CHARACTERISTICS OF SKAMANIA AND BEAVER CREEK HATCHERY ANADROMOUS STOCKS

by

Chris Randolph

Fisheries Management Division
Washington Department of Game
600 North Capitol Way
Olympia, Washington 98504

April, 1986

INTRODUCTION

A detailed history of sea-run cutthroat stocks reared and released at Beaver Creek Hatchery between 1958 and 1979 was presented by Crawford (1979). He noted that the release of a combined stock from the Nenam, Green, and Elochoman drainages in the Elochoman River produced few returns between 1961 and 1965. An domesticated (captive) Oregon stock originally from the North Fork of the Alsea River, Oregon, was released in the Elochoman River to increase returns starting in 1963. The two stocks were spawned separately until 1968. By 1972 the stocks had been combined to form the Beaver Creek stock. Returns from releases of this Beaver Creek captive brood stock continued until 1982. Starting in 1980, Cowlitz sea-run cutthroat were released into the Elochoman River because they were known to have a higher return rate in the Cowlitz River. Currently, returns of Cowlitz sea-run cutthroat stock are numerous and have resulted in a self-sustaining program.

Sea-run Cutthroat returns were low in past years. In his review of historic marked releases (1960-1973) in the Elochoman River, Lucas (1979) showed that the average return to the Beaver Creek Hatchery was 1.8%. He explained this relatively poor return by suggesting that smolts had not imprinted well to the hatchery. Poor imprinting may have also resulted in the 30 percent straying rate for this stock of the stock reported by Royal (1972). Lucas (1979) suggested that the duration of culturing the captive brood

stock may have reduced genetic variability within the stock and forgone natural selection for saltwater adaptability and resistance to saltwater pathogens.

During creel census in 1977 Lucas (1979) found that the overall Elochoman River sea-run cutthroat harvest rate was low and that stream anglers were only slightly more successful than Columbia bar fisherman. Although sea-run cutthroat are not as popular as they are within the Puget Sound many anglers do fish for them from early September through early October in tidewater areas of the Columbia River. Reasons for this poor return rate were further examined using a marking study.

The marking study conducted by Lucas (1979) in 1978 suggested that captive stocks contributed only incidentally to sea-run cutthroat fisheries. Lucas (1979) released two different marked cutthroat groups into Mill Creek, a lower Columbia River tributary, two weeks apart (May 12 and May 26), prior to opening day of fishing season. Data collected by electrofishing and creel census checks, indicated that cutthroat smolts tended to move rapidly out of the stream within a few days of release. Lucas (1979) concluded that the captive broodstock did not remain near the planting site long enough for significant sport harvest.

METHODS

Analysis

Data analysis was conducted via computer as described in the winter-run steelhead section of this report.

Numbers Trapped

Methods used in the analysis of sea-run cutthroat numbers trapped were similar to winter-run steelhead methods presented in that section of this report.

Time of Return to the Hatchery

Similar methods as presented in winter-run steelhead section of this report.

Length at Return

Length data was collected and analyzed in part as described in the corresponding winter-run steelhead section. Return data from marked sea-run cutthroat were compiled and then compared using Mann-Whitney and Kruskal-Wallis one-way ANOVA tests (Conover 1980).

Sex Ratio

Male:female ratios of trapped sea-run cutthroat was calculated for wild, captive brood years, and Cowlitz stocks.

Spawning Time

Total eggs spawned each spawning day were summed until one-half the annual total for each stocks was reached. This

day was designated the median spawning date for each stock each year. Median dates of spawning were plotted and compared using correlations, Mann-Whitney and Kruskal-Wallis one-way ANOVA tests (Conover 1980).

Fecundity

The average annual fecundity of sea-run cutthroat spawned at Beaver Creek Hatchery was determined by dividing daily totals of eggs spawned by the number of females for each day of spawning. The fecundity of mixed wild and captive stocks were compared using Mann-Whitney and Kruskal-Wallis tests (Conover 1980).

Smolt to Adult Survival

Smolt to adult survival was determined using methods similar to those presented under winter-run steelhead section.

RESULTS

Numbers Trapped

Numbers of sea-run cutthroat trapped at Beaver Creek Hatchery underwent a dramatic decrease in the early 1970's and then increased to approximate previous levels after 1981 (Figure 21). The average annual number of sea-run cutthroat trapped between 1965 and 1970; 1971 and 1981, and 1982 and 1985 was 1189, 85, and 1421, respectively.

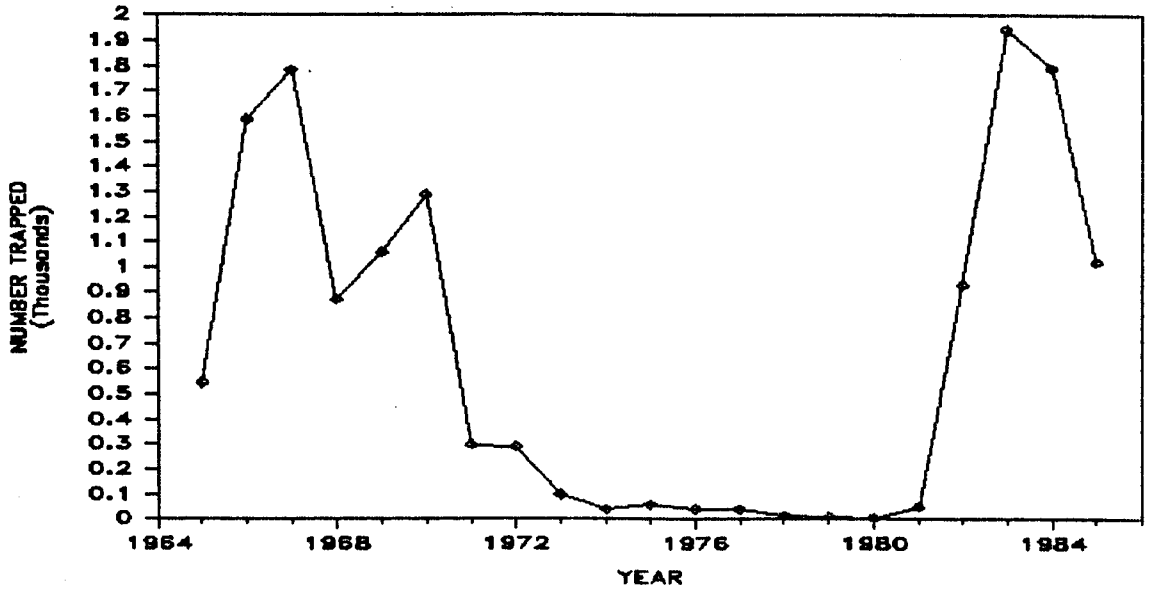

Figure 21. The numbers of hatchery cutthroat trapped at Beaver Creek Hatchery (1965-1985).

Time of Return to the Hatchery

Cutthroat returns to the Beaver Creek Hatchery have been dispersed between September and March. The typical sea-run cutthroat return normally has a single peak month occurring in November or December (Figure 22).

