Volume VI, Chapter 3
Coho Capacity Estimation

Estimation of Coho Smolt Production Potential in the Lower Columbia Subbasins

Introduction:

As part of the Lower Columbia River Recovery Planning process, coho smolt production potential was estimated using the EDT in each of the lower Columbia subbasins. Coho smolt capacity estimates were generated via an independent model to provide empirical support for EDT smolt production potential estimates.

This appendix describes methods used to estimate the coho (*Oncorhynchus kisutch*) smolt production potential of select lower Columbia Basins. First, we describe the model chosen to best estimate production potential, and how that model was adapted to be used with data available in the lower Columbia Basins. This report also presents the estimates of production potential and frames those estimates in the context of coho smolt production observed in other basins of the Pacific Northwest. Coho production potential estimates were made in the following basins: Coweeman, East Fork Lewis, Elochoman, Grays, Kalama, lower Cowlitz, lower North Fork Lewis, Skamakowa, Toutle, and Washougal.

Rather than develop a new method for estimating coho smolt production potential, an existing model was adapted to fit the data available in the lower Columbia Basin. The Habitat Limiting Factors Model (HLFM) was proposed in its original version in Nickelson et al. (1992a), and further developed by Solazzi et al. (1998). The HLFM was developed to determine stream capacity and limiting habitat for coho in Oregon coastal streams. The model is based on the concept that a "habitat bottleneck," limits the potential smolt production of a stream. The model in its full capacity consists of the simultaneous examination of the seasonal habitat needs of coho and the availability of this habitat. Data used to develop the model include: seasonal rearing densities specific to different habitat unit types, estimates of spawning habitat requirements, average fecundity, and estimates of density-independent survival rates specific to different life stages. Densities by unit type reflect densities at capacity because they were derived from fully seeded streams. The estimates of coho smolt capacity generated by this model for coastal Oregon streams have been shown to be similar to actual production when summer habitat was fully seeded (Nickelson 1998).

The model estimates capacity for each juvenile life stage of coho (eggs, fry, parr and pre-smolts), and then applies density independent survival rates to estimate smolt production based on the capacity at each of those life stages. The stream capacity is determined by whichever life stage generates the lowest smolt production potential. The habitat required by that life stage is considered the limiting habitat of the stream. For further detail on the HLFM refer to Nickelson et al. (1992a; 1992b) and Solazzi et al. (1998).

METHODS

Modification of the HLFM

Seasonal estimates of surface area by habitat type within a stream are needed to fully utilize the HLFM and determine the life stage that habitat within a stream limits coho smolt production. However, stream surveys by which these data are obtained typically are done during the summer, so data are not usually available to estimate spring and winter seasonal capacity. Nickelson (1998) acknowledged this challenge and cited research that showed that in Oregon coastal streams, winter habitat availability was typically the limiting habitat (Nickelson 1992b). Nickelson (1998) subsequently developed a multiple regression model by which winter habitat capacity could be predicted using summer habitat data. That regression was developed using 74 stream reaches where both summer and winter habitat surveys had been conducted, and predicted smolt production potential (as estimated by the HLFM) from stream reach characteristics estimated during summer habitat surveys. The regression incorporated active channel width, gradient, percentage of pools, and beaver dam frequency to estimate smolt density. The resultant density was subsequently multiplied by the winter surface area of the reach defined as the active channel width multiplied by the length of the reach. Smolt capacities predicted by the multiple regression model were significantly correlated with smolt capacities estimated using the original version of the HLFM ($r = 0.874$, $p<0.001$).

We used an adapted version of the multiple regression of Nickelson (1998) to estimate coho capacity in the lower Columbia Basins. The lack of reliable data on the frequency of beaver dams in stream reaches in the lower Columbia Basin precluded the use of the regression model as presented by Nickelson (1998). We used that regression model to estimate coho smolt capacity density (smolts/m^2) for 1,290 reaches from the Oregon coastal basins and Umpqua Basin where all parameters needed to run the model were available. In selecting those 1,290 reaches, any reach greater than 20m wide or with a gradient greater than 6% was excluded. Reaches greater than 20m wide were not included because the original HLFM was based on data primarily from streams smaller than that width (Tom Nickelson, ODFW, personal comm. 11/03). Reaches with gradient greater than 6% were excluded because coho typically do not use those reaches (Nickelson 2001). The estimated densities from the 1,290 reaches were subsequently correlated to active channel width, gradient and percent pools by reach via multiple regression ($r^2 = 0.56$, $P = 0.000$) as defined by the equation:

$$\ln(\text{Density}) = -1.57712 - 0.226581 \cdot G - 0.700359 \cdot \ln(ACW) + 3.06529 \cdot \text{Pools}$$

where:
Density = smolts/m^2
G = gradient in percent
ACW = active channel width in meters
Pools = arcsine square root transformation of proportion of reach surface area comprised of pools.

This equation was subsequently used to estimate coho capacity in the lower Columbia Basin. Data used to run the model in the lower Columbia Basin were derived from EDT input files for reaches where EDT attributes were available and coho are distributed or suspected to be distributed.

Estimating Capacity in Large Streams

The ability of the HLFM to reliably estimate capacity in streams with active channel widths greater than 15-20m has not yet been tested (Tom Nickelson, ODFW, personal comm. 11/03). The habitat specific densities used to develop the HLFM came primarily from 4th order and smaller streams. Application of the HLFM (or any regressions derived from it) generates exceedingly high capacities as active channel width increases above 15m. The model assumes that all stream area is usable area, though field surveys have shown that in large streams use of mid-channel waters by rearing salmonids is less than that in small streams (Johnson 1985; Cramer 2001). To model this behavior and its effect on capacity, we assumed that in all reaches greater than 15m wide, that *usable* area of the reach would be calculated as the length of the reach multiplied by 15m. This assumes that coho are primarily using the edges of large streams for rearing, but not the middle sections. Also, when calculating rearing density with the multiple regression described earlier, we designated 15m as the maximum active channel width that would be applied in the equation. In reaches greater than 15m wide, 15m was used as the width. This was done because the model was developed and validated by Nickelson (1992a; 1998) with reaches generally narrower than 15m, and to use greater widths would mean going outside the bounds of the model's capabilities.

Habitat Quality Rating

A habitat quality rating was developed for each reach in the lower Columbia Basin supporting coho based on EDT patient and template attribute ratings for each reach. The HLFM was developed in Oregon in the late 1980's and early 1990's when Oregon coastal natural (OCN) coho returns were among lowest observed since 1970. However, habitat specific densities used in the model were derived from streams expected to be at full seeding. Streams were assumed to be at full seeding when spawning populations the previous fall were greater than 25 spawners/km (Nickelson 1992b; Biedler et al. 1980). We inferred that in years of generally low spawner returns, streams that supported these levels of spawners had high quality habitat.

We assumed that habitat quality in those fully seeded Oregon streams was better than the habitat quality of the average coho producing stream in the lower Columbia Basin. We used EDT template and patient attribute ratings to develop a habitat quality index. Specific EDT attributes rated on a scale of 0-4 were incorporated (Table 1). Patient ratings are intended to reflect current stream conditions, and template attributes are intended to reflect stream conditions prior to European settlement of the region. For each attribute included in the index, the difference in the patient and template attribute ratings was calculated, and these differences were summed across all attributes included for the reach. A larger difference in patient and template conditions indicates a greater degree of degradation with respect to template conditions for that reach. The frequency distribution of resultant habitat quality index scores from all reaches (n = 440) was calculated, and it was determined that reaches with scores in the upper 50th percentile of all the reaches scored would be classified as "degraded". Higher scores indicated a higher degree of degradation relative to template conditions. Capacity density in degraded reaches was estimated using the lower 95% confidence limit predicted by the capacity prediction equation described earlier.

Table 1. EDT attributes incorporated into the habitat quality index used in the estimation of coho capacity.

Attribute
Alkalinity
Bed Scour
Benthos diversity
Confinement-natural
Confinement-hydromodifications
Dissolved oxygen
Embeddedness
Flow - Intra daily (diel) variation
Fine sediment
Fish community richness
Fish pathogens
Fish species introductions
Harassment (harvest)
Hatchery fish outplants
Hydrologic regime – natural
Hydrologic regime – regulated
Icing
Metals/Pollutants - in sediments/soils
Metals - in water column
Miscellaneous toxic pollutants - water column
Nutrient enrichment
Obstructions to fish migration
Predation risk
Riparian function
Salmon Carcasses
Temperature - daily minimum (by month)
Temperature - daily maximum (by month)
Temperature - spatial variation
Turbidity
Wood
Water withdrawals

Accounting for Reaches without Data

Coho capacity was estimated using the equation described earlier for all reaches where EDT data were available and coho were distributed. Not all reaches used by coho for rearing had EDT data available. In each basin, we calculated the coho capacity/meter of habitat where EDT data were available. This density was multiplied by the linear length of coho habitat where EDT data were not available. The resultant capacity was added to the capacity of reaches with EDT data to determine total capacity for the basin.

