THE OREGON PLAN *for Salmon and Watersheds*

Calibration of Estimates of Coho Spawner Abundance in the Smith River Basin, 2001

Report Number: OPSW-ODFW-2002-06

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May 2002

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Funds supplied in part by:

Oregon Plan for Salmon and Watersheds

Citation: Jacobs S., 2002. Calibration of estimates of coho spawner abundance in the Smith River basin, 2001; Monitoring Program Report Number OPSW-ODFW-2002-06, Oregon Department of Fish and Wildlife, Portland, Oregon.

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INTRODUCTION

Estimates of coho spawner abundance derived from spawning surveys are a fundamental component of the Oregon Department of Fish and Wildlife's (ODFW) Oregon Plan Monitoring (Jacobs et al. 2001). The basis of these estimates are visual counts of adult spawners in randomly selected stream reaches. To date, survey-derived estimates have not been validated against known spawner abundances. Beginning in 1999, we initiated a study at Smith River (Umpqua Basin) to calibrate survey-based spawner estimates. Smith River provides an ideal location for this type of study because it is typical of many other coastal streams that support coho salmon, contains large quantities of habitat and spawners, and provides the ability to efficiently trap and tag adequate portions of the coho run. The objective of this study is to compare survey-based estimates to rigorous estimates derived from trapping and tagging coho at Smith River Falls. This document reports results obtained for the 2001 run year and discusses the implications of these results and the results obtained for the two prior years to the accuracy of coastal spawner abundance estimates.

APPROACH

Upstream migrating adults were trapped and tagged at Smith River Falls (river mile 30). The second capture event consisted of three components: (1) captures at a weir on the West Fork Smith River, (2) observations of live tagged and untagged fish spawning surveys, and (3) recovery of tagged and untagged carcasses on spawning surveys (Figure 1). Mark-recapture estimates were then calculated and compared to spawner estimates derived from extrapolation of randomly selected spawner surveys.

METHODS

Mark-Recapture Estimate

Upstream migrating coho were trapped as they used the fish ladder to pass Smith River Falls. Trapped fish were individually dip netted and placed into a hooded cradle for tagging. Once in the cradle, fish were measured for fork length, identified for species and sex, tagged and passed upstream. Fish were tagged with pink-colored floy t-bar anchor tags at the base of the dorsal fin. All fish received two tags, one on each side of the dorsal fin.

Tagged and untagged fish were recovered from three sources: West Fork trap, as carcasses recovered from spawning surveys and as live spawners observed on spawning surveys. All fish captured at the West Fork trap or recovered as carcasses were examined for the presence of tags, measured for length and had their sex determined. Counts of live coho observed on spawning surveys were broken into three categories: positively possessing at least one tag, positively untagged or uncertain whether tagged or not. Only the first two categories were used for mark-recapture estimates. Counts of live spawner were also kept separate for jacks ($\leq$ 50 cm fork length) and adults.

