Egg Production of Coastal Cutthroat Trout in Three Pacific Coast Hatcheries

Richard S. Wydoski
Washington Cooperative Fishery Research Unit

and

Jack M. Tipping
Washington Department of Fish and Wildlife

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Preface

The senior author was Assistant Leader of the Washington Cooperative Fishery Research Unit when this study was conducted. This previously unpublished manuscript containing data over 30 years old was deemed worthy of documentation within purview of WDFW agency reports.

Abstract

Egg production and fecundity are important in determining potential recruitment of Pacific salmonids but a paucity of information exists on these factors for coastal cutthroat trout (*Oncorhynchus clarki*). Egg production from hand-stripping females, fecundity (total number of eggs), and egg size by fork length and weight were summarized for coastal cutthroat trout from the Alsea River Fish Hatchery in Oregon and Beaver Creek and Cowlitz Trout Hatcheries in Washington. Stripped egg counts and total egg counts were similar for fish of similar lengths or weights from the three hatcheries, so data were combined. Mean length of 181 ripe females was 424 mm (range 322-556 mm) and mean weight was 790 g (range 340-1,949). Stripped and total egg counts were positively correlated to fish size. Stripped egg counts for fish grouped by length and weight ranged between 653 eggs for fish 336 mm in mean fork length to 1,889 eggs for 531 mm fish and from 705 eggs for fish with a mean weight of 375 g to 2,004 eggs for 1,327 g fish. Fecundity (total number of eggs) for fish grouped by length and weight ranged between 846 for fish 336 mm in mean length to 2,175 eggs for 531 mm fish and from 853 eggs for fish with a mean weight of 375 g to 2,317 eggs for 1,327 g fish. Egg production for coastal cutthroat trout from several locations in Washington were similar to this study with differences being attributed to the number and size of females in the various studies, fish selected for faster growth, or fish reared in saltwater rather than freshwater. The diameter of water-hardened eggs for fish grouped by length increased from 4.88 mm for fish with a mean length of 336 mm to 5.60 mm for 531 mm fish and from 5.00 mm for 374 g fish to 5.31 mm for 1,136 g fish.

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Introduction

Coastal cutthroat trout (*Oncorhynchus clarki*) are the most widely distributed of all western trout (Behnke 1992). This subspecies inhabits lakes, streams, rivers, estuaries, and inshore areas of the Pacific Ocean from the Eel River in northern California, north along the Oregon, Washington, and British Columbia coasts to Prince William Sound in Alaska but rarely occurs farther inland than 150-160 km (Behnke 1992; Trotter 1989, 1997).

Comprehensive reviews of coastal cutthroat trout include life history summaries (Giger 1972, Trotter 1989, 1997), environmental requirements (Pauley et al. 1989), and present knowledge of stock status (Gerstung 1997; Hooton 1997; Leider 1997, Schmidt 1997, Johnson et al. 1999, Blakley et al. 2000). However, detailed information is scarce on egg production and fecundity even though these factors are extremely important to estimate recruitment. Previous studies on reproduction of this subspecies generally reported the mean number of eggs per female (Hansler 1958, Duff 1969, Johnston and Mercer 1976, Jones 1977, Tipping 1981, Mercer 1982). Egg production from hand-stripped females, fecundity (total number of eggs in females), and egg size for coastal cutthroat trout from three Oregon and Washington state fish hatcheries are summarized for individual fish as well as grouped by intervals of length and weight in this report.

Origin of Hatchery Coastal Cutthroat Trout Stocks in Oregon and Washington

Alsea River, Oregon Broodstock

The Oregon Game Commission (now Oregon Department of Fish and Wildlife) developed a broodstock from wild anadromous coastal cutthroat trout that were collected from the North Fork Alsea River in 1936 (Crawford 1979). Production of coastal cutthroat trout ceased at the hatchery in spring 1996 when the last release was made in the Alsea River. Since 1997, no hatchery-reared coastal cutthroat trout have been stocked into streams containing wild sea-run cutthroat trout because of concerns related to potential adverse genetic consequences of stocking hatchery-reared fish (Hooton 1997; Williams et al. 1997).

Beaver Creek, Washington Broodstock

The Beaver Creek Hatchery stock was developed from anadromous fish that were collected from the Elochoman, Green (tributary to the Toutle River), and Nemah rivers in 1959 (Crawford 1979). Beaver Creek is a tributary to the Elochoman River in the lower Columbia River drainage. The Beaver Creek broodstock was originally maintained with progeny of anadromous trout maintained in captivity. Periodically, additional wild anadromous Elochoman River cutthroat trout supplemented the Beaver Creek Hatchery broodstock (Johnston and Mercer 1976). Yearling coastal cutthroat trout from the Alsea River broodstock were obtained in 1962 and maintained separately from the Beaver Creek broodstock until 1972 when they were combined into one hatchery stock (Crawford 1979). Fish from the Beaver Creek Hatchery have been widely stocked in Columbia River tributaries, coastal rivers, and tributaries to Hood Canal and Puget Sound (Johnston and Mercer 1976). Production of coastal cutthroat trout at the Beaver Creek Hatchery was discontinued in early 2000 due to budget constraints, poor returns of stocked fish, and concerns about potential adverse genetic consequences on wild populations.