Model Validation

Coho capacity estimates were validated using observations of coho production from basins around the Pacific Northwest. Results were evaluated in two manners including coho/meter, and coho/mi^2 of watershed area. Coho/meter for the lower Columbia basin was calculated as the total capacity divided by the summed length of reaches within the basin that coho capacity was estimated for.

Coho/mi^2 of watershed was calculated as the total coho capacity for the basin divided by the watershed area of the basin. We only used data from other basins that were greater than 50mi^2 because coho production per watershed area decreases as watershed area increases and watershed areas in the lower Columbia Basin ranged from 63-512 mi^2. We used data from eight migrant traps in the Clackamas, Coquille, Umpqua and Rogue basins. Data from those basins were obtained from Shibahara and Taylor (2001), Vogt (2003), data received from ODFW Salmonid Life Cycle Monitoring Project (Mario Solazzi, personal comm. 3/02), and ODFW (Dave Harris, personal comm. 3/03). Watershed areas above those traps ranged from 61-681 mi^2. From these traps we compiled the maximum outmigration estimate from each trap for the years that the trap was operated. The maximum observations of outmigrants from each trap were chosen because it was believed that those numbers most closely represented the production potential of the basin. Then we calculated the median and maximum number of smolts per watershed area from that data set.

Model performance was also tested by estimating capacity in the Elochoman and Skamokawa basins, and comparing our capacity estimate the EDT smolt equilibrium abundance estimates.

RESULTS AND DISCUSSION

Capacity Estimates

Total smolt production potential estimates among the basins ranged from 22,000 in the East Fork Lewis to 279,000 in the Toutle (Figure 1,Table 2).

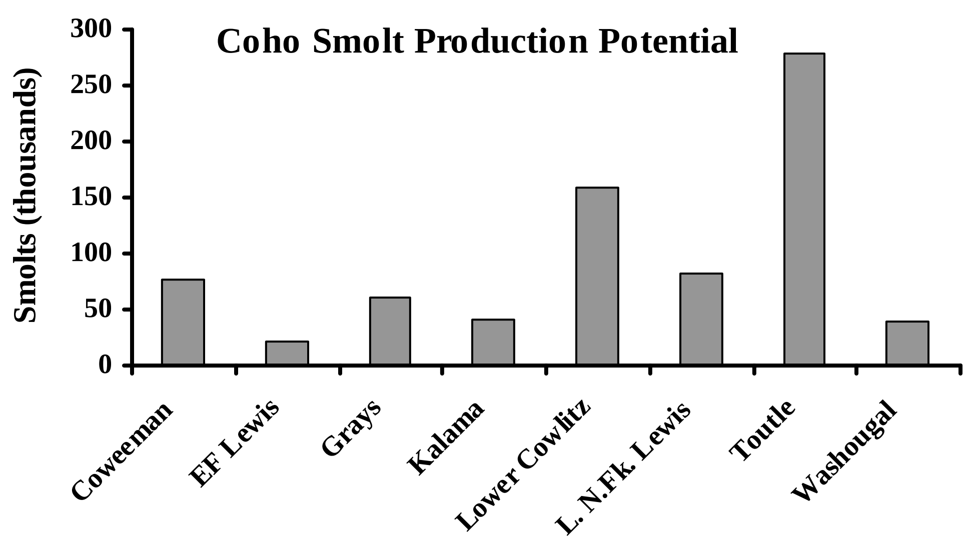

Figure 1. Coho smolt production potential estimates for basins within the lower Columbia Basin.

Table 2. Estimated coho smolt production potential, smolts/meter of available coho habitat, smolts/mi^2 of watershed, percentage of reaches with EDT data that were rated as degraded, and percentage of reaches where coho are suspected to exist where EDT data were available.

