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THE MAGNITUDE OF ARTIFICIAL PRODUCTION OF STEELHEAD TROUT ALONG THE PACIFIC COAST OF NORTH AMERICA

by

Jeffrey T. Light

FISHERIES RESEARCH INSTITUTE
School of Fisheries
College of Ocean and Fishery Sciences
University of Washington
Seattle, Washington 98195
U.S.A.

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ABSTRACT

The number of steelhead smolts released annually from production facilities along the Pacific coast of North America increased from approximately 2.8 million in 1960 to 30 million in 1987, and averaged 24.6 million in the decade 1978-1987. States or provinces contributed to this average production as follows: Idaho (41.9%), Washington (27.6%), Oregon (18.4%), California (9.4%), British Columbia (2.5%), and Alaska (0.2%). Facilities in the Columbia River basin accounted for nearly two-thirds of the average coastwide production. Approximately 738,000 adults would be produced annually from these smolt releases, assuming a 3% smolt-to-adult survival rate for hatchery-reared fish. This figure is close to an earlier estimate (Light 1987) of the coastwide abundance of adult hatchery fish (approximately 800,000), and indicates that artificially-produced steelhead contribute substantially to the total North American steelhead population. Increasing demand for steelhead by the sportfishing community coupled with steady or declining wild populations suggests that hatchery fish will become an even larger component of the total steelhead population.

INTRODUCTION

Artificial propagation of steelhead trout (*Oncorhynchus mykiss*, formerly *Salmo gairdneri*) is an integral part of the management of this important gamefish species along the Pacific coast of North America. Production facilities first began rearing and releasing steelhead in the late 1800s, and are presently operating throughout the Pacific coast region from California to Alaska. Propagation programs are designed to enhance existing populations or to mitigate for losses resulting from habitat destruction or fish passage obstructions such as hydroelectric dams (Wahle and Smith 1979). The commercial importance of steelhead has dwindled since the late 1800s, and today, with the exception of some Native American Indian fisheries in the state of Washington and limited (mostly incidental) non-tribal commercial fisheries in British Columbia and Alaska, steelhead trout are no longer commercially important (Northwest Power Planning Council [NWPPC] 1986, Sheppard 1972). Maintenance and replenishment of stocks is thus undertaken primarily for the benefit of the sport fishery. This document describes the magnitude of artificial production of steelhead along the Pacific coast of North America, with emphasis on the 10-year period from 1978 to 1987. A comprehensive discussion of the history of North American artificial salmonid propagation from its beginnings in the last century through 1976 can be found in Wahle and Smith (1979).

Steelhead production facilities in most areas along the coast are operated by state, provincial, federal, and private groups. In larger facilities, typical operations include artificial spawning, incubation, and rearing to produce smolt-sized fish (approximately 160 mm) within one year. In smaller facilities, eggs or juveniles may be obtained from larger public hatcheries and then reared in small ponds, net pens, or raceways. Many facilities use broodstock derived from populations native to the stream on which the hatchery was built, but some use stocks derived from other systems (Crawford 1979). Some hatcheries, especially in British Columbia, routinely take eggs from naturally-produced "wild" broodstock.

There are currently 82 hatcheries and at least 24 rearing ponds plus several imprinting or acclimation ponds involved in the propagation of steelhead along the Pacific coast of North America (Fig. 1, Table 1). In Washington, Oregon, and Idaho, rearing facilities are concentrated within the Columbia River basin. Alaska's steelhead-producing hatcheries are located in the south central and southeastern portions of the state (Van Hulle 1985). California's hatcheries are found no farther south than the San Francisco Bay area, and in British Columbia, steelhead hatcheries are concentrated in the southern part of the province and on Vancouver Island (Wahle and Smith 1979). Although steelhead occur in Asia, principally in streams along the west coast of Kamchatka (Savvaitova et al. 1973), no artificial rearing of Asian steelhead is known to occur.

