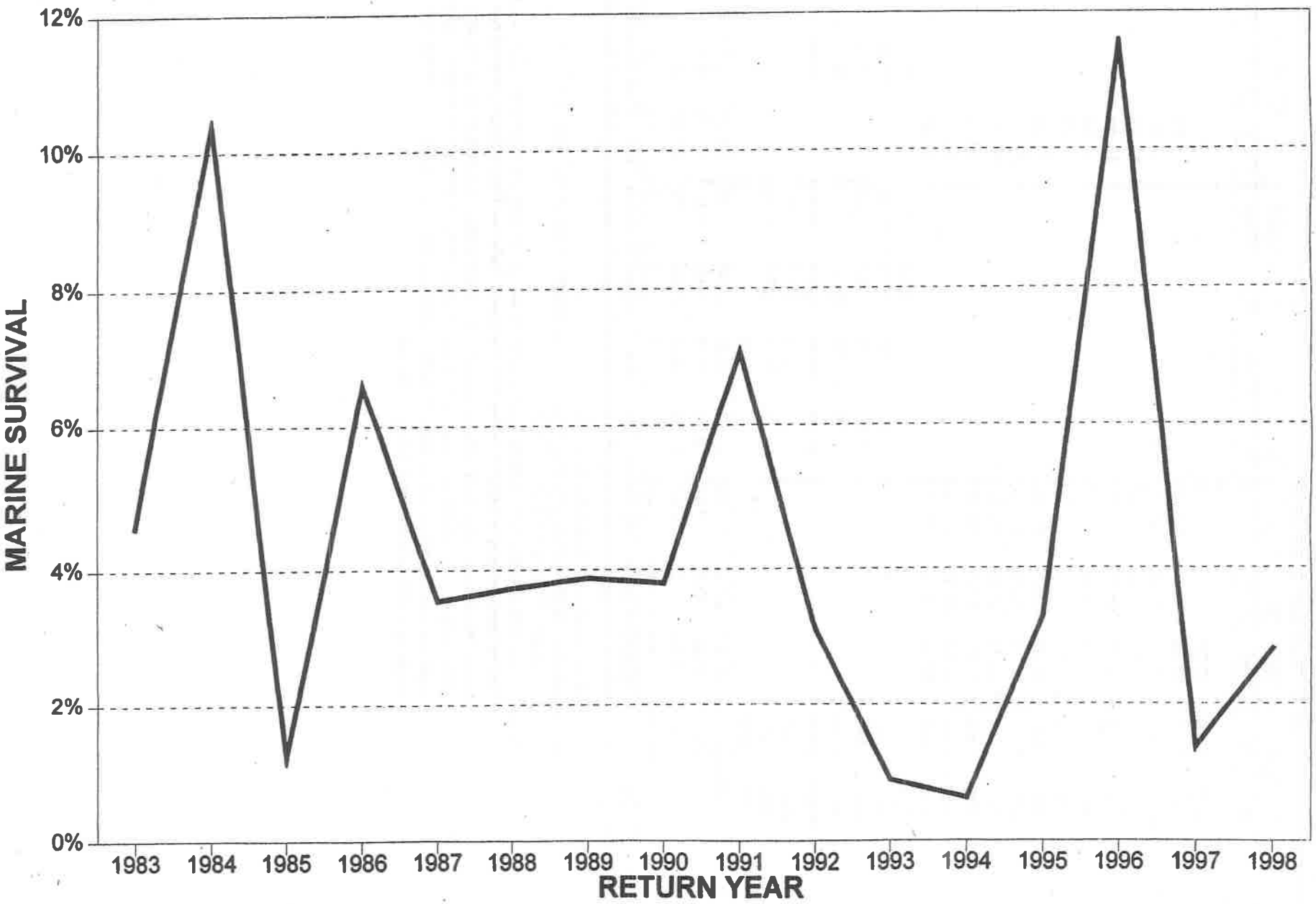


Figure 9. **JACK RETURN vs ADULT MARINE SURVIVAL**
BINGHAM CREEK, BYs 1980-1995

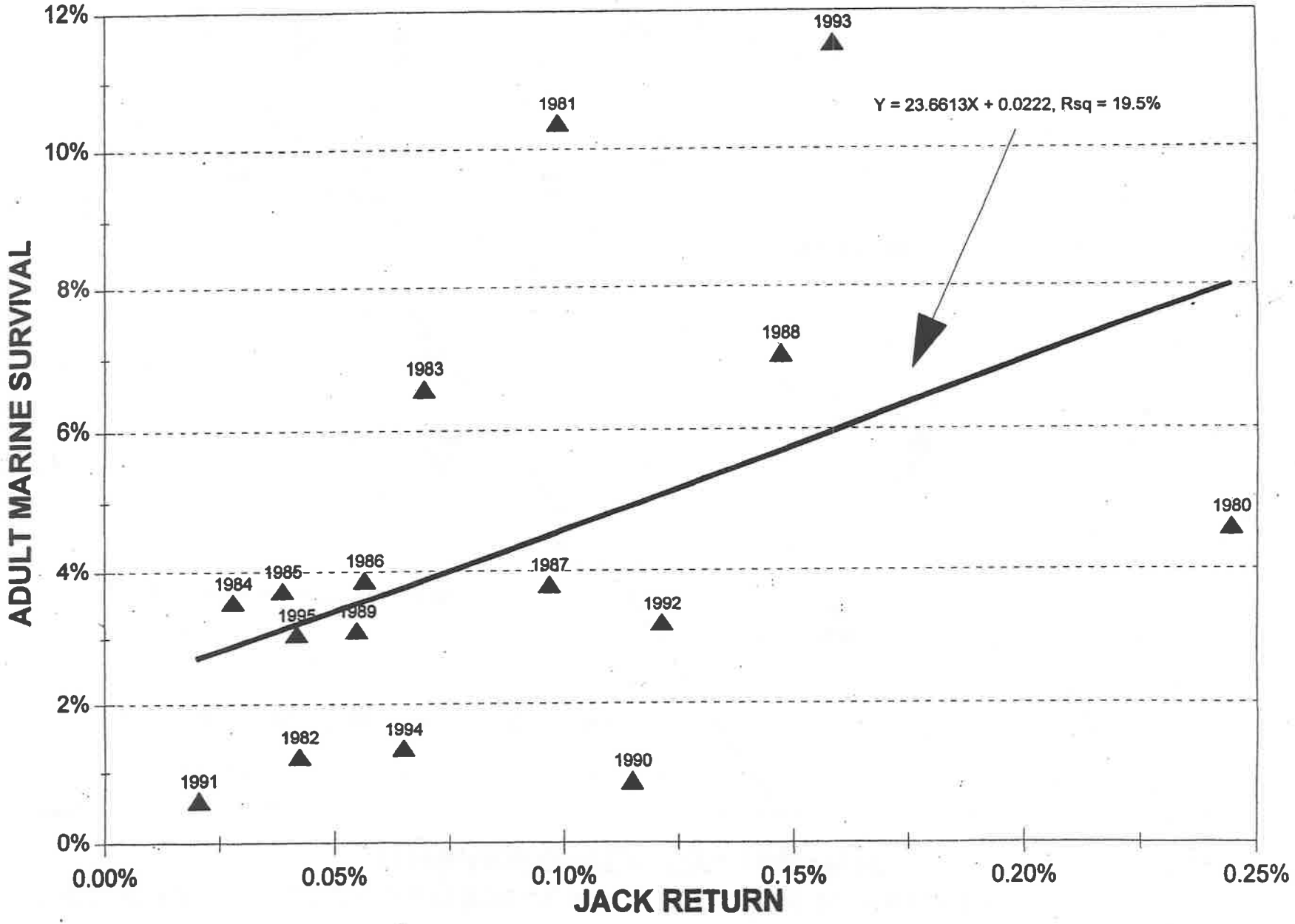


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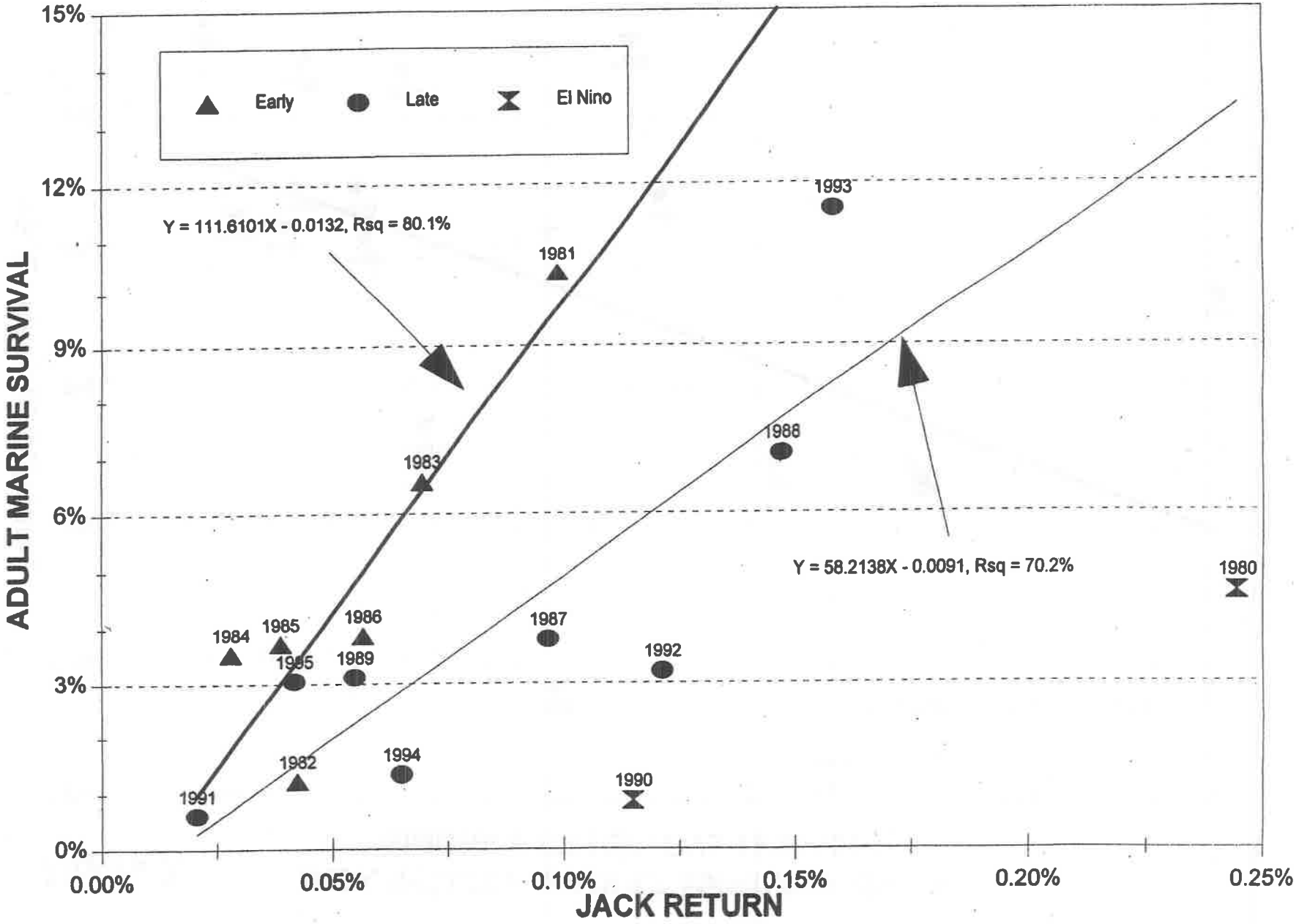
Figure 10. **JACK RETURN vs ADULT MARINE SURVIVAL**
BINGHAM CREEK, BYs 1980-1995



Activity 13: Where Have All The Salmon Gone

Teacher Notes:

- Provide students with the article "Evaluating Salmonid Production in Bear Creek" by Dave Seiler at WDFW, to learn how researchers count wild fish using fish traps.
- Provide students with the graphs from "WILD COHO FORECASTS" by Dave Seiler at WDFW to interpret using the Student Worksheet.

Expected student worksheet response:

Figure 1: SF Skykomish River Wild Coho spawners and recruits, by brood year.