Basin	Smolt Capacity	Smolts per meter	Smolts per mi^2 of Watershed	% of Reaches Degraded	Percent of coho habitat without EDT data
Coweeman	76,651	0.53	360	11%	27%
EF Lewis	22,189	0.16	94	100%	38%
Grays	60,419	0.32	491	40%	30%
Kalama	41,860	1.10	174	0%	43%
Lower Cowlitz	159,482	0.24	370	72%	48%
L. N.Fk. Lewis	82,502	0.54	821	96%	43%
Toutle	278,985	0.35	545	40%	51%
Washougal	38,848	0.29	181	85%	33%

Measures of estimated production potential compared favorably to observed levels of smolt production in other basins of the Pacific Northwest. Solazzi et al. (2003) presented estimates of coho production per meter of habitat in 14 coastal Oregon streams. Migrant traps were operated at those locations for 3-5 years (period varied depending on the trap), and coho outmigrant abundance estimates were made for each year by expanding trap counts by trap efficiency. Of 67 observations (multiple traps in multiple years), coho per meter estimates varied from 0.00 to 1.19 with a median of 0.20. The estimates of coho production potential per meter in the lower Columbia Basins compare favorably to these because no estimate was greater than the maximum reported by Solazzi et al. (2003), and all but one were greater than the median observation (Figure 2). This means that production potential estimates in the lower Columbia Basins are sufficiently high to reflect conditions better than realized in 50% of coastal Oregon observations, but are low enough that they don’t exceed the maximum observation. Some of the observations of Solazzi et al. (2002) have taken place following years of extremely high seeding levels as recent years have produced near record returns from Oregon coastal coho. It should be noted that the data reported by Solazzi et al. (2002) is for basins ranging in size from 3.5 to 24.4 mi^2. Basins of the lower Columbia for which production potential estimates were made range from 63-512 mi^2.

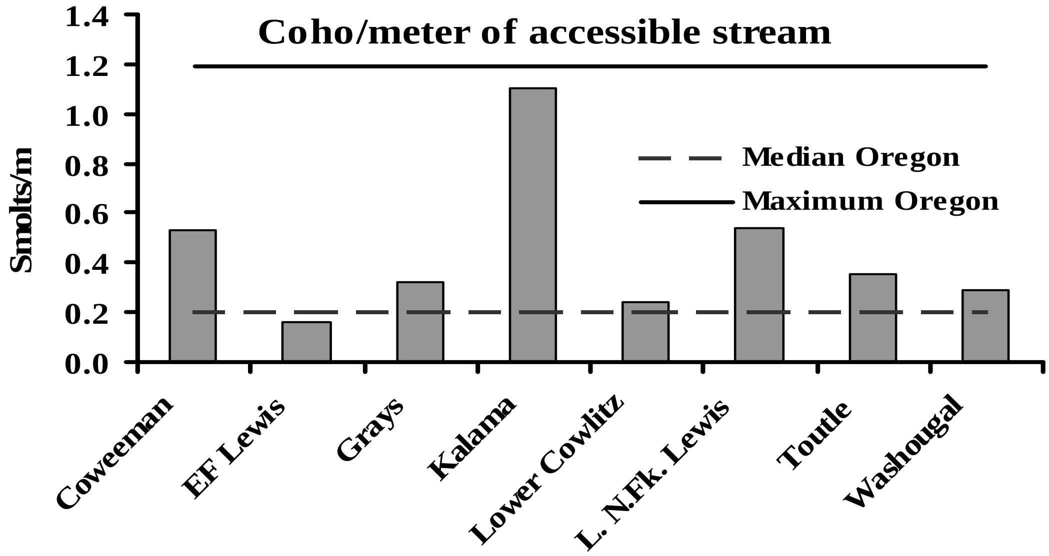

Figure 2. Estimates of coho production per meter of available habitat in the lower Columbia Basins in comparison to values reported by Solazzi et al. (2002) from outmigrant trapping studies on 14 Oregon coastal streams.

Production potential estimates by watershed area in the lower Columbia basins were greater than the median observation at migrant traps in the Coquille, Clackamas, Umpqua and Rogue basins. In 5 of 8 basins, the production potential estimate was greater than the maximum observed outmigration at the migrant traps (Figure 3).

This comparison is useful because it shows that our estimates of production potential are not likely too conservative. However, it also suggests that for the Lower North Fork Lewis, Grays and Toutle the estimates are too high. The Lower North Fork Lewis is unique in that the upper point of the main watershed terminates at a dam, and the proportion of rearing area to watershed area is likely much larger than in a typical basin. This situation likely gives rise to the inflated smolt per watershed area estimate for this basin. Also, the maximum trap estimate was generated from a limited pool of data, and likely does not reflect the true maximum outmigration density that could be achieved in large basins.