A measure of the magnitude of artificial production of steelhead is the number of migrant-sized juveniles produced by hatcheries each year. Steelhead migrants (smolts) are defined as fish deemed both morphologically and physiologically prepared to begin their seaward migration. However, the numbers of smolts released is an imperfect measure of the potential contribution of hatchery fish to offshore populations or to future adult spawning fish owing to variations in post-release survival. Hatchery-reared steelhead are typically released as migrants at a length of 160-180 mm and a weight greater than 45 g after a single year of rearing in the hatchery (Wahle and Smith 1979). In addition to these migrants, a substantial number of "submigrants" (fry and fingerlings) are often released into streams as space is cleared in the hatchery to achieve optimal rearing densities (Wahle and Smith 1979). These fish are not considered ready to begin their seaward migration and a wealth of evidence suggests their chance of survival is negligible (Leider et al. 1986; Seelbach 1986, 1987; Washington 1982). However, some may survive to become smolts the following spring.

Smolts produced from submigrant releases would raise the estimates of smolts that reach the sea above the smolt-release numbers reported by hatcheries. On the other hand, evidence suggests that in some rivers a large proportion of hatchery-produced smolts do not complete their downstream migration and either perish or become resident fish (Kent Ball, Idaho Dept. of Fish and Game [IDFG], pers. comm.; Seelbach 1987). This factor would lower the estimated number of smolts successfully reaching the sea. Thus the number of fish that have the potential to reach the ocean and contribute to marine populations or to future spawning populations may differ from the number of migrants released. On the whole, however, regional release trends still provide an important perspective on the magnitude and extent of hatchery production of steelhead.

SOURCES OF DATA

Information on the number of smolts released between 1960 and 1976 were obtained from Wahle and Smith (1979). All other information was obtained from records of state or provincial fish management agencies (Alaska Dept. of Fish and Game 1978-1988; British Columbia Ministry of Environment unpublished data; California Dept. of Fish and Game [CDFG] 1978-1988; IDFG unpublished data; Oregon Dept. of Fish and Wildlife [ODFW] 1978-1988; Washington Dept. of Wildlife [WDW] 1978-1988), or from individual hatchery records (federal and state, unpublished).

RESULTS

The number of steelhead migrants released annually from Pacific coast rearing facilities has increased dramatically since 1960. Fewer than 3 million smolts were released in 1960, and over 30 million were released in 1985 (Fig. 2, Table 2). Between 1978 and 1987, an

average of 24.6 million steelhead migrants was released each year over the entire region. Releases within the Columbia River basin, an area that includes the inland tributaries of the Columbia River in Washington, Oregon, and Idaho, accounted for approximately two-thirds of these total yearly releases (Table 2). Among Columbia Basin production facilities, those in Idaho produced the greatest number of smolts (63%), followed by Washington (23%) and Oregon (14%). Based on their proportionate contributions to average yearly releases, individual states or provinces are ranked as follows:

State or Province	Average Number of Smolts Released Each Year, 1978-1987	Percent of Total
Idaho	10,320,000	41.9
Washington	6,782,000	27.6
Oregon	4,537,000	18.4
California	2,304,000	9.4
British Columbia	616,000	2.5
Alaska	62,000	0.2
Total Average Releases, All Areas	24,621,000	100.0

The potential contribution of hatchery-produced migrant steelhead to future populations of returning adults is not fully understood but can be estimated from knowledge of smolt-to-adult survival rates. Estimates of steelhead trout smolt-to-adult survival vary among rivers and hatcheries and are frequently only rough approximations based on the number of fish released as smolts and the number of fish that survive to return as adults. Sometimes more precise estimates are derived from tagging studies or from returns of adults to weirs on study streams where emigrating smolts were counted. A survey of the available data and interviews with qualified research personnel indicate the coastwide rate of return for hatchery fish is approximately 3%, and ranges from 1% to 10%. California steelhead returns averaged 2% recently (Steve Taylor, CDFG, pers. comm.). Oregon steelhead are thought to return at a rate of 4-6% (Nancy MacHugh, ODFW, pers.comm.). In Idaho, due to fish passage problems along the mainstem Columbia River, reported rates of return averaged 1.6-2% to the mouth of the Snake River (Dan Diggs, U.S. Fish and Wildlife Service, pers. comm.; Howell et al. 1985). Between 3% and 6% of the steelhead released in Washington coastal streams return as adults, and from 1% to 4% of releases into Puget Sound survive to return (Pete Hahn, WDW, pers. comm.). Up to 10% of steelhead released from British Columbia hatcheries return, but figures vary too much to permit generalization. The Crystal Lake Hatchery in Alaska has reported an average smolt-to-adult survival rate of 2.8% (Van Hulle 1985). If 3% of the 24.6 million hatchery smolts released each year survive to adulthood, an average estimated 738,000 fish would be produced annually.

