Lower Columbia River Coho Status Report 2002 – 2004: Population abundance, distribution, run timing, and hatchery influence.

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Executive Summary

This report provides an assessment of abundance, distribution, spawn timing, and hatchery:wild ratios of spawning adult coho salmon (*Oncorhynchus kisutch*) based on EMAP spawning surveys in the Oregon portion of the Lower Columbia River in the 2002, 2003, and 2004 spawning seasons. The Oregon portion of the Lower Columbia River Evolutionarily Significant Unit (ESU) extends from the mouth of the Columbia River to the Hood River, excluding areas above Willamette Falls. Analysis is conducted at the population complex level, six subsets of the ESU defined during Oregon Department of Fish and Wildlife Status Review (Chilcote 1999).

Population characteristics, most notably the proportion of wild spawners and spawn timing, vary among complexes. Interannual variation within complexes over the last three years is linked to streamflow variation. Most hatchery straying occurred within complex, though the Bonneville complex received strays from further upriver. Abundance increased in areas without evidence of hatchery inputs. Abundance goals established by the ODFW endangered species management plan (Chilcote 2001) in the Clackamas (>1900 adults) and Sandy (>670 adults) have been met the last two years; however, spawner densities and the proportion of wild spawners are lower than on the Oregon Coast.

Introduction

Wild coho salmon (*Oncorhynchus kisutch*) abundance in the Columbia River basin once averaged 618,000 adults (Chapman 1986) but declined to critical low levels in the 1980s (Chilcote 1999). Peak spawner counts conducted since 1949 at ten index sites throughout the Lower Columbia River (LCR) tributaries show a pattern of decline to low levels in the late 1970s and 1980s and continuing on to zero for most years in the 1990s (Ollerenshaw 2003). In 1999, naturally produced coho in the LCR basin were listed as an endangered species by the State of Oregon and in 2005 were listed as threatened under the federal Endangered Species Act (NMFS 2005).

The Oregon Department of Fish and Wildlife's (ODFW) endangered species management plan for LCR coho calls for increased monitoring of wild populations (Chilcote 2001). This project applies the EMAP sampling design developed for coastal Oregon watersheds (Firman and Jacobs 2001) to coho spawning ground surveys in the LCR, enhancing adult spawner assessment and providing a framework for future juvenile and habitat monitoring. This report describes the results of adult spawner surveys conducted during the 2002-2003, 2003-2004, and 2004-2005 spawning seasons during which we measured population attributes such as abundance, distribution, and spawn timing as well as hatchery:wild ratios.

Estimates of parental escapement provide information that feeds into a variety of processes. Parental escapement, with the marine survival index, determines allowable exploitation rates and is a criterion for de-listing (Chilcote 2001). Spawner abundance explains 88% of the variation in juvenile outmigrant abundance in the upper Clackamas River (Cramer and Cramer 1994) and is necessary to determine productivity. Trends in parental escapement, together with distribution patterns, can determine the success of recovery programs. Coho spawn timing, which is highly heritable in coho salmon (Hager and Hopley 1981), can be used to differentiate between populations. External mass marking and coded wire tagging of hatchery produced coho from Oregon Lower Columbia hatcheries allows us to evaluate hatchery straying, with scale analysis providing insight into areas with unmarked hatchery coho.

Methods

Study Area

The lower Columbia River/Southwest Washington coho Evolutionarily Significant Unit (ESU) includes all naturally spawned populations in Columbia River tributaries downstream of the Deschutes River including coastal streams in Washington from the Columbia River to Point Grenville (NMFS 2005). The Oregon portion of the ESU has been tentatively divided into nine historically independent populations (McElhany 2005); the Oregon State recovery plan divides the LCR into six population complexes (Table 1, Figure 1) (Chilcote 2001) of which the Clackamas complex has been divided into early and late run components (Zhou and Chilcote 2004). Analyses for this report are conducted at the population complex level.

Monitoring Design

The Environmental Monitoring and Assessment Program (EMAP) was used to provide a random, spatially balanced selection of sites (Stevens 2002). The selection frame represents our best knowledge of the totality of spawning habitat. In 2002 the selection frame was created by adapting StreamNet's 1:100k coho spawning distribution GIS coverage (StreamNet 2002). The selection coverage did not include habitat above

Marmot Dam, on the Sandy River, or North Fork Dam, on the Clackamas River. We selected 124 points, balanced over the entire ESU. In 2003, in anticipation of future juvenile and habitat surveys, points were selected across all 100k streams and survey points later selected by overlaying the spawning distribution coverage. One hundred seventy four points fell within an expanded coverage that included all spawning habitat on the Sandy and Clackamas Rivers. The 2003 100k sites were used again in 2004, using results from the 2003 sampling to adjust the sample frame and exclude areas above North Fork Dam. In addition to the random EMAP points, ten index spawning surveys, on which peak spawning counts have been conducted since 1949, were surveyed with the same protocol as the EMAP sites.

EMAP points were assigned to about a one mile segment of stream within an existing reach framework. In the June and July preceding each spawning season field crews assessed the habitat quality and site accessibility of new sites. Sites were considered inaccessible if the time to walk into the segment, conduct the survey, and return exceeded three hours and were considered denied if landowners did not grant permission to access the segment. If no habitat was found or if a point was above a permanent, impassible barrier it was considered a zero and that area was removed from the spawning distribution coverage. Field crews also noted habitat and land use variables and recorded permanent (i.e. waterfalls) and impermanent (i.e. culverts) complete and incomplete barriers to salmon migration.

Spawner Surveys

Beginning in the middle of October four two-person crews repeatedly surveyed each site at least once every ten days. Surveyors counted the number of live salmon, noting the presence or absence of adipose fin-clips and separately tallying jacks (≤ 43 cm MEPS (mid-eye to posterior scale) length). Qualitative information on survey conditions such as flow and turbidity were also recorded.

Carcasses found in surveys were examined for fin-clips and tags and MEPS length and sex were recorded. Scale samples were taken from the key scale area from all carcasses. Fin rays for DNA analysis were removed from all non adipose-clipped fish. Snouts were removed from adipose-clipped carcasses to recover coded wire tags (CWT) except at specific sites in the Astoria, Clackamas, and Bonneville complexes where the large number of clipped coho or unclipped hatchery coho necessitated the use of snout wands. The tails of sampled carcasses were removed to prevent rehandling.

Data Analysis

The area-under-the-curve (AUC) technique was used to estimate the total number of coho salmon adults spawning in a given stream segment over the course of the spawning season (Jacobs et al. 2002). Spawning coho were assumed to have an average spawning life of 11.3 days throughout the ESU (Beidler and Nickelson 1980, Perrin and Irvine 1990). Peak counts and the contribution of hatchery spawners in each complex were estimated as in Jacobs et al. (2002). Abundance and timing calculations were not done for stream segments which did not meet criteria for a qualified survey (Jacobs et al. 2002).

Spawning escapement was calculated using the Horvitz-Thompson estimator (Diaz-Ramos et al. 1996). Variance estimates were calculated using the local mean variance estimator. Escapements were calculated for the ESU as a whole with each population complex considered as a separate stratum (Diaz-Ramos et al. 1996).

To determine the temporal distribution of spawners the season was separated into Julian weeks beginning October 1st. The number of adult coho for each period relative to the total coho observed in the complex were summed in each population complex and normalized for effort by dividing the sum of live adults by the sum of miles surveyed during that period.

Stream flow information was obtained from USGS NWISWeb (USGS 2005). Statistical comparisons were conducted with t, χ^2, and GLM-ANOVA tests. Comparisons between all three years exclude data above North Fork and Marmot Dams and the Bonneville complex.

Results

EMAP Efficacy

In 2002 124 EMAP points were drawn across the spawning habitat frame, of which 106 (85%) were verified as within spawning habitat and 87 (70%) were successfully surveyed. The 2003 master sample provided 174 sites, of which 146 (84%) were verified as target sites and 98 (56%) were successfully surveyed. After revisions in the sample frame the 2003 master sample provided 167 sites in 2004 of which 154 (92%) were within spawning habitat and 103 (62%) were successfully surveyed.

Most ineffective surveys (73%) were in the Clackamas and Sandy complexes where problems with accessibility and stream conditions affected success rates. Sites were inaccessible because of steep canyons, snow at higher elevations, and lack of landowner permission. Mainstem reaches of the Sandy River, while still considered spawning habitat, proved impracticable to survey. Stream flashiness and turbidity affected survey rotations in areas such as Johnson Cr and Beaver Cr.

The EMAP master sample did not provide an adequate number of sites in the Bonneville complex. This selection method also did not provide any sites in the western section of the Clatskanie complex. Areas with a low number of spawning miles relative to the number of 100k streams miles may not have a consistent spatial balance with this method.

EMAP estimates above complete barriers in 2003 and 2004 underestimated passage counts by 5 – 10 times at the North Fork and Marmot Dams (Table 3).

Spawn Timing

Spawn timing differed in each population complex as a result of interactions between population characteristics and stream flow patterns. Timing of early freshet events affected the timing of early spawning in complexes with early returning coho.

Interannual variation (streamflow)

Inception of spawning appeared correlated to streamflow conditions for both early and later spawning populations. Streamflow in each year is characterized by a series of peaks and troughs. The timing and duration of those features varied from year to year and by location (Figure 2). Coastal locations tended to have earlier peaks than interior locations.

In 2002 streamflow was extremely low in until November with a second peak in December. The beginning of spawning was correlated with the increase in streamflow. Coho in Astoria and Clackamas reacted strongly to the increased flows, with counts peaking soon after flows increased (Figure 3). December peaks in Clatskanie and Scappoose appear associated with the December streamflow peak.

Streamflow increased in the beginning of October in 2003. Surveys did not start until mid October, so the beginning of spawning activity cannot be correlated with streamflow conditions; however, the streamflow trough and subsequent pickup in November are mirrored in the coho counts in Astoria and Clackamas. Following the October trough streamflow did not appear to be a limiting factor for the rest of the spawning season.

In 2004 early streamflow levels were higher than average throughout September into November. Subsequent flow events were limited to a single mid-December storm. Low flow conditions throughout most of the Clatskanie and Scappoose complexes delayed spawning until the mid-December storm event, upon which counts increased dramatically. Pre-December observations in the Clatskanie were almost entirely confined to areas downstream of the Falls Cr falls. A small response to the December event was observed in the Sandy complex but not in the Clackamas.

Spatial timing patterns (intercomplex variation)

In addition to interannual timing variation due to streamflow conditions spawn timing also varied by location (Figure 3). The Astoria and Clackamas complexes had the earliest timing, with fish present as soon as flows allowed or as soon as surveys started. Spawning was completed by December in Astoria; a small proportion of the total run was present each year in Clackamas in December. We observed intermediate spawn timing in the Sandy and Bonneville complexes. Whereas spawning was usually finished by December in the Bonneville complex a modest proportion of the spawning in the Sandy complex occurred in December. The latest spawning coho were seen in the Clatskanie and Scappoose complexes, with limited spawning continuing into January.

Above North Fork Dam in 2003 the coho spawning within the first two weeks of surveys (October 15th – 29th) consisted of 79.3% of total adults observed (89.8% adjusted for survey effort). No coho were seen above the dam after November 18th, 2003.

Hatchery and wild coho spawn timing

Spawn timing comparisons of adipose-clipped and unclipped coho cannot be done for all population complexes because of low numbers of observed clipped or unclipped coho in the Clatskanie, Scappoose, and Sandy complexes and because fin clips are not an accurate record of hatchery status in the Bonneville complex. Naturally produced coho, however, have been found spawning throughout the spawning period in all population complexes whereas hatchery produced coho finished spawning earlier.

There was no significant difference between naturally produced and hatchery produced coho timing in Astoria in any year (Figure 4). In Clackamas in 2002 the difference between marked and unmarked coho timing was not statistically significant (t_{11}=0.37, P=0.72) and in 2003 too few clipped coho were observed for a comparison; however, in 2004 the differences were significant (t_{11}=3.15, P<0.01) (Figure 4).

Abundance and Distribution

Abundance

Estimates of wild coho escapement were not significantly different among the years surveyed (Table 2). Estimates for the Bonneville complex in 2003 and 2004 are unavailable as only one EMAP survey in the complex was conducted. The precision of wild coho estimates was within ± 35% in 2002 and ± 24% in 2003 and 2004. Precision in individual complexes ranged from ± 34% – ± 71%. Including the area above North Fork Dam increases the Clackamas wild estimate in 2003 to 560 ± 318.

Average annual coho peak counts in the ten standard surveys ranged from twenty one to eight coho/mile from 2002 – 2004, which are higher than the low period of the 1980s and 90s, but below the average for the period from 1949 – 1971 (Figure 5). With three years of data there is no relationship between coho density in standard surveys and EMAP surveys ($F_{1,2}$=1.32, P=0.46).

Distribution

Distribution of coho spawners was more even in 2003 and 2004 than in 2002 (Figure 6). The top 10% of surveyed segments in 2002 accounted for 76% of the total estimate compared to 47% in 2003 and 55% in 2004. 57% of surveys were occupied in 2002 compared to 59% in 2003 and 67% in 2004.