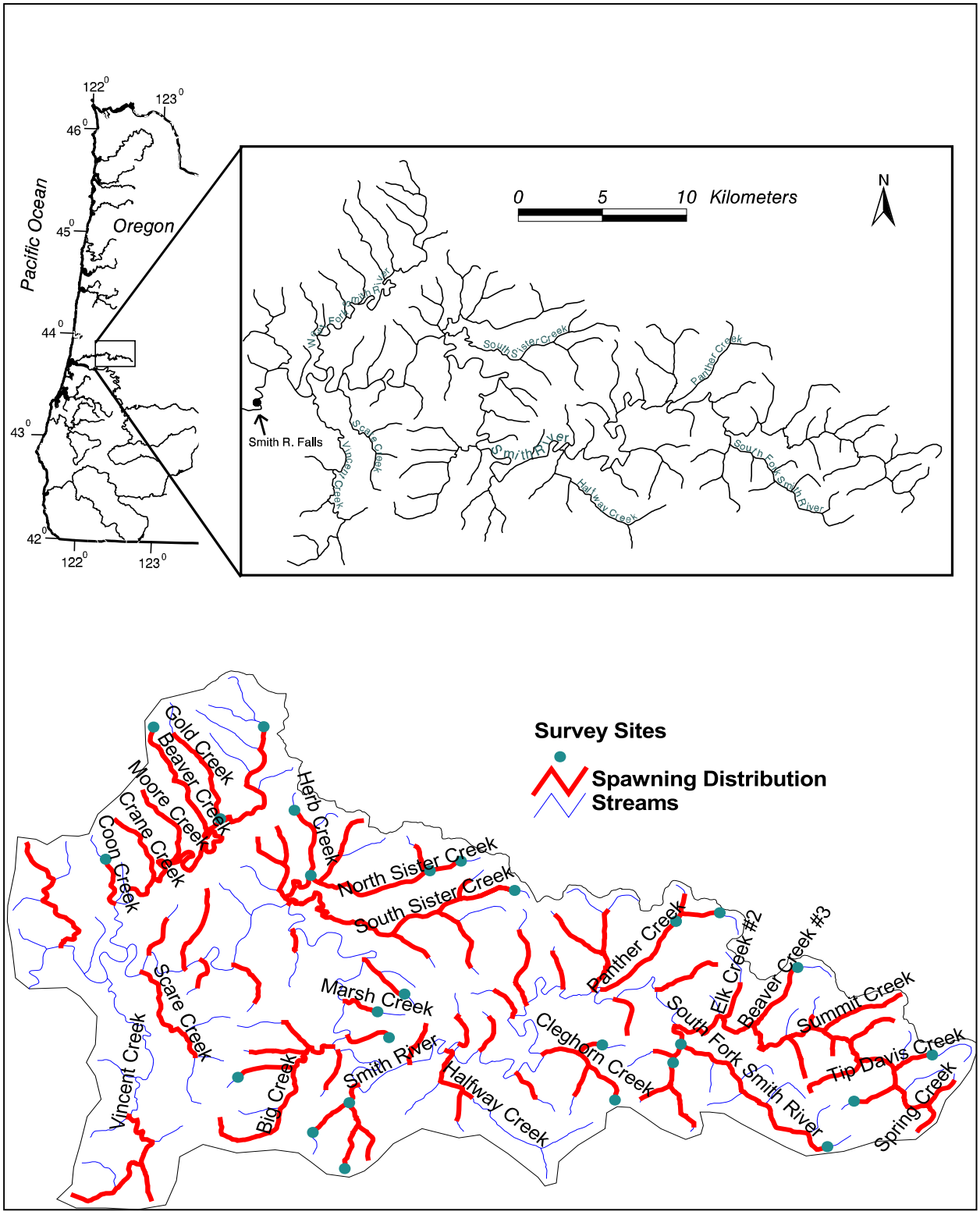


Figure 1. Maps showing the location of the Smith River Basin. Upper panel: location of study site including location of Smith River Falls. Lower panel: portion of Smith River basin where spawning surveys were conducted. Thick lines depict range of coho spawning distribution and points depict locations of spawning surveys.

The Chapman version of the Petersen mark/recapture formula (Ricker 1975) was used to estimate spawner escapement above Smith River Falls:

$$\hat{N}_i = \frac{(M+1)(C+1)}{(R+1)}$$

where

$\hat{N}_i$ = the estimated population of adult coho salmon above the falls.
M = the number of coho salmon tagged at the trap site.
C = the number of coho salmon sampled for tags.
R = the number of tagged coho salmon recovered.

Adjustments were made to the population of tagged fish based on the probability of losing one or both tags (Caughely 1977). This effectively reduced the population of tagged salmon available for recapture as a carcass. Assuming tag loss is independent of one another, the probability of losing a single tag was calculated using the following equation.

$$p = F_1/2F_2 + F_1$$

where

p = the probability of a single tagged salmon losing that tag.
F_1 = the number of carcass recoveries that retain one of the two original tags.
F_2 = the number of carcasses recovered with both tags.

The Petersen formula was modified to account for tag loss as follows:

$$\hat{N}_i = \frac{(M(1-p^2)+1)(C+1)}{(R+1)}$$

where

p^2 = the probability of a double tagged salmon losing both tags.

Confidence Intervals (95%) were calculated from a Poisson distribution as described in Ricker (1975). For the pooled estimate, a bootstrap analysis (Buckland and Garthwaite 1991) was used to calculate the confidence interval.

Spawning Survey Estimate

Spawning surveys randomly selected throughout the range of coho spawning habitat were used to estimate adult spawner abundance (Figure 1). Survey sites were randomly selected using the US Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) design (Stevens 2002). Survey sites were regularly visited throughout the spawning season to obtain Area-Under-the-Curve (AUC) estimates of spawner density (Jacobs et al. 2001). Spawner densities were used to generate an estimate of total spawner abundance using the method described in Stevens (2002). Briefly, this method extrapolates estimates of spawner density observed in spawner surveys to the estimated extent (frame) of spawning habitat in the target area (Smith River).

RESULTS AND DISCUSSION

Trapping at Smith River Falls

Of 1,657 adult coho (> 500 mm fork length) captured at the falls, 1,651 were tagged. Tagging occurred from 23 October through 14 January (Figure 2). Most fish were tagged during three major events that coincided with the first three freshets of the season. Approximately 90% of the fish were tagged by 15 November.

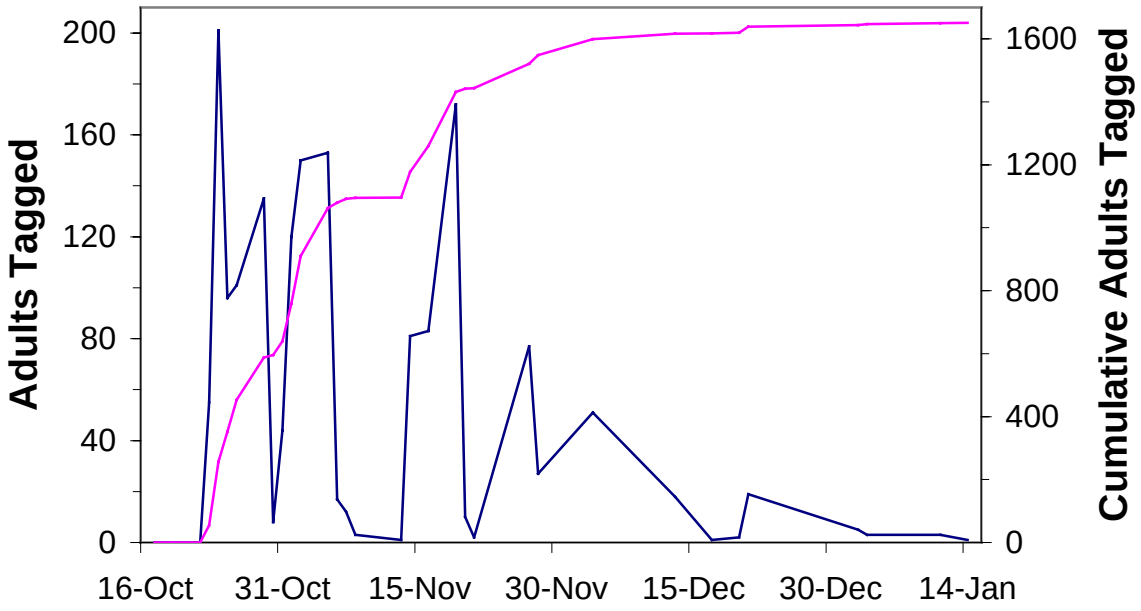


Figure 2. Timing of adult coho tagging at Smith River Falls during the 2001-02 season.

Recovery of Tagged Fish

Overall, 122 adult coho were recovered at the West Fork trap. Of these, 59 fish (48%) were tagged. No single-tagged fish were recovered, indicating that no tag loss occurred between the falls and the West Fork. The duration between tagging and recapture was quite variable, ranging from one to 25 days. However, unlike in 2000, there was no significant relationship between the date of tagging and the duration of time between tagging and recovery (Figure 3). There was an overall difference of 14% for sex determination at tagging versus recovery. The magnitude of discrepancy in length measurements between tagging and recovery averaged about 2% of the average of the two measurements, and ranged as high as 21%. The consistency of the data obtained for the same fish during tagging and tag recovery indicates that the accuracy of data collection in this study was high. Separate crews ran each trap.

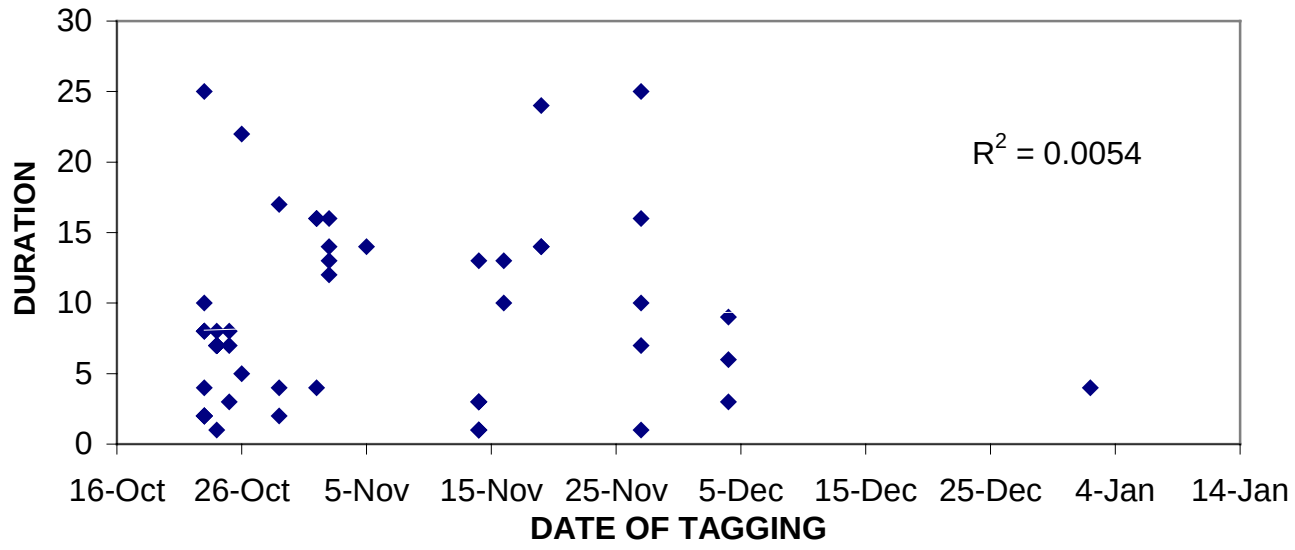


Figure 3. Relationship between the date of tagging of adult coho at Smith River Falls and the duration of migration (days) to the West Fork trap site, 2001.

At the West Fork trap, the timing of tagged and untagged recoveries differed (Figure 4). By the end of October, about 40% of the tagged fish were captured, whereas less than 10% of the untagged fish were captured by this date. High debris load prevented the trap from operating throughout most of the first half of November (Bruce Miller, ODFW Charleston, personal communication). It is likely that this was the period when many untagged fish migrated into the West Fork because the portion of fish passing Smith River Falls that were tagged decreased after the first freshet of the season.

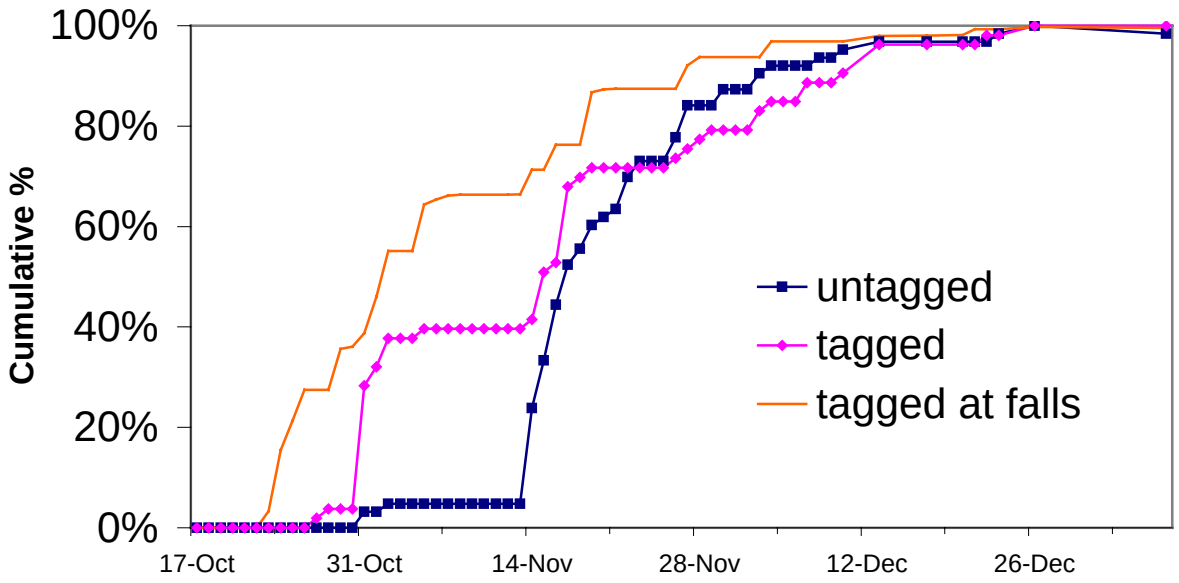


Figure 4. Cumulative frequency distribution of adult coho tagged at Smith River Falls and those recovered at the West Fork trap in 2001. Also shown are the recoveries of untagged adult coho at the West Fork trap.

It appears that the malfunction of the West Fork trap caused it to sample a biased portion of the run into the West Fork Smith River. The portion of tagged adult coho encountered on spawning surveys in the West Fork watershed differed markedly from that observed at the West Fork trap but was similar to that observed on surveys in other portions of the Smith River basin (Table 1). For both live spawner observations and carcass recoveries, the proportion of Falls-tagged fish was similar among surveys in the West Fork and surveys in other portions of the basin. However, the proportion of Falls-tagged fish in the West Fork trap catches was over twice that observed for any set of spawning survey sites. Because of this apparent bias, I did not use West Fork trap catches to estimate the population size of coho above Smith River Falls.

Table 1. Proportion of adult coho tagged at Smith River Falls in the sample of adult coho recovered or observed at the West Fork trap site or on spawner surveys, 2001.

Sampling Site	Spawned Carcasses	Live Spawners	Trap Catches
West Fork trap	--	--	48%
Spawning surveys in the West Fork	17%	23%[a]	--
Spawning surveys in remainder of basin	18%	22%	--

a *Assumed that 48% of the yellow-tagged recoveries were originally tagged at Falls.*

Three hundred fifty-seven adult coho carcasses were recovered on spawning surveys upstream from Smith River Falls. Of these, 57 had two tags and 8 retained one of the two originally placed tags. This equates to a 6.6% rate of single tag loss and a 0.4% rate of double tag loss. The life span between tagging and carcass recovery averaged 45 days and ranged form 18 to 85 days. There was a weak negative relationship between date of tagging and the duration between tagging and recovery (Figure 5). There was no apparent relationship between the distance of the recovery location from the Falls and the duration between tagging and recovery (R^2=0.04, p<0.12). There was an overall difference of 10% for sex determination at tagging versus recovery. The relationship between fork length at tagging and mid-eye-to-posterior-scale (MEPS) length at recovery was similar to that observed during 2000, however the precision of the relationship was not as high.

Surveyors observed 1,152 live adult coho on spawning surveys upstream from the falls. Of these fish, 1,073 were judged to be seen clearly enough to detect the presence or absence of tags. Two hundred forty live spawners (22%) were observed having at least one pink-colored tag. Because it is not possible to read tag numbers on live spawneres observed on spawning surveys, no data are available for assessing the relationship between tagging date and observation timing or spawning distribution.

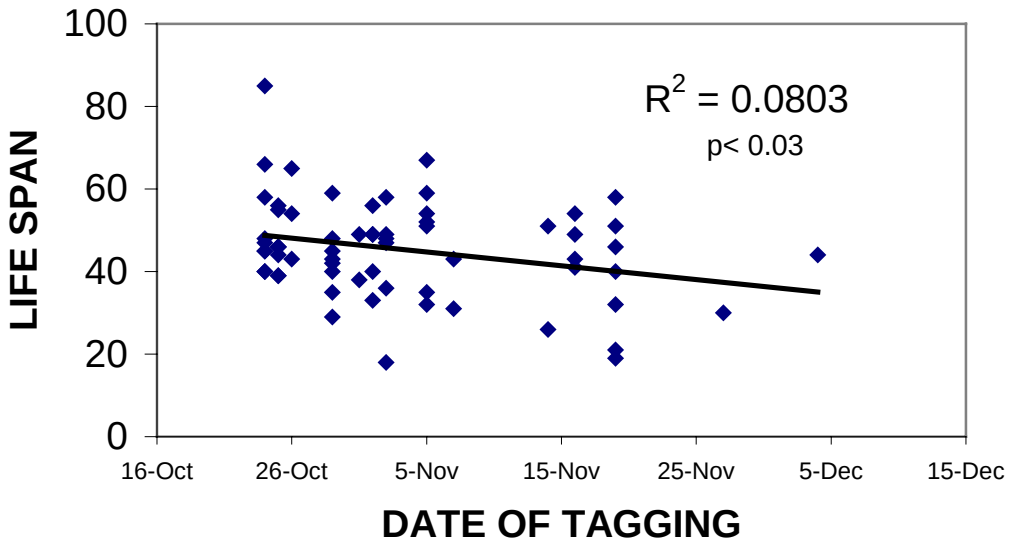


Figure 5. Relationship between date of tagging and the duration between tagging and recovery as spawned carcasses for Smith River adult coho, 2001.

Temporal and Spatial Distribution of Recoveries

A critical assumption of the mark-recapture methodology is that the marked and unmarked portions of the population behave in a similar manner and that each component is equally vulnerable to the second capture event used to estimate the marked-unmarked ratio. Based on the previous discussion, there is evidence that indicates that marked fish were more vulnerable to capture at the West Fork trap than were unmarked fish. It is not possible to directly compare the vulnerability of marked and unmarked fish to the sampling associated with spawner surveys, however we can compare their spatial and temporal distribution. Any differences in these parameters would suggest possible differences in vulnerability, and thus potential bias of resulting population estimates.

Figure 5 compares the temporal distribution of tagged and untagged fish observed as live spawners and of tagged and untagged fish recovered as carcasses. Data are shown as cumulative frequency distributions. In either sampling event, the timing of the occurrence of tagged and untagged fish is similar. Figure 6 compares the spatial distribution of tagged and untagged fish sampled on spawning surveys. Data are grouped by stream reach, with ascending reach numbers corresponding to streams located further upstream in the basin. For both carcasses and live spawners, the spatial distribution of sampling was similar. These results indicate that tagged fish mixed uniformly with the untagged population over the entire spawning season and throughout the portion of the basin where spawning surveys were conducted. This finding indicates that the tagging operation did not have any major effect on the migratory behavior or spawning distribution of the population. It is still possible that tagged fish had a higher vulnerability to being sampled on spawner surveys. The brightly colored pink tags that were used could have increased the probability of observing live spawners or recovering carcasses. If there was a bias associated with these tags, it was similar for live spawner observations and carcass recoveries. The tag rate of sampled carcasses was 18%, and was 22% for live spawners. These values are not significantly different from each other (Chi-Square, P=0.977).