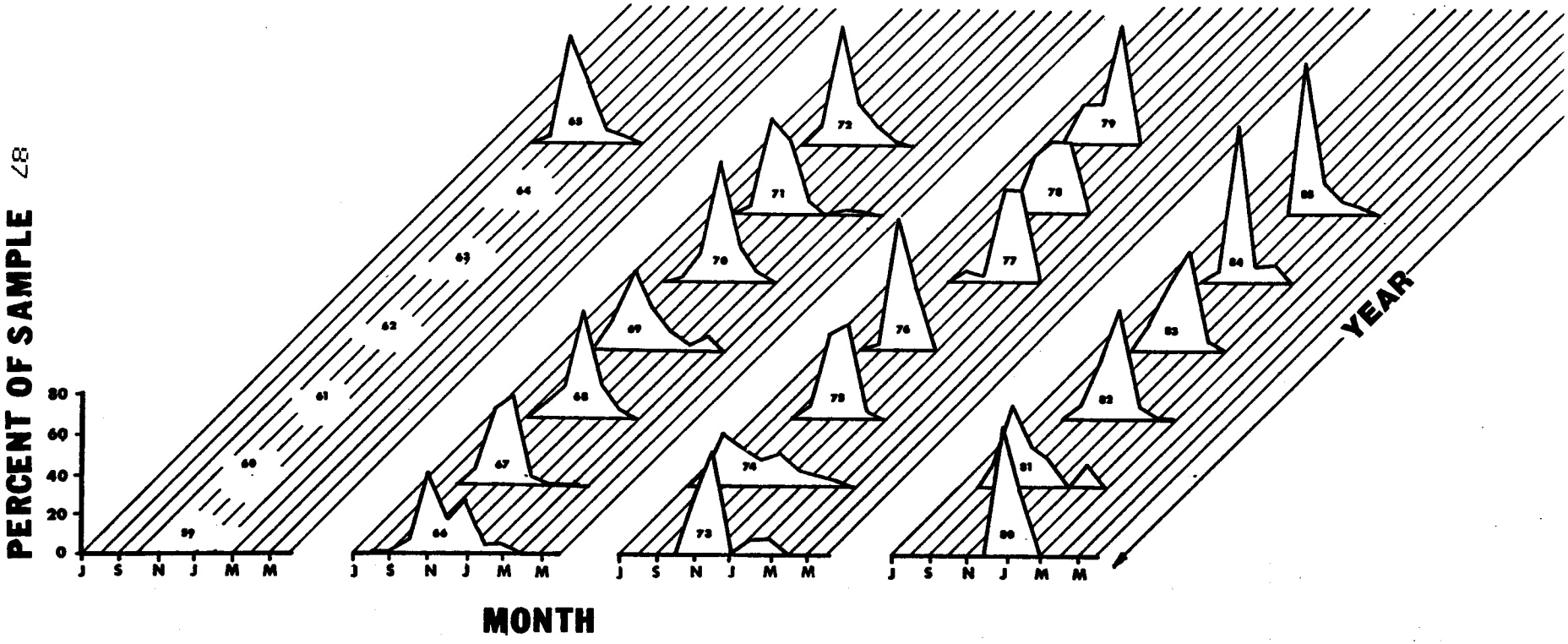

Figure 22. The percent annual number of cutthroat trapped by month at Beaver Creek Hatchery (1959-1985).

The annual median date of trapping ranged from October 30 in 1973 to January 23 in 1980. The average annual median trapping date from 1965 to 1985 was December 10. Linear regression analysis of median trapping date and year showed no significant (P)0.05) trend (Appendix C1). The large range in return timing, within a given year, may have precluded a statistically significant trend in median trapping date.

Length at Return

Male and female length frequency plots show large variations within length groups between years (Figure 23). Mean fork lengths of male and female sea-run cutthroat support these observations (Table 7). During the years of study, differences in survival, age at maturity, and/or numbers stocked may have occurred which affected length frequency distributions.

Mean fork lengths were compared between sexes and return years. Statistical differences between female lengths occurred between 1982 and 1985, and between male and female lengths within 1984 and 1985 (Table 7).

Mean length of marked (1980 release of Cowlitz and Elochoman River stocks) two and three total age female sea-run cutthroat was 361 and 422 mm (14 and 17 inches), respectively. No significant difference was found between marked releases within each age class. Significant differences were found between age classes for marked group releases (Appendix C2).