Cowlitz River, Washington Broodstock

The Cowlitz Trout Hatchery stock was developed from wild Cowlitz River fish and Beaver Creek stock (Crawford 1979). This broodstock was supplemented periodically with additional wild trout from the Cowlitz River. Studies of Cowlitz River anadromous cutthroat were made by various persons including Duff (1969), Tipping (1981, 1986), and Tipping and Blankenship (1993). Since 1976, only trout returning from saltwater are spawned at the hatchery. Trout produced at the hatchery are released into the Cowlitz River to provide recreational fishing as part of a mitigation program following construction of dams on that river (Leider 1997).

Methods

Egg counts and sizes were obtained from 181 females; 36 from the Alsea River in 1968, 70 from Beaver Creek, and 75 from the Cowlitz River in 1969. Hatchery personnel anesthetized the fish, gently stripped the eggs by hand to avoid damage to vital organs, and fertilized them following conventional hatchery procedures. All females were measured to the nearest mm for fork and total lengths and weighed to the nearest g. Analyses were made by fork length but a regression equation was calculated to allow conversion of fork length into total length for comparisons with other studies. A complete count of stripped eggs was made for each female using a hand-held counter. The number of eggs remaining in hand-stripped females was determined through autopsy of females selected within the length frequency of ripe fish at each hatchery. Egg retention was determined as a percentage of the total number of eggs for 30 fish -- 5 from the Alsea River, 12 from Beaver Creek, and 13 from the Cowlitz River (Appendix A). A regression equation was calculated for the relationship between stripped egg counts and fecundity (total egg counts) for 30 females. This equation was used to convert stripped egg counts into fecundity estimates for all females.

Fertilized eggs from 171 fish were kept in separate containers to allow water-hardening for one hour before they were counted and measured. Thirty water-hardened eggs from each fish was measured three times by aligning the eggs in a trough and rearranging the eggs between measurements to average any irregularities in their basic spherical shape (Von Bayer 1908). The three measurements were added together and divided by 90 to obtain the mean egg diameter for individual females.

Stripped eggs, total eggs, and egg diameters for fish from the three hatcheries were summarized graphically to illustrate variation among individual females and among streams. Grouped length and weight data with mean values by length and weight intervals were summarized in tables along with predicted values and 95% confidence intervals for stripped eggs, total eggs, and egg diameters. Regression equations were calculated to express relationships of stripped eggs, total eggs, and egg diameters with length or weight using SPSS, Inc. (1997).

Results

Egg Production

Mean egg production (stripped egg counts) from coastal cutthroat trout at the three hatcheries was 1,157 eggs (SE = 26.3 range 548-2,555 eggs) for 181 females with a mean fork length of 423.8 mm (SE = 2.74, range 322-556 mm) and a mean weight of 783.4 g (SE = 15.63, range 340-1,949 g). The mean number of stripped eggs was 1,277 (SE = 37.3, range 848-1,807 eggs) for 36 coastal cutthroat trout from the Alsea River Hatchery with a mean length of 421.1 mm (SE = 19.36, range 387-453 mm) and a mean weight of 886.4 g (SE = 19.36, range 660-1,170 g). For 70 fish from the Beaver Creek Hatchery, the mean number of stripped eggs was 1,107 (SE = 41.3, range 548-2,544 eggs) for fish with a mean length of 432.0 mm (SE = 5.08, range 327-505 mm) and a mean weight of 794.2 g (SE = 27.20, range 340-1,786 g). The mean number of stripped eggs for 75 coastal cutthroat trout from the Cowlitz Trout Hatchery was 1,133 (SE = 44.6, range 608-2,555 eggs) for females with a mean length of 418.8 mm (SE = 4.13, range 355-505 mm) and a mean weight of 720.1 g (SE = 24.49, 411-1,375 g).

The number of stripped eggs increased with increasing length (Figure 1) and increasing weight (Figure 2) of females. Wide variation occurred in stripped egg counts for females from all three hatcheries. Since the number of stripped eggs for females was similar for fish of comparable sizes at all three hatcheries, a regression equation that describes this relationship was calculated from combined data.

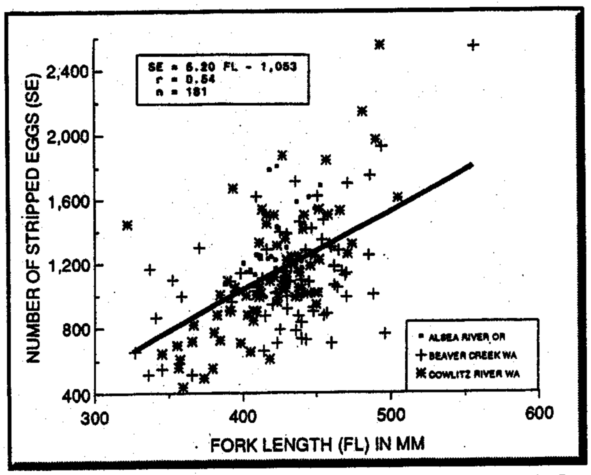

Figure 1. Relation of stripped eggs to fork length for coastal cutthroat trout from three Oregon and Washington hatcheries.