Smolt-to-adult survival of wild steelhead is not well studied but is generally considered to be much better (approximately double) than that of hatchery steelhead (Howell et al. 1985). Recent measures of smolt-to-adult survival for wild steelhead from the Keogh River, British Columbia, ranged from 7% to 26% and averaged 16% (Ward and Slaney

1988). Reasons for the superior survival of naturally-produced steelhead are not well understood.

DISCUSSION

The estimated annual production of 738,000 adult hatchery steelhead by North American hatcheries is close to the annual level of adult hatchery production reported by Light (1987). In that report, the average total abundance of adult steelhead returning to the North American coast each year before harvest by inshore sport and commercial fisheries was estimated to be 1.6 million fish. Hatchery steelhead were thought to constitute about one half of this total population, or around 800,000 fish. With a population size approximately equal that of naturally-produced fish, hatchery-produced steelhead contribute substantially to the total North American coastwide adult population. If the smolt-to-adult survival rate is greater than 3%, then the proportion of hatchery fish in the coastwide population is even more substantial. Clearly, to make full use of smolt production numbers, more accurate estimates of hatchery smolt survival rates are required.

The relative abundance of hatchery and wild steelhead in a given region reflects the intensity of artificial production efforts and the extent and health of wild populations. Wild steelhead are most abundant in Alaska, British Columbia, and California, where artificial production is limited. In these areas the combined (hatchery and wild) steelhead population accounts for around 37% of the total coastwide population, yet 62% of all wild fish are found there (Light 1987). Within the Columbia River basin and surrounding areas (the center of abundance for North American steelhead) wild fish are less abundant, hatchery facilities are numerous, and hatchery fish predominate (Light 1987). In terms of population trends, in their examination of escapements for 85 populations of naturally-produced steelhead along the coast, Konkel and McIntyre (1987) concluded that most were on the decline. The future demand for steelhead as a sportfish will likely increase rather than diminish (Billings 1987), and unless habitat enhancement or other measures result in increased wild production, the reliance on hatchery-produced steelhead for meeting the needs of the fishing public will similarly increase (Northwest Power Planning Council 1986).

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LITERATURE CITED

Alaska Department of Fish and Game. 1978-1988. Annual reports to the state legislature. Fisheries Rehabilitation, Enhancement and Development (FRED) Division. Juneau, Alaska. Various paginations.

Billings, S. J. 1987. Steelhead harvest analysis, 1985-86. B.C. Ministry of Environment and Parks, Fish. Tech. Circ. 76. 38 pp.

California Dept. of Fish and Game. 1978-1988. Annual salmonid production. Anadromous Fish Branch Admin. Reports, Inland Fish Division. Sacramento, California. Various paginations.

Crawford, B. A. 1979. The origin and history of the trout brood stocks of the Washington Dept. of Game. Wash. Dept. Game Fish. Res. Rep. 76 pp.

Howell, P., K. Jones, D. Scarnecchia, L. LaVoy, W. Kendra, and D. Ortmann. 1985. Stock assessment of Columbia River anadromous salmonids, Vol. II. U.S. Dept. Energy, Bonneville Power Administration, Div. Fish. Wildl.: 559-1036.

Konkel, G. W. and J. D. McIntyre. 1987. Trends in spawning populations of Pacific anadromous salmonids. U.S. Fish Wildl. Serv., Fish Wildl. Tech. Rep. 9. 25 pp.

Leider, S. A., M. W. Chilcote, and J. J. Loch. 1986. Movement and survival of pre-smolt steelhead trout in a tributary and mainstem of a Washington river sytem. N. Am. J. Fish. Mgmt. 6:526-531.

Light, J. T. 1987. Coastwide abundance of North American steelhead trout. (Document submitted to the International North Pacific Fisheries Commission.) 18 pp. FRI-UW-8710. Fisheries Research Institute, Univ. Washington, Seattle.

Northwest Power Planning Council. 1986. Compilation of information on salmon and steelhead losses in the Columbia River Basin, Volume I. NWPPC, Portland, OR. 252 pp.

Oregon Department of Fish and Wildlife. 1978-1988. Annual anadromous brood year reports, 1977-1987. ODFW, Portland, Oregon. Various paginations.