The graph reaches a plateau at around 8 to 10 thousand females returning to spawn (spawners)

There is a maximum number of spawners that will produce the maximum number of smolts (new fish). The graph shows that with more females returning upstream there is not more new fish produced. This means the stream has reached carrying capacity - the resources of the stream do not support more new fish (smolt), where there is competition for habitat.

Conclusion: There is a limit or maximum number of female spawners which will produce new fish in a given habitat. By having more fish up-stream spawning does not mean you will get more new fish (smolt production), because the stream has reached its carrying capacity. The research shows that a maximum of 8,000 to 10,000 adult females spawning in the Skykomish River resulted in a maximum of 300,000 smolts produced.

Figure 2: Productivity as a function of spawner abundance, SF Skykomish River Wild Coho

With an increase in spawners (returning females) there is a plateau of smolts produced at around 25,000.

Figure 3: Clear Water River Wild Coho smolt production and Queets River flow during egg incubation

The graph demonstrates a direct inverse relationship. With increased flow during egg incubation periods there are less smolts produced. The higher the flow in cubic feet per second the lower the smolt production.

Figure 4: Coho smolt production and flow (cfs) Chehalis River, brood years 1980-1995.

As the flow increases more smolts are produced by spawners who can get higher up the system and reach more habitat for spawning and rearing.