In the Astoria complex coho density is highest near hatchery release sites such as the South Fork Klaskanine Pond and the Big Creek Hatchery with low to moderate densities in adjacent streams such as the Lewis and Clark River (Figure 9a).

In the Clatskanie complex low to moderate densities were measured throughout the complex (Figure 9b). All surveyed sites were occupied in 2003 but no spawners were observed in surveys above Falls Creek Falls in 2002.

In the Scappoose complex the highest densities were seen on the North and South Fork of the Scappoose River with moderate densities in the Milton Creek subbasin (Figure 9c).

Below North Fork Dam in the Clackamas complex the highest densities occurred in the Eagle Creek subbasin and in the lower Deep Creek drainage (Figure 9d). Moderate densities also occurred at surveyed sites in the Clear Creek subbasin. No coho spawners were seen in Johnson, Tryon, or Abernathy Creeks. No spawners were found at the majority of surveyed sites in the upper Clackamas (Figure 9d). The highest density above North Fork Dam was in the Oak Grove Fork.

Densities in the Sandy complex are low to moderate, with no coho seen at surveys towards the upper end of distribution (Figure 9e).

Densities are high throughout the Bonneville complex within a very small distribution (Figure 9f).

Phenotypic Characteristics

The female:male ratio was 1.14 and did not vary among population complexes ($p=0.22$, $\chi^2 = 6.97$, $df = 5$). There was an association between population complex and jack ratios ($p < 0.001$, $\chi^2 = 25.75$, $df = 5$). In the Astoria complex 23% of male carcasses recovered were jacks, 14% in the Clatskanie complex, 17% in the Scappoose complex, 3% in the Clackamas complex, none in the Sandy, and 5% in the Bonneville complex. There was a significant year x population complex interaction for adult coho spawner MEPS length ($p<0.001$, $F_{17,1159}=6.85$).

Hatchery:Wild Ratios

The relative abundance of hatchery produced coho observed on spawning surveys varied from 0 – 94% among population complexes (Table 4). Unclipped or unknown coho were observed in 34% of streams in 2002, 39% in 2003 and 46% in 2004.

The Astoria complex had the largest number of smolts released in the most locations from a variety of stocks (Appendix I). Hatchery coho made up the majority of carcasses recovered throughout the complex (Table 4, Figure 10a). Live adipose-clipped coho were also seen in areas with low spawner density such as the Lewis and Clark River. Twenty-two coho carcasses containing coded wire tags (CWT) were recovered in

2002 and 14 in 2003 in Astoria. The majority of tagged coho were recovered in the stream where they were released but tagged coho were recovered throughout the complex (Figure 11), for example a coho released in the Klaskanine River was found in the Lewis and Clark River. A stray from the Little White Salmon NFH, located at river mile 162 on the Columbia River, found in Big Creek represents the an extreme level of straying.

The Clatskanie complex contains two stream regimes. Adjacent to the Astoria complex to the west are a group streams descending from the steep bluff; coho spawning habitat is located in short segments between the steep drops and tidal Columbia River sloughs. This section is dominated by hatchery produced spawners (Figure 10b), with only one non adipose clipped coho observed in this area. To the east in the Clatskanie River and its tributaries primarily naturally produced coho have been observed (Figure 10b). No hatchery produced carcasses were recovered in this section in any year, with four clipped live coho observed in 2004. No tagged coho were recovered in the Clatskanie complex.

Spawners observed in the Scappoose complex were predominately naturally produced (Figure 10c). In 2003 two adipose clipped carcasses were recovered. In 2004 six clipped carcasses were recovered; all but one was observed in Goble Cr and included a tagged coho from Kalama hatchery.

In the Clackamas complex hatchery produced coho made up 69% of spawning coho seen in the Eagle Creek and Deep Creek drainages; however, in 2003 hatchery fish were present but in a lower proportion (Figure 10d). No hatchery produced coho were observed in the Clear Creek drainage in any year or above North Fork Dam in 2003.

Two tagged coho were recovered in 2002 (Figure 10d) which were released from Eagle Cr NFH.

In 2002 and 2003 combined only four carcasses, of which one was clipped, were recovered in the Sandy complex. However, in 2002 49 live observations were made, of which 47 were marked, in a single survey. No marked carcasses were recovered in 2004 (Figure 10e).

Carcass fin-marks in 2002 indicated that 35.2% of coho spawning in the Bonneville complex were naturally produced; however, scale analysis indicates that only 25.0% of unclipped fish were wild. Scale analysis indicates that 54.5% of unclipped coho were wild in 2003 and 61.7% in 2004. All CWT were recovered in Viento Creek. One CWT tag recovered in 2002 and 12 CWT recovered in 2003 were released from Little White Salmon/Willard NFH directly across the Columbia River from Viento Creek. Four CWT (25%) recovered in 2003 were released in the Wenatchee River Basin in the upper Columbia River.

H:W ratios by date

From 1984 to 2001 coho spawning peaks were not recorded until after December 1st in an effort to exclude hatchery coho. This method did not agree with recovered carcass mark ratios, providing a higher estimate of hatchery influence in all areas but the Scappoose in 2004 (Figure 7). Live observations and carcass recovery of hatchery produced coho occurred after December 1st in every year, markedly more so in 2002 (62 live observations, 160 carcasses) than in 2003 (7 live, 13 carcasses) and 2004 (9 live, 10 carcasses).

Discussion

Sampling Design

The survey success rate in the Lower Columbia River (LCR) of 62% over the past three years is similar to the overall success rate on the Oregon Coast of 61% over the past seven years (Sounhein in prep). Despite a less developed spawning habitat frame and large areas of privately owned land spatially balanced random sampling was successfully conducted in most areas of the LCR. The exception was the Bonneville complex, in which only one site was surveyed using the master sample method of survey design despite a sample density of 1.26/mile (2000 sites over 2534 stream miles). The absence of such a problem from the 2002 and 2005 draw over spawning habitat suggests that using a master sample in areas with a small amount of patchy habitat may not be effective.

EMAP estimates above the North Fork and Marmot Dams did not corroborate dam passage counts. Recent changes in the timing of coho spawning above North Fork Dam (Cramer and Cramer 1994) make it unlikely our current survey protocol would be effective in this area. The majority of coho were found in the mainstem and Oak Grove Fork of the Clackamas River, from RM 53 – RM 73, consistent with radio tagging results (Shibahara et al. 2001) and other distribution data (Cramer and Cramer 1994) for early-run upper Clackamas coho. However, the early portion of the run spawns very early; our survey start date of mid-October missed most of this run. The late portion of the run is late enough that temperatures in tributaries may be too cold for spawning (Cramer and Cramer 1994). Radio tagging of late-run coho found spawning primarily occurred in the mainstem Clackamas River from RM 33.5 – RM 50.3 with limited spawning in the tributaries Fish Creek and Clackamas North Fork (Cramer and Merritt 1992). These areas are too large to be successfully surveyed with our visual survey protocol. No late-run coho were observed at surveyed tributary sites, supporting Cramer and Merritt's (1992) findings.

A calibration study was been underway since 1999 in the Smith River portion of the Lower Umpqua. As at Marmot Dam, survey based estimates were lower than alternative estimates (dam passage counts at Marmot, mark-recapture in Smith River) (Jacobs 2001, Moore in prep.). Possible explanations for the negative bias of survey based estimates include underestimating visual observation bias, overestimating spawner residence time, and spawning outside of the sampling frame (Jacobs 2001). Coho have been absent from the highest surveys in the Sandy complex, indicating that the upper end of distribution may be incorrect; however, coho spawning may occur in mainstem areas of the Sandy. Revisiting the spawning residency and visual observation bias assumptions may improve survey based estimates.

Coastal comparison

Wild coho density, distribution, and H:W ratios are weaker compared to the Oregon Coast. In 2004 coho density was 5.9 coho/mile in the LCR contrasted with 44.2 coho/mile on the Oregon Coast (Sounhein in prep). Similarly, in 2004 63% of surveys had at least one live coho in the LCR compared to 83% on the Oregon Coast. Across the LCR ESU in 2004 58% of spawners were naturally produced versus 97% coastwide (Sounhein in prep.). Coho escapement in the LCR has improved compared to the 1980's and 1990's but runs are not as strong as on the Oregon Coast.

Population complex comparisons

Though wild coho abundance did not vary significantly among most population complexes (Table 2) abundance does not tell the whole story, as differences among complexes become apparent when other factors are considered. Spawn timing and the proportion of hatchery to naturally produced coho are two of the factors that vary the most among complexes.

Spawn timing is a heritable trait in coho (Hager and Hopley 1981) and other salmonid species (Quinn et al. 2002). Differences in run timing among groups may be linked to genetic differences and could be used to distinguish stocks (Quinn et al. 2002). Early timing is generally selected for during hatchery operations (Quinn et al. 2002) such that early spawn timing is considered evidence of hatchery origin (as in Ollerenshaw 2003). Our results support this idea; Astoria and Clackamas, the complexes with the earliest timing (Figure 3), are also the complexes with the highest proportion of hatchery produced coho (Table 4). However, there are distinctions between these two complexes as well. There are still differences between the timing of hatchery and wild coho in the Clackamas, but naturally produced coho share similar timing characteristics to hatchery coho in the Astoria complex (Figure 4). There are areas in the Clackamas, such as the Clear Creek subbasin (Figure 10d), where no hatchery coho have been found, but hatchery coho have been observed throughout the Astoria complex (Figure 10a). This indicates there may be wild remnants in the Clackamas but not in Astoria suitable for recolonizing areas as habitat is rehabilitated and barriers removed (Flagg et al. 1995, Chilcote 2003). The full extent of hatchery straying in Astoria and Clackamas is still unknown, however, as in 2003 and 2004 coho were observed on the first surveys conducted, indicating that some activity was missed. Surveys in 2005 will begin as early as September.

Similarly the areas with the lowest numbers of hatchery strays also had the latest spawn timing, Clatskanie and Scappoose. Post December 1st peak spawner counts in index surveys were very low throughout the 1990's; from 1987 to 1999 only three coho were seen at the four index surveys within the Scappoose complex (Ollerenshaw 2003). The low level of straying observed into these complexes suggests coho in the complex have rebuilt without substantial input from outside the complex.

Streamflow – spawning interactions

These results also show the interactions between streamflow conditions and spawn timing and distribution. The low wild coho abundance estimate in the Clatskanie in 2002 is probably an artifact of a shift in distribution caused by low streamflow. Coho may not have had access above Falls Creek Falls on the Clatskanie and much of the lower mainstem Clatskanie, where fish may have spawned instead, was not then recognized as spawning habitat. Understanding these interactions also affects how we look at past data. In an effort to avoid counting hatchery produced coho previous index surveys were not started until the end of November from 1984 to 2001 (Ollerenshaw 2003). Using this technique for 2002 – 2004 data produced H:W estimates that did not match carcass mark recoveries and varied from year to year based on differences in streamflow (which affected timing) rather than differences in H:W among years (Figure 7). High peak counts in 1986 and 2000 (Figure 5) may have more to do with changes in flow conditions specific to those years than changes in coho abundance. Additionally, wild coho historically entered spawning streams in October and November (Chilcote 1999) and hatchery produced coho were seen after December 1st, especially in the low streamflow year of 2002.

Oregon state delisting criteria

The ODFW endangered species management plan (Chilcote 2001) presents minimum criteria for de-listing LCR coho based on population distribution, diversity, abundance, connectivity, and resilience.

The population distribution and structure criterion requires that self-sustaining wild populations are present in the Sandy, Clackamas, and at least two other complexes. Counts have increased in the Clackamas complex in areas with little or no evidence of hatchery influence such as the Clear Creek subbasin and above North Fork Dam. Dam passage counts in the Sandy complex indicate that above Marmot Dam abundances have increased without hatchery input; below Marmot Dam, though, abundances at surveyed sites have been low and hatchery influenced. High spawner densities in the Astoria and Bonneville complexes appear to be the result of hatchery straying; however, increases have been observed in the Clatskanie and Scappoose complexes without signs of hatchery subsidization.

Abundances are required to be at least 50% the level necessary to produce maximum smolt recruits in the Sandy, Clackamas, and two other complexes for three consecutive years. This is currently estimated as 670 spawners in the Sandy, 1900 in the Clackamas, and an unknown number in the other complexes. This goal was not met in 2002 but was surpassed in 2003and 2004 if dam passage counts are added to below dam survey estimates.

The diversity criterion requires that naturally produced coho are present in 65% of historical spawning distribution and that artificial selection pressures and hatchery impacts are minimized. Unmarked adult coho were found in 58% of sites surveyed during the three years. The Sandy and Clackamas complexes had the highest rates of surveys with no observed spawners. Some diversity in run timing has been maintained (Figure 3) but this project did not determine the extent that artificial selection still shapes phenotypic characteristics. Ongoing impacts of hatchery fish on wild coho seem to be minimal in the Scappoose complex and sections of the Clatskanie, Clackamas, and Sandy complexes. Hatchery produced coho still have large impacts in the Astoria and Bonneville complexes and sections of the Clackamas and Sandy complexes.

Artificial barriers that prevent the dispersal of wild coho exist in the LCR. This project has documented the success of previous barrier removals and will be able to measure the success of future improvements. Adam Creek (Clatskanie) was surveyed before (2002) and after (2004) culvert replacement near the mouth, documenting fish presence after improvement. We will also be able to document changes following the removal of Marmot Dam and Little Sandy Dam in 2007 – 2009.