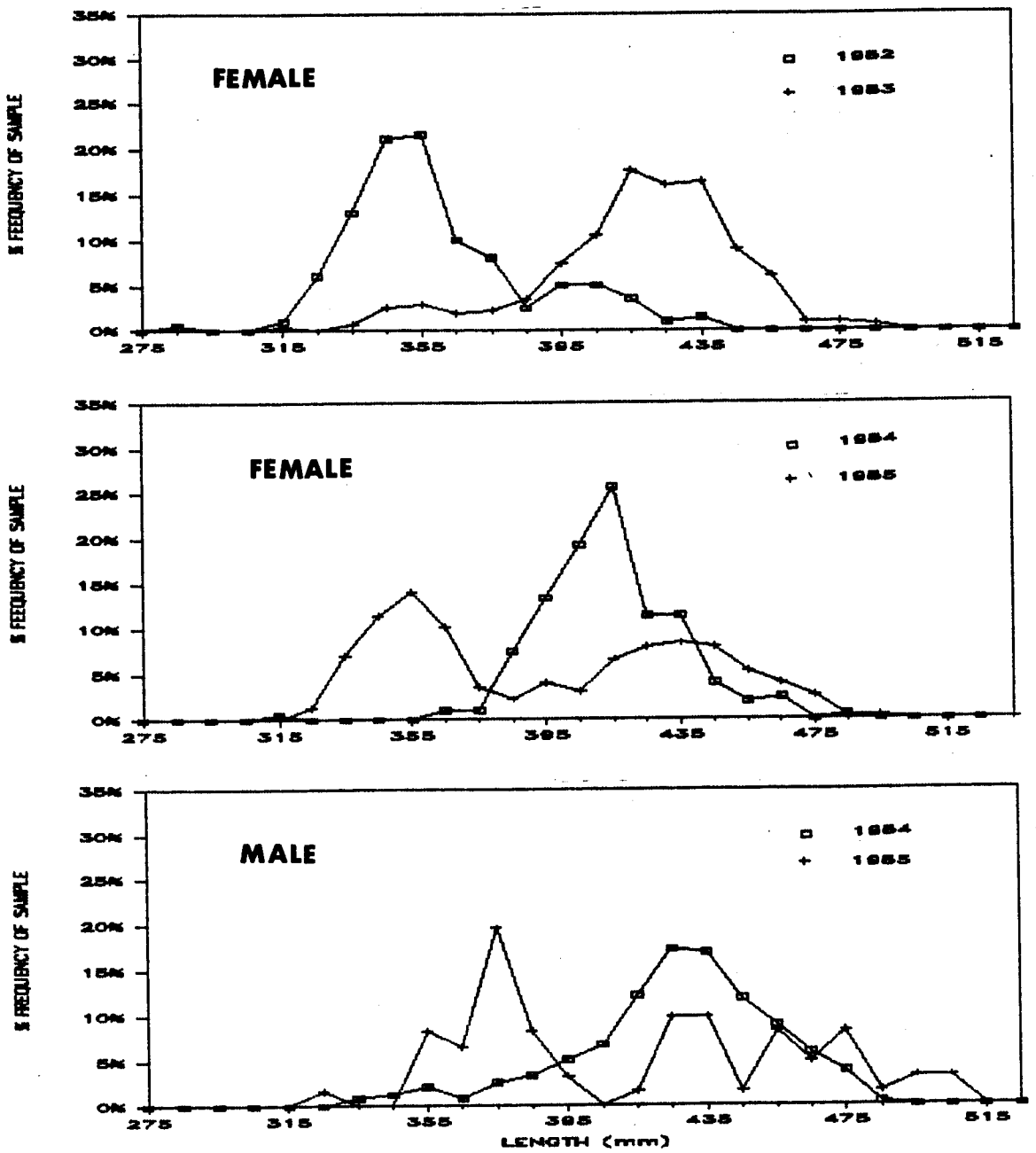

Figure 23. The percent of female and male sea-run cutthroat by length groups (percent length frequency) trapped during 1982 and 1985 at Beaver Creek Hatchery.

Table 7. Comparison of male and female sea-run cutthroat mean fork lengths at Beaver Creek Hatchery.

Year	Male			Female			Male-female	Female
	mean (mm)[a]	N	SD	mean (mm)	N	SD	P-value	P-value
1982	NA[b]	0		335	199	26.03		
1983	NA	0		412	311	28.16		
1984	402.7	237	28.62	408	124	21.13	0.000	
1985	409.8	61	46.91	390	228	44.64	0.000	0.000

[a] inches = mm x 0.03937
[b] Data not available.

Sex Ratio

The male to female ratio of sea-run cutthroat trapped at Beaver Creek Hatchery fluctuated between 1975 and 1978, and 1982 and 1985 (Figure 24). No significant differences were found to exist between these two time intervals. The overall average sex ratio for the two time intervals was 1.4:1.0 (male:female) and ranged from 0.5:1.0 in 1980 to 2.2:1.0 in 1982. No sex ratio data were available from 1979 to 1981.

Spawning Time

Median date of spawning for wild, captive, and Cowlitz stocks were compared between 1959 and 1985. Median date of spawning for wild and captive stocks was similar between years (Figure 25). The median spawning dates of native and captive brood stocks were significantly correlated ($r = 0.871$). No significant difference was found between wild and

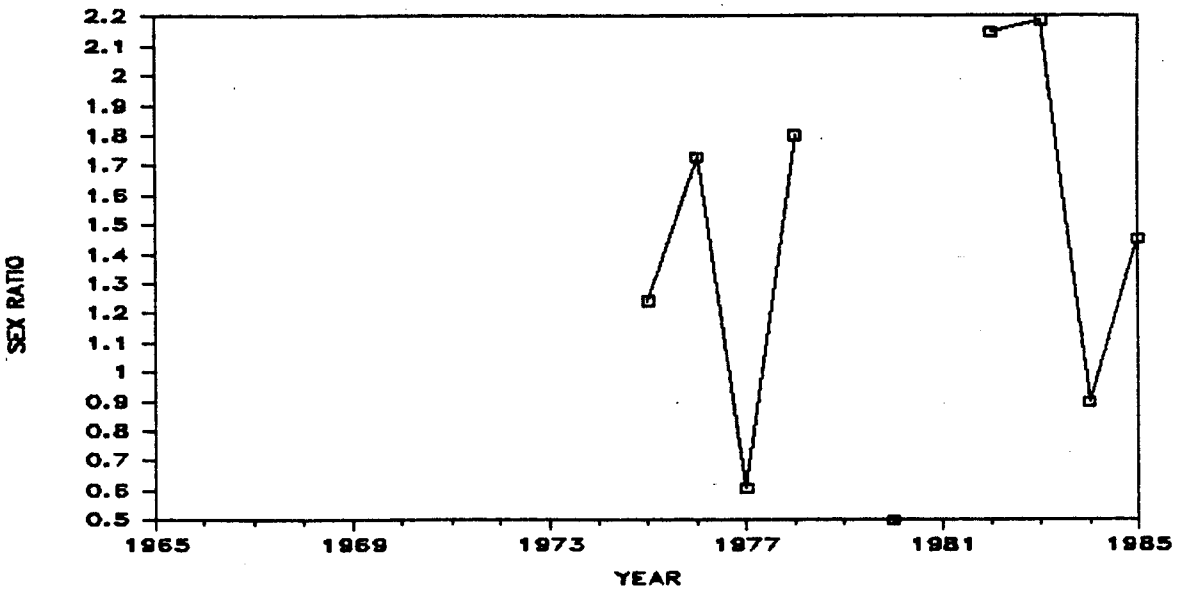

Figure 24. The sex ratio (male:female) of hatchery cutthroat trapped between 1975 and 1985 at Beaver Creek Hatchery.

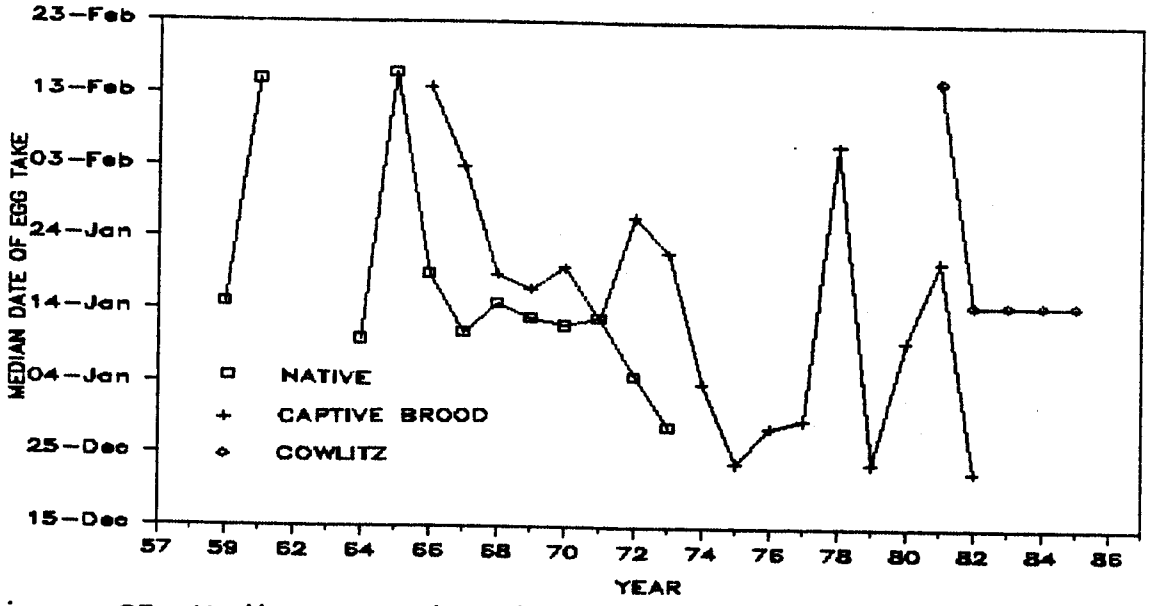

Figure 25. Median spawning dates (date when 50% of eggs were taken) for native (wild), captive, and Cowlitz stocks of cutthroat at Beaver Creek Hatchery (1959-1985).

captive broodstock median spawning dates (Appendix C3). Captive broodstock median spawning dates for ages two, three, and four were significantly different (Appendix C4).

Fecundity

Mean fecundity of wild and captive broodstocks were 898 and 1103 between 1965 and 1973, respectively. Average annual fecundity of mixed age wild and captive stocks were statistically similar ($P>0.05$) between 1965 and 1969, but were distinct ($P<0.05$) between 1970 and 1981 (Appendix C5). This was attributed to an increased percentage of older spawners between 1970 and 1981. Significant differences were found between captive cutthroat broodstock mean annual fecundity within ages two, three, and four. Differences were also found between the fecundity of age two, three and four captive cutthroat.

Egg to Smolt Survival

Production Records

Monthly lot records show that mortalities of sea-run cutthroat averaged 56% (Appendix C6). These mortality rates have been corrected for unknown loss by subtracting unaccountable loss from the total number lost per lot. The numbers of sea-run cutthroat that were in each lot were often larger than expected. This resulted in average overruns in these lots of 4.9%. Mortalities within lots were, in general, lowest during November and December (Appendix C7).

Viral Disease

The sea-run cutthroat program at Beaver Creek Hatchery was dramatically impacted by IHN between 1981 and 1983. During the 1981-1982 spawning season 186,381 eggs were collected from sea-run cutthroat. There were 63,600 eyed eggs destroyed which were IHN positive. The remaining eggs were hatched but later destroyed as they developed symptoms of IHN. Of 219,100 eggs spawned during the 1982-1983 season, 23,824 were shown to be IHN positive and destroyed. As the remaining eggs that were hatched and reared, 90,470 showed IHN symptoms and were destroyed. Smolts from these eggs were considered IHN exposed and planted into the Elochoman River only.

Bacterial Disease

Bacterial diseases of sea-run cutthroat are as described for winter-run steelhead.

Parasitic Disease

Parasitic diseases for sea-run cutthroat are similar to those for winter-run steelhead.

Smolt to Adult Survival

Marked Comparisons

Marked adult sea-run cutthroat returning to Beaver Creek Hatchery were almost equally divided between two and three total age fish, 46.4, and 43.8%, respectively. Returns at four (6.8%) and five (1.7%) year ages were markedly lower. Average percentage return to the hatchery of all age groups

was 1.0% (Appendix C8). Stepwise linear regression was conducted to determine the explainable amount of variation in smolt to adult survival. Independent variables tested were year of release, number of smolts released, average size at release (number/0.45 kg), and percent total return from total age two through five. The analysis used data that were from releases of smolts that had adult returns at several ages (9 of 20 marked releases, Appendix C8). Results of this analysis indicated that the independent variable percentage return at total age five explained 45.9% of the variation in percent return to the hatchery (Appendix C9).

Two significant positive correlations were found between: (1) the number of smolts released and percentage return of three year olds (0.770), and (2) size at release and percentage return of four year olds (0.731). The significant negative correlations were also found between: (1) numbers released and percentage total return of two year olds (-0.869), (2) percentage return and percent return of five year olds (-0.726), and (3) between percentage return of two and three year olds (-0.888, Appendix C10). Correlations between total percentage return and year of release, number released, size at release (number/0.45 kg), percentage of total return at age two, three, four, and five were not significantly different than zero.

Size and Year of Release

Returns of marked cutthroat smolts released between 1966 and 1970 decreased dramatically. This decline may have been

a result of using progeny of captive cutthroat broodstock for marked release groups (Figure 26). Declining returns were reversed as captive stocks were replaced with a migratory stock (Cowlitz stock) in 1980. The use of these two stocks influenced the relationship between size at release and percent return.

Marked cutthroat returns were higher for releases at 6.5 per 0.45 kg (1966 and 1967 releases) than releases at larger sizes (releases after 1967, Figure 26). The decline in percent return may have been influenced more by the brood stock used than by increased size at release.

Paired Experimental Releases

Paired releases were used to test the effect of (1) rearing sea-run cutthroat at Vancouver Hatchery, and (2) the use of Cowlitz stock on adult returns to Beaver Creek Hatchery on percent return to the hatchery. No significant difference in percent return the hatchery was found between sea-run cutthroat reared at Vancouver and Beaver Creek Hatcheries and released into Beaver Creek in 1964. Furthermore, no significant difference was found between returns of Beaver Creek and Cowlitz stocks of sea-run cutthroat to Beaver Creek Hatchery (Appendix C11).

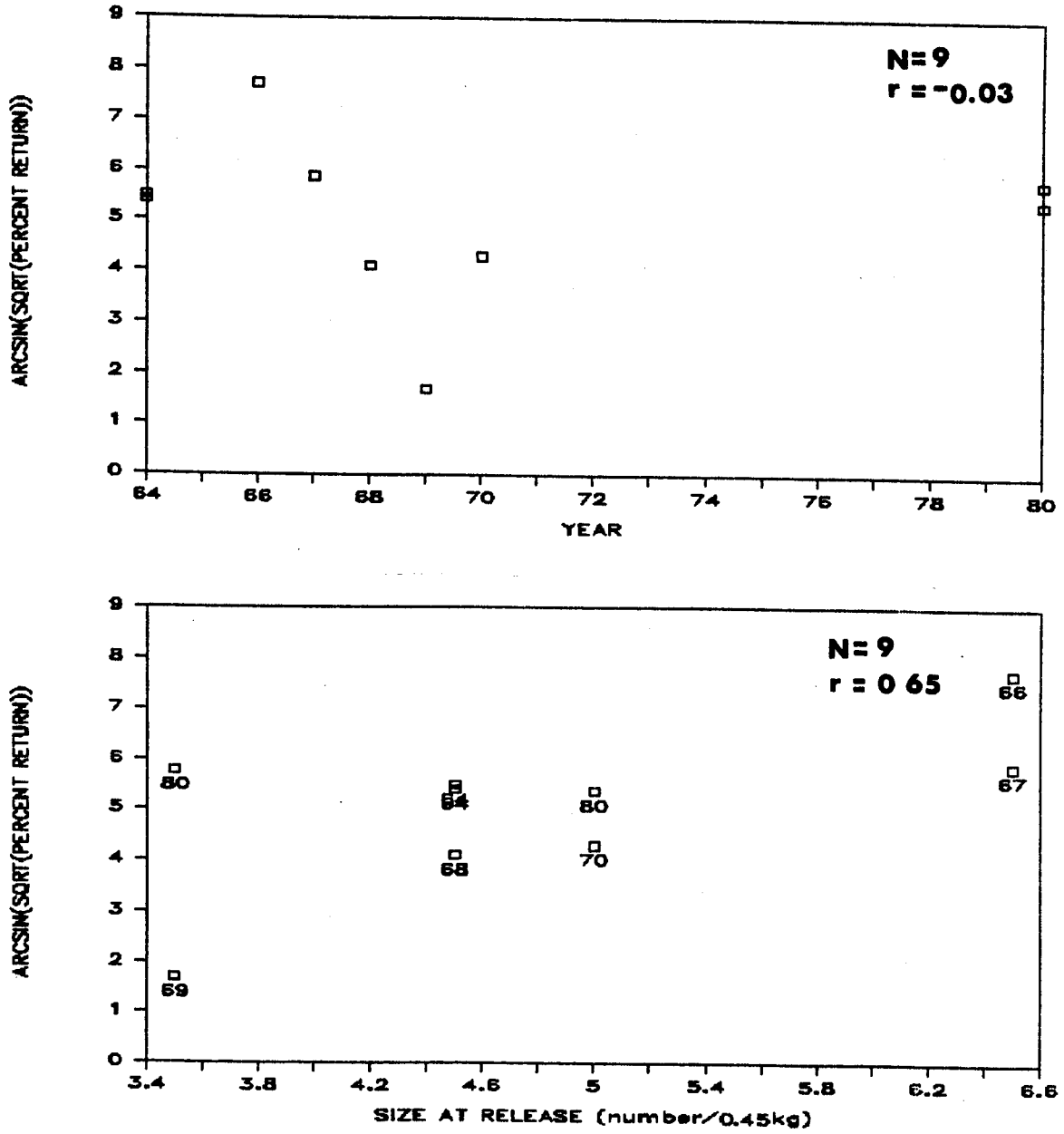

Figure 26. Plot of percent return to the hatchery, year and size (number per 0.45 kg) at release of cutthroat at Beaver Creek Hatchery.

DISCUSSION

Hatchery Returns

Change from a captive brood stock to a truly anadromous stock has dramatically increased adult returns. During years when a captive brood stock was used for hatchery production, returns were low. Currently, the use of Cowlitz stock has provided adequate increased numbers of returning adults.

Sea-run cutthroat return to Beaver Creek Hatchery later (November-December) than at the Cowlitz Hatchery (October-November; Tipping and Springer 1980). Migration distances, discharge and temperature differences between the Cowlitz and Elochoman drainages may explain these inconsistencies.

Length frequency distributions were similar for cutthroat trapped at Cowlitz and Beaver Creek Hatcheries. Tipping (1982) showed that females exhibited modal peaks at 34 and 38 cm and males had frequency peaks at 34 and 41 cm. Length frequency plots of Cowlitz data did not indicate differential year class survival similar to Beaver Creek. Year class strength differences between rivers may reflect the occurrence of IHN in cutthroat at Beaver Creek Hatchery prior to release.

Cutthroat male:female ratios favored males at Beaver Creek and Cowlitz Hatcheries. Both cutthroat runs had approximately 1.4 males per female (Tipping 1982).

Beaver Creek Hatchery sea-run cutthroat (Cowlitz stock) spawn during approximately the same time period as cutthroat

at the Cowlitz Hatchery. Tipping (1982) showed spawning occurred between November and January at the Cowlitz Hatchery.

Before 1981, captive and wild stocks at Beaver Creek had different spawn timings. This is attributed to the use of younger spawners during earlier years. Variable spawn timing of different year classes was described by Tipping (1982) and Mercer (1982). Tipping (1982) noticed a decline in mean length of ripe females over time. Mercer (1982) working with pen-reared cutthroat, showed that the spawning timing of age two fish was later than age three fish.

Mean fecundity of mixed age captive and wild cutthroat at Beaver Creek Hatchery were higher than fecundity calculated at the Cowlitz hatchery. The average fecundity of Cowlitz stock was 809 eggs per female (Tipping and Springer 1980) compared to 889 and 1103 for Beaver Creek wild and captive stocks, respectively. The proportion of ages used in calculation of means and stock differences may explain these findings. Loch (1982) examined 19 maturing wild female cutthroat trout captured within the lower Columbia River estuary for fecundity. He found the number of eggs per female ranged from 304 to 1,587 with an average number of eggs per female of 931. Johnston (1979) and Mercer (1982) reported age specific fecundities that were lower than calculated for captive brood stock age groups at Beaver Creek Hatchery. The use of a fish stock that had been domesticated for many years (Alsea stock) at Beaver Creek may explain this finding. Mercer (1982) calculated fecundity of net pen

reared cutthroat and Johnston (1979) reported on native Stillaguamish River stock.

Hatchery Smolt to Adult Survival

The age composition of returning cutthroat was found to be nearly equally divided between two and three year olds at Beaver Creek, whereas data collected on the Cowlitz River during a creel census showed a higher proportion to two year old and corresponding lower proportion of three year and older fish (Tipping 1982). Stock differences may explain these distinctions. Results of linear regression analysis were of little value in prediction of percent return to the hatchery. Changes in stocks used during the years study confounded interpretation of these results.

Recommendation for Future Research and Changes in Management

Sea-run cutthroat and steelhead have similar relationships between production cost, size at release, residualism, age composition, condition factor at release, and to a lesser extent ocean conditions. Far less information relating these variables has been compiled for cutthroat, this increases the need for future research. Data from these relationships would then be used to improve smolt to adult survival and develop run-size predictive models (Figure 12).

A larger factor for sea-run cutthroat than steelhead is the amount of straying that occurs in returning adults. Surveys of adjacent watersheds for wild-population

distribution and life history patterns in conjunction with smolt mark-recapture studies would prove invaluable to managers.

Evaluation of the sea-run cutthroat fishery would provide effective means for its enhancement. Use of sea-run cutthroat should be enhanced to provide recreation during the late summer and fall seasons.

The current study identified differences in age structure between sowlitz and Beaver Creek sea-run cutthroat stocks. As Cowlitz stock had a higher proportion of two than three year old adults, Beaver Creek stock ages were equally divided between the two and three year class. Having an older age structure may result in lower smolt to adult survival. Beaver Creek stock originated from Cowlitz stock as recently as 1981. Such a rapid change in age structure merits attention.

REFERENCES CITED

Armstrong, G. 1985. Fish culture characteristics of Skamania strain steelhead in Indiana. Indiana Department of Natural Resources Report. 607 State Office Building, Indianapolis, IN 46204.

Bedell, G.W. 1972a. Annual report Trinity River Salmon and Steelhead Hatchery thirteenth year of operation 1970-71. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 72-4.

Bedell, G.W. 1972b. Annual report Trinity River Salmon and Steelhead Hatchery fourteenth year of operation 1971-72. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 72-4.

Bedell, G.W. 1975. Annual report Trinity River Salmon and Steelhead Hatchery 1973-74. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 75-4.

Bedell, G.W. 1978. Annual report Trinity River Salmon and Steelhead Hatchery 1975-76. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 78-1.

Bjornn, T.C. and R.R. Ringe 1984. Evaluation of two-year rearing program for steelhead trout at Dworshak National Fish Hatchery. Techtical Report 84-7..