(cfs = cubic feet of water per second)

What year had the best smolt production in millions: __1984____year __3.5__ millions of smolts

What two years had the least smolt production 1993, 1989 years 1.12 approx millions of smolts

Equation for line of best fit: Y= 1,653.1417X + 1,071,591.7885

Figure 5: Wild Coho Smolt production vs. summer low flow, Bingham Creek, brood years 1980-81

There is a direct relationship between smolts and summer low flow index. The higher the flow during the summer the more smolts are produced. The lower the flow the fewer smolts are produced. The more water in the stream over summer the more smolts survive. Presence and access to summer habitat makes a big difference to production of smolts.

Equation for line of best fit: Y=3,097.15X + 1,372.99

Figure 6: Marine Survival: Puget Sound Wild Coho (age 3)

The marine survival of Wild Coho depends on ocean production, El Nino, La Nina, ocean pollution from natural factors like red tides or human impacts such as effluents of human wastes. The trend over 20 years has been a gradual decline for each coho run studied.

What year were you born._____

Find the percentage of survival of Puget Sound Coho for each run that returned that year to each Puget Sound Stream.

Big Beef: _____% survival

Deschutes: _____% survival

SF Skykomish: _____% survival

Baker: _____% survival.

As a fish manager, what you would do to ensure salmon are around for our grandchildren based on the research (on spawners females returning, habitat and flow) reported through the graphs.

Spawners (females returning): I would make sure there are not too many spawners for the habitat available.

Habitat: I would open up more habitat so more habitat is available for more female spawners, so more smolt can be produced. By opening up habitat I am also increasing the carrying capacity so more smolt can survive if there are a large number of females spawning.

Flow: I would make sure the flow is consistent and continuous. I would find out what affects the summer flow in streams and make changes so the flow remains. For example I would watch that development of homes and agriculture in the area leaves enough

Figure 1: SF Skykomish River Wild Coho spawners and recruits, by brood year.

Choose the correct graphic interpretation in brackets. Use the conclusion to help you make a decision.

The graph reaches a plateau at around 8 to 10 thousand females returning to spawn (spawners)

There is a (maximum/minimum) number of spawners that will produce the (minimum/maximum) number of smolts (new fish). The graph shows that with more females returning upstream there are (more/not more) new fish produced. This means the stream has reached carrying capacity - the resources of the stream (do not/do) support more new fish (smolts), where there is competition for habitat.

Conclusion: There is a limit or maximum number of female spawners which will produce new fish in a given habitat. By having more fish up-stream spawning does not mean you will get more new fish (smolt production), because the stream has reached its carrying capacity. The research shows that a maximum of 8,000 to 10,000 adult females spawning in the Skykomish River resulted in a maximum of 300,000 smolts produced.

Figure 2: Productivity as a function of spawner abundance, SF Skykomish River wild coho.

Find the plateau number of smolts on the graph.

With an increase in spawners (returning females) there is a plateau of smolts produced at around _____ smolts.

Figure 3: Clearwater River wild coho smolt production & Queets River flow during egg incubation.

Interpret the meaning of the graph by choosing the words in brackets below which make sense.

The graph demonstrates a direct inverse relationship. With increased flow during egg incubation periods there are (more/less) smolts produced. The (lower/higher) the flow in cubic feet per second the (higher/lower) the smolt production.

Figure 4: Coho smolt production and flow (cfs) Chehalis River, Brood Years 1980-1995.

Interpret the meaning of the graph by choosing the words in brackets which make sense.

As the flow increases (less/more) smolts are produced by spawners who can get higher up the system and reach (more/less) habitat for spawning and rearing.

What year had the best smolt production in millions: _____year _____ millions of smolts

What two years had the least smolt production _____ _____ years _____ millions of smolts

What is the equation for the line of best fit the scientist used: Y=

Figure 5: Wild coho smolt production vs. summer low flow, Bingham Crk, brood years 1980-1991

There is a direct relationship between smolts and summer low flow index. The (lower/higher) the flow during the summer the more smolts are produced. The (higher/lower) the flow the fewer smolts are produced. The (more/less) water in the stream over summer the more smolts survive. **Conclusion:** Presence and access to summer habitat makes a big difference to production of smolts.

What is the algebraic equation for the line of best fit: Y=

Figure 6: Marine survival: Puget Sound Wild Coho (age 3)

The marine survival of Wild Coho depends on ocean production, El Nino, La Nina, ocean pollution from natural factors like red tides or human impacts such as effluents of human wastes. The trend over 20 years has been a gradual decline for each run of coho studied.

What year were you born. _____

Find the percentage of survival of Puget Sound Coho for each run that returned that year to each Puget Sound Stream.

Big Beef: _____% survival

Deschutes: _____% survival

SF Skykomish: _____% survival

Baker: _____ % survival

As a fish manager, what you would do to ensure salmon are around for our grandchildren based on the research (on spawners females returning, habitat and flow) reported through the graphs.

Spawning (females returning):

Habitat:

Flow: