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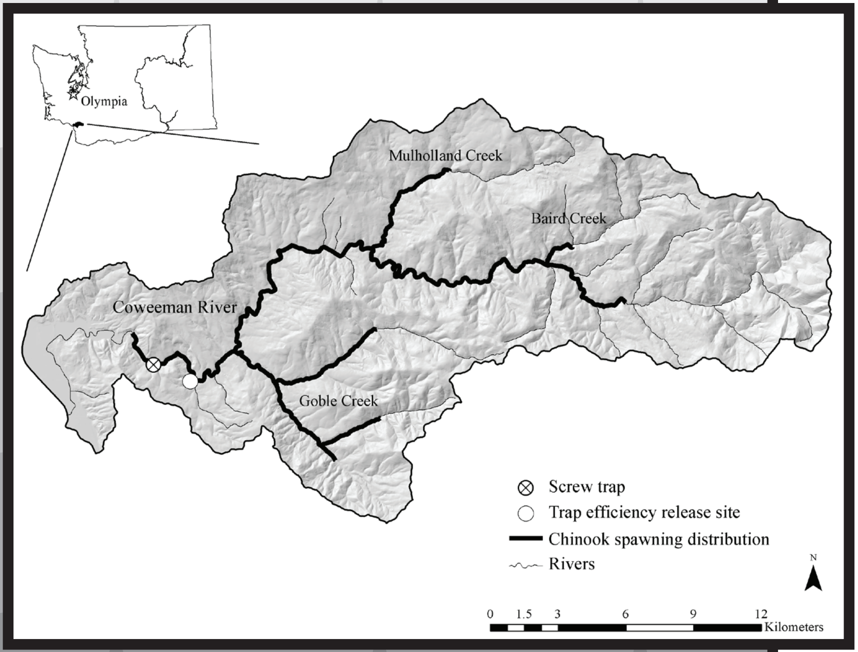
Evaluation of Coweeman River Salmonids in 2012 and 2013: Juvenile Production and Other Activities



by Jamie Lamperth, Mara S. Zimmerman, Andrew M. Claiborne, Lance Campbell, and Anna Hildebrandt

Washington Department of FISH AND WILDLIFE
Fish Program
Science Division

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Fish Science Division

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Executive Summary

Viable salmonid population (VSP) parameters are monitored in the Coweeman River basin as part of a broader monitoring program in the Lower Columbia Evolutionary Significant Unit. The primary goal of this study is to monitor juvenile abundance, diversity, and timing (distribution) that contribute to VSP parameters for ESA-listed species ("tule" fall Chinook, coho, and steelhead), and coastal cutthroat. Additional study of tule fall Chinook includes collection of genetic tissue for a genetic mark-recapture estimate of adult spawner escapement, application of strontium marks to investigate freshwater residency of juvenile Chinook, and application of coded-wire tags (CWT) to understand where wild tule fall Chinook are intercepted in ocean fisheries. Releases of hatchery-origin winter-run steelhead (the number planted vs. the number that emigrate) are also monitored. This report provides the results of work conducted in 2012 and 2013.

To meet the study objectives, a 1.5 m (5-foot) diameter rotary screw trap was operated near river kilometer (rkm) 12.0 from February 8, 2012 to August 24, 2012 (sampled 93% of the time), and February 6 to August 23, 2013 (sampled 100% of the time).

In 2012, the outmigrant abundance estimate ± 95% CI of fall Chinook was 245,008 ± 44,856 (CV = 9.3%). This estimate includes 200,556 ± 44,655 (CV = 11.4%) fry and 44,452 ± 4,245 (CV = 4.9%) subyearling smolts. Of these, 14,940 were marked with strontium and/or CWTs. The estimates for the other species were 14,014 ± 3,790 (coho, CV = 11.4%), 13,488 ± 4,458 (natural-origin steelhead, CV = 16.9%), and 2,658 ± 774 (cutthroat, CV = 14.9%). The estimated number of hatchery steelhead released from the acclimation pond (11,492 ± 3,437, CV = 15.3%) was significantly more than the estimated number that passed the trap (7,738 ± 2,783, CV = 18.3%; $Z = 1.66$, $p = 0.05$, one-tailed test).

In 2013, the abundance estimate ± 95% CI of fall Chinook was 138,273 ± 20,779 (CV = 7.7%). This estimate includes 98,698 ± 20,675 (CV = 10.5%) fry and 39,574 ± 4,179 (CV = 5.4%) subyearling smolts. Of these, 7,500 were marked with strontium and/or CWTs. The estimates for the other species were 13,354 ± 2,400 (coho, CV = 9.2%), 17,924 ± 1,901 (natural-origin steelhead, CV = 5.4%), and 2,841 ± 799 (cutthroat, CV = 14.4%). The estimated number of hatchery steelhead released from the acclimation pond (8,958 ± 1,676, CV = 9.5%) was not significantly different than the estimated number that passed the trap (10,510 ± 1,562, CV =

7.6%; $Z = 1.33$, $p = 0.09$, one-tail test). An estimate for smaller, late migrating (mid-June to mid-July) coho was estimated for the first time. The estimate for this group was 2,192 ± 261 (CV = 6.1%).

Introduction

The Coweeman River is a left bank tributary of the lower Cowlitz River which supports wild populations of Chinook (*Oncorhynchus tshawytscha)* and coho salmon (*O. kisutch)* as well as steelhead (*O. mykiss*) and coastal cutthroat trout (*O. clarki clarki*). With the exception of cutthroat trout, these species are federally protected as *threatened* under the Endangered Species Act. Coweeman River populations are part of the Lower Columbia Evolutionary Significant Unit (ESU, Myers et al. 2006) and Chinook, coho, and steelhead populations in this watershed have been listed as primary populations in the Cascade strata for the purpose of recovery planning (LCFRB 2010).

Viable salmonid population (VSP) parameters are monitored in the Coweeman River basin as part of a broader monitoring program in the Lower Columbia Evolutionary Significant Unit. The primary goal of this study is to monitor juvenile outmigrant abundance, diversity, and timing (distribution) that contribute to VSP parameters for ESA-listed species ("tule" fall Chinook, coho, and steelhead), and coastal cutthroat. Methods are used to generate unbiased estimates of annual juvenile abundance for each species with a coefficient of variation (CV) of less than 15% for salmon species and 30% for steelhead in order to meet NOAA recommendations (Crawford and Rumsey 2011). Annual information provided in this report describes the current state of these populations in the Coweeman River. Long-term monitoring will contribute to a comprehensive evaluation of changes in characteristics of ESA-listed stocks.

This juvenile evaluation study is focused on Chinook salmon, although information is collected for all salmonid species encountered. Chinook salmon in the Coweeman River are a genetically distinct stock (Myers et al. 2006), moderately abundant, and relatively free of hatchery influence. Coweeman River Chinook salmon exhibit a "tule fall" Chinook life history, meaning that adults enter freshwater in August and September and spawn within a few weeks of freshwater entry (LCFRB 2010). Tule fall Chinook are one of three adult life histories recognized for the Lower Columbia Chinook ESU (Myers et al. 2006).

Despite the important status of Coweeman River Chinook, intense monitoring of this population did not exist until recently. In 2005, the Washington Department of Fish and Wildlife initiated a pilot study to directly estimate juvenile production in the basin using a rotary screw trap. Refinements to the study design were made (e.g., temporal extent of trapping) during the first few years and by 2010 the general sampling methodology used today was established.

Additional studies beyond juvenile production have been implemented in order to provide a more complete understanding of Chinook abundance, productivity, distribution, and diversity in the Coweeman River. Juvenile Chinook genetic material has been collected to develop parentage-based genetic mark-recapture methods to improve adult escapement estimates (Blankenship and Rawding 2012). In addition, Chinook otoliths have been marked with strontium (Sr) in order to use otolith microchemistry to better understand the importance of freshwater rearing habitats (natal stream versus Columbia River estuary) on overall Chinook productivity (i.e., return rates). Finally, larger Chinook subyearlings have been marked with coded-wire tags (CWT) to estimate fishery contributions of ESU-wide, natural-origin tule fall Chinook and to compare this with fishery distributions of hatchery fish that have been used as surrogates to estimate harvest of naturally produced fish.

Initial results on Chinook salmon juvenile production indicate that at least two juvenile life history strategies exist within the same population (Sharpe et al. 2009, Lamperth et al. 2013). Coweeman River Chinook salmon emigrate primarily as subyearlings and the outmigration is bimodal. Fry migrants emigrate early and at smaller sizes (< 45 mm FL). Subyearling smolt migrants emigrate later and at larger sizes (60-115 mm FL), presumably having used the natal stream habitat for early growth. These life history strategies are consistent with those observed for summer and fall Chinook salmon populations in Puget Sound (Topping and Zimmerman 2011; Kiyohara and Zimmerman 2012) and have even been observed in regions where Chinook salmon populations were introduced (Carl 1984; Davis and Unwin 1989).

Monitoring of stream temperature began in 2012 to investigate the effects of temperature on juvenile production estimates and migration timing. Stream temperature is an important factor influencing development, survival, and behavior of anadromous species at all life stages. It also can be measured precisely and accurately over a wide range of spatial and temporal scales.

The effectiveness and magnitude of Sr marks applied at various strontium chloride hexahydrate concentrations and exposure times was tested in 2013. The goal of the experiment was to identify a combination of concentration and exposure time that reduced exposure time from 6 h (current protocol) to 2 h or 3 h. The current protocol is time intensive, often problematic in regards to field logistics, and limits the number of fish marked due to health concerns. The biggest challenge occurs when large numbers of Chinook are captured and this intensifies when stream temperatures are near upper temperature thresholds for handling. A reduction in exposure time would allow fish to be Sr-marked the same day they are caught, reduce fish holding time, and increase the number of subyearling smolts marked with Sr.

In 2012 and 2013, the objectives of this study were to:

- Estimate juvenile production, outmigration timing, and body size of fall Chinook by life stage.
- Estimate juvenile production, outmigration timing, body size and age-structure of natural-origin winter-run steelhead, wild coho salmon, and wild coastal cutthroat smolts,
- Estimate the number of hatchery-origin steelhead leaving the Coweeman River and compare it to the number planted.
- Insert coded-wire tags into fall Chinook salmon ≥ 65 mm to evaluate fishery interceptions.
- Strontium-mark the otoliths of fall Chinook salmon in order to use otolith microchemistry to (a) determine the relative contribution of early life history strategies to adult returns, and (b) estimate juvenile freshwater residency in the Columbia River estuary.
- Collect genetic material from 1% of the weekly fall Chinook outmigrants. These genotypic data, in conjunction with adult genotypic data, will be used to derive adult escapement estimates using genetic mark-recapture methods.
- Test assumptions of mark-recaptures studies focusing on Bismarck brown mark retention, effects of Bismarck brown on catchability, and size-biased capture rates.
- Conduct an experiment to test whether shorter strontium chloride exposure times produce acceptable marks for analysis.
- Deploy temperature data loggers throughout the Coweeman basin.

Methods

Study Site

The Coweeman River is a third-order tributary to the Cowlitz River located in Cowlitz County, WA (Figure 1). The mouth of the Coweeman River is approximately 120 km from the Pacific Ocean. The Coweeman River basin drains approximately 329 square kilometers and is a relatively low elevation watershed with elevations ranging from 1 - 1358 m. Along the known extent of salmonid spawning and rearing in the mainstem, the stream gradient is 0.6%. The vast majority of land use in the watershed is timber production with limited residential and commercial use near the river mouth. Native anadromous salmonids in the Coweeman River include tule fall Chinook salmon, coho salmon, winter-run steelhead, and coastal cutthroat trout. Chum salmon were once present in the watershed but are currently at very low abundance or extirpated. Hatchery smolt releases of winter-run steelhead occur annually through a cooperative effort with a local fishing club, the Cowlitz Game and Anglers, a private landowner, and the Washington Department of Fish and Wildlife.

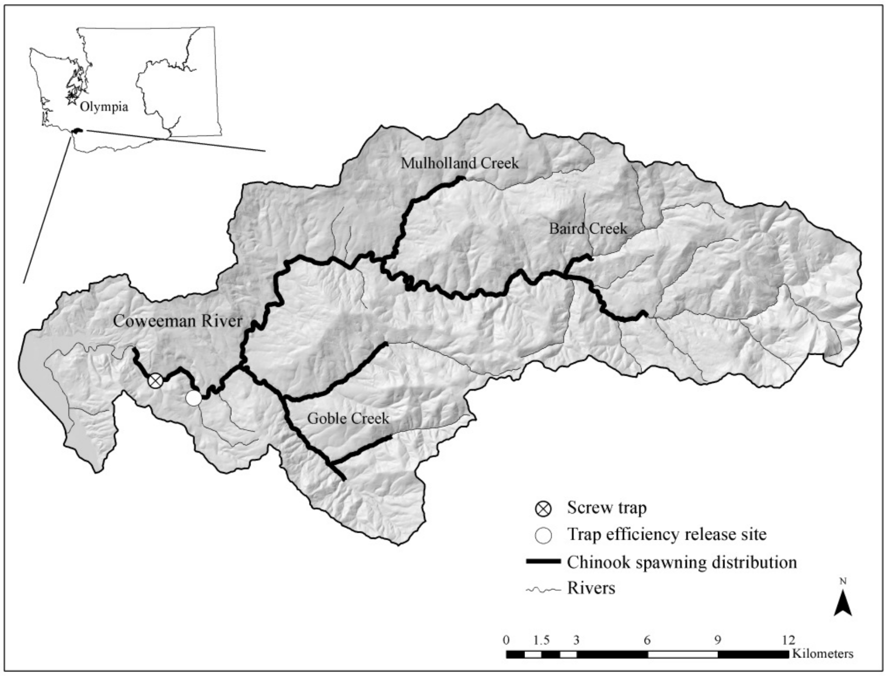

Figure 1. Map of the Coweeman River basin, WA showing the screw trap location and Chinook spawning distribution.

Juvenile Trap Operation

A 1.5 m (5-foot) diameter rotary screw trap was operated near river kilometer (rkm) 12.0 of the Coweeman River to capture juvenile outmigrants (Figure 1). The target species were Chinook, coho, steelhead, and cutthroat. This site was selected because it is the lowest point in the basin conducive to operating a screw trap with adequate thalweg constriction to help ensure high trap efficiency during most flow conditions. Most of the lower 12 km is a tidally influenced slough and very few anadromous fish spawn below this point (WDFW, unpublished data). The site is located on private property, providing some measure of security, and is easily accessible. During summer low flows, weir panels were installed to force more surface water into the trap and to increase the proportion of outmigrants captured. The trap was operated continuously unless unscheduled trap outages occurred due to high flows and/or trap malfunctions due to woody debris (cone stoppers).

In 2012, the trap operated from February 8, 2012 to August 24, 2012 and sampled 93% of the time. Unscheduled trap outages occurred four times from February 21 – 27 (repairs after flood event), March 12 – 16 (high water event), March 29 – 31 (high water event), and July 9 (log jammed in screw). In 2013, the trap operated continuously from February 6 to August 23, 2013 with no unscheduled trap outages.

Juvenile Fish Collection

The trap was cleaned and checked for fish each morning. Fish were safely removed from the live box with a net and transferred in 19 L buckets from the trap to a shore-side field processing station. On the river bank, fish were held either in 19 L aerated buckets or 150 L totes depending on the number of fish present. The totes were plumbed with a continuous supply of river water to maintain temperature and oxygen concentration. Prior to biological sampling, fish were anaesthetized in a buffered ($NaHCO_3$) tricaine methanesulfonate (MS-222) solution (~60 mg/L). All fish were sampled as quickly as possible and were allowed to fully recover before release.

Fish caught in the trap were identified to species using Pollard et al. (1997) and Wydoski and Whitney (2003). Target species (Chinook, coho, steelhead, and cutthroat) were also classified by life stage. In 2012, we used 4 life stage categories (fry, parr, transitional, and smolt). Fry and adults were assigned based on length criteria alone. Fry were < 45 mm FL and adults were > 300 mm (cutthroat), 301 – 499 mm FL (rainbow), or ≥ 500 mm (steelhead). Parr, transitional, and smolt life stages were assigned based on morphological characteristics. Parr had distinct parr marks or showed no signs of smoltification, transitionals showed initial signs of smoltification (i.e., silvery appearance and faded parr marks), and smolts showed advanced signs of smoltification (i.e., faded parr marks, deciduous scales, silvery appearance, and/or black banding along the trailing edge of the caudal fin).

In 2013, the classification framework was expanded to 12 life stage categories using basin-wide protocols developed for the Lower Columbia ESU monitoring program. The expanded categories were defined by a combination of appearance (fry, parr, transitional, smolt; same as 2012) and age class (subyearling, yearling+, adult). In 2013, parr, transitionals, and smolts were further broken down into subyearling and yearling+ age classes. The yearling+ category included all fish one year and older (one, two or three year old fish typically have overlapping length distributions and cannot be identified in the field). Subyearling and yearling categories were assigned based on a combination of length and date criteria and are specific to watershed and species. The current Coweeman protocol is based on length distributions from previous trapping seasons but not age data (Tables 1 – 4). These age assignments will be validated over time with scale sampling. All steelhead and cutthroat transitionals and smolts observed in the Coweeman basin have been yearlings. Therefore, these life stages are assumed yearlings and there are no length and date criteria.

Table 1. **Chinook** life stage and age class designation criteria. Based on 2010 – 2012 Coweeman River outmigration. See text for morphological traits used to define Parr, Transitionals, and Smolts.

Date Criteria	Length Criteria (mm FL)	Life Stage and Age Class
All season	< 45	Fry
January 1 – April 30	45 – 80	Parr, Transitional, or Smolt– Subyearling
January 1 – April 30	> 80	Parr, Transitional, or Smolt– Yearling
May 1 – May 31	45 – 110	Parr, Transitional, or Smolt– Subyearling
May 1 – May 31	> 110	Parr, Transitional, or Smolt– Yearling
After May 31	≥ 45	Parr, Transitional, or Smolt– Subyearling

Table 2. **Coho** life stage and age class designation criteria. Based on 2010 - 2012 Coweeman River outmigration. See text for morphological traits used to define Parr, Transitionals, and Smolts.

Date Criteria	Length Criteria (mm FL)	Life Stage and Age Class
All season	< 45	Fry
January 1 – April 30	45 – 60	Parr, Transitional, Smolt – Subyearling
January 1 – April 30	> 60	Parr, Transitional, Smolt – Yearling
May 1 – May 31	45 – 80	Parr, Transitional, Smolt – Subyearling
May 1 – May 31	> 80	Parr, Transitional, Smolt – Yearling
June 1 – June 30	45 – 100	Parr, Transitional, Smolt – Subyearling
June 1 – June 30	> 100	Parr, Transitional, Smolt – Yearling
After June 30	≥ 45	Parr, Transitional, Smolt – Subyearling

Table 3. ***O. mykiss*** life stage, age class, and species designation criteria. All transitionals and smolts observed in the Coweeman River have been yearlings. Therefore, there are no length and date criteria associated with these life stages. See text for morphological traits used to define Parr, Transitionals, and Smolts. Based on 2010 – 2012 outmigration.