Chilcote, M.W., S.A. Leider, and R.P. Jones Jr. 1981. Kalama River studies, 1980 progress report. Washington Department of Game Fishery Research Report 81-11. Contract 80-ABH-0006.

Chilcote, M.W., S.A. Leider,and J.J. Loch 1982. Kalama River salmonid studies, 1981 progress report. Washington Department of Game Fishery Research Report 82-4. Contract 81-ABH-00025.

Chilcote, M.W., S.A. Leider, J.J. Loch, and R.F. Leland 1983. Kalama River salmonid studies, 1982 progress report. Washington Department of Game Fishery Research Report 83-3. Contract 82-ABH-37.

Chilcote, M.W., S.A. Leider, and J.J. Loch. 1984 Kalama River salmonid studies, 1983 progress report. Washington Department of Game Fisheries Management Division Report 84-5. Contract 84-ABH-00018.

Conover, W.J. 1980. Practical nonparametric statistics, second edition. John Wiley and Sons, New York, New York.

Crawford, B.A., S.A. Leider, J.M. Tipping and M.W. Chilcote 1978. Kalama River steelhead investigations. Progress report for fiscal year 1978. Washington Department of Game Fishery Research Report. Contract 88-E-25061; 03-78-M02-38.

Crawford, B.A., S.A. Leider, and M.W. Chilcote 1979. Kalama River steelhead investigations progress report for fiscal year 1979. Washington Department of Game Fishery Research Report. Contract 79-ABC-00022.

Crawford, B.A. 1979. The origin and history of the trout brood stocks of the Washington Department of Game. Washington Department of Game Fishery Research Report.

Evenson, M.D., R.D. Ewing, E.K. Birks, and A.R. Hemmingsen 1982. Cole River's Hatchery evaluation. Oregon Department of Fish and Wildlife Project AFS-71-5.

Evenson, M.D. and R.D. Ewing 1984. Cole Rivers hatchery evaluation. Oregon Department of Fish and Wildlife Project AFC-123-1-1 and AFS-78-1-1. Period covered January 1, 1983 to June 30, 1984.

Garrison, R.J. and N.M. Rosentreter 1980. Stock assessment and genetic studies of anadromous salmonids. Oregon Department of Fish and Wildlife Project AFS-73-3.

Gibson, M., Personal Communication 1985. Senior Fisheries Biologist Division of Fish and Wildlife. Box 218, West Kingston, R.I. 02892.

Hisata, J.S., M.L. Schuck, M.W. Mobbs, T.Y. Cho, G.R. Martinsen, V. Rasmussen, H.T. Kurose and W.T. Pederson 1980. Columbia River tag recovery project report. Pacific Northwest Regional Commission Grant Number 10990057, National Marine Fisheries Service Contract Number 80-ABS-00039.

Hull, M. 1968. Skamania steelhead hatchery-increase in size of returning summer-run adult steelhead. Proceedings of the Northwest Fish Culture Conference, Idaho Fish and Game, Boise, Idaho.

Hull, M. 1976. Skamania summer-run steelhead summary. Unpublished Washington Department of Game Report to Jack Ayerst.

Janson, V. 1980. Skamania standard hatchery operation procedure report. Unpublished Washington Department of Game manuscript to Bruce Crawford.

Janson, V., Personal Communication 1985. Manager Skamania Trout Hatchery. Washington Department of Game 5405 N.E. Hazel Dell Avenue, Vancouver, WA 98663.

Jochimsen, W.H. 1974. Annual report Nimbus Salmon and Steelhead Hatchery 1972-73 fiscal year. California Department of Game, Anadromous Fisheries Branch, Administrative Report number 74-8.

Johnston, J.M. 1979. Sea-run cutthroat Stillaguamish River creel census (1978) and harvest limit recommendations. Washington Department of Game. Fisheries Research Report.

Kendra, W. 1985. Assessment of steelhead trout stock in Washington's portion of the Columbia River basin. Washington Department of Game Fisheries Management Division Report 85-94.

Kleinbaum, D.G. and L.L. Kupper 1978. Applied regression analysis and other multivariable methods. Duxbury Press, Massachusetts.

Lagler, K.F., J.E. Bardach, and R.R. Miller 1962. Icthyology. John Wiley and Sons, Incorporated, New York, New York.

Lavier, D.C. 1967. Skamania Steelhead Hatchery-transfer of adult summer-run steelhead to various Washington rivers. Unpublished manuscript.

Leider, S.A. 1985. Precise timing of upstream migrations by repeat steelhead spawners. Transactions of the American Fisheries Society 114:906-908.

Leider, S.A., M.W. Chilcote, and J.J. Lock 1985. Kalama River studies final report part III adult steelhead life history and movement studies. Washington Department of Game Research Report 85-13.

Loch, J.J. 1982. Juvenile and adult steelhead and sea-run cutthroat trapped within the Columbia River Estuary, 1980. Washington Department of Game Fisheries Management Report 82-2.

Lotus Development Corporation 1983. Lotus 123 users manual, release 1A. 1983 Lotus Development Corporation, 161 First Street, Cambridge, MA 02142.

Lucas, R. 1979. Cutthroat studies in southwest Washington. Washington Department of Game. Fisheries Research Report 80-13.

Mercer, S.P. 1982. Sea-run cutthroat broodstock development and evaluation of enhancement techniques. Washington Department of Game Project Number F-68-R-6.

Reingold, M., Personal Communication 1985. Regional Fishery Manager Idaho Fish and Game. Box 1336, Salmon, ID 83467.

Royal, L.A. 1972. An examination of the anadromous trout program of the Washington State Game Department. Washington Department of Game Report.

Seeley, G. Jr., Personal Communication 1985. Environmental Conservation Bureau of Fisheries. 50 Wolf Road, Albany, NY 12233.

Smith, E.M. 1979. Willamette River spring chinook evaluation; Marion Forks hatchery evaluation; McKenzie River hatchery evaluation. Oregon Department of Fish and Wildlife Contract Numbers 14-16-001-79-403; DACW-49-C-4163; DACW57-74-c-0192.

Sokal, R.R. and F.J. Rohlf 1969. Biometry The principles and practices of statistics in biological research. W.H. Freeman and Company, San Francisco, CA.

Sokal, R.R. and F.J. Rohlf 1981. Biometry, second edition. W.H. Freeman and Company, New York, New York.

SYSTAT Incorporated 1984. SYSTAT the system for statistics. SYSTAT Incorporated, 603 Main Street, Evanston, IL 60202.

Tipping, J.M. and S.G. Springer 1980. Cowlitz River sea-run cutthroat creel census and life history study. Washington Department of Game.

Tipping, J.M. 1982. Cowlitz sea-run cutthroat 1979-1981. Washington Department of Game Fisheries Research Report 82-9.

Tipping, J.M. 1984. A profile of Cowlitz River winter steelhead before and after hatcherey propagation. Washington Department of Game Fishery Report 84-11.

VanTussenbrook, L., Personal Communication, 1985. Hatchery Manager Vancouver Hatchery Washington Department of Game 5405 N.E. Hazel Dell Avenue, Vancouver, WA 98663.