Savvaitova, K. A., V. A. Maksimov, M. V. Mina, G. G. Novikov, L. V. Kokhmenko, and V. E. Matsuk. 1973. The noble trouts of Kamchatka (systematics, ecology, and the possibilities of using them as the object of trout-culture and acclimatization). The Voronezh Univ., Publishers. 119 pp.

Seelbach, P. W. 1986. Population Biology of steelhead in the Little Manistee River, Michigan. Ph.D. Dissertation. Univ. Michigan, Ann Arbor. 145 pp.

_____. 1987. Smolting success of hatchery-raised steelhead planted in a Michigan tributary of Lake Michigan. N. Amer. J. Fish. Mgmt. 7:223-231.

Sheppard, D. 1972. The present status of the steelhead trout stocks along the Pacific coast. Pages 519-556 in D. H. Rosenberg (ed.), A Review of the Oceanography and Renewable Resources of the Northern Gulf of Alaska. IMS Report R72-23, Sea Grant Rep. 73-3, Inst. Mar. Sci., Univ. Alaska, Fairbanks.

Van Hulle, F. D. 1985. Steelhead workshop. Alaska Dept. of Fish and Game, Sport Fish Division. 124 pp.

Wahle, R. J. and R. Z. Smith. 1979. A historical and descriptive account of Pacific coast anadromous salmonid rearing facilities and a summary of their releases by region, 1960-1976. NOAA Tech. Rep. NMFS SSRF-736. 40 pp.

Ward, B. R. and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Can. J. Fish. Aquat. Sci. 45: 1110-1122.

Washington, P. M. 1982. The influence of the size of juvenile coho salmon (*Oncorhynchus kisutch*) on seaward migration and survival. Pages 146-152 in E. L. Brannon and E. O. Salo (eds.) Salmon and trout migratory behavior symposium. School of Fisheries, Univ. Washington, Seattle.

Washington State Department of Wildlife. 1978-1988. Summary of steelhead stocked in Washington by the Washington Dept. of Wildlife. (July 1-June 30, 1980-1987). Fish. Mgmt. Div. Reports. Olympia, WA. Various paginations.