Conclusions and Recommendations

- An EMAP survey design was successfully implemented in the Lower Columbia.
    - Further tests of residence time, visual bias, and spawning habitat estimates will improve survey based abundance estimates.
    - Surveys need to begin in September to describe the full extent of hatchery straying
- Abundances have increased in areas without hatchery inputs.

    - Additional releases may not be necessary to recover depressed populations.
    - Abundance goals in the Clackamas and Sandy have been met in the last two years.
    - Occupancy rates are still below goals.
- There are differences in population characteristics among population complexes.
  - CWT recoveries indicate hatchery straying is largely within complex. The exception is the Bonneville complex, in which strays were found from upriver.
  - Astoria has high levels of hatchery straying throughout the complex, and naturally produced coho have similar timing as hatchery produced coho.
  - In Clackamas hatchery straying is limited to certain areas and naturally produced coho retain separate timing characteristics.
  - The Clatskanie and Scappoose complexes had very low levels of straying and the latest spawn timing.
- There are interactions between interannual streamflow variation and spawn timing and distribution.
  - Streamflow can affect the timing of both early and late spawning populations.
  - Multiple years of data are necessary to elucidate population characteristics.
  - Historical index surveys with fixed cut-off dates may not provide consistent trend estimates.

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Table 1. Lower Columbia River coho salmon population complexes.

Complex Name	Description	Total Stream Miles	Coho Spawning Miles	Percent Spawning Miles Surveyed (Average)
Astoria	All Columbia tributaries from mouth upstream to, and including, the Gnat Creek basin.	367	82	21%
Clatskanie	All Columbia tributaries upstream of Gnat Creek to and including the Clatskanie River Basin.	287	53	21%
Scappoose	All Columbia River tributaries upstream of Clatskanie River to but not including the mouth of the Willamette River	377	69	24%
Clackamas	The Clackamas River basin and all tributaries of the Willamette River downstream of Willamette Falls	1337[a]	256	10%
		557[b]	147	16%
Sandy	All Columbia River tributaries upstream of the mouth of the Willamette River to and including the Sandy River basin.	684[a]	101	18%
		169[c]	26	14%
Bonneville	All Columbia River tributaries upstream of the Sandy River to and including the Hood River.	819	11	5%

a *Entire basin.*

b *Downstream from North Fork Dam.*

c *Downstream from Marmot Dam.*

Table 2. Lower Columbia River coho salmon escapement estimates for the 2002 - 2004 spawning seasons (estimates are derived from counts in random EMAP spawning surveys).

					Adult Coho Spawner Abundance[a]			
			Survey Effort		Total		Wild[b]	
Year	Population Complex	Spawning Miles[c]	Number of Surveys	Miles	Estimate	95% Confidence Interval	Estimate	95% Confidence Interval
2002	Astoria	71.3	15	16.2	4,472	2,760	281	173
	Clatskanie	36.9	17	13.4	229	164	104	74
	Scappoose	64.5	19	18.8	452	174	452	174
	Clackamas[d]	117.3	28	30.5	3,689	2,306	850	531
	Sandy[e]	26.3	4	3.4	339	530	0	0
	Total	**316.3**	**83**	**82.3**	**9,182**	**3,599**	**1,685**	**592**
	Bonneville	7.0	4	1.0	1,078	761	178	125
2003	Astoria	80.6	21	18.1	1,459	652	217	97
	Clatskanie	39.0	10	8.3	563	217	563	217
	Scappoose	60.2	16	15.0	354	164	319	148
	Clackamas	117.2	18	14.7	684	468	385	263
	Sandy	101.5	18	17.4	219	108	204	101
	Total	**398.5**	**83**	**73.5**	**3,280**	**862**	**1,687**	**397**
	Bonneville	10.5	1	0.4	12,050		3,040	
2004	Astoria	72.1	20	18.1	1,385	715	142	73
	Clatskanie	49.1	14	11.5	398	177	398	177
	Scappoose	66.3	18	16.7	786	269	722	247
	Clackamas[d]	132.9	28	25.0	1,511	722	963	460
	Sandy	108.0	22	19.1	320	200	320	200
	Total	**428.4**	**102**	**90.4**	**4,400**	**1,095**	**2,545**	**590**
	Bonneville	10.0	1	0.4	8,040		4,153	

a *Estimates derived using EMAP protocol and adjusted for visual observation bias.*

b *Estimates of wild spawners derived through application of carcass fin-mark recoveries in random survey sites, except in the Sandy complex in 2002 and 2003 where observations of live fin-marked fish were used and in the Bonneville complex where results of scale analysis were applied.*

c *EMAP sampling estimate of the total habitat.*

d *Excludes spawning habitat upstream of North Fork Dam.*

e *Excludes spawning habitat upstream of Marmot Dam.*

Table 3. Adult coho salmon counts at complete barriers in the lower Columbia River in the 2002 - 2004 spawning seasons (marked coho are not passed above North Fork or Marmot Dams).

Year	Barrier (Population Complex)	Wild[a]	Total	Percent Wild[a]
2002	Bonney Falls (Scappoose)	66	66	100%
	North Fork (Clackamas)	864	1007	85.7%
	Marmot (Sandy)	289	289	100%
2003	Bonney Falls (Scappoose)	40	41	97.5%
	North Fork (Clackamas)	2105	2117	99.4%
	Marmot (Sandy)	1199	1204	99.6%
2004	Bonney Falls (Scappoose)	39	39	100%
	North Fork (Clackamas)	1761	1763	99.9%
	Marmot (Sandy)	1047	1069	97.8%

a *The number of wild coho is adjusted for hatchery releases in that complex.*

Table 4. **Mark rates based on observations of adipose fin clips on live and dead coho spawners in random coho surveys during the 2002 - 2004 spawning seasons (values are adjusted for mark rates of local hatchery releases).**

	2002				2003				2004			
	Live		Carcasses		Live		Carcasses		Live		Carcasses	
Population Complex	Total	% Marked	Total	% Marked	Total	% Marked	Total	% Marked	Total	% Marked	Total	% Marked
Astoria	357	94.2%	214	93.7%	127	65.8%	63	85.2%	198	68.1%	96	89.7%
Clatskanie	10	80.4%	11	54.8%	73	0.0%	17	0.0%	44	9.1%	20	0.0%
Scappoose	66	0.0%	52	0.0%	69	0.0%	20	10.1%	136	3.0%	61	8.2%
Clackamas	342	29.4%	278	77.0%	55	7.7%	29	43.7%	113	28.1%	39	36.3%
Sandy	50	100.0%	1	0.0%	15	7.0%	3	34.8%	36	0.0%	12	0.0%
Bonneville[a]	202	82.9%	138	85.4%	192	34.0%	76	38.5%	317	23.4%	36	19.4%
Total	1027	64.5%	694	77.6%	531	29.0%	208	47.4%	844	29.5%	264	42.5%

a *Live % Marked is corrected for scale analysis results which indicate that 76.5% in 2002, 28.4% in 2003, 19.4% in 2004 of unmarked coho were of hatchery origin. Carcasses % Marked is based on scale analysis.*

Table 5. Lower Columbia River coho salmon density estimates for the 2002 – 2004 spawning seasons (estimates are derived from counts in random EMAP spawning surveys).

			Survey Effort		Adult Coho Spawner Density[a] Total		Wild[b]	
Year	Population Complex	Spawning Miles[c]	Number of Surveys	Miles	Estimate	95% Confidence Interval	Estimate	95% Confidence Interval
2002	Astoria	71.3	15	16.2	62.7	9.4	3.9	0.6
	Clatskanie	36.9	17	13.4	6.2	1.5	2.8	0.7
	Scappoose	64.5	19	18.8	7.0	0.7	7.0	0.7
	Clackamas[d]	117.2	28	30.5	31.5	3.5	7.3	0.8
	Sandy[e]	26.3	4	3.4	13.0	13.1	0.0	
	Total	**316.2**	**83.0**	**82.3**	**29.1**	**13.0**	**5.3**	**2.2**
2003	Astoria	80.6	21	18.1	18.7	2.2	2.7	0.3
	Clatskanie	39.0	10	8.3	14.4	2.0	14.4	2.0
	Scappoose	56.0	16	15.0	5.9	0.7	5.3	0.6
	Clackamas	226.4	32	25.6	4.4	0.6	2.5	0.3
	Sandy	101.5	18	17.4	2.2	0.3	2.0	0.3
	Total	**503.5**	**97.0**	**84.4**	**7.1**	**2.3**	**3.7**	**1.1**
2004	Astoria	72.1	20	18.1	19.2	3.3	2.0	0.3
	Clatskanie	49.1	14	11.5	8.1	1.2	8.1	1.2
	Scappoose	66.3	18	16.7	11.8	1.3	10.9	1.2
	Clackamas[d]	132.9	28	25.0	11.4	1.3	7.2	0.8
	Sandy	108.0	22	19.1	3.0	0.5	3.0	0.5
	Total	**428.4**	**102.0**	**90.4**	**10.3**	**3.7**	**5.9**	**1.9**

a *Estimates derived using EMAP protocol and adjusted for visual observation bias.*

b *Estimates of wild spawners derived through application of carcass fin-mark recoveries in random survey sites, except in the Sandy complex in 2002 and 2003 where observations of live fin-marked fish were used and in the Bonneville complex where results of scale analysis were applied.*

c *EMAP sampling estimate of the total habitat.*

d *Excludes spawning habitat upstream of North Fork Dam.*

e *Excludes spawning habitat upstream of Marmot Dam.*

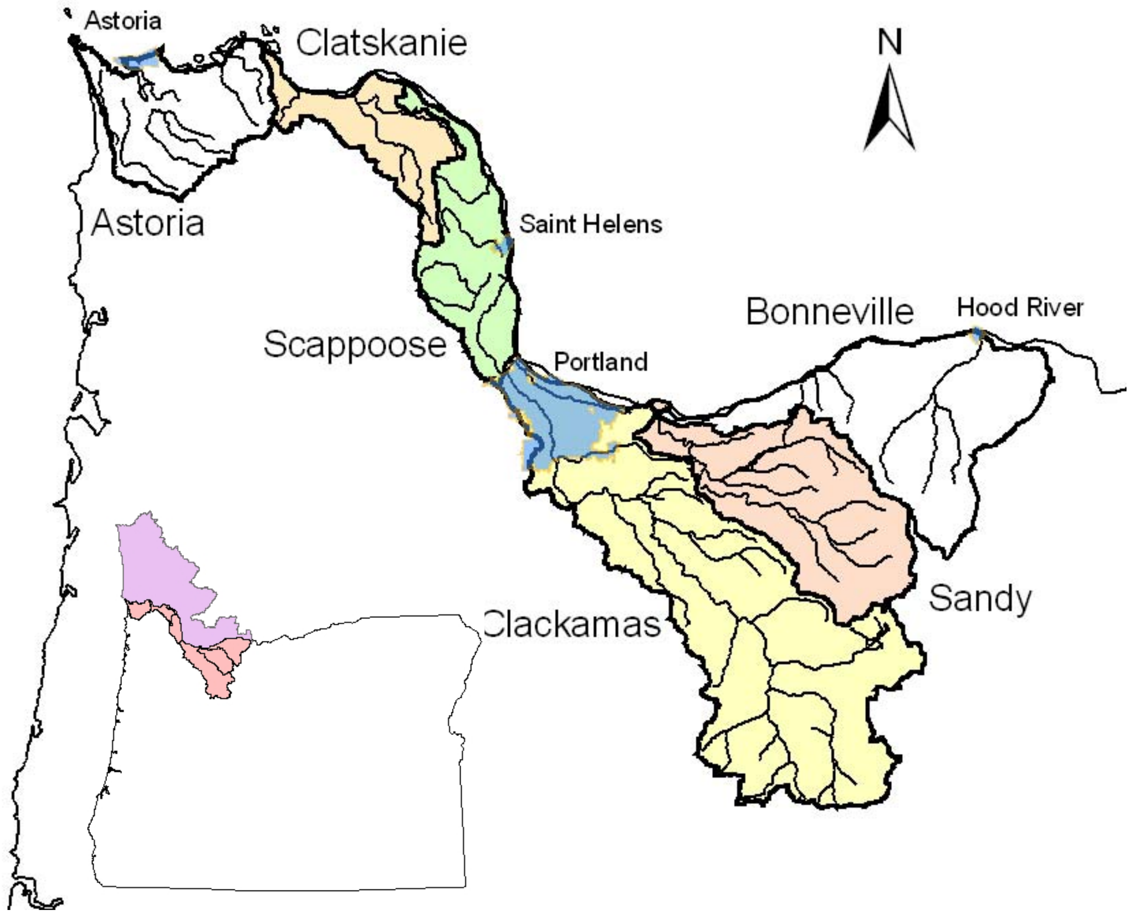


Figure 1. The Oregon portion of the lower Columbia River ESU with the boundaries of the Astoria, Clatskanie, Scappoose, Clackamas, Sandy, and Bonneville population complexes and area cities.