Date Criteria	Length Criteria (mm FL)	Life Stage	Species designation
All season	< 45	Fry	Trout-General
January 1 – May 15	45 – 300	Parr – Yearling[1]	Steelhead
May 16 – June 30	45 – 80	Parr – Subyearling[1]	Steelhead
May 16 – June 30	81 – 300	Parr – Yearling	Steelhead
After June 30	45 – 100	Parr – Subyearling[1]	Steelhead
After June 30	101 – 300	Parr – Yearling	Steelhead
All season	301 – 499	Adult[2]	Rainbow
All season	≥ 500	Adult	Steelhead

[1] Until defining features (maxillary length, presence of throat slashes, etc.) become evident (~65 mm FL), steelhead and cutthroat trout may not be identifiable to species and were recorded as “Trout-General”.

[2] Rainbow Adults show no signs of smoltification

Table 4. **Coastal cutthroat** life stage, age class, and species designation criteria. All transitionals and smolts observed in the Coweeman River have been yearlings. Therefore, there are no length and date criteria associated with these life stages. See text for morphological traits used to define Parr, Transitionals, and Smolts. Based on 2010 – 2012 outmigration.

Date Criteria	Length Criteria (mm FL)	Life Stage	Species designation
All season	< 45	Fry	Trout-General
January 1 – May 15	45 – 300	Parr – Yearling[1]	Cutthroat
May 16 – June 30	45 – 80	Parr – Subyearling[1]	Cutthroat
May 16 – June 30	81 – 300	Parr – Yearling	Cutthroat
After June 30	45 – 100	Parr – Subyearling[1]	Cutthroat
After June 30	101 – 300	Parr – Yearling	Cutthroat
All season	> 300	Adult[2]	Cutthroat

[1] Until defining features (maxillary length, presence of throat slashes, etc.) become evident (~65 mm FL), steelhead and cutthroat trout may not be identifiable to species and were recorded as “Trout-General”.

[2] Cutthroat Adults show no signs of smoltification.

Target salmonids were examined for hatchery marks (e.g., missing adipose fin), and other internal (i.e., CWT) and external marks (including efficiency trial marks), and enumerated. Fork length (FL) was measured to the nearest millimeter from a subsample of each species. Scale samples were collected from a subsample of natural-origin steelhead, coho, and cutthroat transitionals and smolts. In 2012, scale samples were haphazardly collected from 120 individuals per species throughout the emigration. In 2013, a systematic sampling design for scale collections was used where every 5th individual per species was sampled. Genetic material was collected from Chinook using a systematic sampling design to obtain samples from 1% of the weekly total outmigrants. Typically, ~ 4% of the fry outmigrants are captured (i.e., trap efficiency ~ 4%) so DNA was collected from every 4th fry. The range of trap efficiencies for larger outmigrants (i.e., parr, transitionals, and smolts) is 10% - 75%. To ensure the collection goal was met, genetic material was collected from every 10th parr, transitional, or smolt. The tissue sample was taken from the upper or lower caudal fin (~ 4 mm^2). Non-salmonids were identified to species and enumerated. All fish were sampled as quickly as possible and were allowed to fully recover before release.

Environmental, trap status, and sampling water temperature data were collected at each trap check. Instantaneous stream temperature was collected once during the sampling event and the holding vessel temperatures were monitored throughout the sampling event. Fish were counted and released immediately (i.e., no bio-sampling) if stream temperature at the time of the trap check was ≥ 19.0 ^{o}C. Sampling ceased and fish were released if holding vessel temperatures could not be maintained below 20 ^{o}C. Stream temperature was also monitored with a temperature data logger (HOBO Water Temp Pro V2; Onset Computer Corporation) deployed ~ 1 km downstream of the trap. Flow trend (increasing, deceasing or stable) was documented daily and discharge data collected at Department of Ecology flow monitoring station # 26C075 was downloaded at the end of the trapping season. The flow station is located ~ 100 m upstream of the trap site and records discharge and temperature at 15 minute intervals (data last accessed on September 19, 2013). Cone revolutions per minute and total daily cone rotations were recorded to document cone speed and sampling continuity. Total daily cone rotations were counted using a hub counter.

Trap efficiency trials were conducted using all life stages of Chinook, and transitional and smolts life stages for coho, steelhead (natural and hatchery origin), and coastal cutthroat.

The methods varied by species, life stage, and year as described in detail below. In general, trap efficiency trials were conducted by marking a subsample of maiden caught individuals (i.e., fish captured for the first time) in good condition and releasing them upstream of the trap for subsequent recapture. The trials were stratified by week and were conducted throughout the emigration period of each group to account for temporal heterogeneity in capture probabilities. All other fish, including recaptures and non-target species, were released 100 m downstream of the trap site. All releases occurred during daylight hours.

In 2012, efficiency trial mark types varied by species and all marked fish were released 3.0 km upstream of the screw trap. Chinook (all life stages) were generally marked with Bismarck brown Y (Product # B2759, Sigma-Aldrich, St. Louis, MO). Fish were immersed in a 15.8 mg/L aerated solution for 45 minutes. Bismarck brown trials were conducted between one and five days per week with several days of no marking between each period to allow adequate time for marked fish to pass the trap before the next marking period. This marking schedule increased the probability that all recaptures were captured during the week they were marked. In June, coded-wire tags were used as an efficiency mark for one week but discontinued for logistical reasons. Starting in August, Chinook were marked with a partial caudal clip because stream temperatures were too high to safely use Bismarck brown. Coho, steelhead, and coastal cutthroat transitionals and smolts were marked with colored biophotonic formulations on the anal or caudal fin (MicroJect; New West Technologies http://newwesttechnologies.com). Biophotonic formulation color was changed weekly in order to detect delayed recaptures among the temporally stratified release groups.

In 2013, efficiency trial mark types varied by species and fish were released at two locations. Fry (< 45 mm) were released 245 m upstream of the trap. Fish released from this location traveled through two riffle/pool sequences before reaching the trap. Parr, transitionals, and smolts were released 3.0 km upstream of the trap. The different release locations were selected to maximize mixing of marked and unmarked fish and to minimize mortality of marked fish for each life stage. Chinook were marked with Bismarck brown through June 2013. Fish were immersed in a 23.2 mg/L Bismarck brown solution for 60 minutes. The concentration and soak time were both increased from 2012 as a result of mark retention tests (see Assumption Testing section). Fry releases typically occurred seven days a week to maximize release numbers (fry efficiencies are typically low [~4%]). Releases of larger Chinook, later in the season, occurred between 1 and 4 days per week. Starting in July, Chinook were marked with either Bismarck brown, partial caudal clips (upper caudal or lower caudal), or Bismarck brown and a partial caudal clip. The same Bismarck brown immersion protocol was used as earlier in the season. These marks were administered as paired releases to test whether Bismarck brown affected fish behavior and capture probabilities (see Assumption Testing section). Partial caudal clips were changed on a weekly basis in order to detect delayed recaptures among the temporally stratified release groups.

Steelhead (natural and hatchery-origin), coho, and cutthroat transitionals and smolts were marked with partial caudal clips (upper caudal or lower caudal). The marks were changed on a weekly basis in order to detect delayed recaptures among the temporally stratified release groups. These fish were released 245 m upstream of the trap through April 27, 2013. Starting April 29, 2013, these fish were released 3.0 km upstream of the trap.

Winter-run hatchery steelhead (Chambers Creek origin) are annually released into the Coweeman River and effectiveness of the release (the number of fish planted vs. the number of fish that emigrate) is monitored. Approximately 10,000 fish are planted into a private acclimation pond in January or February. The fish are force-released from the acclimation pond, down a small tributary and into the Coweeman River as soon after April 15 (earliest date recommended by hatchery guidelines) as possible. The pond is approximately 1.0 km from the Coweeman River near rkm 21.0 which is approximately 9 km upstream of the trap. A fish counter (SR-1601; Smith Root, Inc.,Vancouver, WA) was put in place in the pond outflow to count the number of fish released.

Hatchery steelhead release success was monitored using two mark-recapture study designs. A one-trap design (the same as all other species in this document) was used to estimate the number of hatchery steelhead passing the smolt trap. A two-trap design (Volkhardt et al. 2007) was used to estimate the number of hatchery steelhead leaving the pond. For the two-trap design, a random subsample of fish were collected from the acclimation pond, measured to the nearest mm FL, and marked on the anal fin with red biophotonic formulation (MicroJect). If hatchery steelhead leaving the pond move directly out of the river with minimal mortality, the one-trap and two-trap estimates should not differ. These estimates were compared with a Z

statistic using the following formula where N_1 and N_2 are the one-trap and two-trap estimates respectively:

$$Z = \frac{(N_1 - N_2)}{\sqrt{V(N_1) + V(N_2)}}$$

Juvenile Production Estimates

Juvenile production estimates were generated for all life stages of Chinook and transitional and smolt life stages of coho, steelhead (natural and hatchery-origin), and cutthroat. In general, a one-trap mark-recapture study design stratified by time period was used to estimate the number of juvenile migrants for each species. For hatchery steelhead, a one-trap design and a two-trap design were implemented. For Chinook, the total abundance was partitioned into fry and subyearling smolt estimates based on a demarcation date selected by mean weekly FL. Chinook continuously grow through the trapping season so a demarcation date corresponding to a 45 mm FL threshold was used to categorize the run into fry (< 45 mm FL) and subyearling smolts (≥ 45 mm FL). The caveat with this approach was each category was not exclusively one life stage or the other because multiple life stages were present around the demarcation date.

For the one-trap design, one of two analytical approaches was used to estimate production of each species. Catch and efficiency trial data were organized by week, weekly trials were stratified with statistical guidance, and total abundance and variance estimates were generated. The first approach was based on the Darroch (1961) stratified-Petersen estimator and was used when delayed recaptures were detected and missed catch was negligible. This approach was used for coho, steelhead, and cutthroat (except late coho migrants in 2013, see below). Strata, capture probabilities and estimates for each stratum, and total abundance and variance were calculated using DARR (Darroch Analysis with Rank Reduction) 2.0.2 (Bjorkstedt 2005; Bjorkstedt 2010) in the R-platform (R Core Team 2012). The second approach was based on the one-trap Petersen estimator described in Carlson et al. 1998 with adjustments outlined in Topping and Zimmerman (2011) and was used when missed catch was notable and/or delayed recaptures were not detected. This approach was used for Chinook and late coho migrants. Efficiency trials were stratified using a *G*-test (Sokal and Rohlf 1981) and missed catch and associated variance during unscheduled trap outages were estimated and added to the maiden catch for each stratum. An abundance estimator appropriate for a one-trap design (Carlson et al. 1998, Volkhardt et al. 2007) was used to generate abundance and variance for each stratum. Variance of this estimate accounted for variance associated with missed catch.

The two-trap design was applied only to hatchery steelhead and was a Petersen estimator with Chapman modification (Seber 1982, Volkhardt et al. 2007). Data were pooled into a single estimate as the random subsample of marked fish released from the pond was assumed to be representative of all hatchery steelhead released.

Preliminary data screening was performed before running the final estimates. Marks were removed when a recapture event did not occur (e.g. unscheduled trap outage) or if efficiencies were unreliable. For example, during late June 2013, capture rates of Bismarck brown marked fish were up to 50% less than temporally adjacent strata that had similar discharge. This observation and the results of an experiment included in this report suggest Bismarck negatively biased capture rates and these efficiencies were unreliable. In addition, erratic trap efficiencies were observed when coho, cutthroat, and steelhead were released 245 m above the trap in 2013 (through April 27, 2013). Therefore, average species-specific trap efficiencies from the upper release site (releases after April 30th) were applied to the species-specific release and catch numbers through April 27, 2013. The adjusted data set was entered as one row in the DARR matrix and held as its own stratum. Trials starting April 30 were stratified using DARR as described above.

In 2013, coho migrants were partitioned into two groups based on migration timing and size. The first pulse of fish consisted mainly of age 1+ transitional or smolt emigrants. This group represents the typical outmigrant group. The second pulse of fish were a presumed mix of age 0 and age 1 transitional and smolt emigrants. This group migrated later and was smaller in size compared to the first group. June 17, 2013 was used as the demarcation date between the two estimates.

Size of outmigrants for all species was summarized by weighting weekly mean lengths by the weekly proportion of total outmigrants to calculate a weighted average length for the season.

Mark-Recapture Assumption Testing

In 2013, three of six assumptions of mark-recapture studies were tested. The first experiment investigated catchability (i.e., mortality caused by marking) and/or caused mark loss (i.e., mark retention) associated with Bismarck brown dye. This was done by testing Chinook fry (< 45 mm) mark-related mortality and mark retention at varying Bismarck brown concentrations and exposure times. Six trials were run during the first 1.5 months of trapping. Concentrations ranged from 15.8 – 33.8 mg/L and exposure ranged from 20 – 60 minutes.

The second experiment tested whether Bismarck brown affected capture probabilities of Chinook subyearling smolts. To test this, paired-releases occurred with equal or near-equal numbers of fish marked with either a partial caudal clip (CC), or Bismarck brown (BB), or a partial caudal clip and Bismarck brown (CC&BB). All fish were released 3.0 km upstream of the trap in July. The null hypothesis was that capture efficiency would be equal among mark groups. To test this hypothesis, a 2X3 *G*-test with Williams' correction was used to compare frequencies of seen (i.e., recaptures) and unseen (i.e., marks – recaptures, or marked fish not seen) fish with significance level set at $\alpha = 0.05$. The 95% confidence intervals for each group were calculated using methods described in Zar (1999; p. 527).

Finally, size-biased capture rates were tested for each species to determine if all fish had an equal probability of capture in the first period. This was done by comparing the cumulative length frequency distributions of marked and recaptured fish using the Kolmogorov-Smirnov test. The test was run for the entire trapping season and for each stratum during peak migration periods to account for temporal heterogeneity in trap efficiency and fish size. The number of stratum tested for each species differed because the emigration curves differed. Five strata were tested for Chinook (> 45 mm FL), three for natural-origin steelhead, and three for coho. Stratum tests were not run for hatchery-origin steelhead and cutthroat.

Coded-Wire Tagging and Strontium Marking of Juvenile Chinook

A subsample of juvenile Chinook caught in the trap was marked with CWTs and/or Sr for long-term evaluations. CWTs were inserted into Chinook ≥ 65 mm FL using a Northwest Marine Technology (NMT, Shaw Island, WA, USA) Mark IV automatic tagging system. The sagittal otoliths of Chinook (all sizes) were marked with Sr by placing the fish in a 400 L vessel containing an aerated solution of strontium chloride hexahydrate ($SrCl_2 \cdot 6H_2O$) at 2,000 ppm for 6 h. The Sr bath was sterilized by pumping the solution through an ultra-violet light filter. The goal was to CWT and/or Sr-mark as many Chinook as possible while balancing the sampling needs of other study objectives. The Sr-marking procedure (Schroder et al. 1995) has been successfully used for marking emigrating chum salmon fry (Hillson 2006) and fall Chinook (Schroder et al. 1996). Hillson (2006) reported low mortality (0.044%) during marking and no delayed mortality 48 h after marking.

Thermal Rearing Habitat

Stream temperature data were collected to describe the general thermal regime of the Coweeman River basin and to describe the thermal conditions experienced by rearing juvenile salmonids. In total, 16 loggers were deployed by July 2013, 11 in the main stem and six in tributary habitats. Spatially-fixed temperature data loggers (Optic Stowaway Temp; Onset Computer Corporation, Pocasset, MA; accuracy ± 0.2°C) were initially deployed in November 2012 in the main stem at rkms 10.8, 17.9, and 30.1. An additional Stowaway logger was deployed at rkm 40.4 in March 2013. In July 2013, these loggers were replaced with newer, HOBO U22 Water Temp Pro V-2 loggers (Onset Computer Corporation, Pocasset, Massachusetts, USA accuracy ± 0.2°C) and additional loggers were added throughout the basin. Main stem sites were added at rkm 0.2, 14.9, 21.7, 25.0, 35.7, 44.0, and 50.8. Tributary sites were added in Goble (rkm 0.1 and 8.5), Mulholland (rkm 0.1 and 2.5), and Baird (rkm 0.8) creeks.

Logger site selection was based on water depth, water velocity, and distance to anchor point. Loggers were typically placed in pool/glide habitat to minimize dewatering during low flow periods, in locations with water velocities sufficient to produce well-mixed water (i.e., minimize influence of microhabitat temperature differences), and near stream-side anchor points to minimize movement and bank-stranding during high stream discharge events. Temperature differences in the vicinity of several loggers were evaluated by probing the area with a hand-held thermometer. No differences were found. Each logger was housed in a white polyvinyl chloride pipe (to protect logger from natural disturbances and to reflect solar radiation) perforated with drill holes (to maximize water movement across the sensor) and secured to a stable stream side feature with braided cable. Data were downloaded from the units *in situ* on several occasions using the HOBO Waterproof Shuttle (Onset Computer Corporation, Pocasset, MA; Part No. U-DTW-1). The final download for this report occurred the first week of November, 2013. The units have not been removed and are currently deployed.

Temperature data were summarized two ways. Mean daily temperature from November 2012 through October 2013 was used to describe seasonal temperature variation of the Coweeman mainstem using temperature sites with the longest time series. Maximum annual temperature of all temperature sites in the basin was used to describe the thermal regime and variation throughout the basin. Maximum temperature is a typical metric used to summarize temperature data and has been used to predict the occurrence of salmonid species (Dunham et al. 2003).

Effects of Strontium Chloride and Duration of Exposure on Otolith Marking

Treatment Groups

Juvenile hatchery-origin Chinook salmon were marked and reared at the Kalama Falls Hatchery in Kalama, Washington. A total of 174 juveniles were marked with a $SrCl_2 \cdot 6H_2O$ solution at two concentrations and three exposure times. Approximately 35 fish per treatment were measured, weighed, and placed in an aerated five gallon bucket. Fish were exposed to a 2,000 ppm solution for 2, 3, and 6 hours or a 3,000 ppm solution for 2 and 3 hours (Table 5). Note that the primary Chinook salmon Sr-marking treatment currently used by WDFW is 2,000 ppm for 6 hours. After fish were marked, each treatment group was moved to a perforated tank placed in a raceway. All fish were fed protein pellets (Oregon Moist Pellet ®) for the duration of the experiment. After two to three weeks individuals across tanks were extracted, given a lethal dose of MS 222, and stored in ethanol. Note that all individuals from the 2000 ppm 6hr treatment were moribund two weeks after marking which was related to unforeseen changes in the rearing conditions of this group (lethal temperature increase and reduced oxygen).