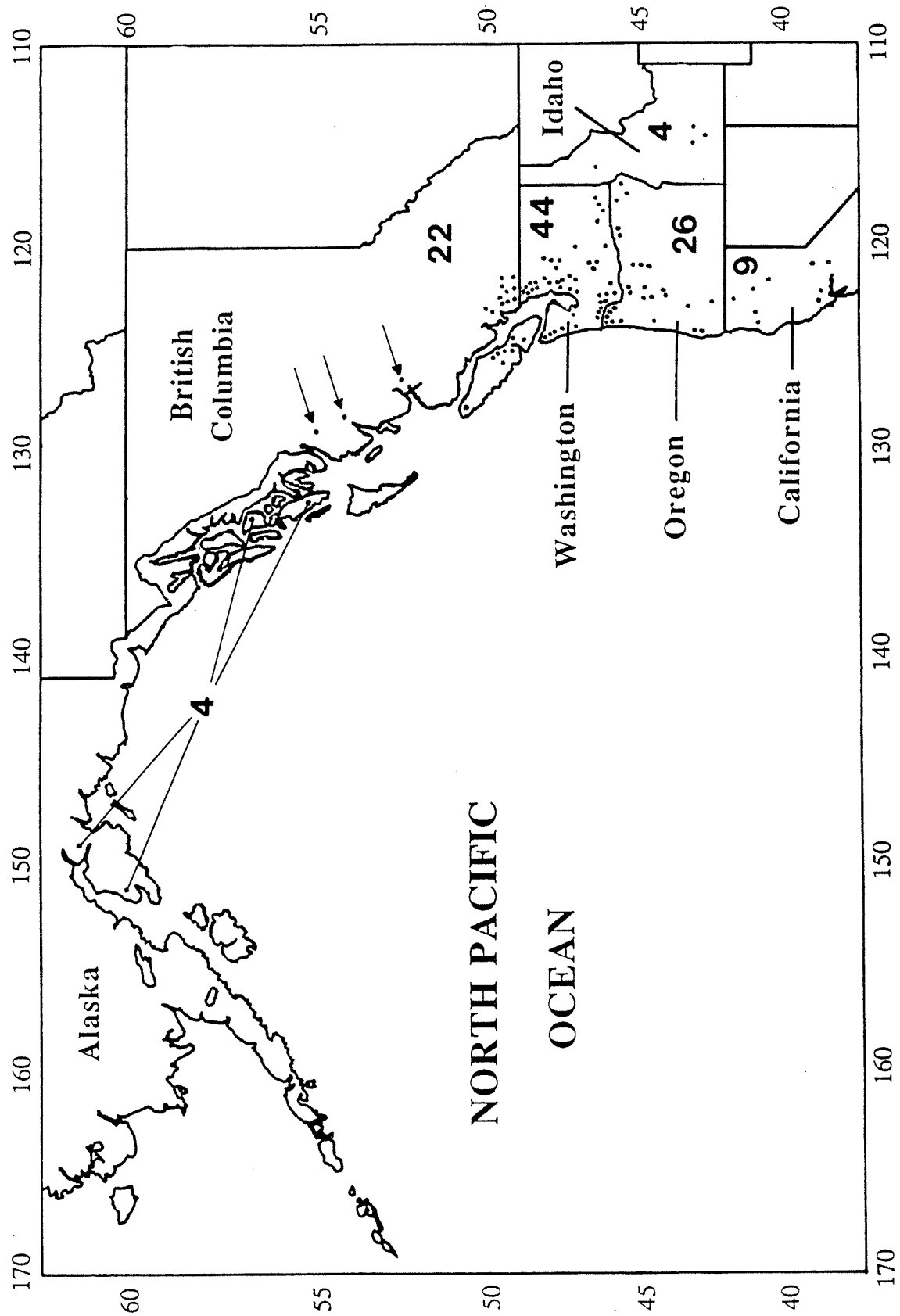

Figure 1. Approximate locations of steelhead rearing facilities along the Pacific coast of North America. Numbers show the total facilities in each state or province.