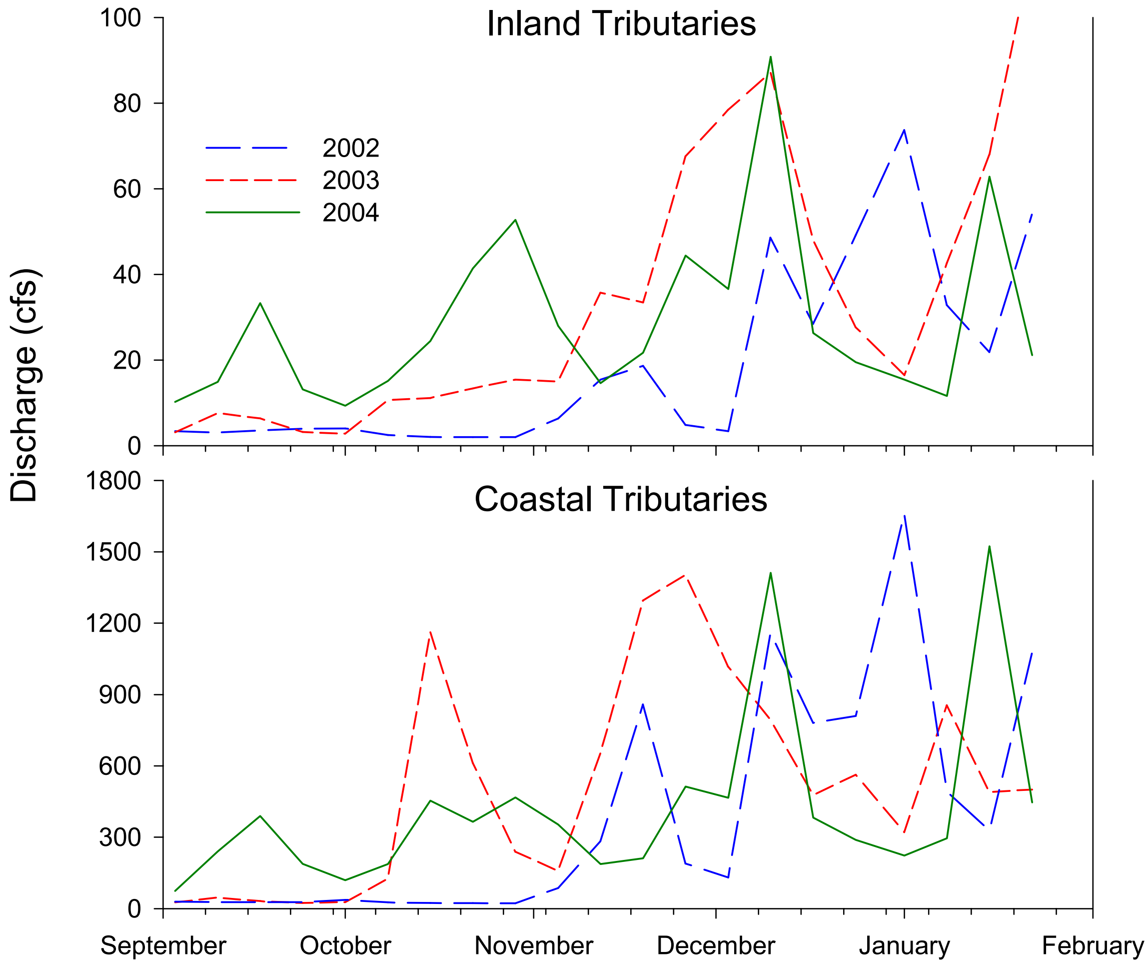


Figure 2. Flow regimes in lower Columbia River inland (Fir Creek, upper Bull Run basin) and coastal (Naselle River, coastal SW Washington) tributaries. Values are averaged by Julian week. The inland mean is based on a 28 year time series and the coastal mean is based on a 72 year time series.

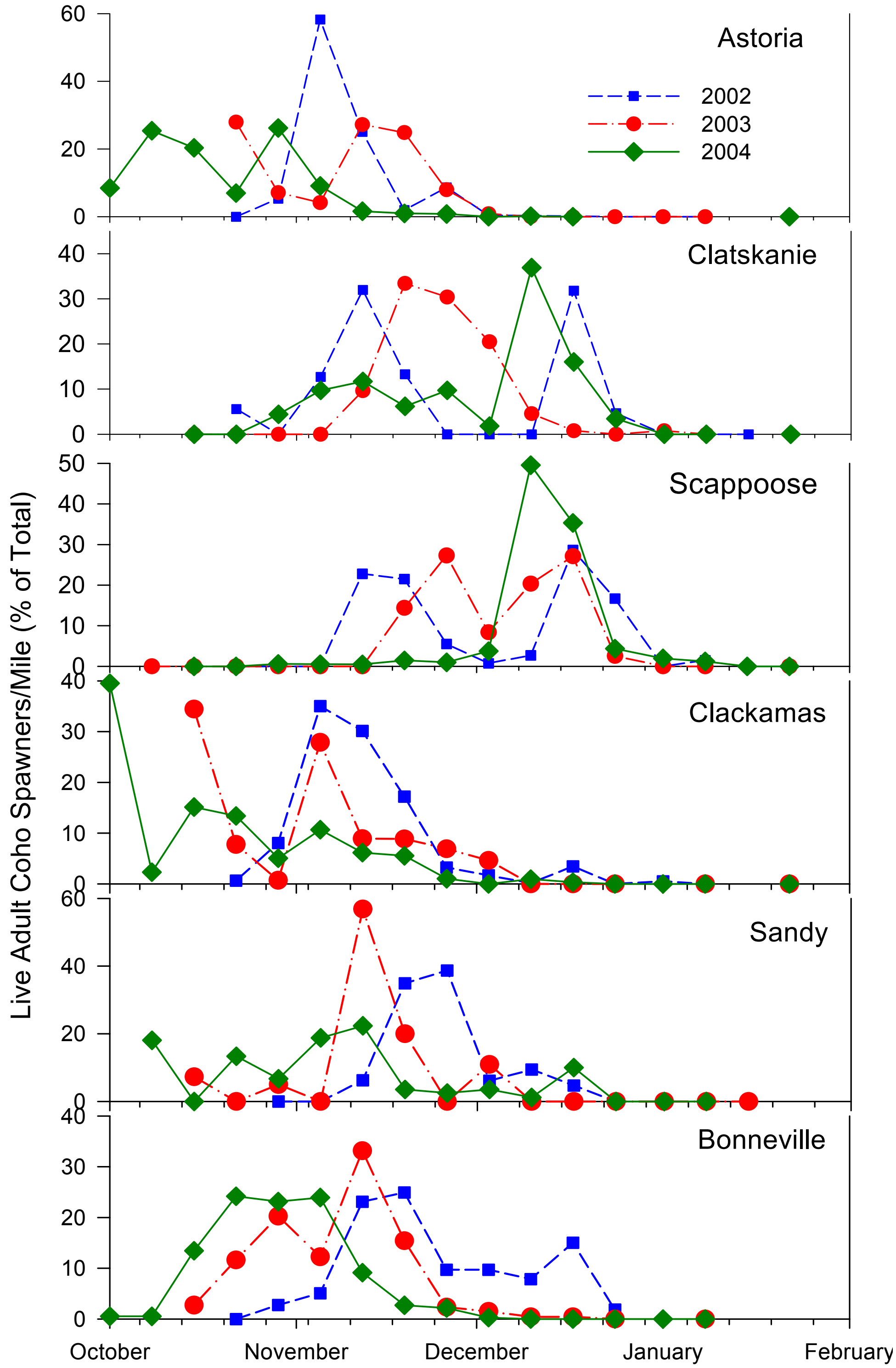


Figure 3. Temporal distribution of spawning coho salmon within each population complex during the 2002 and 2003 spawning season. Values represent the percentage of total live adults observed in surveyed EMAP segments by Julian week adjusted for survey effort. Surveys with poor visibility were excluded.

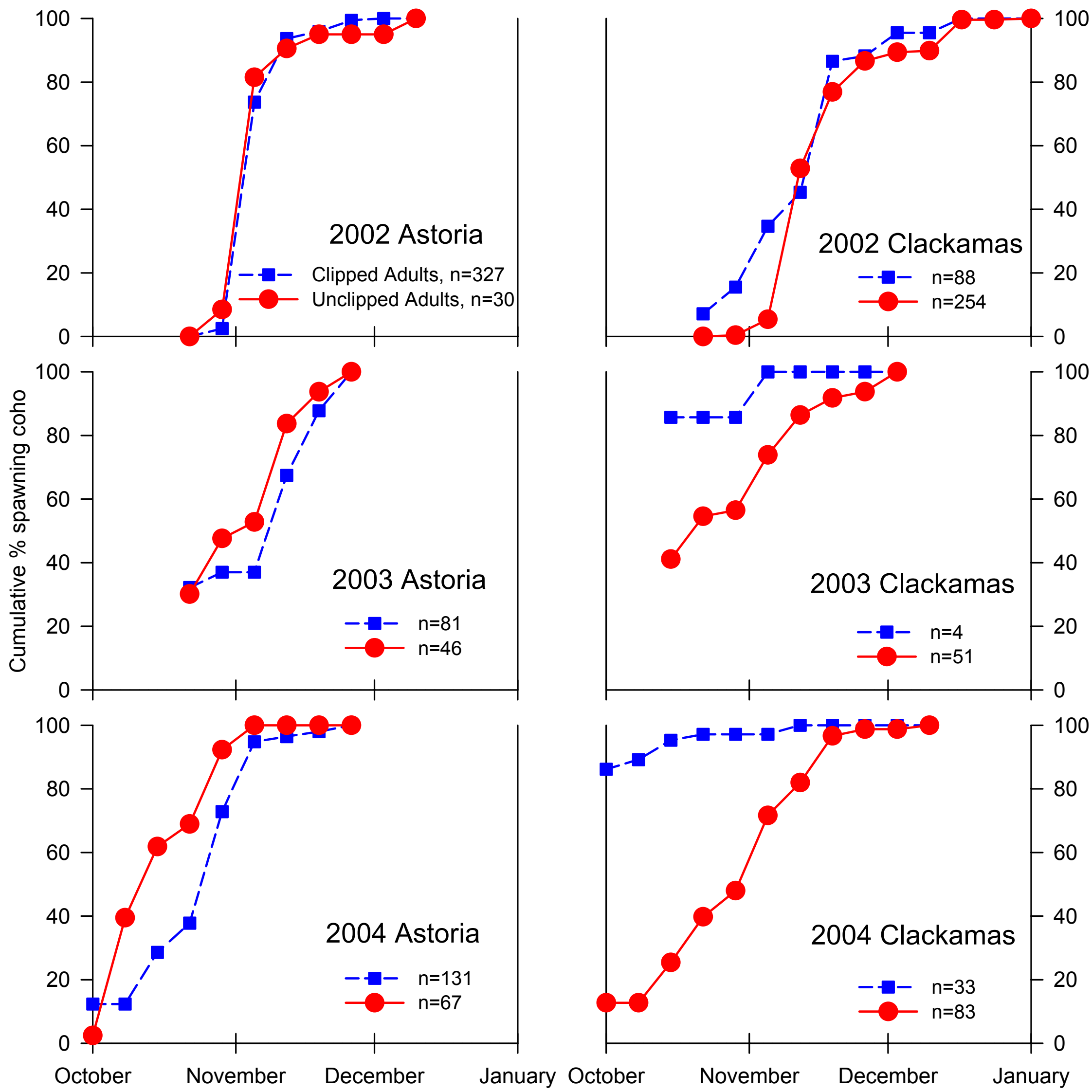


Figure 4. The cumulative temporal distribution of adipose-clipped (–■–) and unclipped (–●–) coho in the Astoria and Clackamas population complexes during the 2002 – 2004 spawning seasons. Values represent the cumulative percentage of total live adults observed in surveyed EMAP segments by Julian week adjusted for survey effort. Surveys with poor visibility were not included.