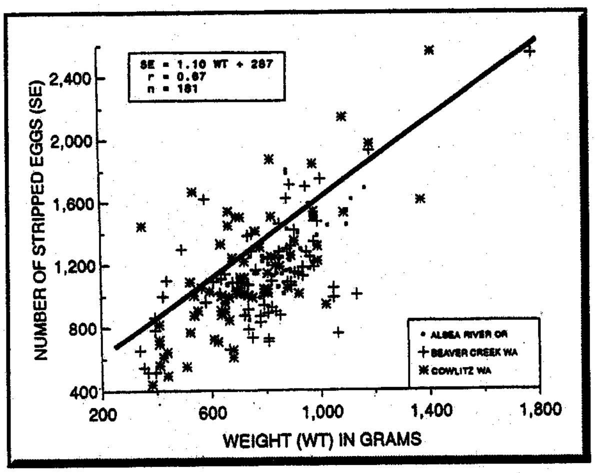

Figure 2. Relation of stripped eggs to weight for coastal cutthroat trout from three Oregon and Washington hatcheries.

Predicted stripped egg counts for 181 females from the three hatcheries increased from 653 eggs for fish with a mean length of 336 mm to 1,889 eggs for 531 mm fish (Table 1) and from 705 eggs for 375 g fish to 2,004 eggs for 1,327 g fish (Table 2). Less variation occurred in the 95% confidence intervals of length and weight for groups with a larger number of fish. Predicted stripped egg numbers and 95% confidence intervals for females grouped by length are summarized for each of the three hatcheries in Appendix B and by weight in Appendix C.

Table 1. Fecundity (total number of eggs, TE) and stripped egg counts (SE) by length frequency of coastal cutthroat trout from three Oregon and Washington hatcheries.

Fork Length				No. stripped eggs[1]		Total egg number[2]	
Interval (mm)	Mean (mm)	Std. error	# of fish	Predicted mean	95% CI[3]	Predicted mean	95% CI[3]
326-350	336.1	3.33	7	653	439-866	846	623-1,068
351-375	361.5	2.02	11	814	640-989	1,019	838-1,201
376-400	390.0	1.58	18	995	855-1,133	1,213	1,068-1,358
401-425	414.3	0.92	54	1,150	1,029-1,271	1,379	1,253-1,506
426-450	437.1	0.92	53	1,297	1,177-1,417	1,538	1,413-1,663
451-475	461.0	1.35	27	1,447	1,311-1,583	1,700	1,558-1,841
476-500	488.2	1.82	9	1,600	1,436-1,764	1,865	1,693-2,035
501 +	530.5	25.50	2	1,889	1,654-2,123	2,175	1,931-2,419

1 Calculated from the regression equation SE = 6.36 FL - 1483; r = 0.96, n = 8 groups (181 fish), F = 63.55, p = 0.0002.
2 Calculated from the regression equation TE = 6.84 FL - 1451; r = 0.96, n = 8 groups (181 fish), F = 67.58. p = 0.0002.
3 CI = confidence interval

Table 2. Fecundity (total number of eggs, TE) and stripped egg counts (SE) by weight (WT) interval of coastal cutthroat trout from three Oregon and Washington hatcheries.

Weight				No. stripped eggs[1]		Total egg number[2]	
Interval (g)	Mean (g)	Std. error	# of fish	Predicted mean	95% CI[3]	Predicted mean	95% CI[3]
301-400	374.6	7.52	9	705	570-841	853	635-1,070
401-500	430.0	8.52	10	769	644-894	924	724-1,124
501-600	550.0	8.26	12	906	801-1,010	1,079	911-1,245
601-700	657.9	4.68	27	1,025	935-1,116	1,213	1,068-1,358
701-800	750.1	4.74	36	1,132	1,050-1,215	1,334	1,202-1,466
801-900	850.0	5.62	42	1,241	1,161-1,322	1,457	1,328-1,586
901-1,000	953.1	5.62	29	1,357	1,271-1,442	1,587	1,450-1,724
1,001-1,100	1,050.0	12.69	8	1,475	1,378-1,571	1,720	1,565-1,875
1,101-1,200	1,135.7	15.19	5	1,584	1,473-1,695	1,843	1,665-2,022
1,200+	1,327.2	69.73	3	2,004	1,819-2,188	2,317	2,021-2,612

1 Calculated from the regression equation SE = 1.13 WT + 284; r = 0.97, n = 8 groups (181 fish), F = 118.84, p = 0.0001.
2 Calculated from the regression equation TE = 1.27 WT + 378; r = 0.94, n = 8 groups (181 fish), F = 58.64. p = 0.0001.
3 CI = confidence interval

Average egg retention for 5 trout from the Alsea Hatchery was 12.1%, 19.5% for 9 fish from the Beaver Creek Hatchery, and 17.7% for 12 fish from the Cowlitz Trout Hatchery (Appendix 1). Cutthroat trout were spawned by one person at the Alsea Hatchery while those at Beaver Creek and Cowlitz River hatcheries were spawned by three persons.