Table 5. Experimental conditions of Sr- marking experiment. n= number of fish exposed to each treatment. T_{SS} = water temperature at beginning of treatment. T_{SE} = water temperature at end of treatment and T_{SP} = temperature of water during grow out period

Treatment	SrCl (ppm)	Exposure time (hrs)	*n*	Fork length (mm)	T_{SS} (°C)	T_{SE} (°C)	T_{SP} (°C)
1-Standard	2000	6	35	63 (4.5)	10.0	11.5	9.5
2	2000	2	35	64 (3.9)	9.5	10.0	9.5
3	2000	3	34	67 (1.9)	9.5	10.5	9.5
4	3000	2	35	65 (3.4)	10.0	10.5	9.5
5	3000	3	35	65 (3.0)	10.0	11.0	9.5

Otolith Preparation and Analysis

All otoliths were extracted, cleaned, and stored dry. Otoliths were mounted on a glass slide with thermoplastic resin. Otoliths were ground first on the proximal, then distal side using successive grits of lapping film (Precision Fiber Products ®), and polished using an aluminum oxide slurry. To detect the point of the Sr mark, we measured otolith Sr and calcium (Ca) using a Thermo X series II inductively coupled mass spectrometer (LA-ICPMS) coupled with a Photon Machines G2 193 nm excimer laser at the Keck Collaboratory for Plasma Mass Spectrometry. Scans were completed along a transect running from the ventral to dorsal edge through the primordia perpendicular to the dorsal and ventral increment structure. The laser was set at a pulse rate of 8 Hz traveling across the sample at 5 µm s^{-1-s}, with a spot size of 30 µm. Normalized ion ratios were converted to elemental concentrations using a glass standard from the National Institute of Standards and Technology (NIST 610) and finally converted to molar ratios for analysis. We successfully processed 23-35 otoliths per treatment for LA-ICPMS analysis (Table 2). For all comparisons we enumerated Sr:Ca on the dorsal portion of the otolith and because parametric assumptions were met we used two-way Analysis of Variance to determine if there was an effect of exposure duration and concentration on otolith Sr:Ca. To test for any differences in dorsal Sr:Ca between treatment groups we used bonferroni corrected pairwise comparisons.

Results

Juvenile Production Estimates

Chinook

The demarcation date for fry and subyearling smolt life stage categories was May 14, 2012 and April 29, 2013.

In 2012, the total estimated catch of juvenile Chinook salmon (all life stages) was 22,462 (actual catch = 21,342; estimated missed catch = 1,120) between February 8 and August 24, the first and last days this species was encountered in the trap. Of these, 8,193 (actual catch = 7,275; estimated missed catch = 918) were categorized as fry (i.e., captured on or before May 14) and 14,269 (actual catch = 14,067; estimated missed catch = 202) were categorized as subyearling smolts (i.e., captured after May 14) for life stage specific production estimates. The actual life stages for the fry production estimate group included 7,266 fry (99.9%) and 9 parr (0.1%). The actual life stages for the subyearling smolt production estimate group included 119 fry (0.9%), 90 parr (0.6%), 2,702 transitionals (19.2%), and 11,156 smolts (79.3%). Four hatchery Chinook were captured, evident by a missing adipose fin. The hatchery fish (FL range; 96 – 141mm) were caught on February 21, March 26, and April 24, 2012. Release location of these fish is unknown as hatchery Chinook are not released in the Coweeman basin. These fish were not included in the catch total or production estimate.

During the fry outmigration, we conducted 35 efficiency trials over 14 weeks and released between 10 and 156 marked fish per trial. These trials were summed by week. In total, we marked 2,116 and subsequently recaptured 86 Chinook fry. The *G*-test pooled the 14 weeks into 3 strata with trap efficiencies ranging from 3.2% to 9.7%.

During the subyearling smolt outmigration, we conducted 29 efficiency trials over 16 weeks and released between 7 and 69 marked fish per trial. These trials were summed by week. In total, we marked 983 and subsequently recaptured 307 Chinook subyearling smolts. The *G*-test pooled the 16 weeks into 4 strata with trap efficiencies ranging from 19.5% to 47.6%.

The abundance estimate ± 95% CI of fall Chinook emigrating from the Coweeman River in 2012 was 245,008 ± 44,856 (CV = 9.3%). This estimate includes 200,556 ± 44,655 (CV = 11.4%) fry and 44,452 ± 4,245 (CV = 4.9%) subyearling smolts (Table 6).

The temporal distribution of Chinook body size shows the fry emergence period and continual juvenile growth throughout the trapping season (Figure 2). Fry (<45 mm FL) began emerging from the gravel at least at the beginning of February (i.e., the beginning of trapping) and continued through the end of June. Fry were the most abundant life stage through early May. Some juveniles began to show signs of smoltification at the end of May, and all Chinook were classified as smolts after July 2.

The middle 50% of fry and subyearling smolt emigrants passed the trap between March 20 and April 13 and between June 27 and July 23, respectively. Fry and subyearling smolt mean FL ± 1 SD was 36.4 ± 1.8 mm (*n* = 1,136) and 85.7 ± 7.4 mm (*n* = 2,177), respectively. Overall mean FL ± 1 SD weighted by weekly abundance was 45.6 ± 2.8 (*n* = 3,313).

In 2013, we captured 18,676 juvenile Chinook salmon (all life stages) between February 6 and August 19, the first and last days this species was encountered in the trap. Of these, 5,886 were categorized as fry (i.e., captured on or before April 29) and 12,790 were categorized as subyearling smolts (i.e., capture after April 29) for life stage specific production estimates. The actual life stages for the fry production estimate group included 5,844 fry (99.3%) and 42 subyearling parr (0.7%). The actual life stages for the subyearling smolt group included 47 fry (0.4%), 1,723 subyearling parr (13.5%), 1,803 subyearling transitionals (14.1%), and 9,217 subyearling smolts (72.0%). Four hatchery Chinook were captured, evident by a missing adipose fin. The hatchery fish (FL range; 132 – 180 mm) were caught on February 8, February 12, February 28, and April 21, 2013. Release location of these fish is unknown as hatchery Chinook are not released in the Coweeman basin. Three yearling Chinook with an intact adipose fin were also captured. These wild yearling migrants were captured on February 10 (FL; 84 mm), March 23 (FL; 150 mm), and March 27 (FL; 155 mm). The hatchery and wild yearling Chinook were not included in the catch total or production estimate.

During the fry outmigration, we conducted 51 efficiency trials over 12 weeks and released between 1 and 339 marked fish per trial. These trials were summed by week. In total, we marked 2,881 and subsequently recaptured 211 Chinook fry. The *G*-test pooled the 12 weeks into 5 strata with trap efficiencies ranging from 3.0% to 11.0%.

During the subyearling smolt outmigration, we conducted 47 efficiency trials over 13 weeks and released between 6 and 187 marked fish per trial. These trials were summed by week. In total, we marked 1,237 and subsequently recaptured 315 Chinook subyearling smolts. The *G*-test pooled the 13 weeks into 5 strata with trap efficiencies ranging from 10.6% to 54.6%.

The abundance estimate ± 95% CI of fall Chinook emigrating from the Coweeman River in 2013 was 138,273 ± 20,799 (CV = 7.7%). This estimate includes 98,698 ± 20,375 (CV = 10.5%) fry and 39,574 ± 4,179 (CV = 5.4%) subyearling smolts (Table 6).

The temporal distribution of Chinook body size shows the fry emergence period and continual juvenile growth throughout the trapping season (Figure 3). Fry (<45 mm FL) began emerging from the gravel at least at the beginning of February (i.e., the beginning of trapping) and continued through mid-June. Fry were the most abundant life stage through the end of April. Some juveniles began to show signs of smoltification at the end of May, and all Chinook were classified as smolts after June 17.

The middle 50% of fry and subyearling smolt emigrants passed the trap between March 17 and April 2, and between May 27 and June 30, respectively (Figure 2). Fry and subyearling smolt mean FL ± 1 SD was 37.4 ± 2.3 mm (*n* = 1,411) and 82.6 ± 7.9 mm (*n* = 1,938), respectively. Overall mean FL ± 1 SD weighted by weekly abundance was 50.4 ± 3.9 (*n* = 3,349).

Table 6. Juvenile production estimates for Chinook salmon in the Coweeman River, WA, 2007-2013. Juvenile production is reported separately for two outmigrant life histories (fry, subyearling smolt SYS) observed each year. There are no estimates for 2009 because the screw trap did not operate.

			95% CI			Proportion of	25%-75% Emigration
Year	Life Stage	Estimate	Lower	Upper	CV (%)	Annual Emigrants	Date Range
2007	Fry	89,821	22,405	157,237	38.3	0.46	03/17-04/08
2007	SYS	104,545	89,641	119,449	7.3	0.54	06/10-06/28
2008	Fry	42,440	24,606	60,274	21.4	0.41	03/14-03/29
2008	SYS	60,467	52,956	67,978	6.3	0.59	06/30-07/15
2010	Fry	371,234	303,430	438,956	9.3	0.82	03/10-03/26
2010	SYS	79,170	67,759	90,581	7.4	0.18	06/23-07/16
2011	Fry	260,476	173,764	347,189	17.0	0.84	03/12-03/28
2011	SYS	48,469	37,968	58,970	11.1	0.16	07/03-07/16
2012	Fry	200,556	155,901	245,210	11.4	0.82	03/20-04/13
2012	SYS	44,452	40,207	48,697	4.9	0.18	06/27-07/23
2013	Fry	98,698	78,323	119,073	10.5	0.71	03/17-04/02
2013	SYS	39,574	35,396	43,753	5.4	0.29	05/27-06/30

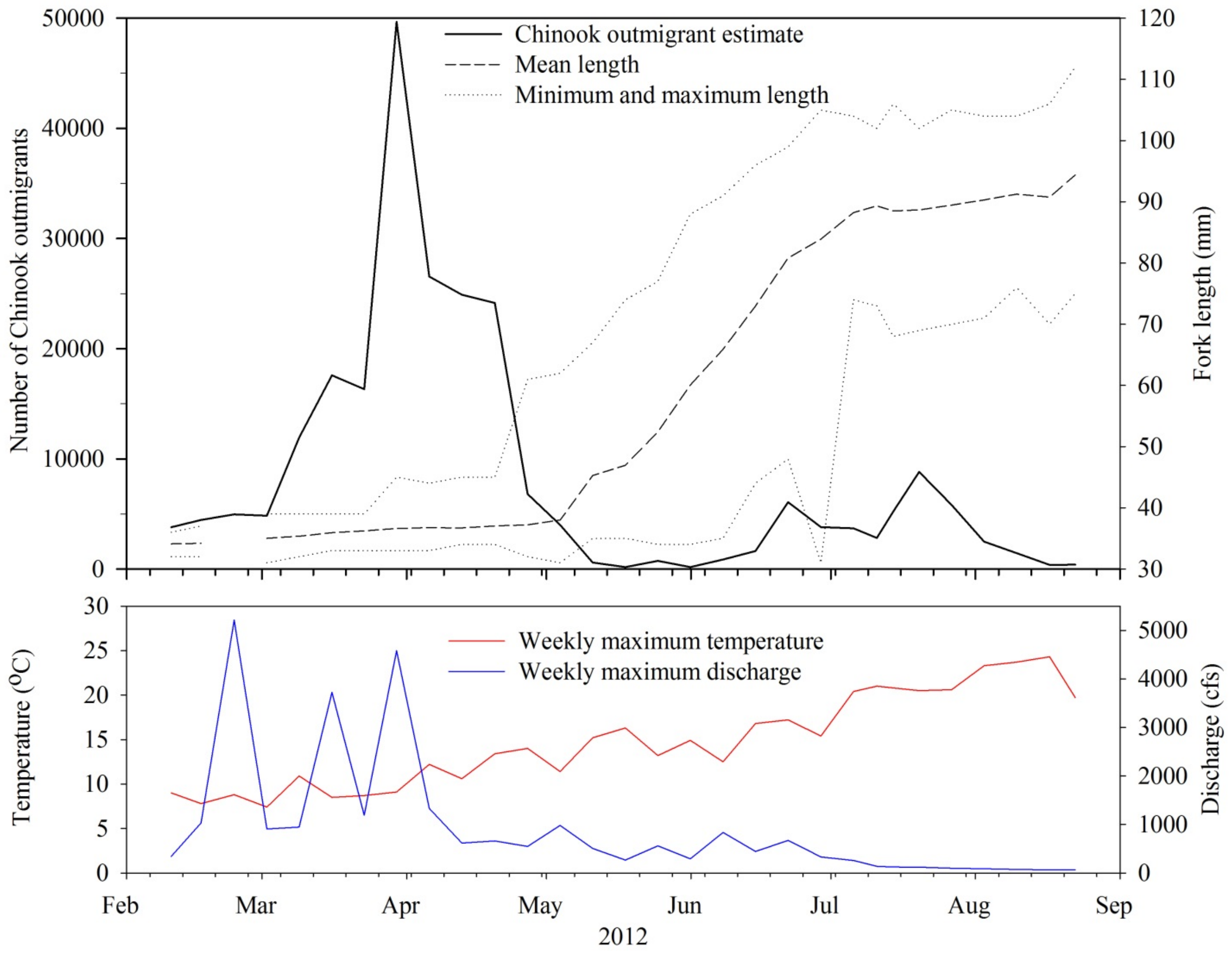

Figure 2. Juvenile Chinook outmigration timing, temporal size distribution, stream temperature, and discharge in the Coweeman River, **2012**. Data are summarized by week.

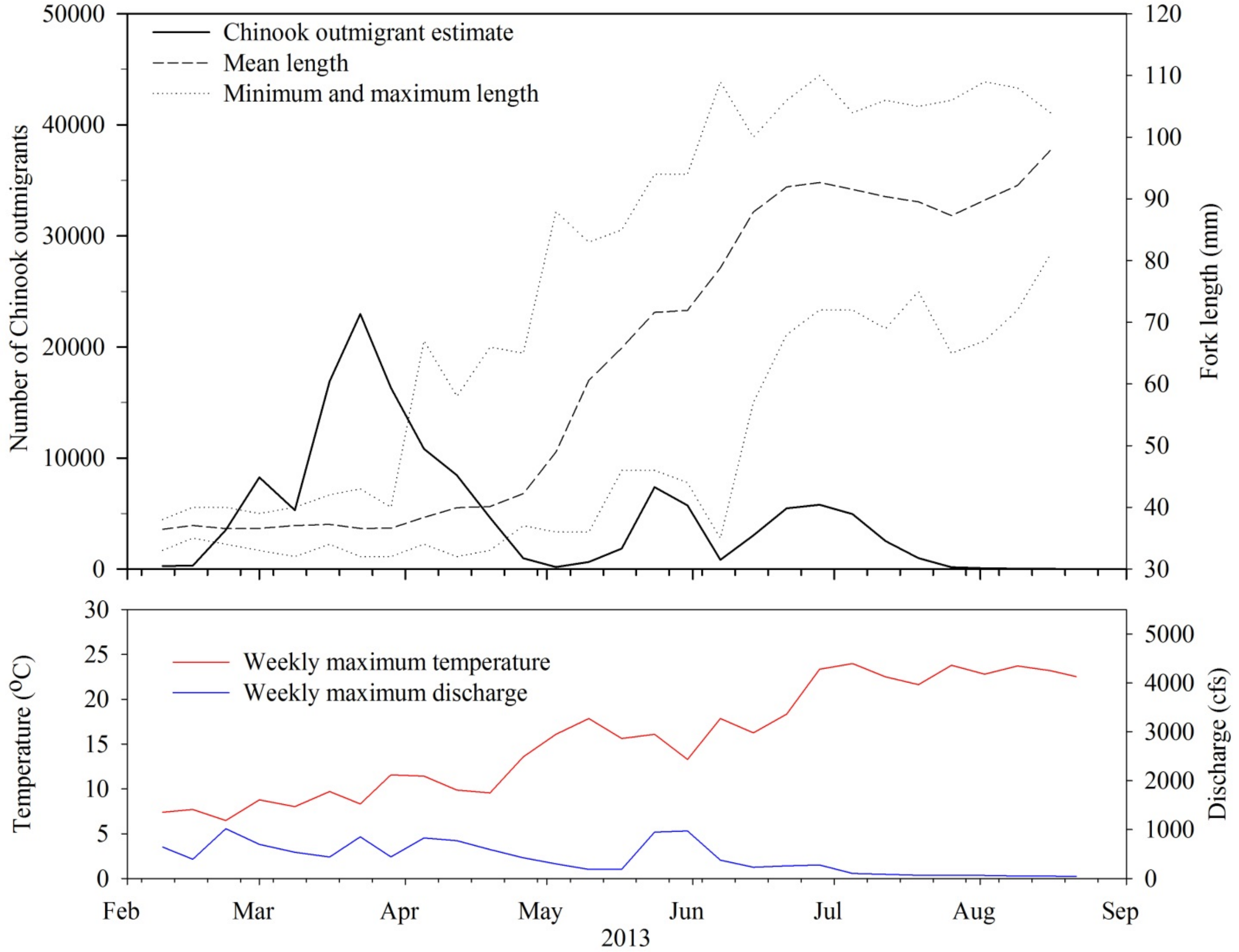

Figure 3. Juvenile Chinook outmigration timing, temporal size distribution, stream temperature, and discharge in the Coweeman River, **2013**. Data are summarized by week.

Coho

In 2012, we captured 1,693 coho migrants between March 28 and August 24, the first and last days this species was encountered in the trap. This total includes transitional and smolt life stages. No adipose clipped coho were captured, consistent with the absence of a hatchery program in this watershed.

We conducted 41 efficiency trials between April 18 and June 22 (10 weeks) when the majority of coho were emigrated and summed the trials by week. The number of marked fish used during each trial ranged from 1 – 75, and weekly marks ranged from 9 – 229 coho. In total, we marked 670 and subsequently recaptured 89 coho migrants. DARR pooled the 10 weeks into 4 strata with trap efficiencies ranging from 9.7% to 26.9%.

The 2012 production estimate ± 95% CI was 14,014 ± 3,790 (CV = 13.8%) with the middle 50% of emigrants passing the trap between May 21 and June 2 (Table 7). Coho size increased through the peak outmigration period and then precipitously decreased in July (Figure 4). By mid-July mean FL was ~ 80.0 mm. Overall mean FL ± 1 SD weighted by weekly abundance of coho transitionals and smolts in 2012 was 111.5 ± 8.0 mm (*n* = 858).

In 2013, we captured 1,967 coho (transitionals and smolts) between March 20 and June 17, 2013 during the typical migration period. Six hatchery coho were captured, evident by a missing adipose fin. These fish (fork length range; 107 – 126 mm) were caught on February 13, February 21, March 7, March 12, and March 25. Release location of these fish is unknown as hatchery coho are not released in the Coweeman basin. These fish were not included in the catch total or production estimate.

We conducted 49 efficiency trials between March 20 and June 17, 2013 and summed the trials by week (13 weeks). The number of marked fish used during each trial ranged from 1 – 125 and weekly marks ranged from 1 – 434 coho. In total, we marked 1,054 and subsequently recaptured 163 coho migrants. The recaptures include adjusted numbers for the weeks when coho were released at the Near Trap Release site (see Methods for explanation). DARR pooled this adjusted data set into 5 strata with trap efficiencies ranging from 6.9% to 20.7%.

The 2013 production estimate ± 95% CI for the typical outmigrant group was 13,354 ± 2,400 (CV = 9.2%) with the middle 50% of emigrants passing the trap between May 14 and May 23 (Table 7). Coho size continually increased prior to the peak emigration and then continually decreased through the end of the typical migration and into the late coho migration (Figure 5). Overall mean FL ± 1 SD weighted by weekly abundance of typical migrants (transitionals and smolts) in 2013 was 116.3 ± 8.6 mm (*n* = 1,097).