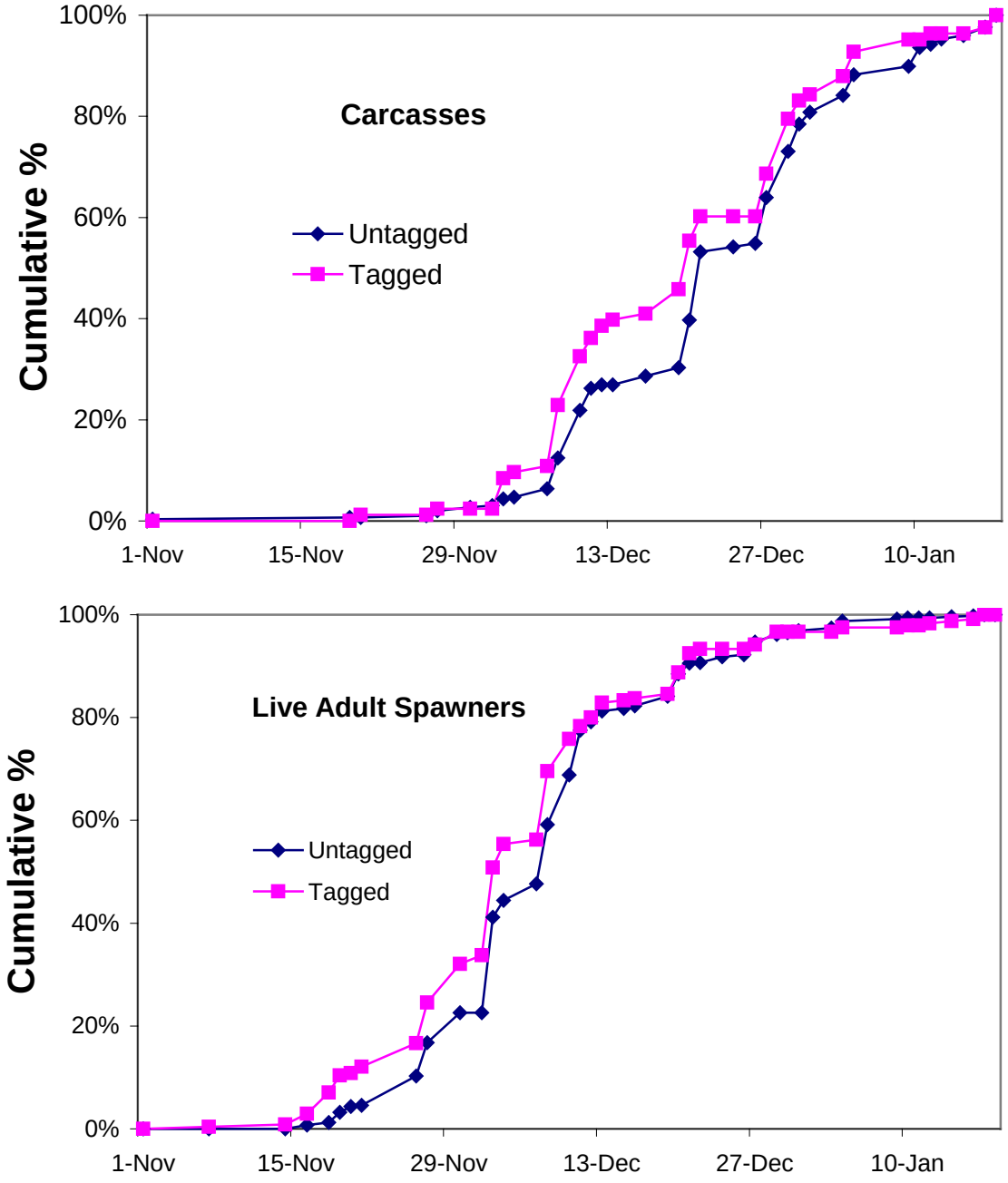
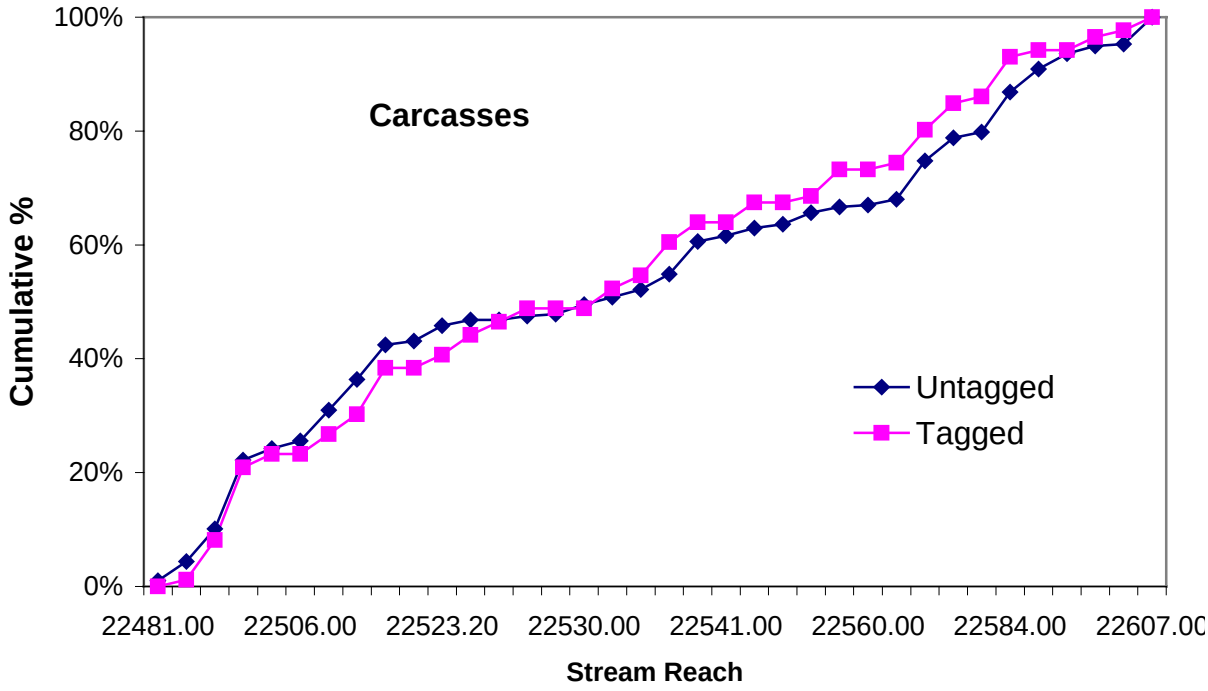