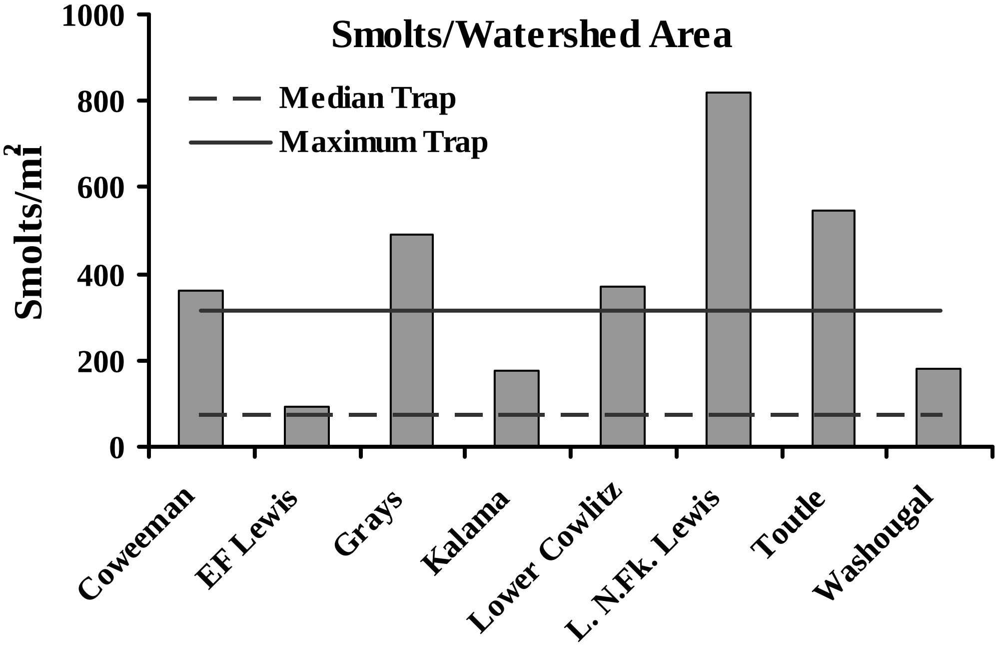

Figure 3. Production potential in terms of coho smolts per watershed area for the lower Columbia basins in comparison to observations from migrant traps of similar sized basins.

Coho production potential estimates made by the HLFM derived regression for the Elochoman and Skamakowa basins were greater than the smolt equilibrium abundances estimated by EDT for those basins, though the estimates were reasonably similar to one another (Table 3). The relative proportion of the Elochoman to the Skamokawa estimate via the HLFM derived regression was similar to the proportion of the EDT estimates. These observations indicate that while the estimates of the two models are somewhat different, both models similarly rated relative production potential between the two basins.

Table 3. Production potential estimates for the Elochoman and Skamakowa basins generated by the EDT and the HLFM derived regression.

	Elochoman	Skamakowa	Ratio
EDT	27,015	19,736	1.37
HLFM	37,364	23,283	1.62

Model Assumptions and Constraints

Several assumptions were made in applying the HLFM derived regression to streams in the lower Columbia Basin. Primarily, the HLFM was developed for estimating coho smolt production potential in coastal Oregon streams, and was developed based on data from those streams. By applying the HLFM to streams within the lower Columbia basin, the model is being applied to streams in a region that it was not developed or validated for. This may cause erroneous estimates that might arise by inherent differences in coho production potential between basins in the lower Columbia and those along the Oregon coast.

Secondly, by using the regression developed by Nickelson (1998) to derive a secondary regression, we are assuming that the habitat bottleneck for coho in the lower Columbia Basins is winter habitat availability. In the winter, coho seek slow off channel habitat types such as beaver ponds, alcoves and backwater pools for refuge (Nickelson 1992a; Bustard and Narver 1975; Tshaplinski and Hartman 1983). It is likely that in the lower Columbia Basin, as in the Oregon coastal basins that anthropogenic influences of the last 150 years have reduced the availability of these habitat types, and caused the lack of these habitats to be limiting coho production. If the habitat availability of another life stage is limiting, then we have overestimated production potential in this exercise.

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