During the late coho migration, we captured 990 fish between June 18 and July 17, 2013 (5 weeks). We did not conduct efficiency trials with these migrants. Instead, we used Chinook mark-recapture data during this time period to estimate coho capture probabilities. We think this is a reasonable approach because Chinook and coho sizes were similar and the trap was fishing ~ 90% of the water column so any behavioral differences (e.g. migrating at different depths in the water column) most likely did not affect capture probabilities between the species. We pooled all data during this five week period to generate an estimate. Trap efficiency during this period was

45.2%. The abundance estimate ± 95% CI for the late coho migrants was 2,192 ± 261 (CV = 6.1%). The peak of the migration occurred on July 2, 2013. The weighted mean FL ± 1 SD for this group was 87.0 ± 1.7 (*n* = 261).

In addition to the ocean-bound coho migrants, 365 parr yearling, 801 parr subyearling, and 678 fry were captured throughout the trapping season and were not included in the outmigrant estimates.

Scale samples were collected from 120 and 415 coho transitionals and smolts in 2012 and 2013, respectively but have not yet been analyzed.

Natural-origin Steelhead

In 2012, we captured 1,750 natural-origin steelhead migrants between March 21 and June 9, the first and last days they were encountered in the trap. This total included transitional and smolt life stages. We conducted 34 efficiency trials between April 18 and June 8 when the majority of steelhead emigrated and summed the trials by week (8 weeks). The number of marked fish used during each trial ranged from 1 – 88, and weekly mark groups ranged from 15 – 283 fish. In total, we marked 946 and subsequently recaptured 144 steelhead emigrants. DARR pooled the 8 weeks into 6 strata with efficiencies ranging from 4.5% to 24.0%.

The 2012 production estimate ± 95% CI was 13,488 ± 4,458 (CV = 16.9 %) with the middle 50% of emigrants passing the trap between May 1 and May 16 (Table 7; Figure 4). Body size showed a decreasing trend throughout the emigration. Mean FL ± 1 SD weighted by weekly abundance for natural-origin steelhead transitionals and smolts was 166.3 ± 14.9 mm (*n* = 1,116).

In 2013, we captured 3,161 natural-origin steelhead migrants between March 20 and July 22, the first and last days they were encountered in the trap. This total included transitional and smolt life stages. We conducted 52 efficiency trials between March 23 and June 14, 2013 and summed the trials by week (13 weeks). The number of marked fish used during each trial ranged from 1 – 125 and the weekly mark groups ranged from 1 – 493 natural-origin steelhead. In total, we marked 2,064 and subsequently recaptured 393 migrants. The recaptures included adjusted numbers for the weeks when fish were released at the Near Trap Release site (see Methods for explanation). DARR pooled this adjusted data set into 6 strata with trap efficiencies ranging from 12.4 % to 24.7%.

The 2013 production estimate ± 95% CI was 17,924 ± 1,901 (CV = 5.4%) with the middle 50% of emigrants passing the trap between April 30 and May 12 (Table 7; Figure 5). Body size showed a decreasing trend throughout the emigration. Mean FL ± 1 SD weighted by weekly abundance for natural-origin steelhead transitionals and smolts was 172.6 ± 14.7 mm (*n* = 1,864).

Scale samples were collected from 101 and 625 steelhead transitionals and smolts in 2012 and 2013, respectively but have not been analyzed.

Hatchery-origin Steelhead

In February 2012, hatchery steelhead smolts were planted in an acclimation pond. The pond is on private property, ~ 1.0 km from the main-stem Coweeman River, and ~ 9 km upstream of the screw trap. We measured, weighed, and marked (MicroJect) 485 of these fish on April 19. The marks were administered to estimate the number of smolts leaving the pond using a two-trap design. Smolts were force-released on April 23. The Smith Root fish counter enumerated 9,483 fish leaving the pond.

In 2012, 874 hatchery steelhead were captured between April 22 and June 4, the first and last days they were encountered in the trap. Two fish were captured prior to the 2012 release. These fish either escaped the pond early or were hold-overs from the 2011 release. For the two-trap design, we recaptured 36 of the 485 marked fish. The estimate ± 95% CI of steelhead smolts leaving the pond was 11,492 ± 3,437 (CV = 15.3 %).

For the one-trap design, we conducted 22 efficiency trials between April 24 and June 1 and summed the trials by week (6 weeks). The number of marked fish for each trial ranged from 1 – 65, and weekly mark groups ranged from 3 – 230. In total, we marked 474 and subsequently recaptured 65 hatchery steelhead. DARR pooled the 6 weeks into 4 strata with efficiencies ranging from 9.4% to 34.5%.

Based on the one-trap design, the estimate ± 95% CI of hatchery- steelhead smolts passing the smolt trap was 7,738 ± 2,783 (CV = 18.3 %) with the middle 50% of emigrants passing the trap between April 25 and May 8 (Table 7; Figure 4). Body size showed a decreasing trend throughout the emigration. Mean FL ± 1 SD weighted by weekly abundance for hatchery steelhead was 179.8 ± 14.8 mm (*n* = 575).

The two-trap design estimated the number of fish leaving the acclimation pond (11,492 ± 3,437). The number enumerated by the fish counter (9,483) was within the 95% confidence interval of the two-trap estimate. This suggests the fish counter provided an accurate count of the number planted in the river. The one-trap design estimated the number of fish passing the smolt trap (7,738 ± 2,783). The number of hatchery steelhead passing the smolt trap was less than the number planted in the river (*Z* = 1.66, *p* = 0.05, one-tail test).

On January 15, 2013, hatchery steelhead smolts were again planted in the private acclimation pond. We measured, weighed, and marked (MicroJect) 500 of these fish on April 18. The marks were administered to estimate the number of smolts leaving the pond using a two-trap design. The smolts were force-released on April 20. The Smith Root counter enumerated 7,376 fish leaving the pond.

In 2013, 1,519 hatchery steelhead were captured between April 21 and July 17, the first and last days they were encountered in the trap. This total included transitional and smolt life stages. For the two-trap design, we recaptured 84 of the 500 marked fish. The estimate ± 95% CI of steelhead smolts leaving the pond was 8,958 ± 1,676 (CV = 9.5 %).

For the one-trap design, we conducted 20 efficiency trials between April 21 and June 11, 2013 and summed the trials by week (9 weeks). The number of marked fish used during each trial ranged from 1 – 164 and weekly mark groups ranged from 1 – 645 hatchery steelhead. In total, we marked 1,033 and subsequently recaptured 149 migrants. The recaptures include adjusted numbers for the weeks when fish were released at the Near Trap Release site (see Methods for explanation). DARR pooled this adjusted data set into 3 strata with trap efficiencies ranging from 13.9 % to 16.7%.

For the one-trap design, the estimate ± 95% CI of hatchery steelhead smolt spassing the smolt trap was 10,510 ± 1,562 (CV = 7.6 %) with the middle 50% of emigrants passing the trap between April 24 and April 30 (Table 7; Figure 5). Body size showed a decreasing trend throughout the emigration. Mean FL ± 1 SD weighted by weekly abundance of hatchery-origin steelhead was 207.8 ± 14.3 mm (*n* = 1,183).

The two-trap design estimated the number of fish leaving the acclimation pond (8,958 ± 1,676). The number enumerated by the fish counter (7,376) was within the 95% confidence interval of the two-trap estimate. This suggests the fish counter provided an accurate count of the number planted in the river. The one-trap design estimated the number of fish passing the smolt trap (10,510 ± 1,562). The number of hatchery steelhead passing the smolt trap was not different than the number planted in the river ($Z = 1.33$, $p = 0.09$, one-tail test).

Coastal Cutthroat

In 2012, we captured 470 cutthroat migrants between March 27 and July 1, the first and last days this species was encountered in the trap. This total included transitional and smolt life stages.

We conducted 36 efficiency trials between April 18 and June 21 when the majority of cutthroat emigrated and summed the trials by week (9 weeks). The number of marked fish used during each trial ranged from 1 – 21, and weekly mark groups ranged from 8 – 59 fish. In total, we marked 217 and subsequently recaptured 38 cutthroat emigrants. DARR pooled the 9 weeks into 3 strata with efficiencies ranging from 15.3 % to 20.6%.

The 2012 production estimate ± 95% CI was 2,658 ± 774 (CV = 14.9 %) with the middle 50% of emigrants passing the trap between May 7 and May 26 (Table 7; Figure 4). Body size showed a decreasing trend throughout the emigration. Mean FL ± 1 SD weighted by weekly abundance of cutthroat transitionals and smolts was 177.1 ± 18.5 mm ($n = 410$).

In 2013, we captured 501 cutthroat between February 19 and July 5, the first and last days this species was encountered in the trap. This total included transitional and smolt life stages. Three hatchery cutthroat were captured, evident by a missing adipose fin. These fish were captured on May 7 (FL; 233 mm), May 15 (FL; 220 mm), and May 17 (FL; 230 mm). The only known release location of hatchery cutthroat in the Lower Columbia is the Cowlitz River. Hatchery cutthroat were not included in the catch total or production estimate.

We conducted 51 efficiency trials between March 20 and June 17 and summed the trials by week (14 weeks). The number of fish marked during each trial ranged from 1 – 51, and weekly mark groups ranged from 1 – 109. In total, we marked 353 and subsequently recaptured

67 cutthroat. The recaptures include adjusted counts during periods when trap efficiencies were unreliable (see Methods for explanation). These periods were March 20 – April 29 (Near Trap Releases; 6 weeks) and May 28 – June 17 (extremely low efficiencies; 3 weeks). Each of these periods were pooled into one stratum *a priori* The adjusted data set had six rows (one row for March 20 – April 29, four rows for April 30 – May 27, and one row for May 28 – June 17) and DARR did not pool any of the data. The efficiency of the six strata ranged from 13.7% to 33.3%.

The 2013 cutthroat production estimate ± 95% CI was 2,841 ± 799 (CV = 14.4 %) with the middle 50% of emigrants passing the trap between May 10 and May 23 (Table 7; Figure 5). Body size showed a decreasing trend throughout the emigration. Mean FL ± 1 SD weighted by weekly abundance of cutthroat transitionals and smolts was 179.3 ± 17.5 mm (*n* = 467).

Scale samples were collected from 113 and 131 cutthroat transitionals and smolts in 2012 and 2013, respectively but have not been analyzed.

Table 7. Smolt production estimates, migration timing, and body size for coho salmon, natural and hatchery-origin steelhead, and coastal cutthroat trout in the Coweeman River, WA, 2007-2013. There are no estimates for 2009 because the screw trap did not operate. Migration timing is described as the range of dates that the middle 50% of smolts passed the juvenile trap. Body size is described as the mean and standard deviation (SD) for the number of smolts measures (*n*).

Coho								
		95% CI			25%-75% Emigration	Length (mm)		
Year	Estimate	Lower	Upper	CV (%)	Date Range	Mean	SD	*n*
2007	10,121	7,448	12,794	13.5	NA	123.8	10.4	563
2008	13,393	10,772	16,014	10.0	05/22-06/04	122.6	8.8	397
2010	22,924	14,098	31,750	19.6	05/19-05/27	111.7	19.7	818
2011	14,879	11,213	18,545	12.6	05/28-06/11	119.1	8.4	1,388
2012	14,014	10,224	17,804	13.8	05/21-06/02	111.5	8.0	858
2013	13,354	10,954	15,754	9.2	05/14-05/23	116.3	8.6	1,097

Natural-origin Steelhead								
		95% CI			25%-75% Emigration	Length (mm)		
Year	Estimate	Lower	Upper	CV (%)	Date Range	Mean	SD	*n*
2007	13,757	11,313	16,201	9.1	NA	177.0	19.8	1,102
2008	13,260	7,323	19,197	22.8	05/07-05/25	171.7	27.8	721
2010	37,909	28,899	46,919	12.1	04/29-05/19	177.6	16.9	516
2011	29,127	12,843	45,412	28.5	05/10-05/23	170.2	14.4	999
2012	13,488	9,030	17,945	16.9	05/01-05/16	166.3	14.9	1,116
2013	17,924	16,023	19,825	5.4	04/30-05/12	172.6	14.7	1,864

Hatchery-origin Steelhead								
		95% CI			25%-75% Emigration	Length (mm)		
Year	Estimate	Lower	Upper	CV (%)	Date Range	Mean	SD	*n*
2007	19,578	10,172	28,984	24.5	NA	178.1	13.9	663
2008	2,846	2,005	3,687	15.1	04/16-05/19	183.6	15.0	275
2010	4,407	3,327	5,487	12.5	04/29-05/14	200.5	15.2	268
2011	7,235	2,578	11,891	32.8	05/05-05/12	193.8	19.4	228
2012	7,738	4,955	10,521	18.3	04/25-05/08	179.8	14.8	575
2013	10,510	8,947	12,072	7.6	04/24-04/30	207.8	14.3	1,183

Coastal Cutthroat								
		95% CI			25%-75% Emigration	Length (mm)		
Year	Estimate	Lower	Upper	CV (%)	Date Range	Mean	SD	*n*
2007	2,841	1,389	4,293	26.1	NA	186.4	24.7	172
2008	1,628	875	2,381	23.6	05/22-06/10	190.1	30.8	168
2010	5,552	3,649	7,455	17.5	04/29-05/25	179.4	24.5	265
2011	2,033	692	3,374	33.7	05/23-06/11	179.0	16.8	209
2012	2,658	1,884	3,432	14.9	05/07-05/26	177.1	18.5	410
2013	2,841	2,042	3,640	14.4	05/10-05/23	179.3	17.5	467

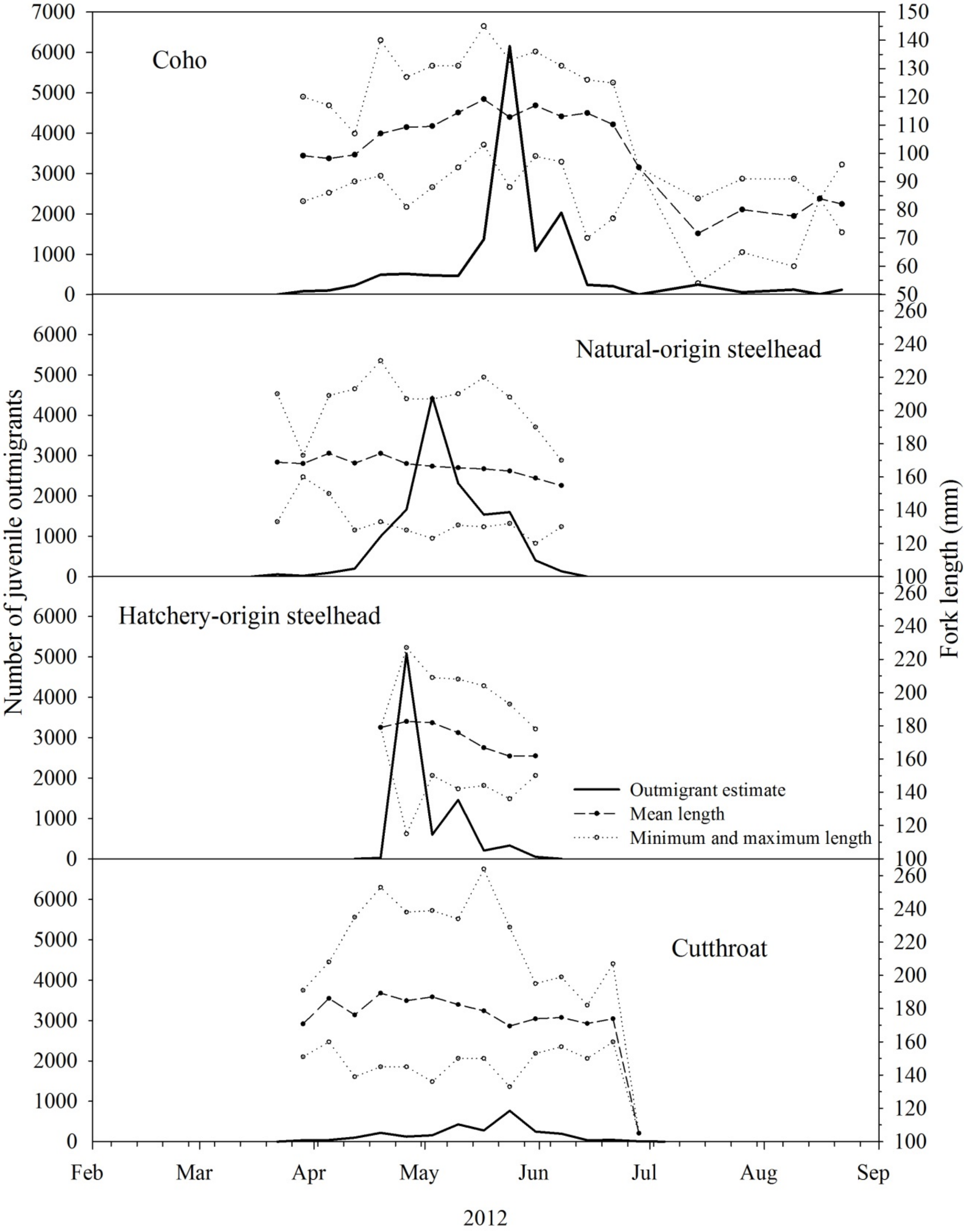

Figure 4. Migration timing and length of coho, steelhead, and cutthroat in the Coweeman River, WA, **2012**. Data are summarized by week.

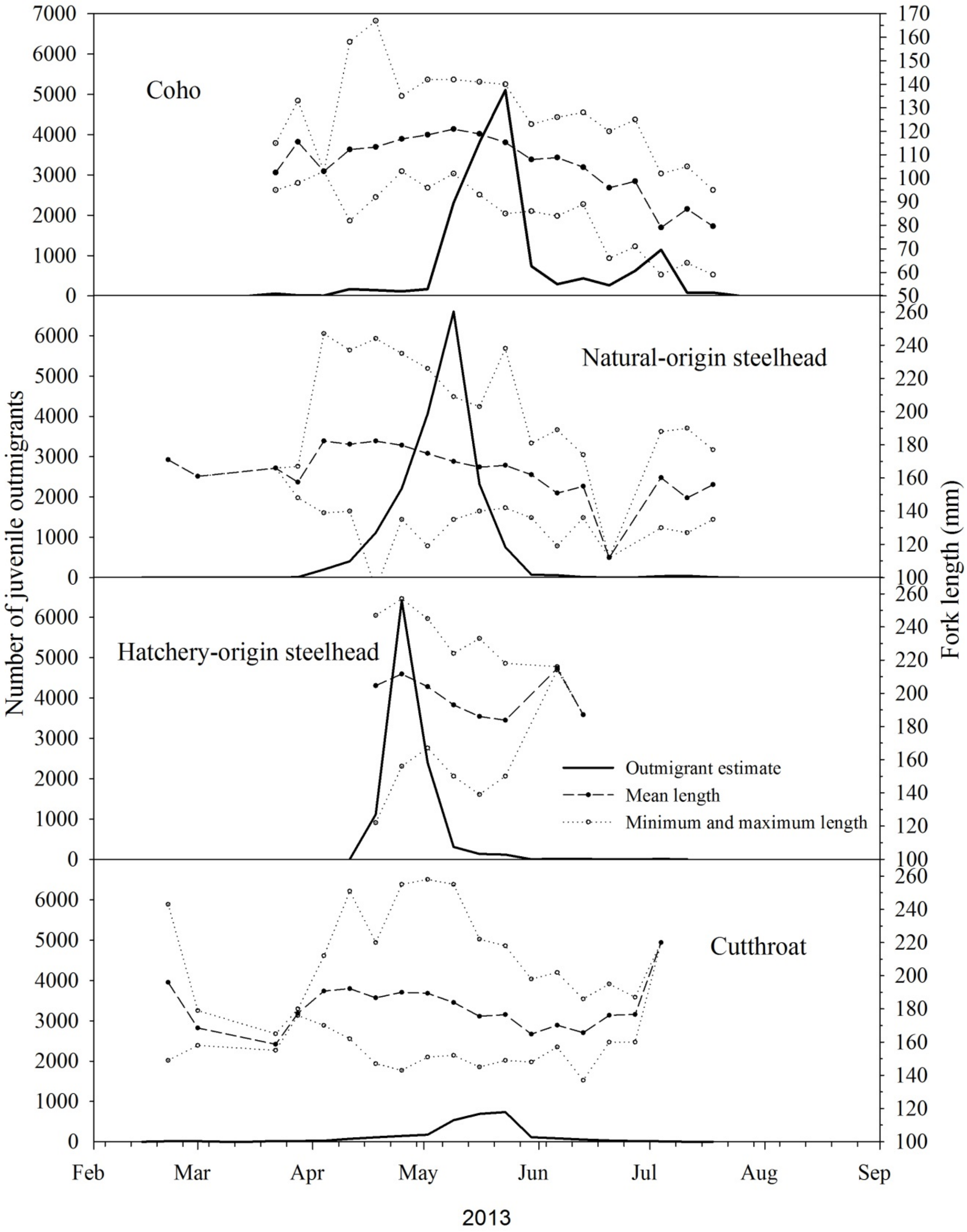

Figure 5. Migration timing and length of coho, steelhead, and cutthroat in the Coweeman River, WA, **2013**. Data are summarized by week.