Fecundity

Fecundity or total number of eggs (TE) was estimated from stripped egg counts (SE) from the regression equation TE = 0.94 SE + 330 ($r = 0.94$, $n = 30$, $F = 250.7$, $p < 0.0001$). Mean fecundity of the 181 female cutthroat trout was estimated to be 1,389 eggs per fish (SE = 29.53, range 752-2,741 eggs) with a mean fork length of 424 mm (SE = 2.74, range 322-556 mm) and a mean weight of 783 g (SE = 15.63, range 340-1,949 g). Predicted mean total egg numbers increased from 846 eggs for fish with a mean length of 336 mm to 2,175 eggs for 531 mm fish (Table 1) and from 863 eggs for 375 g fish to 2,317 eggs for 1,327 g fish (Table 2). Predicted fecundity and 95% confidence intervals for females grouped by length and weight are summarized for each of the three hatcheries in Appendix 1 and Appendix 2, respectively. The total number of eggs increased in concert with increasing fork length of individual females but exhibited wide variation among individual fish (Figure 3).

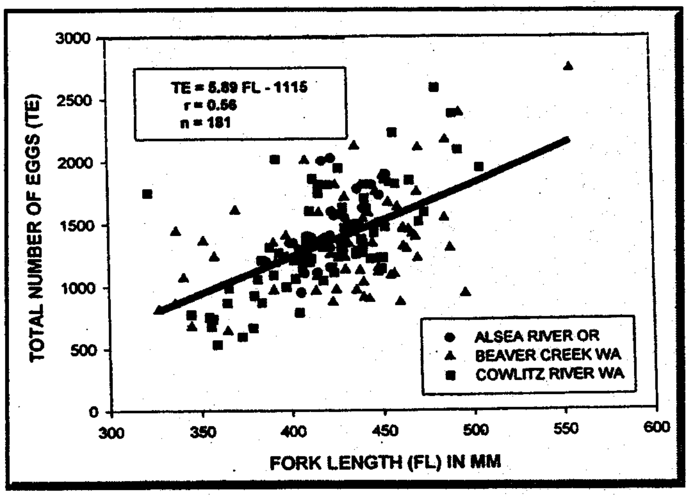

Figure 3. Relation between fecundity (total number of eggs) to fork length for coastal cutthroat trout from three Oregon and Washington hatcheries.

Size of Water-Hardened Eggs

The mean diameter of water-hardened eggs from 171 ripe cutthroat trout was 5.25 mm (SE 0.04; range 4.37-5.90 mm). Egg diameter increased with increasing length with a wide variation among individuals (Figure 4). Predicted mean diameter of water-hardened eggs increased from 4.88 mm for females with a mean length of 336 mm to 5.60 mm for 531 mm fish and from 5.00 mm for 374 g fish to 5.31 mm for 1,136 g fish (Table 3).

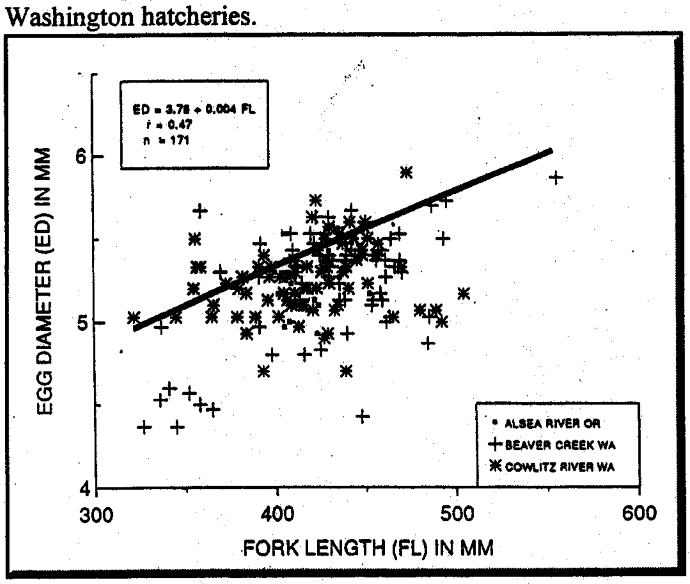

Figure 4. Relation between mean egg diameter and fork length for coastal cutthroat trout from three Oregon and Washington hatcheries.

Table 3. Mean diameter of water-hardened ripe eggs for 171 ripe coastal cutthroat trout grouped by size from three Oregon and Washington hatcheries.

Fork Length

Length interval (mm)	Mean (mm)	Std. error	No. of fish	Predicted mean egg diameter[1]	95% CI[2]
326-350	336.1	3.33	7	4.88	4.71-5.04
351-375	362.0	2.16	10	4.97	4.84-5.11
376-400	390.0	1.67	16	5.08	4.97-5.18
401-425	414.8	1.30	51	5.17	5.08-5.26
426-450	437.7	1.20	50	5.25	5.16-5.35
451-475	460.7	1.39	27	5.34	5.24-5.44
476-500	489.1	1.80	8	5.44	5.32-5.57
501+	530.5	25.50	2	5.60	5.42-5.78

[1] Calculated from regression equation ED = 0.0037 FL + 3.63; r = 0.93, n = 8 groups (171 fish), F = 37.10, p = 0.0009.