Figure 5. Cumulative frequency distributions of the timing of tagged and untagged adult coho recovered as carcasses or observed as live spawners on spawning surveys in the Smith River basin upstream from Smith River Falls, 2001.



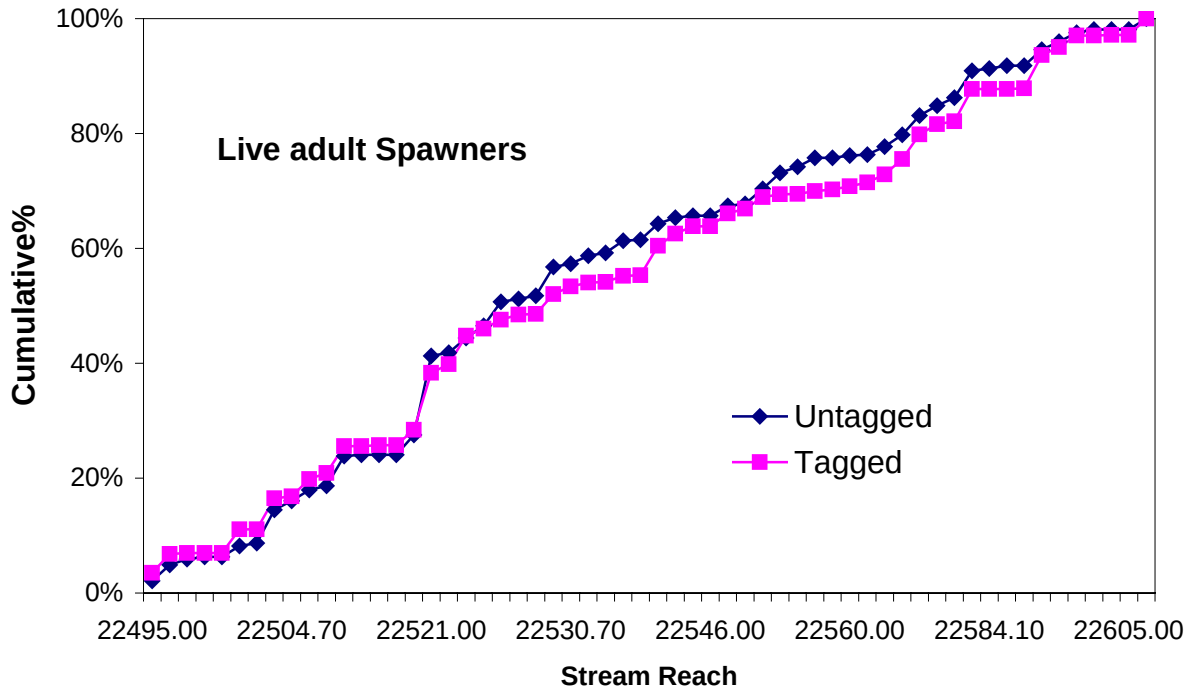


Figure 6. Cumulative frequency distributions of the spatial distribution of tagged and untagged adult coho recovered as carcasses or observed as live spawners on spawning surveys in the Smith River basin upstream from Smith River Falls, 2001. Ascending stream reach numbers correspond to streams located further upstream in the basin.

Mark-Recapture Population Estimates

Table 2 lists input values, population estimates and confidence limits for the spawning run of adult coho upstream from Smith River Falls. Point estimates ranged from about 3,300 spawners based on recoveries at the West Fork trap to 8,800 spawners based on carcass recoveries. The precision of the three estimates ranged between ± 22% to ± 11%, and was inversely proportional to the number of tagged fish recovered at each site. As previously discussed, the marked-unmarked ratio observed at the West Fork trap is likely biased, and therefore this estimate is not valid. There was no significant difference between the two remaining estimates derived from spawner sampling. Therefore, I pooled the data obtained from the spawner sampling as the best estimate of the marked: unmarked ratio. The resulting estimate has 95% confidence limits ranging from 7,097 to 7,727 adult coho.

Table 2. Estimate of adult coho escapement upstream of Smith River Falls derived from several recovery locations, 2001.

Recovery Location	Tagged	Sampled	Tags Recovered	Estimate	95% Confidence Limits
West Fork Trap	1,651	122	59	3,387	2,779 – 3,995
Spawning Survey Carcasses	1,626[a]	357	65	8,825	6,917 – 10,734
Live Spawners	1,626[a]	1,073	240	7,354	6,538 – 8,170
Pool of spawner recoveries	1,626[a]	1,430	305	7,720	7,097 – 7,727[b]

a *Tagged population has been adjusted to account for tag loss.*
b *Confidence Interval derived through bootstrap analysis.*

Estimate Based on Spawning Surveys

AUC estimates of spawning density were obtained from 30 randomly selected spawning survey sites upstream from Smith River Falls in 2001 (Table 3). On average, these sites were surveyed 11 times each over the course of the spawning season. The average date of peak observation was 5 December. Spawner densities ranged from 0 to 96 adults per mile. There was no discernable spatial pattern of spawner density; spawners were spread fairly uniformly throughout the watershed (Figure 7).