Mark-Recapture Assumption Testing

Fry Mark Retention and Mark Loss

Mark retention ranged from one to at least 9 days for all concentrations and exposure times (Table 8). No mortalities were observed. The best concentration and exposure time for mark retention was 23.2 mg/L and 60 minutes. Fish marked with this protocol maintained an easily recognizable mark after 4 days and retained the mark for at least 8 days (the fish were released before the mark faded). A higher concentration (33.8 mg/L) and shorter exposure time (30 minutes) yielded retention of at least 9 days (the fish were released before the mark faded). This concentration was not selected as the best because the mark needed for mark-recapture objectives was met with a lower concentration.

Table 8. Mark retention and mortality of Chinook (<45 mm FL) marked with Bismarck brown at various concentrations and exposure times.

Trial	Mark Date	Concentration (mg/L)	Exposure (min)	Mark Retention (days)	Mortalities (%)
1	2/07/2013	15.8	45	3	0.0
2	2/12/2013	23.2	60	at least 8	0.0
3	2/26/2013	27.5	20	1	0.0
4	2/28/2013	33.8	20	4	0.0
5	3/13/2013	33.8	30	at least 9	0.0

Capture Probabilities Among Mark Types

Four trials were conducted to compare capture probabilities of Bismarck brown versus caudal clip marks using Chinook subyearling smolts between July 9 and July 26, 2013. One trial was removed from the analysis because fish condition upon release was suspect. A *G*-test was used to test for differences in ratios of seen:unseen fish between trials within groups. All tests were insignificant (*p* range: 0.15 – 0.92) so counts for each mark type across all trials were pooled in order to increase statistical power for the comparison. There were 79 marks in each group (mean FL; 89.4 mm) and capture efficiencies were 0.69 (CC), 0.39 (BB), and 0.29 (CC&BB) (Figure 6.). Capture efficiencies were significantly different among groups (G = 19.8, df = 2, $p < 0.001$). Paired comparisons showed CC recapture probabilities were higher than both BB (G = 9.1, df = 1, $p = 0.002$) and CC&BB (G = 18.1, df = 1, $p < 0.001$), and there was no difference between BB and CC&BB (G = 1.8, X^2 df = 1, $p = 0.181$).

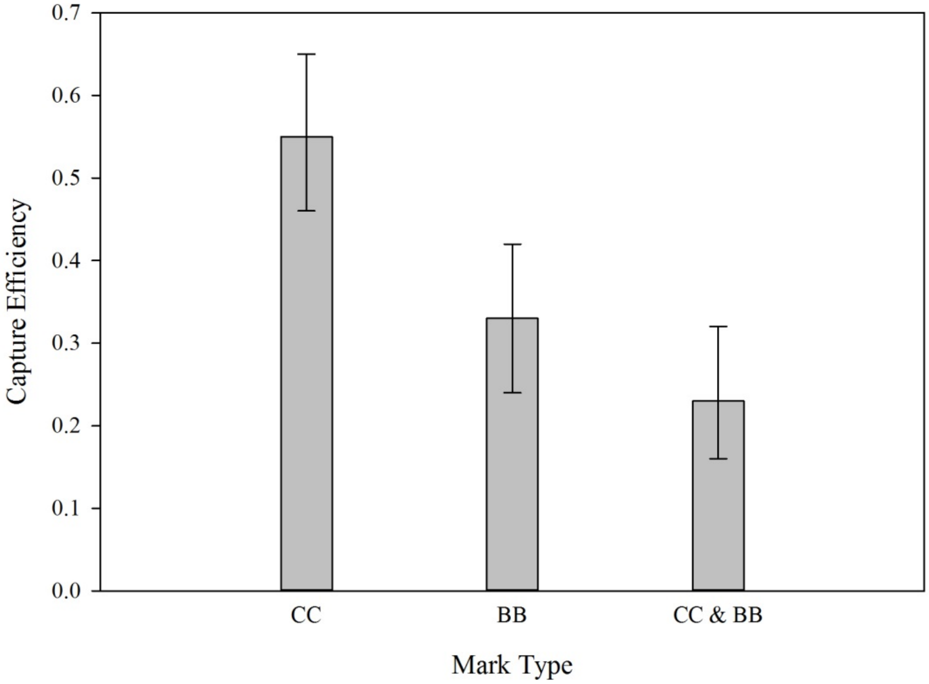

Figure 6. Capture efficiencies of mark types applied to Chinook subyearling smolts in the Coweeman River during 2013. CC is partial caudal clip and BB is Bismarck brown dye. Error bars are 95% confidence intervals.

<u>Size-Biased Capture Rates</u>

Evidence for size-biased capture rates depended on the temporal extent of the data set and/or species. For cutthroat and hatchery-origin steelhead, size-biased capture rates did not occur (cutthroat, D = 0.10, $p = 0.75$; hatchery-origin steelhead, D = 0.09, $p = 0.87$). Similarly, size selectivity of coho did not occur whether the data set included all marks and recaptures (D = 0.04, $p = 0.97$), or was partitioned by stratum during peak emigration (Stratum 2, D = 0.32, $p = 0.31$; Stratum 3, D = 0.09, $p = 0.70$; Stratum 4, D = 0.09, $p = 0.92$). In contrast, Chinook (> 45 mm FL) and natural-origin steelhead captures were size-biased if all marks and recaptures were included in the data set (Chinook, D = 0.21, $p < 0.001$; natural-origin steelhead, D = 0.11, $p = 0.009$). For Chinook, larger fish were captured at a higher rate than smaller fish (mean FL_{marks} = 77.1 mm; mean $FL_{recaptures}$ = 82.0 mm), and for steelhead, smaller fish were captured at a higher rate than larger fish (mean FL_{marks} = 170.5 mm; mean $FL_{recaptures}$ = 167.5). However, size selectivity was not evident when stratum-specific data were tested (Chinook: Stratum 6, D = 0.21, $p = 0.14$; Stratum 7, D = 0.08, $p = 0.96$; Stratum 8, D = 0.26, $p = 0.18$; Stratum 9, D = 0.09, *p* = 0.87; Stratum 10, D = 0.21, *p* = 0.20; natural-origin steelhead: Stratum 2, D = 0.15, *p* = 0.14; Stratum 3, D = 0.17, *p* = 0.11; Stratum 4, D = 0.11, *p* = 0.38).

Coded-Wire Tagging and Strontium Marking of Juvenile Chinook

In 2012, coded-wire tags were inserted into 11,168 Chinook subyearling smolts (Table 9). This represents approximately 25% of the estimated outmigration for this life stage. Fish were coded-wire tagged on 55 days between June 12 and August 23 with daily mark counts ranging from 12 to 637 (median; 149). Mean length ± SD of coded-wire fish was 88.0 ± 7.4 (*n* = 1,009).

A Sr mark was applied to the otoliths of 5,233 juvenile Chinook in 2012 (Table 10). Of this total, 3,597 were fry and 1,636 were subyearling smolts. This represents approximately 1.8% (fry) and 3.7% (subyearling smolts) of the estimated outmigration for each life stage. Fry were marked on 14 days between March 12 and April 18 and subyearling smolts were marked on 13 days between June 17 and July 6. The number of fry and subyearling smolts marked each day ranged from 73 to 686 (median; 227.5) and 53 to 236 (median; 133), respectively. We ceased marking fish after the first week of July due to increased stream temperature.

A small proportion of Sr-marked fish were length measured. To obtain a more precise representation of the size of Sr-marked fish, lengths from all fish measured during the Sr-marking time period were combined to calculate summary statistics. Mean length ± SD for fry and subyearling smolts was 36.4 ± 1.7 (*n* = 501) and 82.3 ± 10.2 (*n* = 435), respectively.

In 2013, coded-wire tags were inserted into 4,929 Chinook subyearling smolts between June 11 and July 22 (Table 9). This represents approximately 12.5% of the estimated outmigration for this life stage. The sample size for length summary statistics was the number of fish that were measured and coded-wire tagged.

A Sr mark was applied to the otoliths of 6,753 juvenile Chinook in 2013 (Table 10). Of this total, 2,332 were fry, 26 were subyearling parr, 1,091 were subyearling transitionals, and 3,304 were subyearling smolts. Fry and subyearling parr were marked on 18 days between March 22 and April 22 and the total number marked each day ranged from 6 to 406 (median; 111). Transitionals and subyearling smolts were marked on 28 days between June 2 and July 23 and the total number marked each day ranged from 23 to 601 (median; 130). The fry and parr represent 2.4% of the estimated fry outmigration and the transitionals and smolts represent 11.1% of the estimated subyearling smolt outmigration.

A small proportion of Sr-marked fish were length measured. To obtain a more precise representation of the size of Sr-marked fish, lengths from all fish measured during the Sr-marking time period were summarized. Mean length ± SD for fry (and parr) and subyearling smolts (and transitionals) was 37.4 ± 2.1 (*n* = 710) and 88.4 ± 9.2 (*n* = 1,291), respectively.

Beach seining near the trap site occurred on two days in April in an attempt to increase Sr-marked fry. During those efforts, 325 fry and 9 parr were captured and Sr-marked. These fish were included in the total number marked.

Table 9. The number of tule fall Chinook subyearlings smolts coded wire tagged by year in the Coweeman River, WA, 2007-2013. Subyearling smolts were not tagged in 2009 because the smolt trap did not operate. In 2007 – 2010, recorded lengths typically were not associated with individual tag codes. For these years, length data were summarized for all fish measured during the CWT marking time period (typically June through the end of the trapping season). ND = no data, SD = standard deviation, and *n* = sample size.

2007

			Proportion of	Length (mm)		
Tag Code	Size Range (mm)	Number	Production Estimate	Mean	SD	*n*
634075	55 - 65	1,198	0.011	ND	ND	ND
634076	66 - 75	5,006	0.048	ND	ND	ND
634077	76 - 105	5,029	0.048	ND	ND	ND
634079	76 - 105	5,405	0.052	ND	ND	ND
634089	76 - 105	1,544	0.015	ND	ND	ND
634078	55 - 105	4,710	0.045	ND	ND	ND
		22,892	***0.219***	***82.2***	***7.7***	***655***

2008

			Proportion of	Length (mm)		
Tag Code	Size Range (mm)	Number	Production Estimate	Mean	SD	*n*
634676	55 - 65	318	0.005	ND	ND	ND
634677	66 - 75	2,614	0.043	ND	ND	ND
633493	76 - 117	18,534	0.307	ND	ND	ND
634678	70 - 113	1,289	0.021	ND	ND	ND
		22,755	***0.376***	***86.4***	***12.5***	***848***

Table 9, continued.

2010

Tag Code	Size Range (mm)	Number	Proportion of Production Estimate	Length (mm)		
				Mean	SD	*n*
635071	NA	31	0.000	ND	ND	ND
635072	NA	1,398	0.018	ND	ND	ND
635073	NA	7,139	0.090	85.4	7.7	41
635074	NA	1,788	0.023	98.1	2.4	13
634679[a]	NA	3,122	0.039	86.7	4.2	35
		13,478	***0.170***	***87.9***	***6.9***	***1,273***

2011

Tag Code	Size Range (mm)	Number	Proportion of Production Estimate	Length (mm)		
				Mean	SD	*n*
636087	65 - 75	428	0.009	71.3	3.4	42
636088	76 - 85	1,461	0.030	82.2	2.8	192
636089	86 - 95	3,946	0.082	91.0	2.7	256
635075	86 - 95	1,588	0.033	90.9	2.5	230
636090	96 - 112	2,584	0.053	99.9	3.5	215
		10,007	***0.207***	***90.3***	***7.7***	***935***

2012

Tag Code	Size Range (mm)	Number	Proportion of Production Estimate	Length (mm)		
				Mean	SD	*n*
636435	65 - 75	512	0.012	71.0	3.5	69
636436	76 - 85	2,923	0.066	82.2	2.6	273
636437	86 - 95	5,122	0.115	89.8	2.9	348
636438	96 - 104	1,472	0.033	97.9	2.2	153
636439	86 - 95	1,139	0.026	91.3	3.2	166
		11,168	***0.251***	***88.0***	***7.4***	***1,009***

2013

Tag Code	Size Range (mm)	Number	Proportion of Production Estimate	Length (mm)		
				Mean	SD	*n*
636450	65-106	4,929	0.125	90.9	6.3	602
		4,929	***0.125***	***90.9***	***6.3***	***602***

[a] Previously reported as 635079.

Table 10. The number of juvenile Chinook salmon marked with strontium, the proportion of the annual life stage-specific estimate marked with strontium, and length summary statistics by life stage in the Coweeman River, WA, 2007-2013. Salmon were not marked with strontium in 2009 because the screw trap did not operate.

Fry					
		Proportion of	Length		
Year	Number	Production Estimate	Mean	SD	*n*
2007	2,193	0.024	38.7	4.5	567
2008	1,109	0.026	38.1	3.1	356
2010	21,749	0.059	37.5	3.4	1,572
2011	3,954	0.017	37.1	2.1	1,216
2012	3,597	0.018	36.4	1.7	501
2013	2,332	0.024	37.4	2.1	710

Parr-Subyearling Smolt					
		Proportion of	Length		
Year	Number	Production Estimate	Mean	SD	*n*
2007	18,182	0.174	82.3	8.3	663
2008	20,386	0.337	84.4	14.7	900
2010	174	0.002	62.6	8.1	128
2011	4,305	0.089	90.6	7.4	520
2012	1,636	0.037	82.3	10.2	435
2013	4,421	0.111	88.4	9.2	1,291

Table 11. The number and proportion (in parentheses) of marked and unmarked subyearling tule fall Chinook outmigrants during migration years (MY) 2007 – 2013. Mark type includes coded-wire tags (CWT) and/or strontium (Sr). Unmarked fish and all proportions are based on the annual production estimates.

MY	CWT Only	Sr Only	CWT and Sr	Unmarked	Production Estimate
2007	4,710 (0.02)	2,193 (0.01)	18,182 (0.09)	169,281 (0.87)	194,366
2008	2,369 (0.02)	1,109 (0.01)	20,386 (0.20)	79,043 (0.77)	102,907
2010	13,478 (0.03)	21,923 (0.05)	0 (0.00)	414,962 (0.92)	450,363
2011	5,702 (0.02)	3,954 (0.01)	4,305 (0.02)	271,951 (0.95)	285,912
2012	9,707 (0.04)	3,881 (0.02)	1,352 (0.01)	230,068 (0.94)	245,008
2013	747 (0.01)	2,571 (0.02)	4,182 (0.03)	130,772 (0.95)	138,272

Thermal Rearing Habitat

The temperature data loggers with the longest time series in the main-stem Coweeman River (4 temperature sites) showed seasonal patterns of thermal heterogeneity (Figure 7). From early fall to mid-spring, mean daily temperature was similar among the loggers positioned between Rkm 10.8 and 40.4. Temperature difference among sites during this period was typically less than 1 ^{o}C. Beginning in late spring-early summer, thermal heterogeneity increased with cooler temperatures higher in the basin, warmer temperatures lower in the basin, and maximum differences in daily temperature ranged between 3.5 ^{o}C and 5.5 ^{o}C

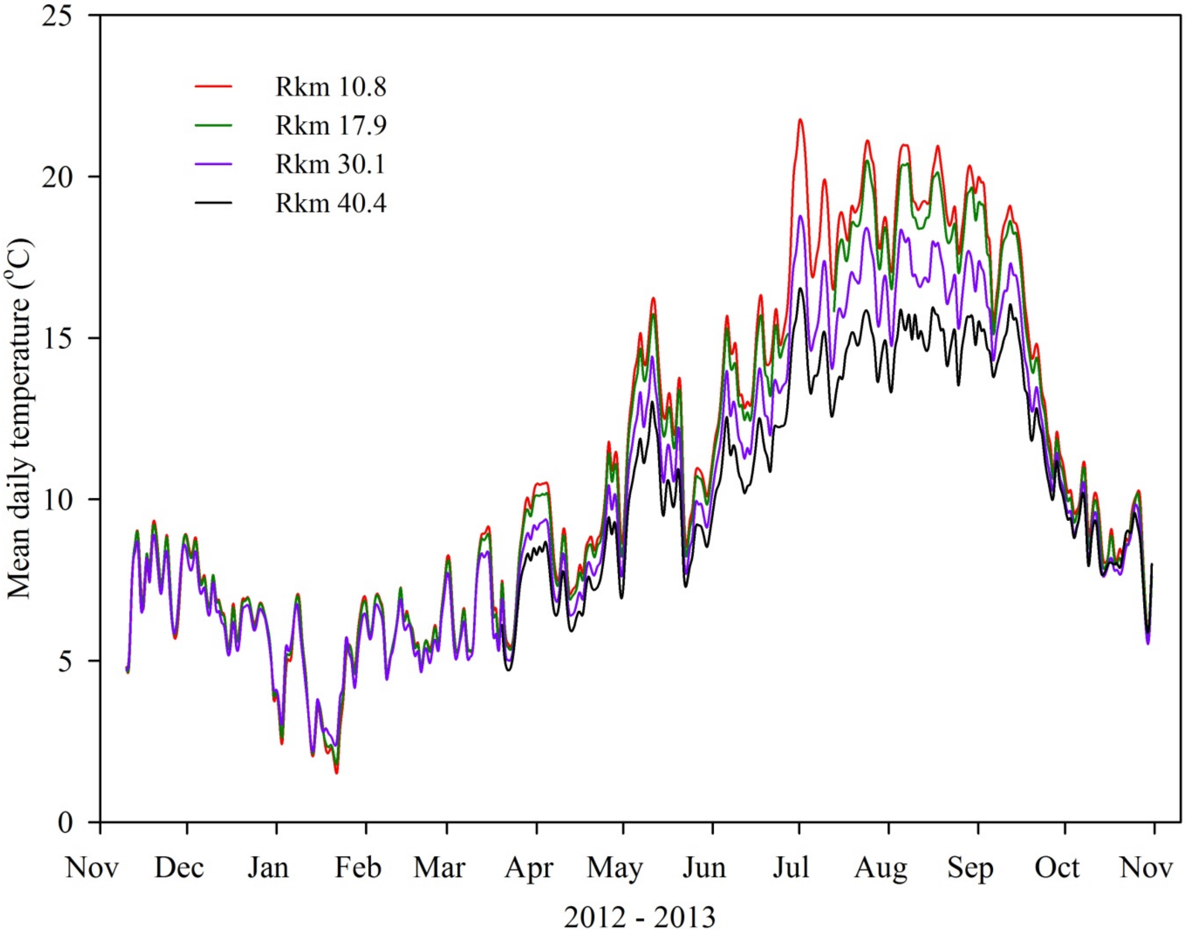

Figure 7. Mean daily temperature at four locations in the Coweeman River, WA between November 2012 and October 2013. Note: the rkm 40.4 site was deployed March 20, 2013 and the rkm 17.9 site was non-operational from June 28 to July 12, 2013.