[2] CI = confidence interval

Weight

Weight interval (g)	Mean (g)	Std. error	No. of fish	Predicted mean egg diameter[1]	95% CI[2]
301-400	374.1	9.45	8	5.00	4.84-5.16
401-500	428.8	10.30	9	5.03	4.89-5.18
501-600	550.2	8.26	11	5.10	4.99-5.22
601-700	657.9	4.68	27	5.17	5.08-5.27
701-800	750.1	4.74	36	5.23	5.14-5.32
801-900	850.0	5.62	42	5.29	5.20-5.39
900-1000	952.4	5.80	27	5.36	5.24-5.47
1001-1100	1,046.3	12.86	7	5.42	5.28-5.55
1101-1200	1,136.2	16.14	4	5.31	5.31-5.64

[1] Calculated from regression equation ED = 0.0006 WT + 4.77; r = 0.84, n = 8 groups (171 fish), F = 16.92, p < 0.0045.

[2] CI = confidence interval

Discussion

The variation in stripped egg counts in this study may have been due to using ripe fish that may have shed some of their eggs or "green" fish in which some eggs were still intact in the ovaries. The low number of eggs for some females was probably due to spawning of "green" or partly spent fish. Ripeness of females was based on the judgement of hatchery personnel to minimize low counts of stripped eggs. However, counts of stripped eggs that appeared low were included in the analyses if the fish were judged by hatchery personnel to be fully ripe. Females at peak ripeness were stripped almost completely of eggs while fish that had not reached peak ripeness were not stripped as completely, resulting in more variation in stripped egg counts and egg retention.

Egg production of coastal cutthroat trout reported for other hatchery studies were similar to this study (Appendix D). Slight differences in stripped egg counts were more than likely due to the number and size of females that were spawned in the various studies, fish selected for faster growth, or fish reared in saltwater rather than freshwater. For example, the mean number of stripped eggs calculated from this study for a 350 mm female was 792 eggs. That number was similar to 781 eggs for the same size fish calculated from Tipping (1981) but lower than calculations from Hansler (1958) and Mercer (1982) of 941 and 975 eggs, respectively. Egg production in Hansler's study were from fish that were selected for faster growth at the University of Washington experimental hatchery and egg production reported by Mercer were from trout that were reared in saltwater pens in Puget Sound.

The number of eggs in coastal cutthroat trout increases with increasing size of females -- a characteristic that is shared by all species in the family Salmonidae (Rounsefell 1957). In general, larger salmonid females are also older so that fecundity is often related to age (Larsson and Pickova 1978). However, faster growing and larger females of the same age produced larger numbers of eggs that is more closely related to size rather than age. Larger coastal cutthroat trout spawned earlier and produced more eggs than smaller fish at the Cowlitz Trout Hatchery in 1979 and 1980 (Tipping 1981): In 1980, the first ripe trout were spawned on December 2 (mean fork length 389 mm producing an average of 924 eggs), trout with a mean length of 348 mm produced an average of 741 eggs, and the last fish were spawned on February 4, 1981 (mean length of 315 mm producing an average of 657 eggs). Egg production of coastal cutthroat trout reared in Puget Sound saltwater pens increased with both age and size (Mercer 1982): Age II females with a mean fork length between 229 and 265 mm produced an average of 345 to 473 eggs; Age III females with a mean length between 318 and 368 mm produced an average number of eggs between 841 and 1192; Age IV females with a mean length of 351 mm produced an average of 1025 eggs; and Age V females with a mean length of 442 produced 1508 eggs.

In general, egg size tended to increase in concert with increasing fork length and weight of female coastal cutthroat trout. Johnston and Mercer (1976) reported that eggs from anadromous trout at the time of deposition ranged between 4.3 and 5.1 mm in diameter. The sizes of water-hardened eggs in this study were larger in diameter by about 0.25 to 0.5 mm (Table 3). Alevins at hatching and fry upon emergence were related to egg size in five species of Pacific salmon with the larger alevins and fry produced from larger eggs (Beacham and Murray 1990). Larger eggs are expected to produce larger alevins at hatching and larger fry at swimup in coastal cutthroat trout that may provide a competitive advantage in survival in hatcheries or after release into the wild.

Growth rate differs greatly among hatchery-reared salmonids from the same cohort. If faster growing anadromous trout maintain their growth rates throughout rearing in hatcheries, then it is reasonable to assume that they will also be larger at smoltification. The smolt-to-adult survival of coastal cutthroat trout increased substantially (to nearly 9% returns) for smolts released at 210 mm in fork length with optimum returns (slightly over 18%) from smolts released when they were 220 mm long (Tipping 1986). Larger cutthroat trout smolts from later releases at the Cowlitz Trout Hatchery also had better survival after their first migration to saltwater (Tipping and Blankenship 1993).

Between 1990 and 1998, the survival of returning coastal cutthroat trout that were released at the Cowlitz Trout Hatchery was between 1.8 and 10.3 percent in contrast to survival of 11.0 to 16.8 during the 1980s. The lower survival of coastal cutthroat trout during the 1990s may be related to initial spawners that are smaller fish. Smaller fish produce fewer and smaller eggs that hatch as smaller alevins than larger fish with lower smolt-to-adult survival. Larger coastal cutthroat trout must survive two or more migrations to saltwater that exposes them to higher predation by fish, bird, and marine mammal predation. Reduced survival of repeat anadromous cutthroat trout spawners has been attributed to increased predation by Caspian terns (*Sterna caspia*), sea lions (*Eumetropias jubata*), and harbor seals (*Phoea vitulina*) in the Columbia River estuary. Caspian terns increased significantly when prime nesting areas were formed from deposits of dredged material from the Columbia River to create Sand and Rice Islands while sea lions and harbor seals dramatically increased from protection provided to them by the Marine Mammal Protection Act of 1972.