Using the EMAP protocol to calculate the adult spawner population from these surveys yields an estimate of 5,979 ± 1,066 fish. The 95% confidence limits of this estimate range from 4,914 to 7,045. This equates to a precision level of within ±18%. This level of precision was almost twice our preseason target of ±30% or the precision of the 2000 estimate (±32%).

Table 3. Results of randomly selected spawning surveys used to estimate the population abundance of adult coho spawners upstream from Smith River Falls, 2001.

Reach ID	Seg-ment	Name	Length (miles)	Times Surveyed	Adults/mile
22500.00	1	Coon Cr	0.74	11	50.0
22502.70	1	Moore Cr	0.77	11	46.7
22504.00	2	Beaver Cr	1.50	11	32.0
22505.00	1	Smith R, W Fk	0.49	11	95.7
22507.00	3	Smith R, W Fk, Gold Cr To Headwaters	1.06	11	50.9
22523.95	1	S Sister Cr	1.14	11	21.1
22526.00	2	N Sister Cr, Russell Cr To Herb Cr	0.90	12	18.9
22527.00	2	Herb Cr	1.24	10	8.9
22530.00	1	N Sister Cr, Sweden Cr To Trib A	0.90	12	20.0
22530.70	1	N Sister Cr	1.03	11	14.6
22535.00	1	Devils Club Cr	1.03	10	2.9
22537.00	1	Marsh Cr	0.43	13	34.9
22538.30	1	Rock Cr	0.25	11	0.0
22540.70	1	Big Cr, Trib B	1.24	12	52.3
22541.00	2	Big Cr	0.75	11	33.3
22545.00	1	Mosetown Cr	0.60	11	30.1
22546.30	1	Mosetown Cr, E Fk, Trib A	0.86	10	25.7
22546.70	2	Mosetown Cr, E Fk	0.72	10	25.0
22547.00	1	Mosetown Cr	1.03	11	27.2
22560.00	1	Cleghorn Cr, Trib B	0.81	12	8.6
22563.00	1	Cleghorn Cr	0.75	12	12.0
22577.00	1	Panther Cr	1.33	9	34.6
22577.00	2	Panther Cr, Mouth To Trib A	1.24	10	22.5
22577.70	1	Panther Cr	1.35	10	28.1
22583.00	1	Smith R, S Fk	0.81	12	18.4
22584.00	1	Smith R, Little S Fk, Mouth To Trib 1	0.96	12	28.1
22585.00	4	Smith R, S Fk	0.97	12	34.0
22589.00	2	Beaver Cr	1.03	9	28.2
22605.00	1	Tip Davis Cr	1.00	10	0.0
22607.00	1	Sleezer Cr	1.24	10	28.9

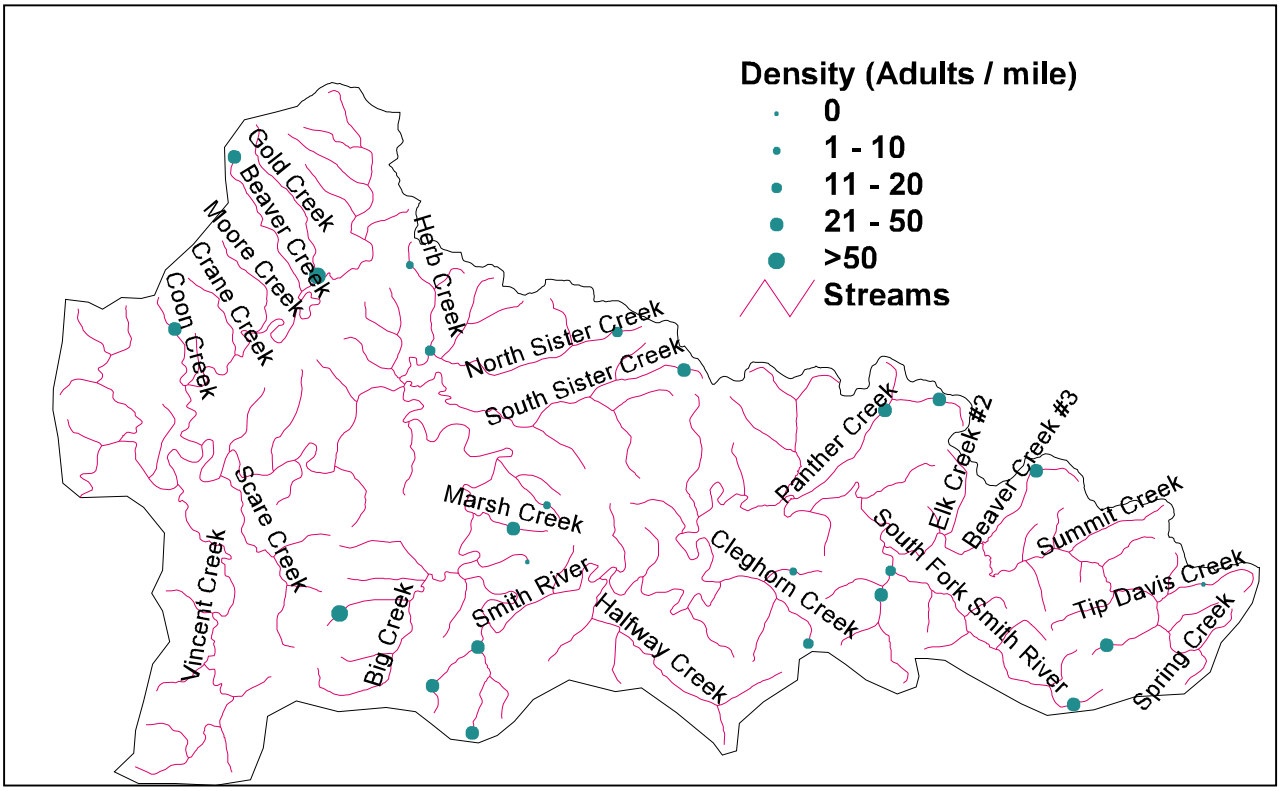


Figure 7. Spatial pattern of adult coho spawner density in randomly selected survey sites in the Smith River Basin upstream from Smith River Falls, 2001.