Annual maximum temperatures in the Coweeman basin recorded at the 16 sites with temperature loggers ranged from 16.6 °C to 24.0 °C in 2013 (Figure 8). The date of maximum temperatures typically occurred between July 23 and July 26. Nearly all the variation in maximum annual stream temperature along the length of the main-stem Coweeman River was explained by elevation ($r^2 = 0.94$, $p < 0.001$; Figure 9). The greatest rates of temperature change (^{o}C/rkm) occurred between rkms 44.0 – 35.7 and 25.0 – 17.9.

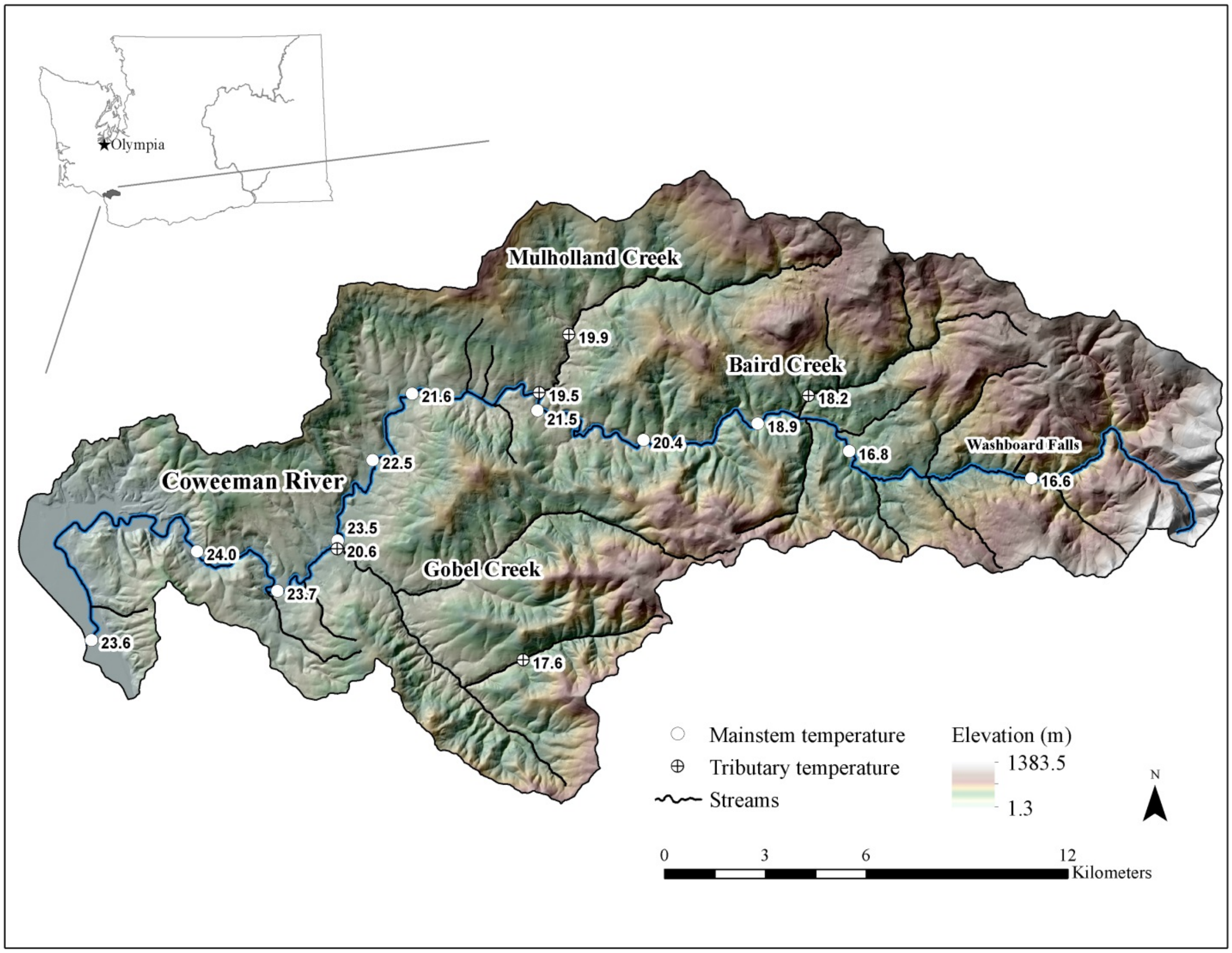

Figure 8. Map of the Coweeman River basin, WA showing maximum instantaneous stream temperatures in 2013.

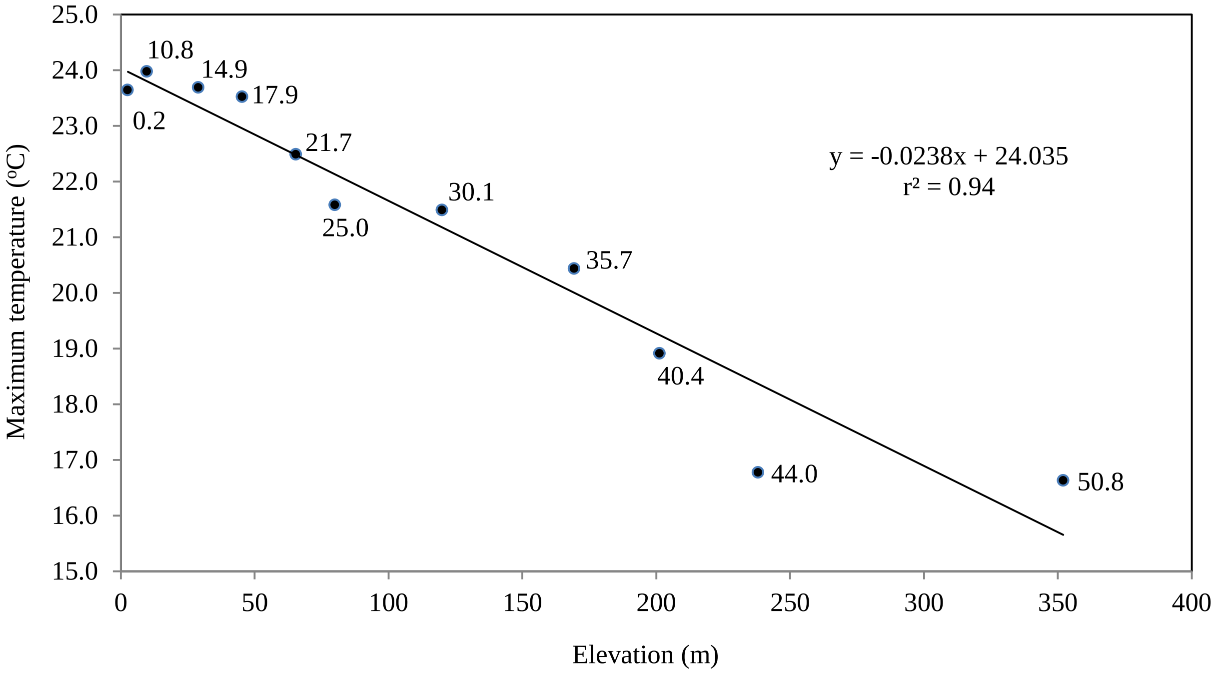

Figure 9. Maximum stream temperature as a function of elevation of the mainstem temperature loggers operated in the Coweeman River, WA, 2013. Data labels are river kilometers.

Effects of Strontium Chloride and Duration of Exposure on Otolith Marking

Otolith Sr:Ca was quantified for five treatment groups; 2,000 ppm $SrCl_2 \cdot 6H_2O$ for 2, 3, and 6 hours, as well as 3,000 ppm $SrCl_2 \cdot 6H_2O$ for 2, and 3 hours (Table 12). As expected there was a significant positive effect of concentration and duration of exposure on otolith Sr:Ca (ANOVA, $p < 0.01$), but no interaction between concentration (2,000 ppm and 3,000 ppm) and exposure time (ANOVA, $p = 0.84$). The lack of an interaction is explicable given the limited range of concentrations (2,000 and 3,000 ppm) and durations (2, 3, 6 hours) used in this study. In all treatments mean otolith Sr:Ca was at least twice as high as marine levels of otolith Sr:Ca observed in returning adult Coweeman River Chinook salmon (Figure 10). However, otolith Sr:Ca varied between all treatments significantly except 2,000 ppm for 3 hours, and 3,000 ppm for 2 hours. Similarly peak otolith Sr:Ca did not differ between 2,000 ppm for 6 hours and 3,000 ppm for 3 hours. Current field protocol concentration and exposure (2,000 ppm for 6 hours) resulted in mean otolith Sr:Ca of 7.94 (1.41 SE) mmol mol^{-1}. Our results suggest that immersing fish in 3,000 ppm SrCl for half the duration of current marking protocols results in a mean otolith Sr:Ca of 8.08 (2.17 SE) mmol mol^{-1}. The increased concentration with reduced treatment duration may therefore be suitable for field studies. However, a tradeoff may exist between decreasing the time it takes to mark the otoliths and the accuracy in detecting marks. For example, the 3000 ppm and 3 hour treatment (Treatment 5, SE = 2.17) had higher variation in otolith Sr:Ca among samples then the standard treatment (Treatment 1, SE = 1.41, Table 12) which may increase the likelihood of confusing marine Sr:Ca values with those indicating a Sr mark.

Table 12. Results of Sr marking experiment. Pre Sr:Ca refers to the mean (SE) molar ratio of Sr to Ca observed in otoliths prior to Sr treatment. Peak Sr:Ca refers to the mean (SE) otolith molar ratio of strontium (Sr) to calcium (Ca) observed at peak inflection. *n* represents the number of otoliths processed per treatment.

Treatment	SrCl (ppm)	Duration (hrs)	*n*	Pre Sr:Ca (mmol mol^{-1})	Peak Sr:Ca (mmol mol^{-1})
1-Standard	2000	6	27	0.92 (0.07)	7.94 (1.41)
2	2000	2	35	0.92 (0.08)	4.87 (1.59)
3	2000	3	26	0.97 (0.10)	6.50 (1.60)
4	3000	2	23	0.98 (0.09)	6.32 (1.29)
5	3000	3	27	0.90 (0.08)	8.08 (2.17)

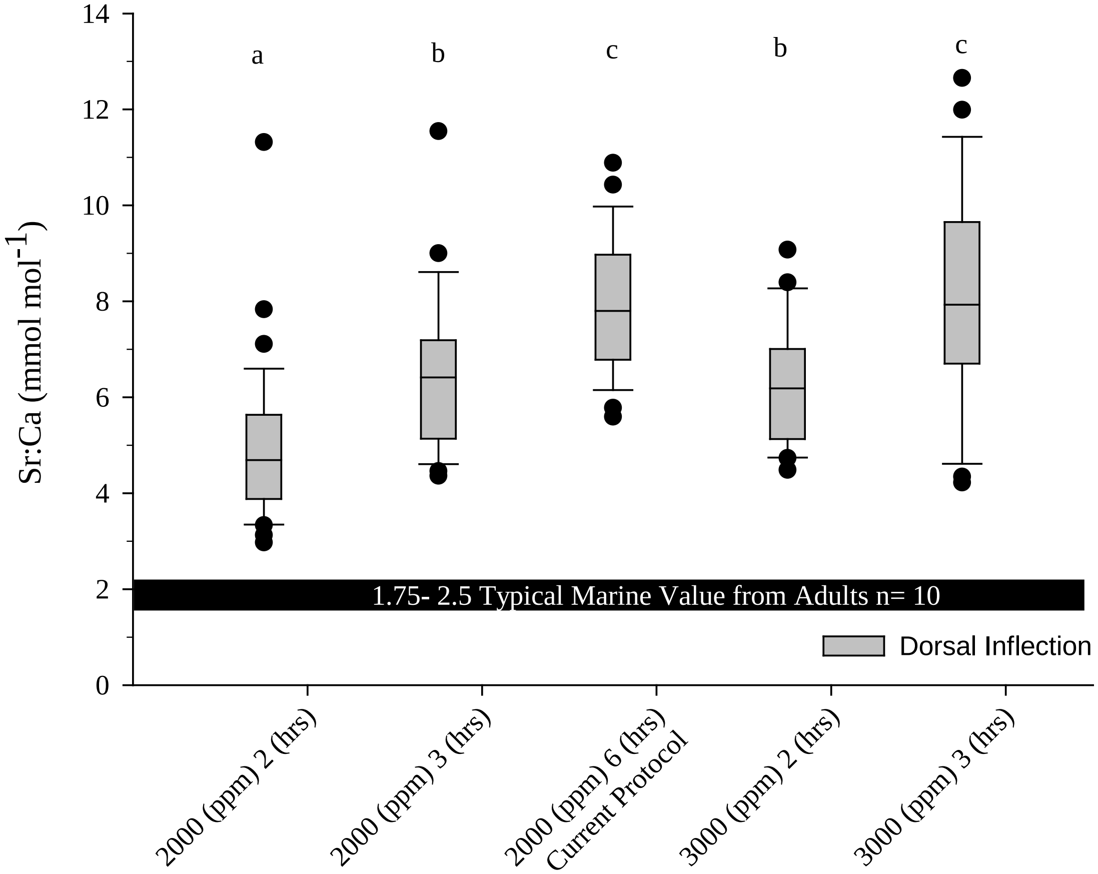

Figure 10. Box plots depicting molar ratio of strontium (Sr) to calcium (Ca) observed in otoliths of Chinook salmon marked with $SrCl_2 \cdot 6H_2O$ with regard to duration and concentration of treatments. Horizontal line represents the median, box dimensions show 25th to 75th percentile ranges, whiskers indicate 5th – 95th percentile ranges. Black dots represent outliers. Unlike letters indicate significant differences, $p<0.05$. See table 12 for sample sizes (*n*). Also shown is the typical range of otolith Sr:Ca after marine entry observed in adult Chinook salmon returning to the Coweeman River.

Discussion

Mark-Recapture Assumption Testing

A mark-recapture approach was used to estimate juvenile abundance. There are six basic assumptions that must be met to ensure that mark-recapture data provide an unbiased estimate (Seber 1982; Volkhardt et al. 2007). The six assumptions are 1) the population is closed, 2) all fish have an equal probability of capture in the first period, 3) marking does not affect catchability, 4) all fish (marked and unmarked) have an equal probability of being caught in the second sample, 5) fish do not lose their marks, and 6) all recovered marks are reported. The field methods used to estimate abundance were designed to minimize any violations of the assumptions, and violation of several assumptions were directly tested.

Assumption one is technically violated during outmigrant abundance studies because fish are actively leaving the study area. However, it was assumed that the loss of marked and unmarked fish was equal, and the violation of this assumption was kept to a minimum (Arnason et al. 1996).

Assumption two and four are most likely violated in outmigrant abundance studies when capture probabilities change over time due to changing river conditions and when size-biased capture rates occur. To account for variable trap efficiencies over time and to mitigate any associated bias, efficiency trials were continually conducted and changes in trap efficiency, or capture probabilities, were tested and accounted for by time-stratifying the data sets. Size-biased capture rates were tested for all species, and the results suggested all fish had an equal probability of capture.

Violation of assumption three was tested for Chinook (subyearling smolts) marked with Bismarck brown or a caudal clip. The results of the test suggested Bismarck brown negatively affected catchability of the subyearling smolt life stage. Therefore, caudal clip efficiency trials were used to estimate abundance of larger Chinook. Mark effects on other species and life stages were not tested and were assumed to be negligible because only fish in good condition at release were used for efficiency trials.

Violations of assumption four due to release site effects (i.e., distance between release site and trap) were tested for Chinook fry (see below).

Assumption five was tested using Chinook fry (<45 mm) marked with Bismarck brown. The results suggest the mark was retained for at least 8 days. Observations from various efficiency trials suggest fish move passed the trap within 4 days after release. Therefore, it was assumed assumption five was met for this outmigrant group. Mark loss was not tested for other species and was assumed to be negligible.

Assumption six was not directly tested, however, all fish were thoroughly examined during sampling and the marks used (Bismarck brown, caudal clips, and biophotonic formulation) are easily detectable. Therefore, it was assumed that violations of assumption six were negligible.

Juvenile Production Estimates

In 2012 and 2013, Chinook emigration in the Coweeman River basin once again exhibited a bimodal pattern with a higher proportion of fry (<45 mm) migrants compared to subyearling smolt migrants (Sharpe et al. 2009; Sharpe et al. 2011; Lamperth et al. 2013), however, variation in migration timing, growth rates, and total abundance was observed. The proportion of fry migrants was very similar (2012, 0.82) or slightly smaller (2013, 0.71) compared to recent years. Peak outmigration of fry has been relatively consistence across study years and typically occurs between the mid-March and the beginning of April. The 2012 and 2013 results were consistent with this pattern. Interestingly, there was a peak in fry outmigration in the absence of a high discharge event in 2013 supporting the conclusion that this life stage actively migrates and is not only the result of physical displacement.

Growth rates and timing of subyearling smolt life stage have been more variable than the fry life stage across study years and this variability was captured in the 2012 and 2013 emigrations. Chinook grew slightly faster in 2013 compared to 2012 but both were within the range observed previously. Outmigration timing was strikingly different between the two years with 2012 being slightly later than the time series average and 2013 being the earliest that has been observed over the entire time series. Migrants left nearly one month earlier in 2013 than 2012. The initial peak observed in 2013 (May 20 – 27) was the earliest prominent migration peak observed since trapping began. Furthermore, in all other years Chinook have been caught during the last week of trapping, but in 2013 zero fish were captured.

Analyzing relationships among juvenile abundance, spawner abundance and environmental variables is planned for future work. However, the variation in growth and migration timing may have resulted from varying incubation and early rearing conditions (e.g., flow and temperature regimes) and total abundance (i.e., density-dependent factors). For example, the 2013 total Chinook juvenile abundance was second lowest observed to date and corresponded with one of the lowest spawner abundances documented above the trap site and .abnormally low discharge with no extreme high water events during incubation and rearing.