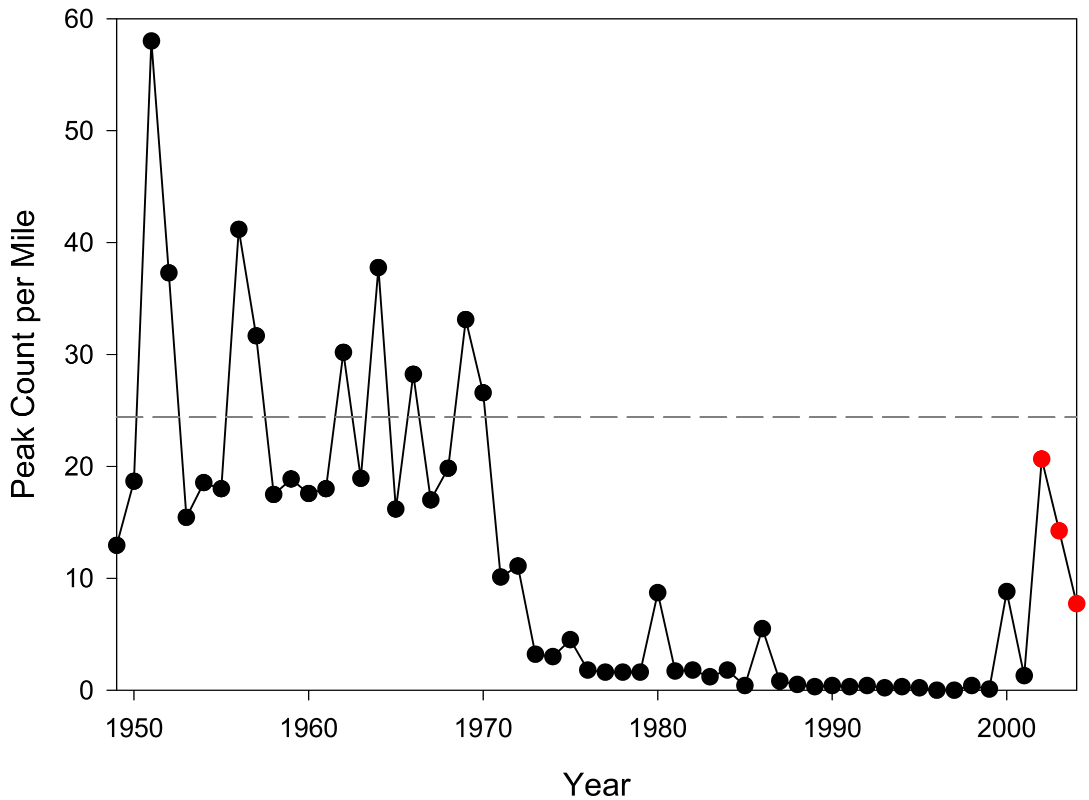


Figure 5. Average annual coho peak counts from Lower Columbia spawner index surveys with the average for the period from 1949–1971. From 1984 to 2001 counts were only recorded after December 1st in an attempt to exclude hatchery produced coho.

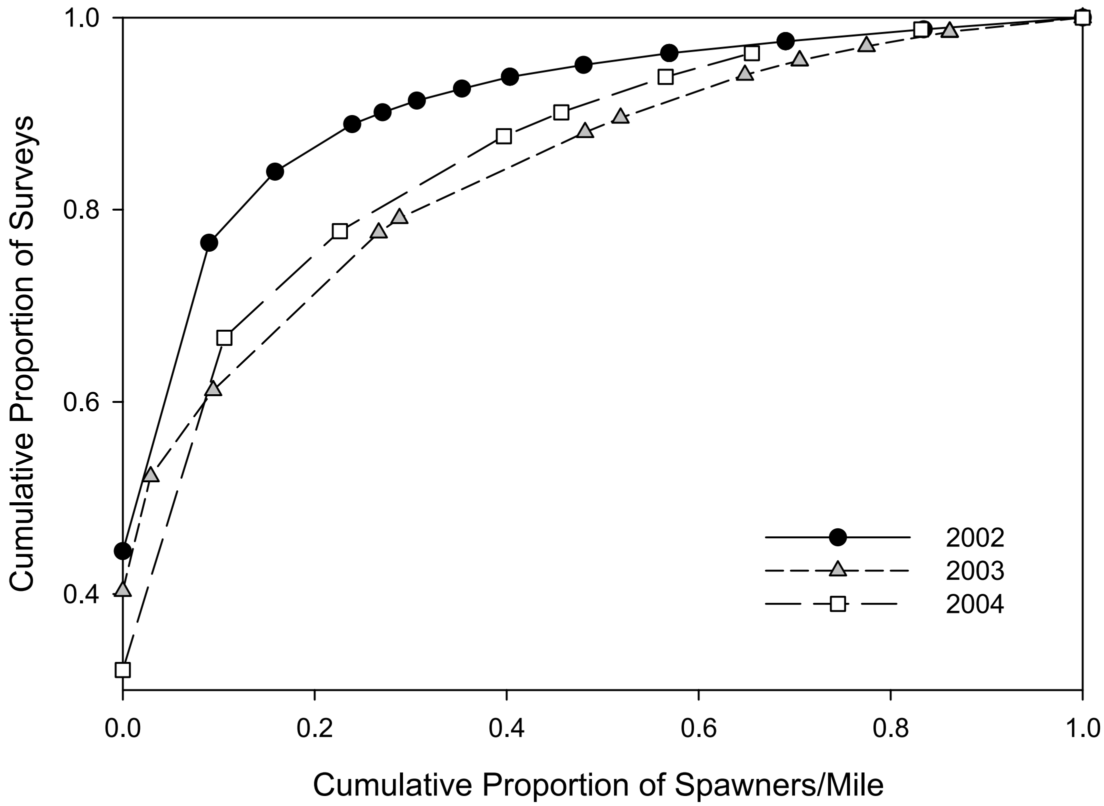


Figure 6. Cumulative proportion of total spawner density among surveyed segments during the 2002 – 2003 spawning seasons. To facilitate comparisons between years we excluded surveys above North Fork and Marmot Dams and in the Bonneville complex.

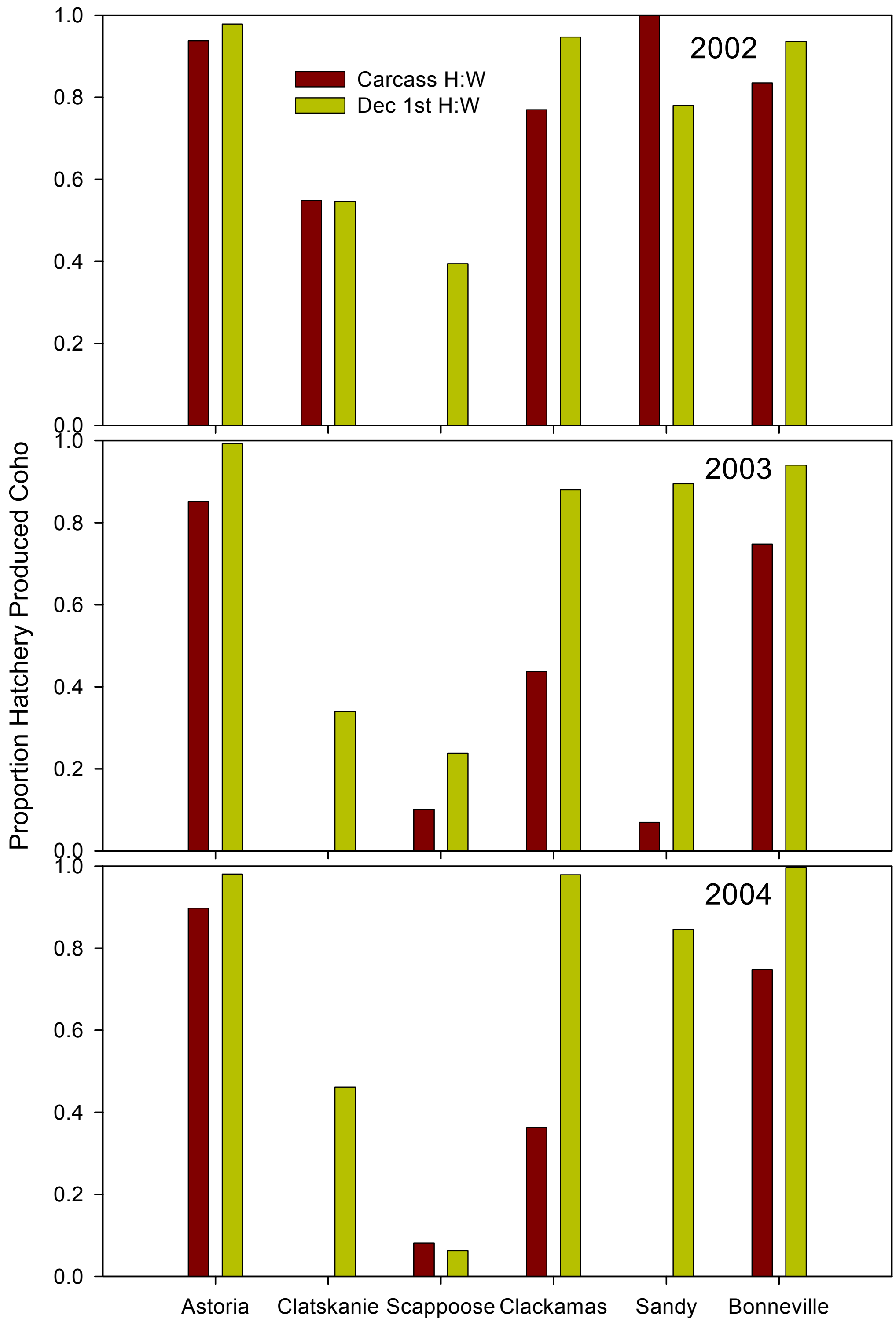


Figure 7. Comparisons of hatchery:wild ratios of naturally spawning coho in population complexes 2002 – 2004. The first bar shows the ratio as estimated by fin-mark recoveries or scale analysis. The second bar in for each population complex illustrates the hatchery:wild ratio determined by applying a December 1st cutoff date.

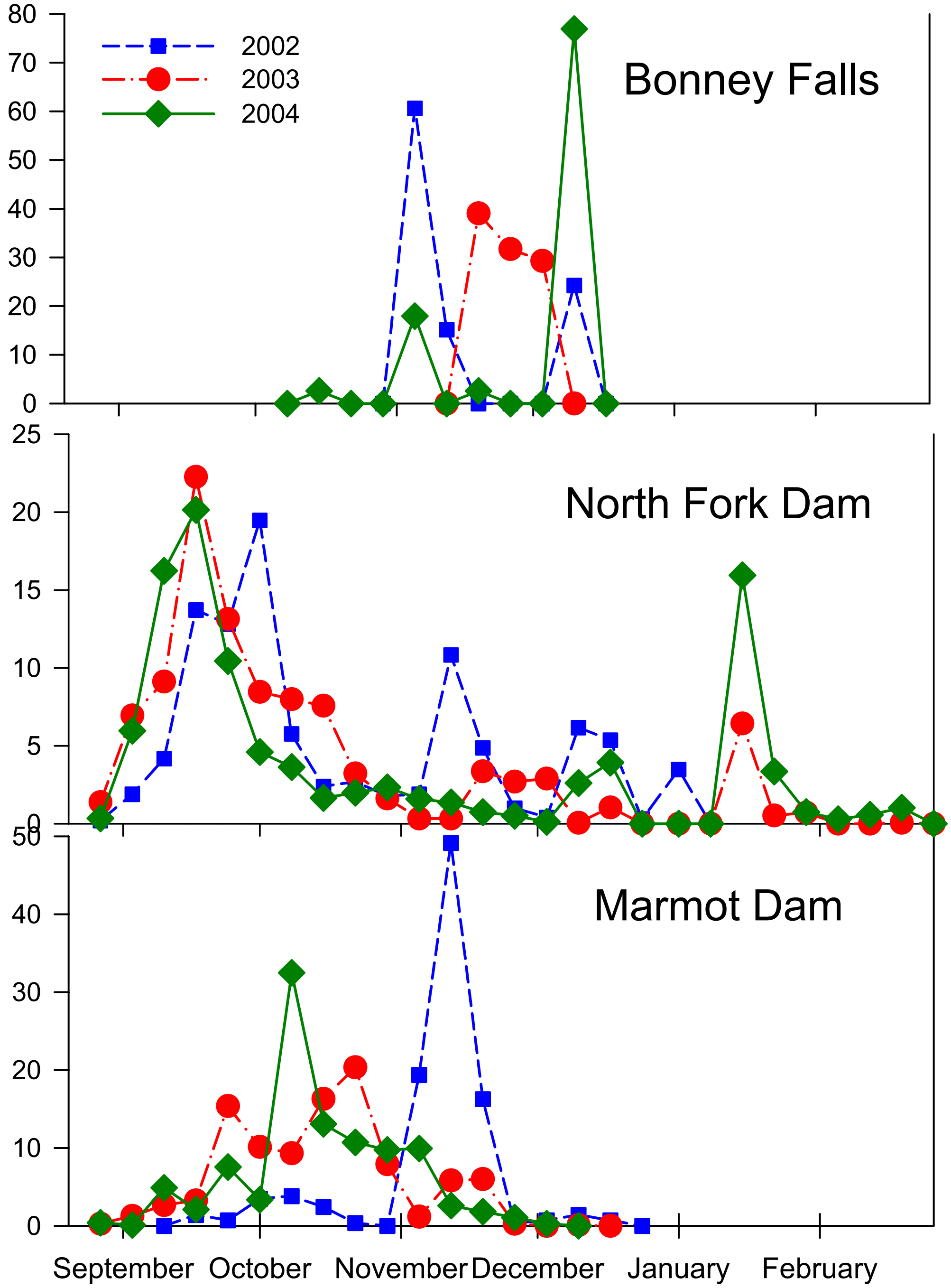
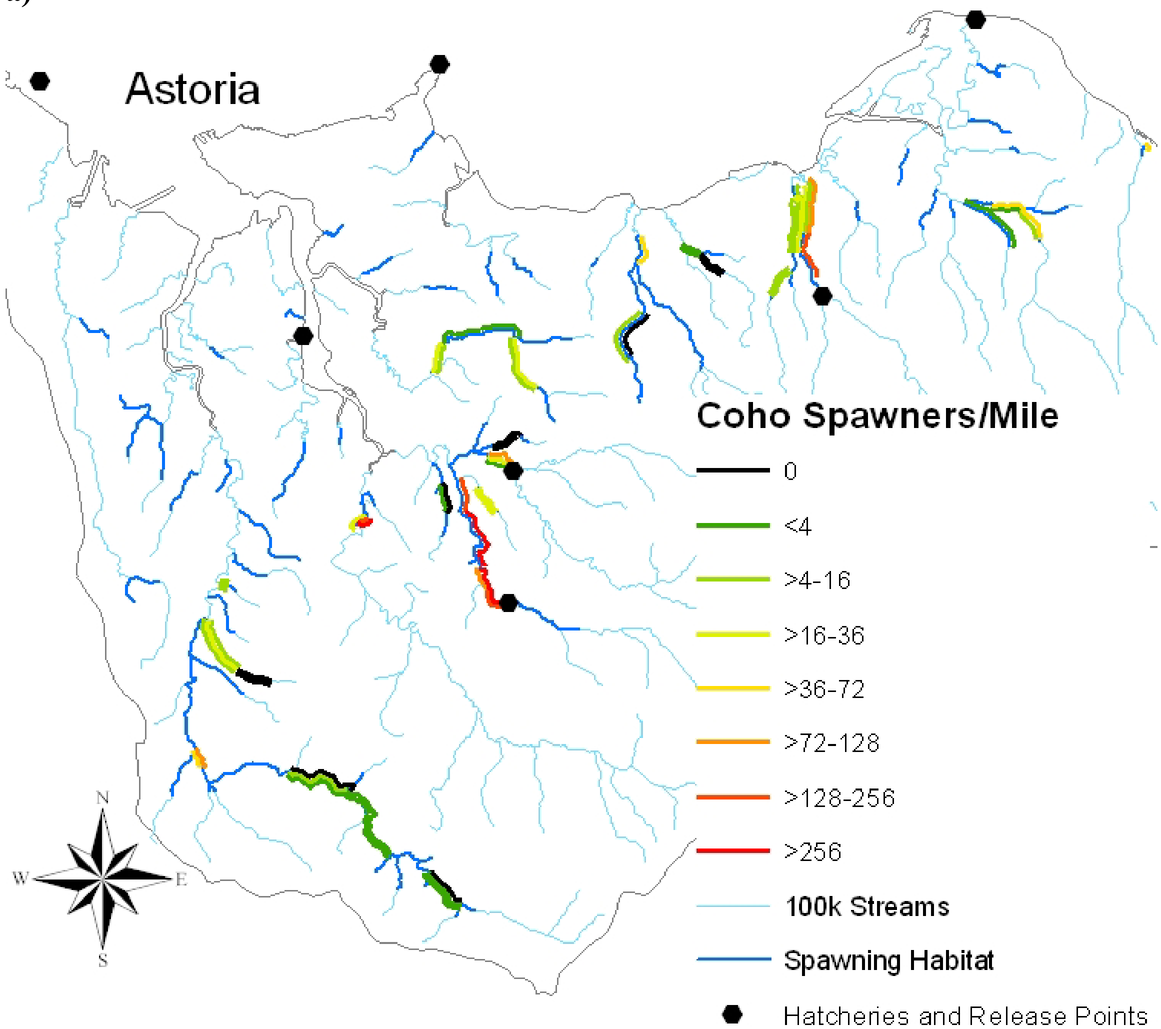