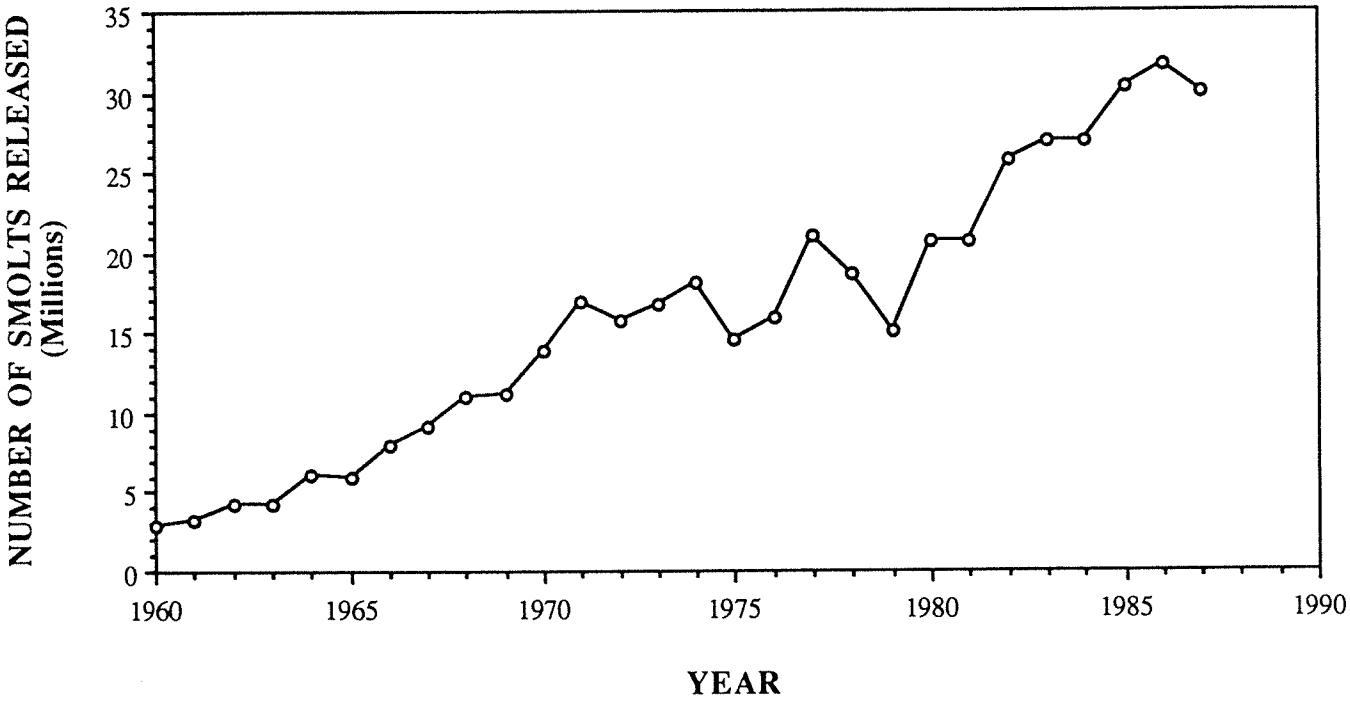

Figure 2. Number of steelhead smolts released annually by production facilities along the Pacific coast of North America.

Table 1. List of steelhead rearing facilities along the Pacific coast of North America.

Region	Rearing Facility Type and Name
Alaska[1]	**Hatcheries**
	Crooked Creek
	Crystal Lake
	Elmendorf
	Klawock
British Columbia[2]	**Hatcheries**
	ARCC
	Bell-Irving
	Big Qualicum
	Birkenhead
	Capilano
	Chehalis
	Chilliwack
	Conuma
	Inch Creek
	Kitimat
	Little Campbell
	Little Qualicum
	Nitinat
	Puntledge
	Quatse
	Quinsam
	Robertson Creek
	Seymour
	Snootli
	Spius Creek
	Tenderfoot
	Tobaggan
Washington[3,7]	**Hatcheries**
	Aberdeen
	Beaver Creek
	Bellingham
	Chambers Creek
	Chelan PUD
	Columbia Basin
	Cowlitz
	Lake Whatcom
	Landsburg Co-op
	Leavenworth NFH
	Lyons Ferry
	Makah NFH
	Naches
	Puyallup

Table 1, continued.

Region	Rearing Facility Type and Name
	Quinault NFH
	Shelton
	Skamania
	South Tacoma
	Tokul Creek
	Vancouver
	Wells
	Yakima
	Rearing Ponds or Pens
	Alder Creek
	Barnaby Slough
	Bellingham Maritime Heritage Center
	Bogachiel-Calawah
	Cottonwood Pond
	County Line
	Coweeman
	Curl Lake
	Davis Slough
	Dayton
	Gobar
	Green River
	Marblemount Salmon Hatchery
	Merwin
	Nelson Springs
	Ringold Springs
	Skookumchuck
	Skykomish
	Snider Creek
	Turtle Rock
	Whitehorse
	White Salmon
Idaho[4,7]	**Hatcheries**
	Dworshak NFH
	Hagerman NFH
	Magic Valley
	Niagara Springs
Oregon[5,7]	**Hatcheries**
	Alsea
	Bandon
	Big Creek
	Cedar Creek
	Clackamas
	Cole Rivers
	Eagle Creek NFH

Table 1, continued.

Region	Rearing Facility Type and Name
	Elk River
	Gnat Creek
	Irrigon
	Klaskanine
	Leaburg
	Marion Forks
	McKenzie
	Nehalem
	Oak Springs
	Roaring River
	Rock Creek
	Round Butte
	South Santiam
	Umatilla
	Wallowa
	Warm Springs NFH
	Rearing or Acclimation Ponds
	Trojan
	Big Canyon
	Little Sheep
California[6,7]	**Hatcheries**
	Coleman NFH
	Feather River
	Iron Gate
	Mad River
	Mokelumne River
	Nimbus
	Silverado Field Op. Base
	Trinity River
	Warm Springs

[1]Holland, J. S. 1989. FRED 1988 annual report to the Alaska State Legislature. Alaska Dept. of Fish and Game, Fish. Rehab., Enhance. and Develop. Div. No. 89. 110 pp.

[2]British Columbia Ministry of Environment. Recreational Fisheries Branch, Victoria, B.C. Unpublished data.

[3]Gearheard, J. 1988. Hatchery program, 1987-88. Washington State Department of Wildlife, Fish Mgmt. Div. 88-10. 38 pp.

[4]Idaho Department of Fish and Game. Unpublished data. Boise, Idaho.

[5]Oregon Department of Fish and Wildlife. 1989. Fish propagation facilities. Portland, Oregon.

[6]California Department of Fish and Game. Unpublished data. Sacramento, California.