References

Beacham, T.D. and C.B. Murray. 1990. Temperature, egg size, and development of embryos and alevins of five species of Pacific salmon: a comparative analysis. Transactions of the American Fisheries Society 119: 927-941.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society, Monograph 6.

Blakley, A., B. Leland, and J. Ames, editors. 2000. Salmonid stock inventory: Coastal cutthroat trout. Washington Department of Fish and Wildlife, Olympia.

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

Duff, R.L. 1969. 1968-69 Cowlitz River sea-run cutthroat spawning data. Washington State Department of Game, Olympia.

Gerstung, E.R. 1997. Status of coastal cutthroat trout in California. Pages 43-56 in J.D. Hall, P.A. Bisson, and R.E. Gresswell, eds. Sea-run cutthroat trout: biology, management, and future conservation. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Giger, R.D. 1972. Ecology and management of coastal cutthroat trout in Oregon. Oregon State Game Commission, Final Report, Federal Aid Project F-72-R.

Hansler, D.D. 1958. Some effects of artificial selection upon a stock of cutthroat trout, Salmo clarki clarki, with related hybridization studies. M.S. Thesis, University of Washington, Seattle.

Hooton, B. 1997. Status of coastal cutthroat trout in Oregon. Pages 57-67 in J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: Biology, management, and future conservation. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Johnson, O.W., M.H. Ruckelshaus, W.S. Grant, F.W. Waknitz, A.M. Garrett, G.J. Bryant, K. Neely, and J.J. Hard. 1999. Status review of coastal cutthroat trout from Washington, Oregon, and California. U.S. Department of Commerce, National Marine Fisheries Service, Technical Memorandum NMFS-NWFSC-37.

Johnston, J.M. and S.P. Mercer. 1976. Sea-run cutthroat in saltwater pens: Broodstock development and extended juvenile rearing (with a life history compendium). Washington State Game Department, Federal Aid Project AFS-57-1.

Jones, D.E. 1977. A study of cutthroat/steelhead in Alaska: Life history of sea-run cutthroat trout. Alaska Department of Fish and Game, Juneau. Completion Report, Federal Aid Project AFS-42-5-B: 78-105.

Larsson, P-O. and J. Pikova. 1978. Egg size of salmon (Salmo salar L.) in correlation to female age and weight in three river stocks. Laxforskningsinstitutet, Alvkarleby, Sweden. Salmon Research Institute Report 1978-2.

Leider, S.A. 1997. Status of sea-run cutthroat trout in Washington. Pages 68-76 in J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: biology, management, and future conservation. American Fisheries Society, Corvallis.

Mercer, S.P. 1982. Sea-run cutthroat: Broodstock development and evaluation of enhancement techniques. Washington State Game Department, Fisheries Management Division, Olympia. Final Report, Federal Aid Project F-68-R.

Pauley, G.B., K. Oshima, K.L. Bowers, and G.L. Thomas. 1989. Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest): Sea-run cutthroat trout. U.S. Department of the Interior, Fish and Wildlife Service, Biological Report 82 (11.86) and U.S. Army Corps of Engineers, TR EL-82-4.

Rounsefell, G.A. 1957. Fecundity of North American Salmonidae. U.S. Fish and Wildlife Service, Fishery Bulletin 57(122): 451-468.

Schmidt, A.E. 1997. Status of sea-run cutthroat trout stocks in Alaska. Pages 80-83 in J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: biology, management, and future conservation. American Fisheries Society, Corvallis.

SPSS, Inc. 1997. SigmaPlot 4.0 for windows. SPSS, Inc., Chicago, Illinois.

Tipping, J.M. 1981. Cowlitz sea-run cutthroat study, 1980-1981. Washington State Game Department, Report 81-12, Olympia.

Tipping, J.M. 1986. Effect of release size on return rates of hatchery sea-run cutthroat trout. Progressive Fish-Culturist 48: 195-197.

Tipping, J.M. and H.L. Blankenship. 1993. Effect of condition factor at release on smolt-to-adult survival of hatchery sea-run cutthroat trout. Progressive Fish Culturist 55:184-186.

Trotter, P.C. 1989. Coastal cutthroat trout: a life history compendium. Transactions of the American Fisheries Society 118:463-473.

Trotter, P.C. 1997. Sea-run cutthroat trout: life history profile. Pages 7-15 in J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: Biology, management, and future conservation. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Von Bayer, H. 1908. A method of measuring fish eggs. Bulletin of the United States Bureau of Fisheries 28(2): 1009-1014.