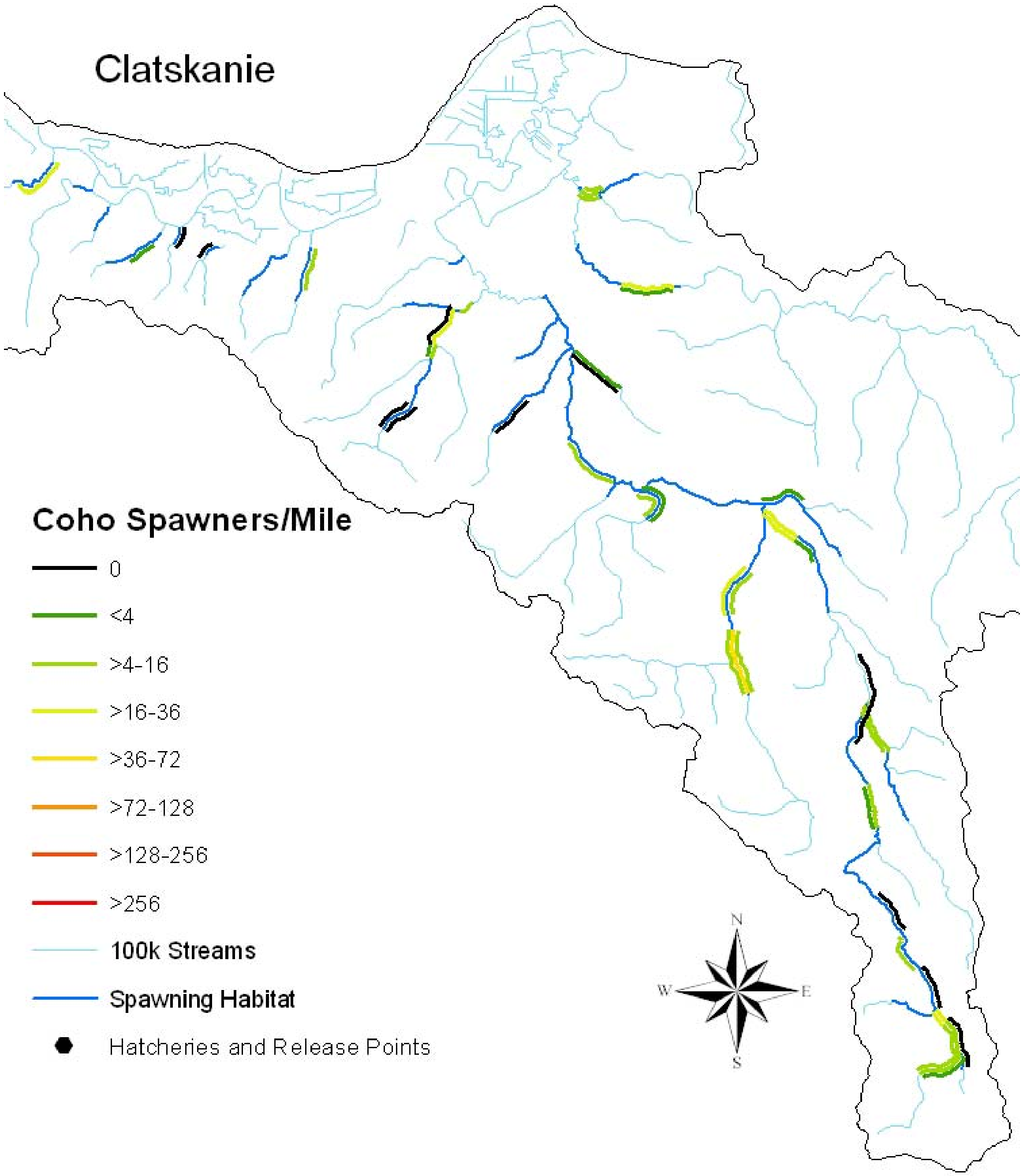
Figure 8. Temporal distribution of migrating adult coho salmon at three complete barriers in the Lower Columbia during the 2002 and 2003 spawning season. Values represent the percentage of total live adults passing the barrier by Julian week.

a)



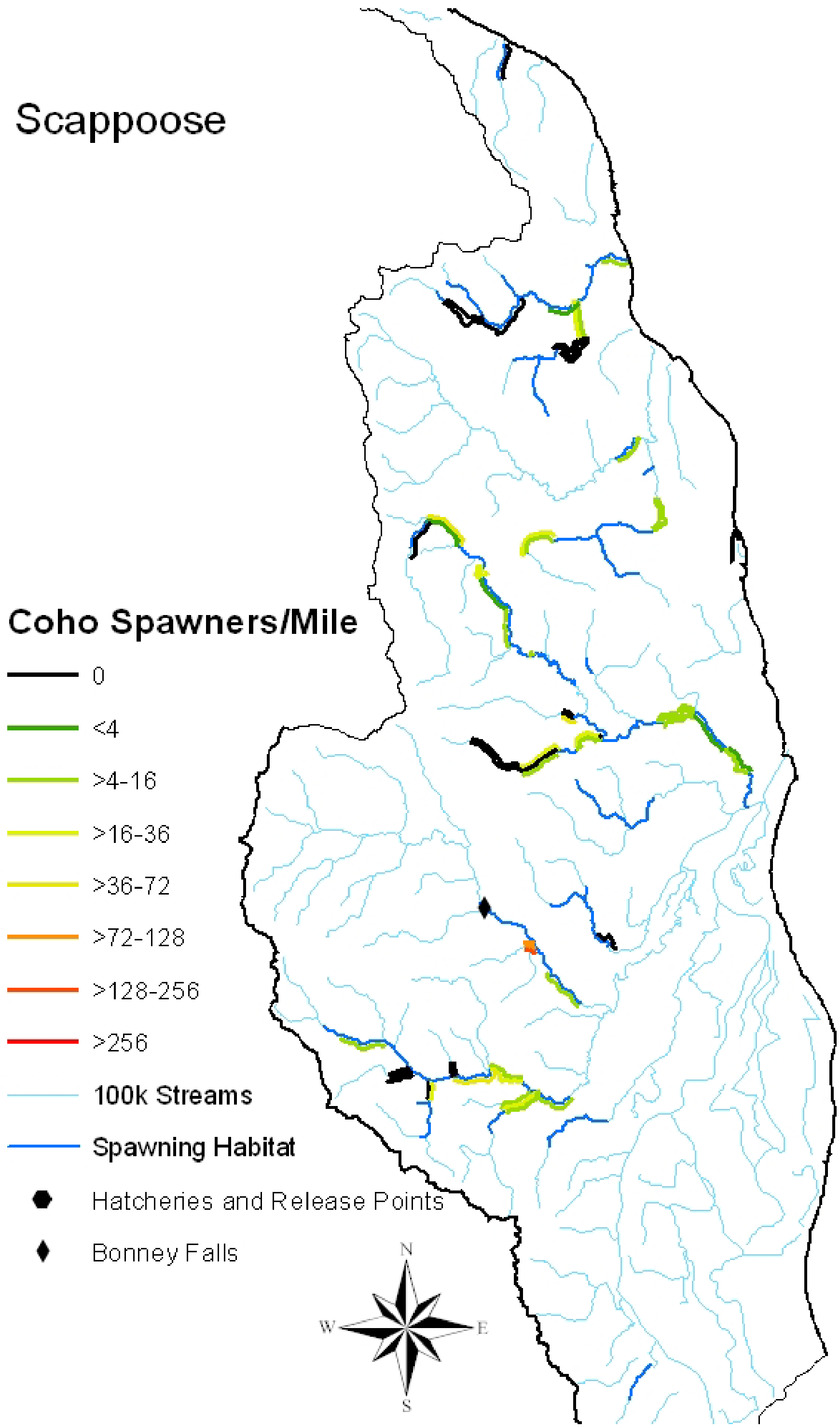
Astoria
Coho Spawners/Mile
0
<4
>4-16
>16-36
>36-72
>72-128
>128-256
>256
100k Streams
Spawning Habitat
Hatcheries and Release Points
N
W
E
S

b)