Wagner, H.H. 1967. A summary of investigation of the use of hatchery reared steelhead in the management of a sport fishery. Oregon State Game Commission Fishery Report Number 5.

Washington Department of Game 1977. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Pond: July 1, 1976 - September 30, 1977. Washington Department of Game.

Washington Department of Game 1978. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Pond: October 1, 1977 - September 30, 1978. Washington Department of Game.

Washington Department of Game 1980. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Station: October 1, 1978 - September 30, 1979. Washington Department of Game Report 80-4.

Washington Department of Game 1981. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Station: October 1, 1979 - September 30, 1980. Washington Department of Game Report 81-3.

Washington Department of Game 1982. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Station: October 1, 1980 - September 30, 1981. Washington Department of Game.

Washington Department of Game 1984a. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Station: October 1, 1982 - September 30, 1983. Washington Department of Game Report 84-7.

Washington Department of Game 1984b. Operation and maintenance-Beaver Creek and Skamania hatcheries and Ringold Rearing Station: October 1, 1981 - September 30, 1982. Washington Department of Game Report 84-1.

Watson, R.E. 1962. Investigations of the control of the snail Oxytrema. Unpublished Washington Department of Game manuscript.

Watson, R.E. 1963. Elochoman adult steelhead tagging program. Proceedings of the Northwest Fish Conference, Tumwater, WA 1963.

Will, R.D. 1973. Annual report Mad River Salmon and Steelhead Hatchery second year of operation 1971-1972. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 74-1.

Will, R.D. 1975. Annual report Mad River Salmon and Steelhead Hatchery 1973-1974. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 75-1.

Will, R.D. 1976. Annual report Mad River Salmon and Steelhead Hatchery 1974-1975. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 76-1.

Will, R.D. 1978. Annual report Mad River Salmon and Steelhead Hatchery 1975-1976. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 78-16.

Will, R.D. 1979. Annual report Mad River Salmon and Steelhead Hatchery 1977-1978. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 79-3.

Will, R.D. 1980. Annual report Mad River Salmon and Steelhead Hatchery 1978-1979. California Department of Game, Anadromous Fisheries Branch, Administrative Report Number 80-10.

Woody, S. 1980. Beaver Creek Hatchery standard hatchery operation procedure report. Unpublished Washington Department of Game manuscript to Bruce Crawford.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Incorporated, Englewood Cliffs, New Jersey.

Appendix C1. Results from linear regression analysis for a temporal trend in cutthroat median trapping date (date when 50% of years total had been trapped) at Beaver Creek Hatchery.

Median date	Year
30-Nov	1964
02-Dec	1965
01-Dec	1966
10-Dec	1967
23-Nov	1968
18-Dec	1969
28-Nov	1970
27-Nov	1971
20-Dec	1972
30-Oct	1973
03-Dec	1974
18-Nov	1975
19-Jan	1976
14-Dec	1977
15-Dec	1978
23-Jan	1979
31-Oct	1980
19-Jan	1981
01-Dec	1982
13-Nov	1983
14-Nov	1984

Dependent variable	N	Adjusted R^2	Regression coefficien	Regression coefficient P-value
Median date of trapping	21	0.000	0.895	0.467

Appendix C2. Comparison of known age (marked) returns of sea-run cutthroat trapped at the Beaver Creek Hatchery.

Sex	Total age	Marked group	Mean fork length (mm)[a]	N	SD	Within age P-value	Between age P-value
Female	2	LV	367	47	31.49		
	2	RV	350	22	18.26	0.059	
	3	LV	416	26	23.44		0.000
	3	RV	427	33	16.42	0.060	

[a] inches = mm x 0.03937

Appendix C5. Comparison of mixed age mean annual wild and captive sea-run cutthroat fecundity.

	Wild Brood			Captive Brood			
Year	Mean	N	SD	Mean	N	SD	P-value
1965	889	9	144.3	830	16	200.0	0.396
1966	1116	6	394.4	845	5	140.1	0.100
1967	936	6	170.6	1112	7	291.6	0.391
1968	1017	8	109.8	1176	17	275.4	0.071
1969	790	12	139.4	893	22	277.1	0.220
1970	918	9	208.2	1101	12	125.8	0.016 *
1971	995	6	112.8	1265	18	319.7	0.023 *
1972	785	8	173.0	1310	14	381.5	0.003 **
1973	997	5	0.0	1422	10	406.8	0.013 *
Overall	898	69	207.2	1103	121	341.4	

* significant at P<0.05
** significant at P<0.01

Appendix C6. Summary statistics of sea-run cutthroat production (lot records) at Beaver Creek Hatchery (1980-1985).

Date lot started	Date lot ended	Lot ID	Source of lot	Size at start	Size at end	Mortality percent overall	Mortality percent daily	Percent unaccounted	Percent of starting number known as mortality Ship	Egg	Finger	Planting
Dec-81	May-83	SRC81L4	ELOCHOMAN R		4.41	82.33%	0.160%	-0.37%		26.81%	55.21%	
Aug-81	May-82	SRC81L5	COWLITZ	53.3	4.40	1.82%	0.007%	-3.22%			1.76%	
Feb-81	May-82	SRC81L10	ELOCHOMAN R		4.00	63.08%	0.139%	-14.47%		26.32%	6.58%	
Dec-82	Apr-84	SRC82L5	ELOCHOMAN R		7.02	71.34%	0.146%	42.00%		49.80%	52.07%	
Dec-83	May-85	SRC84L6	ELOCHOMAN		3.14	62.19%	0.121%	0.57%		35.93%	6.99%	
		N		1	5	5	5	5	0	4	5	0
		Average		53.27	4.60	56.15%	0.114%	4.90%		34.71%	24.52%	
		SD			1.45	31.43%	0.062%	21.59%		10.98%	26.68%	
		Maximum		53.27	7.02	82.33%	0.160%	42.00%		49.80%	55.21%	
		Minimum		53.27	3.14	1.82%	0.007%	-14.47%		26.32%	1.76%	

Appendix C7. Time of mortality within sea-run cutthroat production (lot records) at Beaver Creek Hatchery.

Date lot started	Date lot ended	Lot ID	Source of lot	Percent of total mortality occuring during each month											
				JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Dec-81	May-83	SRC81L4	ELOCHOMAN	19.32%	3.68%	10.62%	2.68%	54.70%	3.29%	1.06%	0.49%	2.08%	0.82%	0.24%	1.02%
Aug-81	May-82	SRC81L5	COWLITZ	1.37%	0.91%	1.83%	27.40%	3.65%			4.02%	1.00%	57.44%	1.00%	1.37%
Feb-81	May-82	SRC81L10	ELOCHOMAN	0.40%	80.40%	2.80%	6.80%	2.96%	0.80%	0.32%	1.52%	0.32%	3.68%		
Dec-82	Apr-84	SRC82L5	ELOCHOMAN	32.26%	3.49%	2.58%	1.13%	1.17%	1.11%	22.79%	21.56%	0.45%	0.11%	0.09%	13.25%
Dec-83	May-85	SRC84L6	ELOCHOMAN	69.21%	7.68%	13.00%	1.22%	2.55%	1.08%	0.92%	1.52%	1.43%	0.90%	0.33%	0.15%
		N		5	5	5	5	5	4	4	5	5	5	4	4
		Average		24.51%	19.23%	6.16%	7.85%	13.01%	1.57%	6.27%	5.82%	1.06%	12.59%	0.42%	3.95%
		SD		28.29%	34.28%	5.23%	11.17%	23.32%	1.15%	11.02%	8.89%	0.73%	25.11%	0.40%	6.23%
		Maximum		69.21%	80.40%	13.00%	27.40%	54.70%	3.29%	22.79%	21.56%	2.08%	57.44%	1.00%	13.25%
		Minimum		0.40%	0.91%	1.83%	1.13%	1.17%	0.80%	0.32%	0.49%	0.32%	0.11%	0.09%	0.15%

Appendix C8. Sea-run cutthroat returns, by ocean age, of marked groups released at Beaver Cr Hatchery (1956-1985).