Williams, T.H., K.P. Currens, N.E. Ward III, and G.H. Reeves. 1997. Genetic population structure of coastal cutthroat trout. Pages 16-17 in J.D. Hall, P.A. Bisson, and R.E. Gresswell, editors. Sea-run cutthroat trout: Biology, management, and future conservation. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Appendix A
Retention of Ripe Eggs in Coastal Cutthroat Trout Spawned by Hand

	Fork Length (mm)	Weight (g)	Total number of eggs	Percentage of retained eggs
		Alsea River Hatchery, Oregon[1]		
	387	660	1,198	11.32
	402	770	1,349	15.05
	408	790	1,106	8.68
	422	790	1,409	13.41
	422	865	1,154	12.05
Mean	408.2	775.0	1,243	13.57
		Beaver Creek Fish Hatchery, Washington[2]		
	336	369	863	40.32[3]
	391	638	968	6.61
	414	666	961	31.63
	420	794	1,331	29.37
	425	751	1,816	23.54
	438	723	1,126	22.58
	440	794	1,542	35.19[3]
	451	879	1,885	13.84
	465	950	1,455	17.55
	470	921	1,754	35.11[3]
	488	1,134	1,305	22.91
	556	1,800	2,741	7.77
Mean	449.8	902.4	1,550	19.53
		Cowlitz Trout Hatchery, Washington[2]		
	355	411	752	7.85
	398	624	996	19.21
	407	666	1,204	29.98
	407	638	1,145	29.28
	409	652	1,194	20.96
	409	737	1,348	24.79
	411	709	1,318	10.33
	418	680	1,046	41.87[3]
	424	666	1,111	10.98
	426	695	1,237	16.17
	427	822	1,946	3.75
	436	751	1,259	21.44
	440	794	1,272	18.08
Mean	412.4	680.4	1,232	17.74

[1] All fish were stripped by one person.
[2] Fish were stripped by three persons.
[3] Fish were not completely ripe; some eggs still remained in skeins; these fish were not used for analyses but are included here for comparison with ripe fish.
[4] Means were determined only for ripe fish.

Appendix B

Fecundity (Total Eggs [TE]) and Stripped Egg Counts (SE) by Length Frequency (FL) for Coastal Cutthroat Trout from Three Pacific Coast Hatcheries

Fork Length				No of stripped eggs[1]		Total egg number[2]	
Interval (mm)	Mean (mm)	Std. error	No. of fish	Predicted mean	95% CI[3]	Predicted mean	95% CI[3]
Alsea River State Fish Hatchery, Oregon							
376-400	393.5	6.50	2	1,088	670-1,476	1,222	793-1,651
401-425	414.0	4.53	22	1,263	1,011-1,516	1,418	1,139-1,651
426-450	438.0	1.94	11	1,469	1,203-1,734	1,648	1,354-1,941
451-475	453.0	—	1	1,597	1,230-1,963	1,791	1,386-2,196
Beaver Creek State Fish Hatchery, Washington							
326-350	337.2	3.01	5	815	708-924	1,029	919-1,140
351-375	361.3	3.95	4	893	807-978	1,122	1,034-1,210
376-400	393.0	1.68	5	994	930-1,058	1,244	1,178-1,309
401-425	417.8	1.90	11	1,072	1,014-1,132	1,339	1,279-1,400
426-450	438.0	1.37	21	1,137	1,072-1,203	1,417	1,350-1,484
451-475	461.8	1.42	19	1,213	1,132-1,295	1,508	1,425-1,592
476-500	489.8	2.20	5	1,303	1,196-1,409	1,616	1,507-1,725
Cowlitz Trout Hatchery, Washington							
326-350	333.5	11.50	2	737	358-1,115	871	408-1,333
351-375	361.6	2.51	8	892	595-1,189	1,061	699-1,425
376-400	388.3	2.05	11	1,040	805-1,274	1,244	957-1,530
401-425	413.3	1.48	21	1,178	975-1,381	1,414	1,166-1,662
426-450	437.1	1.61	19	1,309	1,102-1,517	1,576	1,322-1,829
451-475	460.1	3.20	9	1,436	1,193-1,679	1,732	1,435-2,029
476-500	477.8	5.96	4	1,534	1,250-1,819	1,853	1,505-2,200
501+	505.0	—	1	1,684	1,323-2,046	2,038	1,596-2,479

[1] Calculated from the following regression equations:
Alsea River: SE = 8.55 FL - 2,278; r = 0.93, n = 4 groups (36 fish) F = 48.78, p = 0.0009
Beaver Creek: SE = 3.19 FL - 260; r = 0.95; n = 7 groups (70 fish) F = 48.78; p = 0.0098
Cowlitz River: SE = 5.52 FL - 265, r = 0.97; n = 8 groups (75 fish) F = 13.90, p = 0.0098

[2] Calculated from the following regression equations:
Alsea River: TE = 9.57 FL - 2,543; r = 0.93, n = 4 groups (36 fish) F = 13.66, p = 0.066
Beaver Creek: TE = 3.84 FL - 265; r = 0.97, n = 7 groups (70 fish) F = 67.41, p = 0.0004
Cowlitz River TE = 6.80 FL - 1,399; r = 0.84, n = 8 groups (75 fish) F = 14.10, p = 0.0095

[3] CI = confidence interval

Appendix C

Fecundity (Total Eggs - TE) and Stripped Egg Counts (SE) by Weight Frequency (WT) for Coastal Cutthroat Trout from Three Pacific Coast Hatcheries