Comparison of Estimates

The upper bound of the survey-based confidence interval is within 52 fish of the lower bound of the pooled mark-recapture estimate indicating that, within the levels of precision for each estimate, there is a small but significant difference between the two estimates. If you assume that the pooled mark-recapture estimate is unbiased, then it appears that the survey-based estimate in Smith River for 2001 has a slight negative bias. This is consistent with the results observed in 1999 and 2000 (Figure 8). In these years, there was also a suggestion of a slight negative bias associated with survey-based estimates, although this bias was not significant given the precision of the estimates. Although it is difficult to draw conclusions with only three years of data, these results show an average overall negative bias of 27% associated with survey-based estimates.

There are three factors that could contribute to surveys yielding negatively biased spawner abundance estimates: (1) under counting fish on surveys, (2) applying an estimate of spawner life span that is longer than actual and (3) using a sampling frame that underestimates the true amount of spawning habitat. The degree that each of these factors contribute to bias would be difficult to assess. Given this, in the quest for accurate coast-wide spawner abundance estimates, our best approach may be to develop calibration factors from Smith River and possibly other sites and use these to adjust survey-based estimates. If Smith River is assumed to accurately reflect the conditions that occur for spawning surveys conducted throughout coastal watersheds, findings from this study to date indicate that coastal spawner abundance estimates of adult coho derived from random spawning surveys should be increased by 27%.

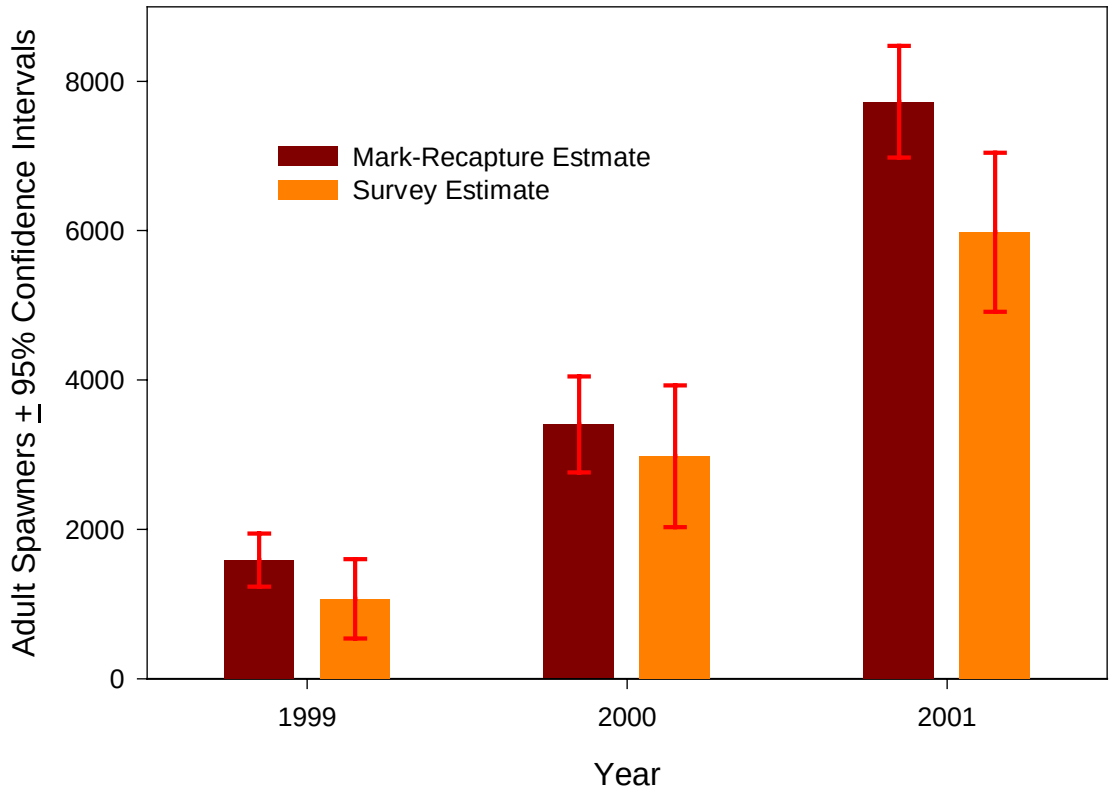


Figure 8. Comparison of estimates of adult coho spawner abundance in the Smith River Basin upstream from Smith River Falls for 1999-2001 derived from mark-recapture and spawning surveys.

ACKNOWLEDGEMENTS

This study would not have been possible without the dedicated and diligent work of the field staff. Accordingly, I would like to thank Dave Harris, Bill Cannaday and Dave Chambers of the Umpqua District for conducting trapping and tagging at Smith River Falls; Bruce Miller and his crew for conducting the sampling in the West Fork Smith River; and Ross Hubbard, Karen Cradler, Brent Reed and Thomas Lossen for conducting the spawner surveys. LaNoah Babcock did an exemplary job of entering the data. The report was improved by the reviews of Mario Solazzi and Tom Nickelson.

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