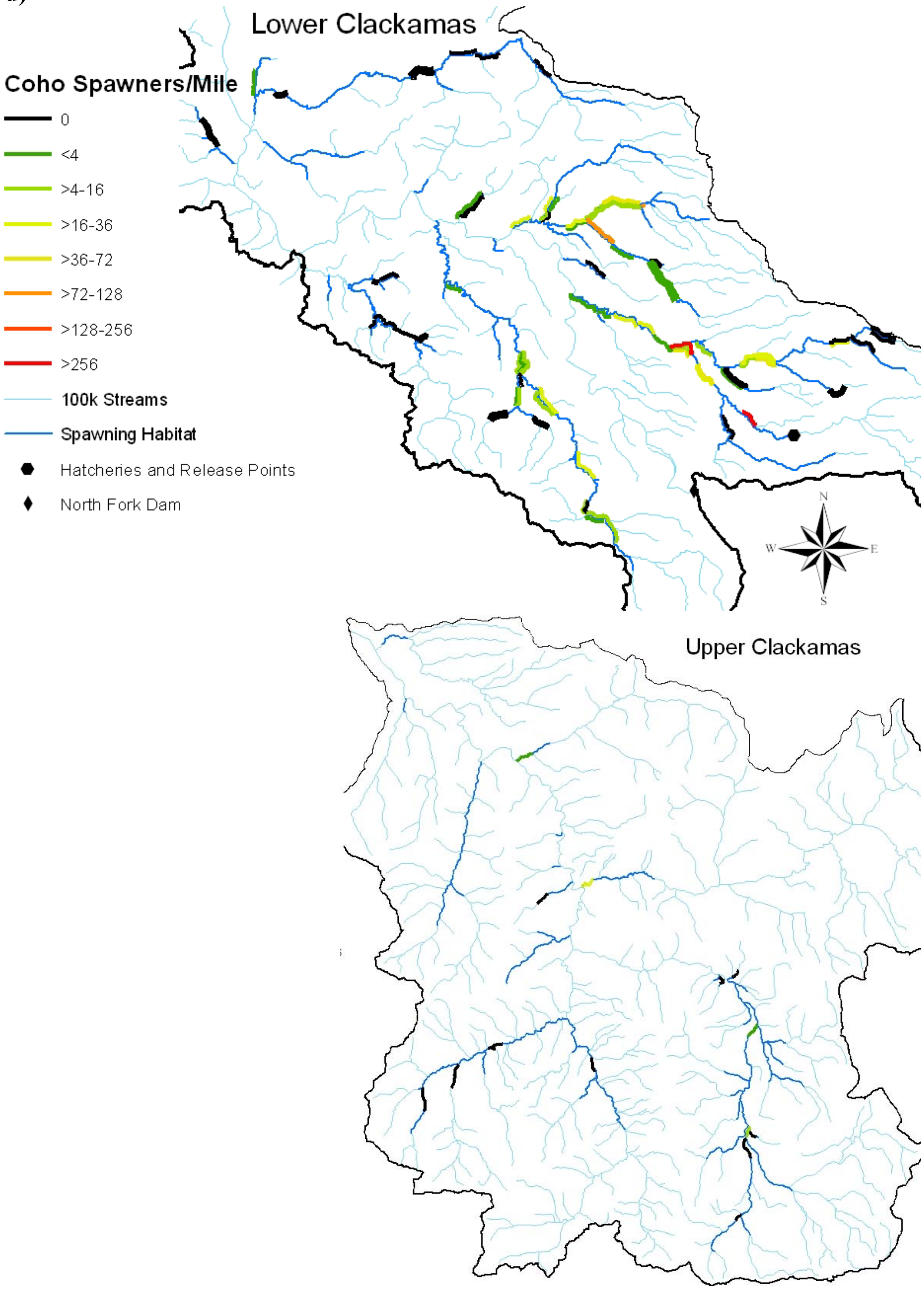
Clatskanie
Coho Spawners/Mile
0
<4
>4-16
>16-36
>36-72
>72-128
>128-256
>256
100k Streams
Spawning Habitat
Hatcheries and Release Points
N
W
E
S

c)

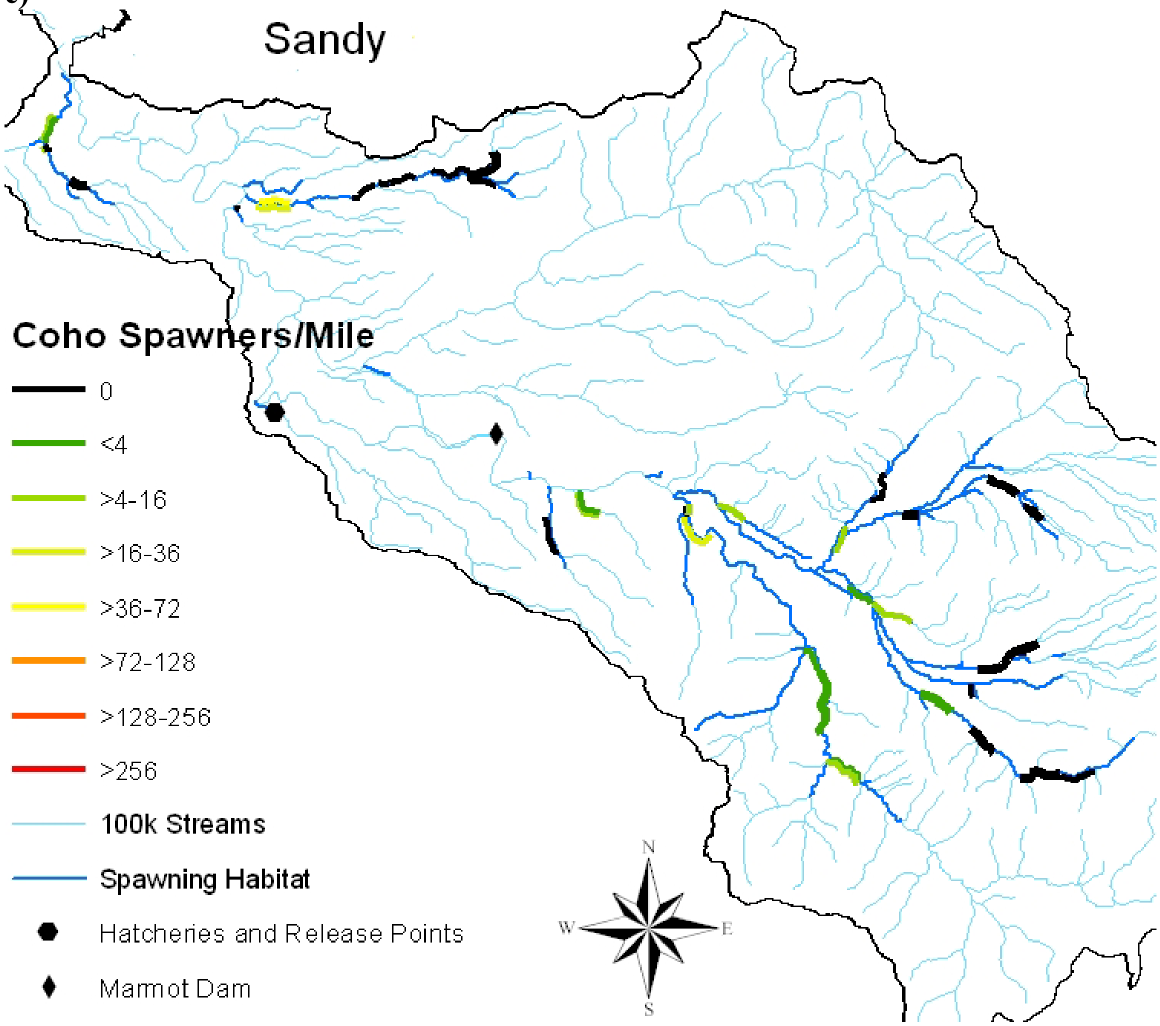


Scappoose
Coho Spawners/Mile
0
<4
>4-16
>16-36
>36-72
>72-128
>128-256
>256
100k Streams
Spawning Habitat
Hatcheries and Release Points
Bonney Falls
N
W
E
S

d)


Lower Clackamas
Coho Spawners/Mile
0
<4
>4-16
>16-36
>36-72
>72-128
>128-256
>256
100k Streams
Spawning Habitat
Hatcheries and Release Points
North Fork Dam
N
W
E
S
Upper Clackamas

e)


Sandy
Coho Spawners/Mile
0
<4
>4-16
>16-36
>36-72
>72-128
>128-256
>256
100k Streams
Spawning Habitat
Hatcheries and Release Points
Marmot Dam
N
W
E
S

f)

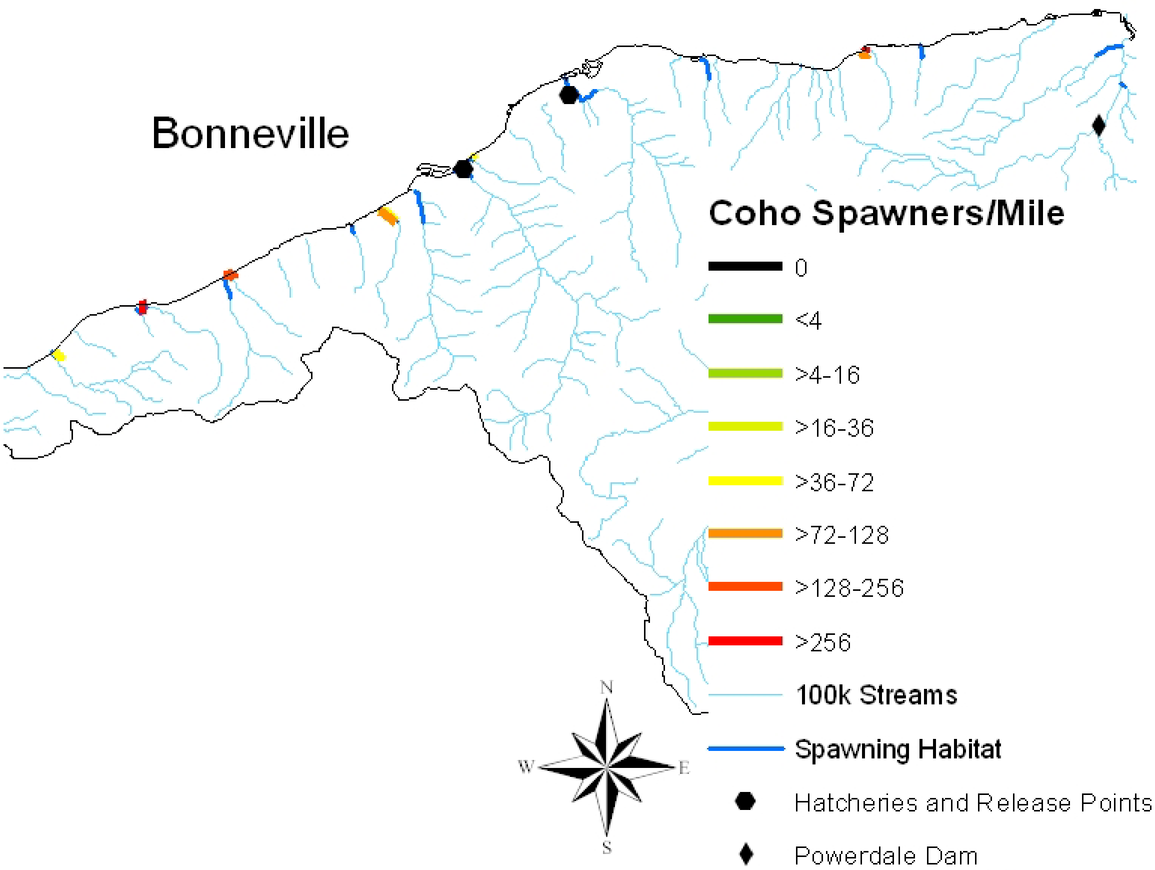
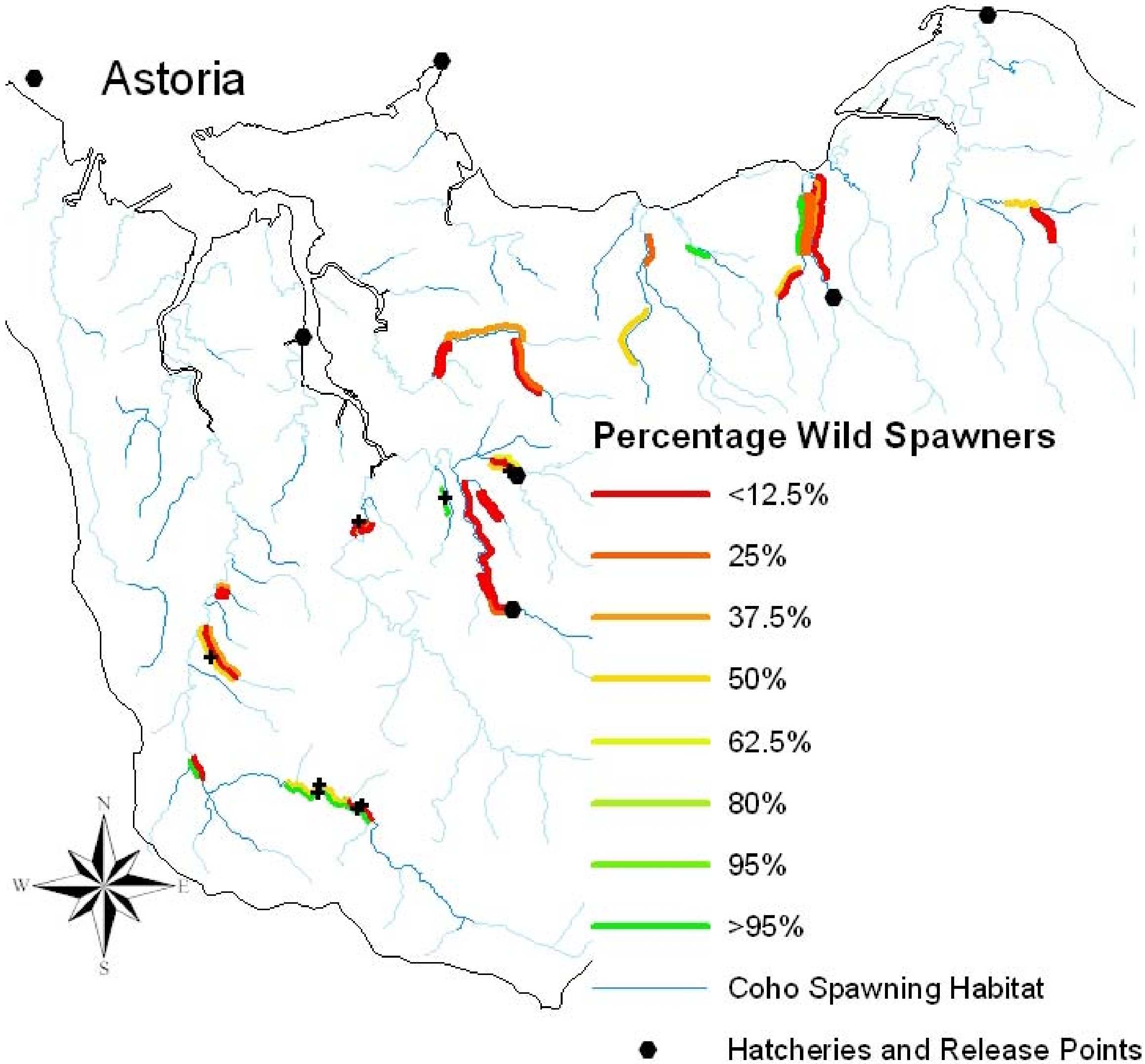