The Chinook outmigration shows a bimodal pattern with a distinct valley. Whether this distinct dip in the estimate is as distinctive for the outmigration itself has come into question because the lull period (April-June) coincides with steelhead, cutthroat, and coho emigrations. These species are larger than Chinook and could be impacting the Chinook catch in at least two ways. First, the presence of the larger species in the trap box could fatigue Chinook to the point that they are more susceptible to rolling out of the trap live box over the debris drum. Second, the larger species may be feeding on the Chinook. Whether Chinook were being retained in the live box after capture was tested by placing a known number of Bismarck brown Chinook in the live box, holding them overnight, and counting the number in the live box the next morning. Early in the season, when the larger fish were absent, all Chinook were retained. In contrast, a significant proportion was not retained when the larger species were present. Typically during the lull period, efficiency trials are not conducted for Chinook because catch is low and not enough marks can be released to get a reliable estimate of efficiency. The catch for this period is pooled into time-adjacent periods that have reliable capture probabilities. The consequence of this approach is estimates during this period are likely biased low. Steps were taken and will continue to be taken to reduce catch loss (e.g. placement of “refuges” in the live box), and the effects of larger species on Chinook catch will continue to be investigated.

Proper selection of a release site for trap efficiency trials is critical to obtain an unbiased estimate of outmigrant abundance. Among the many considerations associated with release sites are mixing of marked and unmarked fish between release and recapture, potential for mark loss, and potential for mortality of marked fish. Mixing of marked and unmarked fish is likely to be improved by maximizing the distance between the release site and the trap site. However, longer migration distances for marked fish also increase the likelihood of mark loss and fish mortality, especially when the marked fish are fry-sized migrants. As noted in Sharpe et al. (2009), if the goal of early migrating Chinook fry is to find suitable rearing habitat for growth prior to entering the ocean, mark-released fish may select and occupy habitat between the release site and trap for an extended period (up to 3 – 4 months) and not pass the trap for a second time before the dye mark fades. In addition to mark loss, mark-released fry may experience predation or general mortality at a higher rate than larger outmigrants. Together, the behavior or fate of fry marked for trap efficiency trials may not accurately mimic actively migrating fry. The effective number of marks released may be less than the actual number of marks released resulting in low-biased trap efficiencies and high-biased abundance estimates.

On the Coweeman River, fry have been released a relatively long distance from the trap (3.0 km) since 2007. In 2013, we released fry 245 m above the trap in an attempt to decrease mark loss and fry mortality between the release site and the trap. Direct comparison between the two release sites (e.g., paired releases) was not performed because only one mark type was available (Bismarck brown). Across year comparisons of overall fry efficiency show that the efficiency in 2013 was 0.7 to 2.2 times that of previous trapping seasons. Among all years, stream discharge in 2013 was most similar to 2010 (i.e., low discharge; overall discharge in 2010 was slightly lower than 2013). Assuming stream discharge is an important factor affecting trap efficiency, these two years facilitate the most direct and appropriate comparison between the two release locations; efficiency in 2013 was 0.7 times that in 2010.

Definitive conclusions about the most appropriate release site are difficult to obtain because of annual variability in environmental conditions and channel shape near the trap site. However, similar efficiencies between release sites during years with similar flow tend to suggest that either site can be used for fry efficiency trials. The release site closer to the trap is more favorable in terms of field logistics and fish health. Transporting fish to the upper release site takes ~ 30 minutes and involves transferring the fish in a truck. Fish can be transported to the near trap release site on foot in less than 5 minutes. Reduced handling time and shorter distance between the trap and release site minimizes adverse handling effects and predation risk of fry and is a benefit of the near trap release site. In comparison to Chinook fry, the closer release site resulted in erratic estimates of trap efficiency for larger outmigrants (coho, steelhead, cutthroat) in 2013 and the upper release site, which is more likely to maximize mixing of marked and unmarked fish, continues to be the preferred release location for these species.

Production estimates for coho, natural-origin steelhead, and cutthroat in 2012 and 2013 fell within the range of estimates among study years, and were the most precise in 2013 compared to other years. High estimate precision in 2013 was due to favorable trapping conditions including relatively low discharge and a change in channel shape that concentrated a higher proportion of flow into the cone. Annual production for each species across years has been quite similar except for 2010 and possibly 2011. Excluding these years, the range in point estimates for each species has been 10,121 – 14,879 (coho), 13,260 – 17,924 (natural-origin steelhead), and 1,628 – 2,841(cutthroat). Migration timing has been similar for each species across years with a trend for earlier migration during low flow years (i.e., 2010 and 2013).

High outmigrant abundance estimates in 2010 (coho, steelhead, and cutthroat) and 2011 (steelhead) may be attributed to over-wintering and migration river conditions and/or mark-recapture methodology. The production estimates for 2010 are approximately two times greater than the next highest estimate to date (6 years of data). One explanation is over-winter and migration period flow conditions in 2010 were favorable and produced more fish than typical. The only other year that can be compared to 2010 in terms of river conditions is 2013. In 2013, river conditions were similar to 2010 yet the estimates in 2013 were 58.3 % (coho), 47.3% (steelhead), 51.2% (cutthroat) of the 2010 estimates. Another explanation for abnormally high production estimates is violations of mark-recapture assumptions. In 2010, species-specific trap efficiencies were the lowest observed and could indicate issues with mark-recapture methods, specifically mark loss. Elastomer tags were used as the efficiency mark and rigid evaluation of mark retention, as was done in previous seasons, was not conducted. Elastomer tags were again used in 2011 and efficiencies were low, however, only steelhead had an unusually high estimate (with low precision). If mark loss did not contribute to low estimates for trap efficiency, an alternate explanation is that trap efficiencies were truly low and resulted from unfavorable channel morphologies. The river channel at the trap site changes annually and it is possible (yet unknown and untestable) that during these years the shape of the channel reduced the proportion of outmigrants that could be captured. Based on this information, the 2010 yearling estimates and the 2011 steelhead estimate may be biased high. Spawner abundance is an additional piece of information that could help explain the variability in juvenile production and will be investigated in the future.

Each year during the study period, ~10,000 hatchery-origin juvenile steelhead have been planted in an acclimation pond for release into the Coweeman River. These fish are planted to provide local fish opportunities in the Coweeman River. Although many factors determine whether these fishing opportunities are realized, one measure of the effectiveness of hatchery plants is whether the smolts released from the pond leave the river and migrate to the ocean. The effectiveness of the release (the number planted vs. the number that leave the system) has been monitored for six years. In some years, uncertainty in the number of fish released and imprecise (and possibly inaccurate) outmigrant estimates has made it difficult to evaluate the effectiveness of the hatchery plant. A fish counter has been used at release in an attempt to get an accurate count of the fish entering the Coweeman River but on several years the counter has malfunctioned. In some years, the trap was non-operational during the period of hatchery steelhead releases due to various factors (e.g., a tree fell in front of the trap). Despite these limitations, in four of the six years, the approximate number of hatchery steelhead counted leaving the acclimation pond fell within the confidence intervals of the hatchery steelhead smolts estimated to have passed the smolt trap. In the years when the smolt trap was fully operational, the migration timing of hatchery steelhead smolts has generally occurred shortly after release. In sum, the majority of hatchery steelhead planted in the Coweeman appear to leave the system and do so quickly. Any differences between our estimates and the number planted could be due to residualism, pre-release predation, or mortality during the outmigration. The effectiveness of this plant will continue to be monitored and the study design used will continue to be evaluated.

Recommendations

The following recommendations are made to improve future evaluation of Coweeman River salmonid populations:

1) Continue to evaluate release locations for Chinook fry.
2) Use Bismarck brown concentration of 23.2 mg/l and a soak time of 60 min for Chinook fry.
3) Use marking techniques other than Bismarck brown on Chinook > 65 mm FL.
4) Reduce soak duration of Sr marking procedure to 3 hours by increasing the concentration of the Sr bath to 3000 ppm.
5) Continue to evaluate Chinook catch loss in the live box during the steelhead, coho, and cutthroat emigration period.
6) Collect scales from all coho migrants > 60 mm FL to determine age structure in general, and specifically to determine the age of smaller fish that emigrate in mid-summer.
7) Conduct efficiency trials with late coho migrants to obtain species-specific capture probability.
8) Differentially mark hatchery-origin transitionals and smolts at the acclimation pond for mark-recapture purposes.

References

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Science 2106. 37 p.

Bjorkstedt, E. P. 2005. DARR 2.0: updated software for estimating abundance from stratified mark-recapture data. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-368. 13 p.

Bjorkstedt, E. P. 2010. DARR 2.0.2: DARR for R. URL http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346

Blankenship, S., and D. Rawding. 2012. Escapement estimates using genetic mark-recapture and sibship distributions: an application to the Coweeman River tule fall Chinook salmon populations - Final report to the Pacific Salmon Commission Chinook Letter of Agreement (Award No. NA10NMF4380185). Washington Department of Fish and Wildlife, Olympia, Washington.

Carl, L. M. 1984. Chinook salmon (*Oncorhynchus tshawutscha*) density, growth, mortality, and movement in two Lake Michigan tributaries. Canadian Journal of Zoology 62:65–71.

Carlson, S.R., L. Coggins, and C.O. Swanton. 1998. A simple stratified design for mark-recapture of salmon smolt abundance. Alaska Fisheries Research Bulletin 5(2): 88–102.

Crawford, B.A., and S. M. Rumsey. 2011. Guidance for monitoring recovery of pacific salmon and steelhead listed under the federal Endangered Species Act. National Marine Fisheries Service, NW Region, Portland, Oregon.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241–260.

Davis, S. F., and M. J. Unwin. 1989. Freshwater life history of chinook salmon (*Oncorhynchus tshawytcha*) in the Rangitata River catchment, New Zealand. New Zealand Journal of Marine and Freshwater Research 23:311–319.

Dunham, J. B., B. E. Rieman, and G. Chandler. 2003. Influences of temperature and environmental variables on the distribution of bull trout within streams at the southern margin of its range. North American Journal of Fisheries Management, 23, 894-904.

Hillson, T. 2006. Re-introduction of Lower Columbia River chum salmon into Duncan Creek, 2004-2005 Annual Report, Project No. 200105300, (BPA Report DOE/BP-00020932-1). 73 p.

Kiyohara, K., and M. S. Zimmerman. 2012. Evaluation of juvenile salmon production in 2011 from the Cedar River and Bear Creek, FPA 12-01. Washington Department of Fish and Wildlife, Olympia, Washington.

Lamperth, J., M. S. Zimmerman, D. J. Rawding, L. Campbell, B. G. Glaser, and C. Sharpe. 2013. Coweeman River salmonid production evaluation: 2011 completion report, FPA 13-01. Washington Department of Fish and Wildlife, Olympia, Washington.

LCFRB. 2010. Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan. Lower Columbia Fish Recovery Board, Kelso, Washington.

Myers, J., and coauthors. 2006. Historical population structure of Pacific salmonids in the Willamette River and lower Columbia River basins. U.S. Department of Commerce, NOAA Technical Memorandum NMFW-NWFSC-73.

Pollard, WR, GF Hartman, C Groot, P Edgell. 1997. Field Identification of Coastal Juvenile Salmonids. Harbour Publishing, British Columbia, Canada.

R Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Schroder, S. L., C. M. Knudsen, E. C. Volk. 1995. Marking salmon fry with strontium chloride solutions. Canadian Journal of Fisheries and Aquatic Sciences 52:1141–1149.

Schroder, S. L., E. C. Volk, C. M. Knudsen, and J. J. Grimm. 1996. Marking embryonic and newly emerged salmonids by thermal events and rapid immersion in alkaline-earth salts. Bull. Natl. Res. Inst. Aquacult. Suppl. 2:79–83.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Griffin and Company, London.

Sharpe, C. S., B. G. Glaser, and D. J. Rawding. 2009. Spawning escapement, juvenile production, and contribution to fisheries of Coweeman River fall Chinook salmon: A completion report for work in 2007 and 2008. FPA 09-01. Washington Department of Fish and Wildlife, Olympia, Washington.

Sharpe, C. S., B. G. Glaser, D. J. Rawding, and L. Campbell. 2011. Spawning escapement, juvenile production, and contribution to fisheries of Coweeman River fall Chinook salmon: A completion report for work in 2010. Delivered to the Pacific Salmon Commission, June 2011. 42 p.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. 2nd edition. W. H. Freeman and Company, New York.

Topping, P., and M. S. Zimmerman. 2011. Green River juvenile salmonid production evaluation: 2009 and 2010 annual report, FPA 11-01. Washington Department of Fish and Wildlife, Olympia, Washington.

Wydoski, R. S., and R. R. Whitney. 2003. Inland Fishes of Washington. Second edition. American Fisheries Society, Bethesda, MD, in association with University of Washington Press, Seattle, WA.

Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane screen traps. Pages 235-266 *in* D. H. Johnson, B. M. Shrier, J. S. O’Neal, J. A. Knutzen, X. Augerot, T. A. O’Neil, and T. N. Pearsons, editors. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Zar, J. H. 1999. Biostatistical analysis. 4th edition. Prentice Hall, New Jersey.

Appendix A

Weekly juvenile Chinook abundance estimates and length summary statistics, 2012

Appendix A. Weekly abundance estimates and length summary statistics of juvenile tule fall Chinook salmon captured in the Coweeman River juvenile screw trap, 2012. Seasonal length statistics are weighted by weekly migration.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/08/2012	02/13/2012	3,789	34.1	1.1	32	36	61
02/14/2012	02/20/2012	4,452	34.2	1.2	32	37	101
02/21/2012	02/27/2012	4,958	ND	ND	ND	ND	0
02/28/2012	03/05/2012	4,831	35.0	1.2	31	39	121
03/06/2012	03/12/2012	11,936	35.3	1.4	32	39	76
03/13/2012	03/19/2012	17,589	35.9	1.5	33	39	60
03/20/2012	03/26/2012	16,326	36.2	1.6	33	39	97
03/27/2012	04/02/2012	49,672	36.6	1.8	33	45	67
04/03/2012	04/09/2012	26,557	36.8	1.7	33	44	85
04/10/2012	04/16/2012	24,898	36.7	1.5	34	45	129
04/17/2012	04/23/2012	24,160	37.0	1.7	34	45	123
04/24/2012	04/30/2012	6,800	37.2	3.4	32	61	101
05/01/2012	05/07/2012	4,000	38.0	4.9	31	62	93
05/08/2012	05/14/2012	587	45.3	8.1	35	67	22
05/15/2012	05/21/2012	169	47.0	12.6	35	74	27
05/22/2012	05/28/2012	737	52.4	9.8	34	77	115
05/29/2012	06/04/2012	164	60.1	14.5	34	88	32
06/05/2012	06/11/2012	854	65.9	11.7	35	91	125
06/12/2012	06/18/2012	1,627	73.0	11.9	44	96	141
06/19/2012	06/25/2012	6,058	80.8	10.4	48	99	176
06/26/2012	07/02/2012	3,798	83.9	9.7	31	105	111
07/03/2012	07/09/2012	3,692	88.3	6.4	74	104	150
07/10/2012	07/12/2012	2,812	89.3	5.6	73	102	90
07/13/2012	07/16/2012	5,225	88.5	7.0	68	106	189
07/17/2012	07/23/2012	8,817	88.7	5.5	69	102	260
07/24/2012	07/30/2012	5,812	89.5	6.3	70	105	280
07/31/2012	08/06/2012	2,479	90.3	6.1	71	104	200
08/07/2012	08/13/2012	1,439	91.3	5.2	76	104	122
08/14/2012	08/20/2012	375	90.8	6.2	70	106	57
08/21/2012	08/24/2012	395	94.4	6.0	75	112	102
		245,008	***45.6***	***2.8***	***31***	***112***	***3,313***

Appendix B

Weekly coho abundance estimates and length summary statistics, 2012

Appendix B. Weekly abundance estimates and length summary statistics of coho transitionals and smolts captured in the Coweeman River juvenile screw trap, 2012. Seasonal length statistics are weighted by weekly migration.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/08/2012	02/13/2012	0	ND	ND	ND	ND	0
02/14/2012	02/20/2012	0	ND	ND	ND	ND	0
02/21/2012	02/27/2012	0	ND	ND	ND	ND	0
02/28/2012	03/05/2012	0	ND	ND	ND	ND	0
03/06/2012	03/12/2012	0	ND	ND	ND	ND	0
03/13/2012	03/19/2012	0	ND	ND	ND	ND	0
03/20/2012	03/26/2012	0	ND	ND	ND	ND	0
03/27/2012	04/02/2012	82	99.2	13.3	83	120	6
04/03/2012	04/09/2012	103	98.2	9.6	86	117	10
04/10/2012	04/16/2012	227	99.5	4.8	90	107	18
04/17/2012	04/23/2012	495	107.0	8.9	92	140	48
04/24/2012	04/30/2012	515	109.3	10.2	81	127	48
05/01/2012	05/07/2012	474	109.6	8.6	88	131	44
05/08/2012	05/14/2012	464	114.4	7.5	95	131	45
05/15/2012	05/21/2012	1,371	119.2	8.1	103	145	73
05/22/2012	05/28/2012	6,156	112.8	8.1	88	133	158
05/29/2012	06/04/2012	1,080	116.9	6.5	99	136	139
06/05/2012	06/11/2012	2,031	113.1	7.1	97	131	109
06/12/2012	06/18/2012	244	114.3	9.0	70	126	47
06/19/2012	06/25/2012	207	110.2	9.1	77	125	38
06/26/2012	07/02/2012	5	95.0	ND	95	95	1
07/03/2012	07/09/2012	0	ND	ND	ND	ND	0
07/10/2012	07/12/2012	0	ND	ND	ND	ND	0
07/13/2012	07/16/2012	249	71.7	9.9	54	84	20
07/17/2012	07/23/2012	0	ND	ND	ND	ND	0
07/24/2012	07/30/2012	57	80.1	8.1	65	91	11
07/31/2012	08/06/2012	0	ND	ND	ND	ND	0
08/07/2012	08/13/2012	124	77.8	10.6	60	91	19
08/14/2012	08/20/2012	10	84.0	ND	84	84	1
08/21/2012	08/24/2012	119	82.0	5.8	72	96	23
		14,014	***111.5***	***8.0***	***54***	***145***	***858***

Appendix C

Weekly natural-origin steelhead abundance estimates and length summary statistics, 2012