Weight				No of stripped eggs[1]		Total egg number[2]	
Interval (g)	Mean (g)	Std. error	No. of fish	Predicted mean	95% CI[3]	Predicted mean	95% CI[3]
Alsea River State Fish Hatchery, Oregon							
601-700	660.0	—	1	1,019	913-1,125	1,148	1,034-1,263
701-800	770.6	7.22	8	1,150	1,073-1,226	1,294	1,211-1,377
801-900	857.0	7.18	15	1,252	1,190-1,314	1,408	1,341-1,475
901-1,000	958.6	9.62	7	1,371	1,310-1,432	1,540	1,474-1,607
1,001-1,100	1,076.7	23.33	3	1,511	1,429-1,594	1,697	1,607-1,786
1,101-1,200	1,145.0	25.00	2	1,592	1,491-1,693	1,786	1,677-1,896
Beaver Creek State Fish Hatchery, Washington							
301-400	375.6	10.25	6	754	618-891	926	776-1,075
401-500	453.3	21.71	3	816	699-934	1,005	876-1,134
501-600	581.0	25.15	3	918	827-1,010	1,135	1,034-1,235
601-700	651.8	9.71	9	975	894-1,056	1,207	1,117-1,296
701-800	755.3	6.24	14	1,057	983-1,132	1,312	1,230-1,394
801-900	854.1	8.34	16	1,136	1,056-1,216	1,413	1,324-1,501
901-1,000	944.4	7.62	13	1,208	1,115-1,301	1,504	1,402-1,607
1,001-1,100	1,041.8	12.37	4	1,286	1,173-1,399	1,603	1,479-1,728
1,101-1,200	1,162.5	28.50	2	1,382	1,241-1,524	1,726	1,571-1,882
Cowlitz Trout Hatchery, Washington							
301-400	367.0	16.00	2	570	459-681	692	552-832
401-500	421.1	5.12	7	651	549-752	789	661-917
591-600	543.4	8.50	9	832	749-915	1,008	903-1,112
601-700	660.3	5.64	19	1,005	935-1,076	1,217	1,129-1,306
701-800	733.1	7.62	14	1,113	1,047-1,180	1,347	1,264-1,431
801-900	835.0	8.66	11	1,265	1,197-1,332	1,530	1,445-1,615
901-1,000	963.7	13.14	7	1,456	1,515-1,703	1,760	1,661-1,860
1,001-1,100	1,067.0	23.67	3	1,609	1,515-1,703	1,945	1,827-2,063
1,201+	1,327.0	69.73	3	1,995	1,854-2,136	2,410	2,233-2,588

[1] Calculated from the following regression equations:
Alsea River: SE = 1.18 WT + 240; r = 0.98, n = 6 groups (36 fish) F = 87.96, p = 0.0007
Beaver Creek: SE = 0.80 WT + 455; r = 0.92; n = 9 groups (70 fish) F = 40.24; p = 0.0004
Cowlitz River: SE = 1.48 WT + 26, r = 0.99; n = 9 groups (75 fish) F = 248.06, p < 0.0001

[2] Calculated from the following regression equations:
Alsea River: TE = 1.31 WT + 280; r = 0.98, n = 6 groups (36 fish) F = 92.83, p = 0.0006
Beaver Creek: TE = 1.02 WT + 544; r = 0.94, n = 9 groups (70 fish) F = 54.18, p = 0.0002
Cowlitz River TE = 1.79 WT + 35; r = 0.99, n = 9 groups (75 fish) F = 226.58, p < 0.0001

[3] CI = confidence interval

Appendix D

Comparison of Egg Production (Stripped Eggs) of Coastal Cutthroat Trout for Selected Fork Lengths from Various Studies

	Fecundity		Stripped Eggs		
Fork Length (mm)	OR-WA[1]	OR-WA[2]	Cowlitz River[3]	Puget Sound[4]	Lk Washington[5]
250	—	—	—	429	397
275	—	—	—	566	533
300	676	547	589	702	669
325	82	669	685	839	805
350	964	792	781	975	941
375	1,107	914	877	1,112	1,213
400	1,251	1,036	973	1,248	—
425	1,395	1,158	—	1,345	—
450	1,539	1,281	—	1,521	—
475	1,682	1,403	—	1,658	—
500	1,826	1,525	—	—	—

1 $E = 5.75\ FL - 1{,}049.3$; $r = 0.53$; $n = 181$; $F = 71.21$; $p < 0.0001$; this study

2 $E = 4.89\ FL - 919.6$; $r = 0.52$; $n = 181$; $F = 65.57$; $p < 0.0001$; this study

3 $E = 3.84\ FL - 563.0$; $r = 0.98$; $n = 6$ groups (699 fish); $F = 100.9$; $p = 0.0002$; calculated from grouped data in Table 3 of Tipping (1981).

4 $E = 5.46\ FL - 935.8$; $r = 0.97$; regression equation from figure 10 of Mercer (1982); early entry broodstock was obtained from the Nooksack and Stillaguamish rivers in northern Puget Sound; late entry broodstock was obtained from an estuary in northern Hood Canal.

5 $E = 5.44\ FL - 962.61$; $r = 0.84$; $n = 10$ groups (245 fish); $F = 18.86$; $p = 0.0025$; calculated from grouped data in Table 1 of Hansler (1958); broodstock was obtained from a tributary to Lake Washington.