[7]U.S. Fish and Wildlife Service. 1985. Propagation and distribution of fishes from the national fish hatchery system. U.S. Interior Dept. Rep. No. 20. 73 pp.

Table 2. Thousands of steelhead smolts released annually by production facilities along the Pacific Coast of North America.

Year	Alaska	British Columbia	Coastal Washington	Coastal Oregon	Columbia River Basin: Washington	Columbia River Basin: Oregon	Columbia River Basin: Idaho	Total Columbia River Basin	California	Coastwide Total
1960	0	0	1128.2	295.5	681.5	406.2	0	1087.7	315.1	2,826.5
1961	0	0	867.4	436.9	1004.1	370.8	0	1374.9	518.1	3,197.3
1962	0	0	1215.3	662.4	1071.0	1096.9	0	2167.9	187.3	4,232.9
1963	0	0	1442.6	591.8	1335.9	752.8	0	2088.7	72.3	4,195.4
1964	0	0	1326.8	845.9	1839.6	831.0	0	2670.6	1163.1	6,006.4
1965	0	0	1336.7	841.5	2120.4	817.2	24.1	2961.7	736.7	5,876.6
1966	0	0	1477.2	823.0	2054.6	1007.0	138.8	3200.4	2436.2	7,936.8
1967	0	0	1230.2	905.7	2453.1	1119.8	1364.8	4937.7	2027.0	9,100.6
1968	0	0	1498.2	1206.6	2697.1	1371.2	2034.2	6102.5	2129.7	10,937.0
1969	0	0	2084.9	1412.8	2731.5	1413.6	1732.5	5877.6	1818.8	11,194.1
1970	0	0	1932.0	1742.6	3692.2	1168.7	3173.3	8034.2	2188.5	13,897.3
1971	0	0	1945.7	1750.1	3306.8	1189.8	4932.0	9428.6	3752.5	16,876.9
1972	0	0	1847.3	1839.1	3176.1	1646.8	2585.1	7408.0	4552.8	15,647.2
1973	0	41.7	2217.8	1731.1	3394.5	1833.5	4619.6	9847.6	2953.8	16,792.0
1974	0	23.0	2061.5	1609.0	2805.2	2047.3	6340.0	11192.5	3222.7	18,108.7
1975	17.5	25.8	2146.8	1662.0	2888.5	1726.5	3511.6	8126.6	2524.3	14,503.0
1976	16.5	80.5	2696.4	1597.2	2786.7	1960.9	3774.4	8522.0	3026.3	15,938.9
1977	0.6	61.5	6031.4	2212.2	3235.3	1749.7	5609.0	10594.0	2064.0	20,963.7
1978	10.7	143.3	2861.2	2785.4	3155.7	3007.2	4706.1	10869.0	1903.6	18,573.3
1979	0	466.4	2927.8	317.0	3333.8	287.7	5141.7	8763.2	2512.7	14,987.1
1980	5.4	415.1	3388.1	2397.3	3248.3	1885.3	7606.9	12740.5	1761.3	20,707.7
1981	10.4	482.7	3316.7	2163.3	3555.2	1989.4	6824.5	12369.2	2336.6	20,678.9
1982	52.1	708.1	3112.7	2345.5	2579.1	1850.5	12865.3	17295.0	2180.4	25,693.8
1983	45.3	693.9	2729.2	2298.1	3972.2	2394.0	11972.3	18338.5	2724.6	26,829.6
1984	22.2	863.7	3238.3	2219.5	4628.3	2704.0	10797.6	18129.9	2422.1	26,895.8
1985	195.0	866.9	2850.0	2425.5	4046.5	2775.2	14215.6	21037.3	2889.9	30,264.7
1986	105.8	724.6	3143.3	2360.0	4281.2	2639.2	16059.8	22980.3	2276.8	31,590.8
1987	171.4	790.9	2662.9	2520.6	4785.1	4003.3	13008.4	21796.8	2036.1	29,978.8
Production Average:	50.2	425.9	2311.3	1571.4	2887.8	1644.5	6219.0	9640.8	2455.5	15,872.6
1978-87 Average:	61.8	615.6	3023.0	2183.2	3758.6	2353.6	10319.8	16432.0	2304.4	24,620.1
Percent:	0.2	2.5	12.3	8.9	15.3	9.5	41.9	66.7	9.4	100.0