Appendix C. Weekly abundance estimates and length summary statistics of natural-origin steelhead transitionals and smolts captured in the Coweeman River juvenile screw trap, 2012.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/08/2012	02/13/2012	0	ND	ND	ND	ND	0
02/14/2012	02/20/2012	0	ND	ND	ND	ND	0
02/21/2012	02/27/2012	0	ND	ND	ND	ND	0
02/28/2012	03/05/2012	0	ND	ND	ND	ND	0
03/06/2012	03/12/2012	0	ND	ND	ND	ND	0
03/13/2012	03/19/2012	0	ND	ND	ND	ND	0
03/20/2012	03/26/2012	59	168.9	23.7	133	210	8
03/27/2012	04/02/2012	22	168.0	7.0	160	173	3
04/03/2012	04/09/2012	96	174.2	20.6	150	209	13
04/10/2012	04/16/2012	199	168.3	22.2	128	213	27
04/17/2012	04/23/2012	997	174.2	20.1	133	230	124
04/24/2012	04/30/2012	1,662	168.0	15.3	128	207	190
05/01/2012	05/07/2012	4,459	166.5	15.0	123	207	195
05/08/2012	05/14/2012	2,315	165.6	13.7	131	210	207
05/15/2012	05/21/2012	1,538	164.9	13.7	130	220	171
05/22/2012	05/28/2012	1,600	163.6	13.0	132	208	118
05/29/2012	06/04/2012	405	159.3	12.3	120	190	45
06/05/2012	06/11/2012	135	154.8	11.3	130	170	15
06/12/2012	06/18/2012	0	ND	ND	ND	ND	0
06/19/2012	06/25/2012	0	ND	ND	ND	ND	0
06/26/2012	07/02/2012	0	ND	ND	ND	ND	0
07/03/2012	07/09/2012	0	ND	ND	ND	ND	0
07/10/2012	07/12/2012	0	ND	ND	ND	ND	0
07/13/2012	07/16/2012	0	ND	ND	ND	ND	0
07/17/2012	07/23/2012	0	ND	ND	ND	ND	0
07/24/2012	07/30/2012	0	ND	ND	ND	ND	0
07/31/2012	08/06/2012	0	ND	ND	ND	ND	0
08/07/2012	08/13/2012	0	ND	ND	ND	ND	0
08/14/2012	08/20/2012	0	ND	ND	ND	ND	0
08/21/2012	08/24/2012	0	ND	ND	ND	ND	0
		13,488	***166.3***	***14.9***	***120***	***230***	***1,116***

Appendix D

Weekly hatchery-origin steelhead abundance estimates and length summary statistics, 2012

Appendix D. Weekly abundance estimates and length summary statistics of hatchery-origin steelhead transitionals and smolts captured in the Coweeman River juvenile screw trap, 2012.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/08/2012	02/13/2012	0	ND	ND	ND	ND	0
02/14/2012	02/20/2012	0	ND	ND	ND	ND	0
02/21/2012	02/27/2012	0	ND	ND	ND	ND	0
02/28/2012	03/05/2012	0	ND	ND	ND	ND	0
03/06/2012	03/12/2012	0	ND	ND	ND	ND	0
03/13/2012	03/19/2012	0	ND	ND	ND	ND	0
03/20/2012	03/26/2012	0	ND	ND	ND	ND	0
03/27/2012	04/02/2012	0	ND	ND	ND	ND	0
04/03/2012	04/09/2012	0	ND	ND	ND	ND	0
04/10/2012	04/16/2012	0	ND	ND	ND	ND	0
04/17/2012	04/23/2012	21	179.0	0.0	179	179	2
04/24/2012	04/30/2012	5,085	182.6	15.9	115	227	253
05/01/2012	05/07/2012	596	181.8	12.3	150	209	81
05/08/2012	05/14/2012	1,457	175.8	12.8	142	208	144
05/15/2012	05/21/2012	203	166.8	11.6	144	204	70
05/22/2012	05/28/2012	328	161.7	16.0	136	193	19
05/29/2012	06/04/2012	48	161.8	10.6	150	178	6
06/05/2012	06/11/2012	0	ND	ND	ND	ND	0
06/12/2012	06/18/2012	0	ND	ND	ND	ND	0
06/19/2012	06/25/2012	0	ND	ND	ND	ND	0
06/26/2012	07/02/2012	0	ND	ND	ND	ND	0
07/03/2012	07/09/2012	0	ND	ND	ND	ND	0
07/10/2012	07/12/2012	0	ND	ND	ND	ND	0
07/13/2012	07/16/2012	0	ND	ND	ND	ND	0
07/17/2012	07/23/2012	0	ND	ND	ND	ND	0
07/24/2012	07/30/2012	0	ND	ND	ND	ND	0
07/31/2012	08/06/2012	0	ND	ND	ND	ND	0
08/07/2012	08/13/2012	0	ND	ND	ND	ND	0
08/14/2012	08/20/2012	0	ND	ND	ND	ND	0
08/21/2012	08/24/2012	0	ND	ND	ND	ND	0
		7,738	***179.8***	***14.8***	***115***	***227***	***575***

Appendix E

Weekly coastal cutthroat abundance estimates and length summary statistics, 2012

Appendix E. Weekly abundance estimates and length summary statistics of coastal cutthroat transitionals and smolts captured in the Coweeman River juvenile screw trap, 2012.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/08/2012	02/13/2012	0	ND	ND	ND	ND	0
02/14/2012	02/20/2012	0	ND	ND	ND	ND	0
02/21/2012	02/27/2012	0	ND	ND	ND	ND	0
02/28/2012	03/05/2012	0	ND	ND	ND	ND	0
03/06/2012	03/12/2012	0	ND	ND	ND	ND	0
03/13/2012	03/19/2012	0	ND	ND	ND	ND	0
03/20/2012	03/26/2012	0	ND	ND	ND	ND	0
03/27/2012	04/02/2012	33	170.8	18.2	151	191	5
04/03/2012	04/09/2012	39	186.2	18.1	160	208	6
04/10/2012	04/16/2012	98	176.1	29.0	139	235	15
04/17/2012	04/23/2012	216	189.3	26.7	145	253	33
04/24/2012	04/30/2012	124	184.7	24.8	145	238	19
05/01/2012	05/07/2012	157	187.0	25.7	136	239	24
05/08/2012	05/14/2012	426	182.4	21.3	150	234	63
05/15/2012	05/21/2012	277	178.6	23.1	150	264	57
05/22/2012	05/28/2012	763	169.5	13.6	133	229	99
05/29/2012	06/04/2012	248	173.9	11.0	153	195	42
06/05/2012	06/11/2012	195	174.6	12.1	157	199	33
06/12/2012	06/18/2012	35	171.0	11.5	150	182	6
06/19/2012	06/25/2012	41	173.9	16.4	160	207	7
06/26/2012	07/02/2012	6	105.0	ND	105	105	1
07/03/2012	07/09/2012	0	ND	ND	ND	ND	0
07/10/2012	07/12/2012	0	ND	ND	ND	ND	0
07/13/2012	07/16/2012	0	ND	ND	ND	ND	0
07/17/2012	07/23/2012	0	ND	ND	ND	ND	0
07/24/2012	07/30/2012	0	ND	ND	ND	ND	0
07/31/2012	08/06/2012	0	ND	ND	ND	ND	0
08/07/2012	08/13/2012	0	ND	ND	ND	ND	0
08/14/2012	08/20/2012	0	ND	ND	ND	ND	0
08/21/2012	08/24/2012	0	ND	ND	ND	ND	0
		2,658	***177.1***	***18.5***	***105***	***264***	***410***

Appendix F

Weekly juvenile Chinook abundance estimates and length summary statistics, 2013

Appendix F. Weekly abundance estimates and length summary statistics of juvenile tule fall Chinook salmon captured in the Coweeman River juvenile screw trap, 2013. Seasonal length statistics are weighted by weekly migration.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/06/2013	02/11/2013	265	36.4	1.9	33	38	16
02/12/2013	02/18/2013	298	37.1	1.2	35	40	18
02/19/2013	02/25/2013	3512	36.5	1.3	34	40	112
02/26/2013	03/04/2013	8249	36.6	1.4	33	39	129
03/05/2013	03/12/2013	5301	37.0	1.5	32	40	148
03/13/2013	03/19/2013	16914	37.2	1.4	34	42	139
03/20/2013	03/25/2013	22972	36.6	1.7	32	43	140
03/26/2013	04/01/2013	16323	36.6	1.4	32	40	240
04/02/2013	04/08/2013	10828	38.3	3.7	34	67	210
04/09/2013	04/15/2013	8442	39.9	4.3	32	58	126
04/16/2013	04/22/2013	4623	40.1	6.1	33	66	104
04/23/2013	04/29/2013	972	42.2	8.2	37	65	29
04/30/2013	05/06/2013	179	49.0	11.7	36	88	52
05/07/2013	05/13/2013	636	60.6	13.1	36	83	128
05/14/2013	05/20/2013	1845	65.9	9.2	46	85	141
05/21/2013	05/27/2013	7369	71.6	10.0	46	94	153
05/28/2013	06/03/2013	5730	72.0	10.2	44	94	189
06/04/2013	06/10/2013	824	78.8	14.3	35	109	137
06/11/2013	06/17/2013	3029	87.9	7.3	57	100	200
06/18/2013	06/24/2013	5461	92.0	6.2	68	106	228
06/25/2013	07/01/2013	5791	92.7	5.5	72	110	212
07/02/2013	07/08/2013	4941	91.6	5.5	72	104	190
07/09/2013	07/15/2013	2513	90.4	6.1	69	106	156
07/16/2013	07/22/2013	980	89.5	6.7	75	105	63
07/23/2013	07/29/2013	159	87.3	9.0	65	106	26
07/30/2013	08/05/2013	70	89.8	9.6	67	109	38
08/06/2013	08/12/2013	35	92.2	11.8	72	108	18
08/13/2013	08/19/2013	13	97.9	8.2	81	104	7
08/20/2013	08/23/2013	0	ND	ND	ND	ND	0
		138,273	***50.4***	***3.9***	***32***	***110***	***3,349***

Appendix G

Weekly coho abundance estimates and length summary statistics, 2013

Appendix G. Weekly abundance estimates and length summary statistics of coho transitionals and smolts captured in the Coweeman River juvenile screw trap, 2013. The migration is partitioned into typical and late migrants. See text for details. Seasonal length statistics are weighted by weekly migration.

Typical Migrants

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/06/2013	02/11/2013	0	ND	ND	ND	ND	0
02/12/2013	02/18/2013	0	ND	ND	ND	ND	0
02/19/2013	02/25/2013	0	ND	ND	ND	ND	0
02/26/2013	03/04/2013	0	ND	ND	ND	ND	0
03/05/2013	03/12/2013	0	ND	ND	ND	ND	0
03/13/2013	03/19/2013	0	ND	ND	ND	ND	0
03/20/2013	03/25/2013	56	102.4	7.0	95	115	9
03/26/2013	04/01/2013	12	115.5	24.7	98	133	2
04/02/2013	04/08/2013	6	103.0	ND	103	103	1
04/09/2013	04/15/2013	168	112.3	20.4	82	158	27
04/16/2013	04/22/2013	143	113.3	15.9	92	167	23
04/23/2013	04/29/2013	112	116.8	9.2	103	135	18
04/30/2013	05/06/2013	168	118.5	10.0	96	142	27
05/07/2013	05/13/2013	2,311	120.9	7.6	102	142	239
05/14/2013	05/20/2013	3,806	118.9	7.1	93	141	365
05/21/2013	05/27/2013	5,108	115.3	8.9	85	140	286
05/28/2013	06/03/2013	740	108.0	10.1	86	123	51
06/04/2013	06/10/2013	290	108.9	11.0	84	126	20
06/11/2013	06/17/2013	435	104.7	11.3	89	128	29
		13,354	***116.3***	***8.6***	***82***	***167***	***1,097***

Late Migrants

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
06/18/2013	06/24/2013	263	96.0	12.9	66	120	56
06/25/2013	07/01/2013	622	98.7	10.9	71	125	56
07/02/2013	07/08/2013	1,145	79.1	9.8	59	102	80
07/09/2013	07/15/2013	80	86.9	8.9	64	105	33
07/16/2013	07/22/2013	82	79.6	8.9	59	95	36
07/23/2013	07/29/2013	0	ND	ND	ND	ND	0
07/30/2013	08/05/2013	0	ND	ND	ND	ND	0
08/06/2013	08/12/2013	0	ND	ND	ND	ND	0
08/13/2013	08/19/2013	0	ND	ND	ND	ND	0
08/20/2013	08/23/2013	0	ND	ND	ND	ND	0
		2,192	***87.0***	***1.7***	***59***	***125***	***261***

Appendix H

Weekly natural-origin steelhead abundance estimates and length summary statistics, 2013

Appendix H. Weekly production estimates and length summary statistics of natural-origin steelhead transitionals and smolts captured in the Coweeman River juvenile screw trap, 2013.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/06/2013	02/11/2013	0	ND	ND	ND	ND	0
02/12/2013	02/18/2013	0	ND	ND	ND	ND	0
02/19/2013	02/25/2013	5	171.0	ND	171	171	1
02/26/2013	03/04/2013	5	161.0	ND	161	161	1
03/05/2013	03/12/2013	0	ND	ND	ND	ND	0
03/13/2013	03/19/2013	0	ND	ND	ND	ND	0
03/20/2013	03/25/2013	5	166.0	ND	166	166	1
03/26/2013	04/01/2013	10	157.5	13.4	148	167	2
04/02/2013	04/08/2013	199	182.3	23.7	139	247	38
04/09/2013	04/15/2013	404	180.4	21.3	140	237	77
04/16/2013	04/22/2013	1,112	182.3	19.4	93	244	211
04/23/2013	04/29/2013	2,208	179.8	17.6	135	235	273
04/30/2013	05/06/2013	4,061	174.8	15.2	119	226	368
05/07/2013	05/13/2013	6,598	170.0	12.9	135	209	386
05/14/2013	05/20/2013	2,316	166.6	11.9	140	203	322
05/21/2013	05/27/2013	756	167.6	14.4	142	238	134
05/28/2013	06/03/2013	72	162.0	12.2	136	181	16
06/04/2013	06/10/2013	59	150.9	19.4	119	189	13
06/11/2013	06/17/2013	14	155.0	19.0	136	174	3
06/18/2013	06/24/2013	5	112.0	ND	112	112	1
06/25/2013	07/01/2013	5	ND	ND	ND	ND	0
07/02/2013	07/08/2013	36	160.2	23.7	130	188	5
07/09/2013	07/15/2013	45	148.0	19.4	127	190	10
07/16/2013	07/22/2013	9	156.0	29.7	135	177	2
07/23/2013	07/29/2013	0	ND	ND	ND	ND	0
07/30/2013	08/05/2013	0	ND	ND	ND	ND	0
08/06/2013	08/12/2013	0	ND	ND	ND	ND	0
08/13/2013	08/19/2013	0	ND	ND	ND	ND	0
08/20/2013	08/23/2013	0	ND	ND	ND	ND	0
		17,924	***172.6***	***14.7***	***93***	***247***	***1,864***

Appendix I

Weekly hatchery-origin steelhead abundance estimates and length summary statistics, 2013

Appendix I. Weekly abundance estimates and length summary statistics of hatchery-origin steelhead transitionals and smolts captured in the Coweeman River juvenile screw trap, 2013.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/06/2013	02/11/2013	0	ND	ND	ND	ND	0
02/12/2013	02/18/2013	0	ND	ND	ND	ND	0
02/19/2013	02/25/2013	0	ND	ND	ND	ND	0
02/26/2013	03/04/2013	0	ND	ND	ND	ND	0
03/05/2013	03/12/2013	0	ND	ND	ND	ND	0
03/13/2013	03/19/2013	0	ND	ND	ND	ND	0
03/20/2013	03/25/2013	0	ND	ND	ND	ND	0
03/26/2013	04/01/2013	0	ND	ND	ND	ND	0
04/02/2013	04/08/2013	0	ND	ND	ND	ND	0
04/09/2013	04/15/2013	0	ND	ND	ND	ND	0
04/16/2013	04/22/2013	1,112	204.6	16.2	122	247	593
04/23/2013	04/29/2013	6,425	211.6	13.2	156	257	284
04/30/2013	05/06/2013	2,397	204.0	15.0	167	245	214
05/07/2013	05/13/2013	306	192.9	18.9	150	224	50
05/14/2013	05/20/2013	132	186.0	23.1	139	233	21
05/21/2013	05/27/2013	114	183.7	24.4	150	218	18
05/28/2013	06/03/2013	0	ND	ND	ND	ND	0
06/04/2013	06/10/2013	12	215.0	1.4	214	216	2
06/11/2013	06/17/2013	6	187.0	ND	187	187	1
06/18/2013	06/24/2013	0	ND	ND	ND	ND	0
06/25/2013	07/01/2013	0	ND	ND	ND	ND	0
07/02/2013	07/08/2013	6	ND	ND	ND	ND	0
07/09/2013	07/15/2013	0	ND	ND	ND	ND	0
07/16/2013	07/22/2013	0	ND	ND	ND	ND	0
07/23/2013	07/29/2013	0	ND	ND	ND	ND	0
07/30/2013	08/05/2013	0	ND	ND	ND	ND	0
08/06/2013	08/12/2013	0	ND	ND	ND	ND	0
08/13/2013	08/19/2013	0	ND	ND	ND	ND	0
08/20/2013	08/23/2013	0	ND	ND	ND	ND	0
		10,510	***207.8***	***14.3***	***122***	***257***	***1,183***

Appendix J

Weekly coastal cutthroat abundance estimates and length summary statistics, 2013

Appendix J. Weekly abundance estimates and length summary statistics of coastal cutthroat transitionals and smolts captured in the Coweeman River juvenile screw trap, 2013.

			Fork Length (mm)				
Start	End	Production Estimate	Mean	SD	Minimum	Maximum	*n*
02/06/2013	02/11/2013	0	ND	ND	ND	ND	0
02/12/2013	02/18/2013	0	ND	ND	ND	ND	0
02/19/2013	02/25/2013	12	196.0	66.5	149	243	2
02/26/2013	03/04/2013	12	168.5	14.8	158	179	2
03/05/2013	03/12/2013	0	ND	ND	ND	ND	0
03/13/2013	03/19/2013	0	ND	ND	ND	ND	0
03/20/2013	03/25/2013	18	158.7	5.5	155	165	3
03/26/2013	04/01/2013	18	177.3	2.3	176	180	3
04/02/2013	04/08/2013	24	190.8	17.5	170	212	4
04/09/2013	04/15/2013	72	192.2	27.0	162	251	12
04/16/2013	04/22/2013	108	186.7	18.7	147	220	18
04/23/2013	04/29/2013	144	190.0	27.8	143	255	24
04/30/2013	05/06/2013	174	189.4	22.9	151	258	58
05/07/2013	05/13/2013	533	183.9	19.5	152	255	73
05/14/2013	05/20/2013	689	175.5	16.0	145	222	109
05/21/2013	05/27/2013	735	176.6	14.8	149	218	99
05/28/2013	06/03/2013	112	164.8	12.1	148	198	23
06/04/2013	06/10/2013	83	170.2	13.5	157	202	17
06/11/2013	06/17/2013	54	165.6	15.2	137	186	10
06/18/2013	06/24/2013	29	176.2	12.0	160	195	6
06/25/2013	07/01/2013	15	176.7	14.6	160	187	3
07/02/2013	07/08/2013	10	220.0	ND	220	220	1
07/09/2013	07/15/2013	0	ND	ND	ND	ND	0
07/16/2013	07/22/2013	0	ND	ND	ND	ND	0
07/23/2013	07/29/2013	0	ND	ND	ND	ND	0
07/30/2013	08/05/2013	0	ND	ND	ND	ND	0
08/06/2013	08/12/2013	0	ND	ND	ND	ND	0
08/13/2013	08/19/2013	0	ND	ND	ND	ND	0
08/20/2013	08/23/2013	0	ND	ND	ND	ND	0
		2,841	***179.3***	***17.5***	***137***	***258***	***467***