	Release date	Mark	Species	Number released	Size released (number/0.45 kg)[b]	Objective	Returns by years of total age 1 Year	2 Year	3 Year	4 Year	5 Year	Total return	Perce retur
	Apr-67	LP	SRC*SW	5055	7	FEMALE CUTTHROAT - CHAMBERS STOCK WSH MALE CROSS. EVALUATE HYBRIDS.		4	9	20	4	37	0.7
	Apr-68	RP	SRC*SW	9310	7	FEMALE SRC - MALE SW CROSS. EVALUATE HYBIRDS.		6	11			17	0.1
	Apr-68	AD	SW*SRC	14820	6	FEMALE SW - MALE SRC HYBRID EVALUATION.						0	0.0
	Apr-61	AD	SRC	6858	9	EVALUATE RETURNS TO HATCHERY						0	0.0
	Apr-62	AD	SRC	1503	15	EVALUATE RETURNS TO HATCHERY						0	0.0
	Apr-63	AD	SRC	10453	16	EVALUATE PLANTING SRC AND DETERMINE DSTREAM MIGRAT. ADULT RETURNS.						0	0.0
	Apr-63	AD	SRC	3900	3	2-YEAR-OLDS WERE CULLED FOR BROOD. REMAINDER RELEASED INTO B. CREEK.						0	0.0
*	Apr-64	AD+RV	SRC	5632	4.5	COMPARE WITH VANCOUVER REARED. THESE ARE BEAVER CREEK REARED FISH.		33	17			50	0.8
*	Apr-64	AD+LV	SRC	17205	4.5	COMPARE WITH BEAVER CREEK REARED FISH. THESE ARE VANCOUVER REARED FISH.		127	18	12		157	0.9
	Apr-64	AD	SRC	18186	4.5	HATCHERY EVALUATIONS-RETURN TO SPORT FISHERY-DOWNSTREAM RELEASE TIME.						0	0.0
	Apr-65	AD	SRC	40495	9	ID HATCHERY FISH IN RETURN. EVALUATIONS OF HAT FISH IN SPORT FISHERY.						0	0.0
	Apr-66	AD+RV	SRC	0[a]	6	DOWN STREAM STUDY OF MIGRANTS THROUGH BEAVER CREEK TRAP.						0	0.0
*	Apr-66	AD+RV	SRC	44005	6.5	EVALUATION OF SEA RUN PROGRAM.		349	335	52	12	748	1.7
*	May-67	AD+LV	SRC	42312	6.5	BUILD UP WILD BROOD STOCK AND EVALUATE SEA-RUN PROGRAM.		138	251	54		443	1.0
*	May-68	ANAL	SRC	41305	4.5	ID HATCHERY REARED CT AND RETURN TO HATCHERY AND SPORT FISHERY.		80	132			212	0.5
	Apr-69	RV	SRC	12120	4	EVALUATE SEA RUN CUTTHROAT PROGRAM.						0	0.0
*	Apr-69	RV	SRC	24150	3.5	EVALUATE SEA RUN CUTTHROAT PROGRAM.		14	2	0	5	21	0.0
	Apr-70	LV	SRC	6800	4	CONTINUATION OF EVALUATION OF SEA RUN PROGRAM.						0	0.0
*	Apr-70	LV	SRC	49998	5	CONTINUATION OF EVALUATION OF SEA RUN PROGRAM.		96	165	15	4	280	0.5
	Apr-73	LP	SRC	3000	3	COMPARE RETURNS OF SRC FED WET AND DRY DIETS. LP MARK FED DRY DIET.						0	0.0
	Apr-73	RV	SRC	3007	3.5	COMPARE RETURNS OF SRC FED MOIST AND DRY DIETS. RV FED WET DIET.						0	0.0
*	May-80	LV	SRC	20000	5	COWLITZ STOCK, TO DETERMINE ADAPTABILITY OF COWLITZ STOCK.	24	97	27	15	12	175	0.8
*	May-80	RV	SRC	14700	3.5	BEAVER CREEK STOCK, TO DETERMINE ADAPTABILITY OF COWLITZ STOCK.	3	104	33	4	5	149	1.0
						Total	27	1038	980	152	38	2235	
						Overall percent return by ocean residency age	1.2%	46.4%	43.8%	6.8%	1.7%	100.0%	0.9

* : Marking experiments used in calculating the overall percent return and regression analyses.

[a] Numbers released and returned combined with data from rearing site experiment.

[b] Pounds = kg x 2.2

Appendix C9. Results of stepwise multiple regression testing; year of release, number of smolts released, average size of smolt at release, and the percent total return of two, three, four, and five total age sea-run cutthroat adults as predictors of percent return to Beaver Creek Hatchery.

Dependent Variable	Step	Independent variable entered	N	R^2	Increase in R^2	Regression coeficient	t-value	P-value	P-value regression
Percent return	1	Five	9	0.527	0.527	-15.424	-2.79	0.027	0.027

Appendix C10. Correlation matrix of variables; percent return to the hatchery, year of release, number released, size at release, and percent total return at two through four total age sea-run cutthroat at Beaver Creek Hatchery.

	Percent return	Year	Number	Size	Two	Three	Four	Five
Percent return	1.000							
Year	-0.026	1.000						
Number	0.032	-0.174	1.000					
Size	0.651	-0.324	0.579	1.000				
Two	-0.099	0.066	-0.869	-0.641	1.000			
Three	0.213	-0.296	0.770	0.556	-0.888	1.000		
Four	0.540	0.055	0.323	0.731	-0.301	0.103	1.000	
Five	-0.726	0.204	-0.163	-0.479	0.287	-0.555	-0.343	1.000

Note : Minimum significant correlation is 0.666 (7 df).

Appendix C11. Comparison of marked sea-run cutthroat return to Beaver Creek Hatchery.

Marked group released	Mark (year released)	Number released	Percent return	P-value
Beaver Cr. reared	AD+RV (1964)	5632	0.89	0.890
Vancouver reared	AD+LV (1964)	17205	0.91	
Beaver Cr. stock	RV (1980)	14700	1.01	0.216
Cowlitz stock	LV (1980)	20000	0.88	