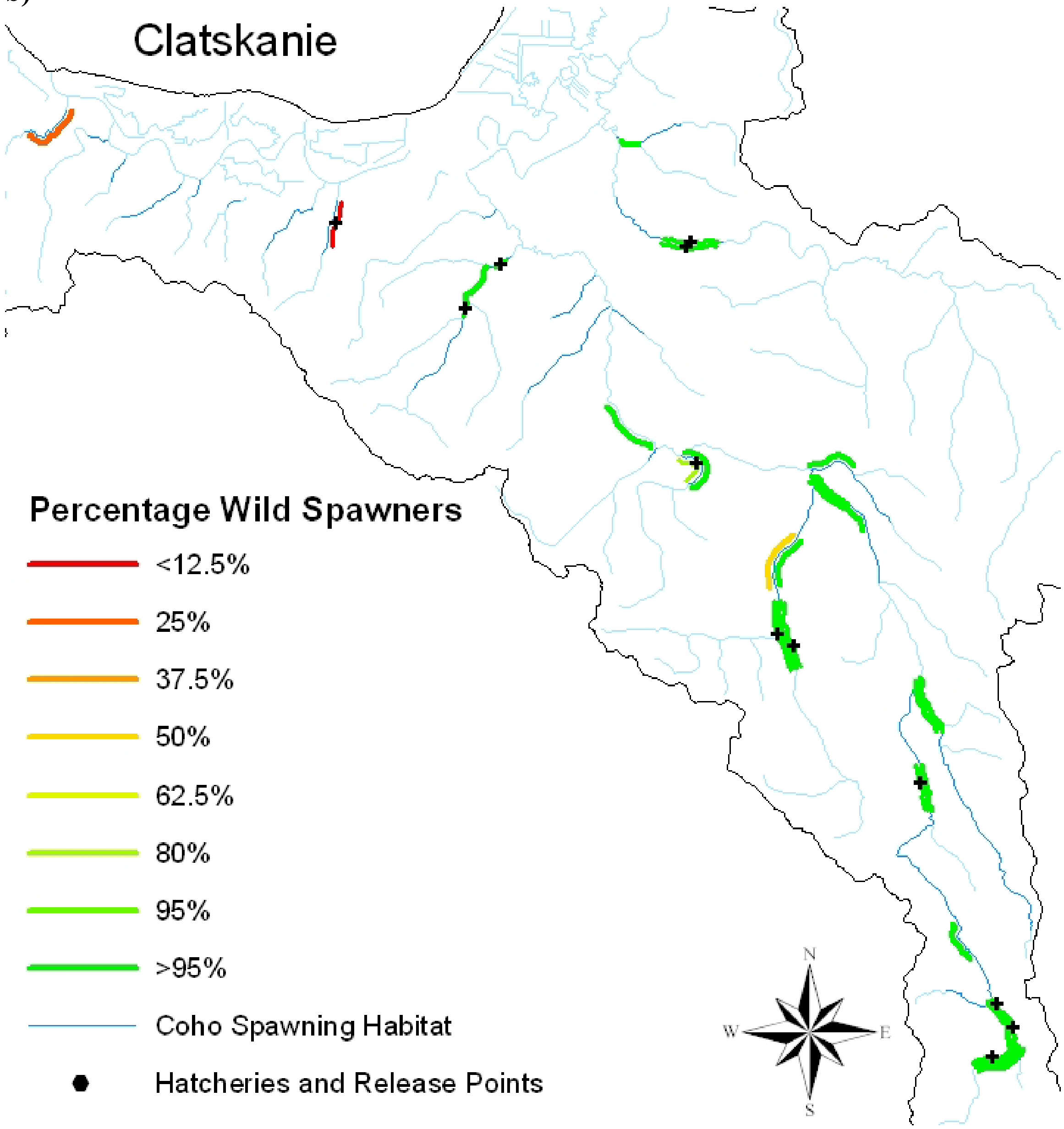
Figure 9. Density of adult coho in surveyed segments in the Lower Columbia River ESU by population complex a) Astoria, b) Clatskanie, c) Scappoose, d) Clackamas, e) Sandy, f) Bonneville. 2002 surveys are offset to the left of the stream, 2003 surveys are centered on the stream and 2004 surveys are offset to the right of the stream.

a)

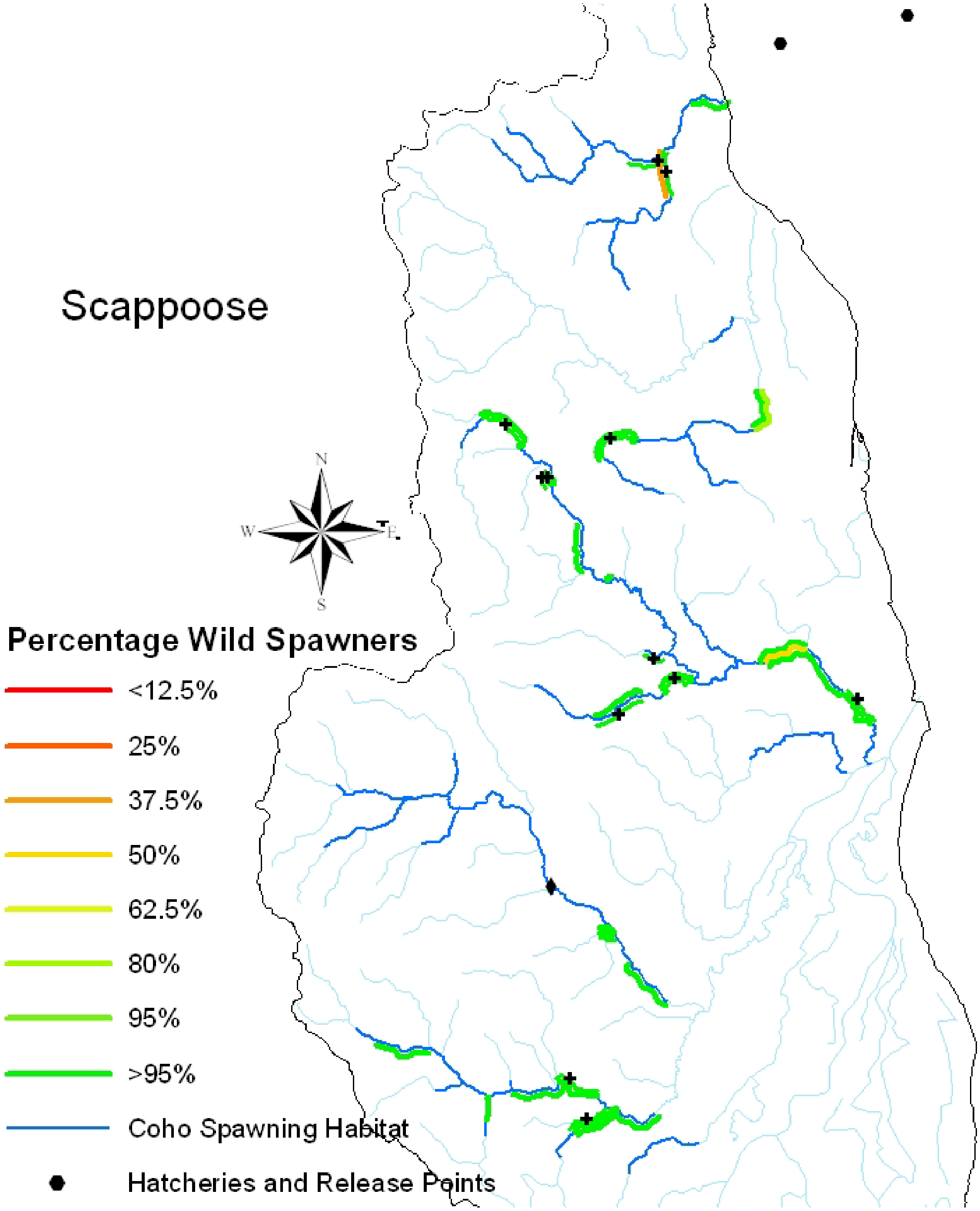


Astoria
Percentage Wild Spawners
<12.5%
25%
37.5%
50%
62.5%
80%
95%
>95%
Coho Spawning Habitat
Hatcheries and Release Points
N
W
E
S

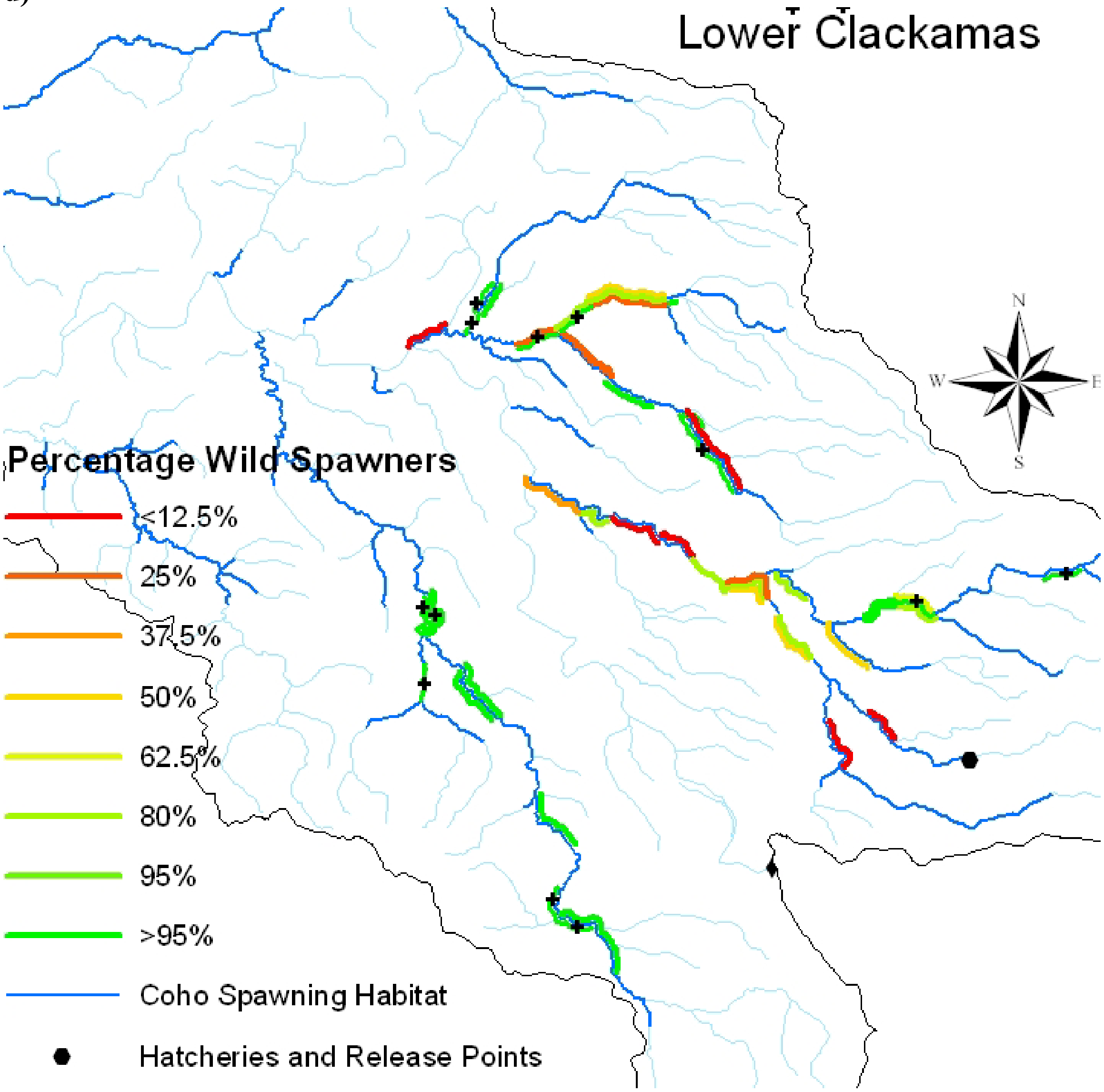
b)


Clatskanie
Percentage Wild Spawners
<12.5%
25%
37.5%
50%
62.5%
80%
95%
>95%
Coho Spawning Habitat
Hatcheries and Release Points
N
W
E
S

c)


Scappoose
N
W
E
S
Percentage Wild Spawners
<12.5%
25%
37.5%
50%
62.5%
80%
95%
>95%
Coho Spawning Habitat
Hatcheries and Release Points

d)



Lower Clackamas
N
W
E
S
Percentage Wild Spawners
<12.5%
25%
37.5%
50%
62.5%
80%
95%
>95%
Coho Spawning Habitat
Hatcheries and Release Points

e)

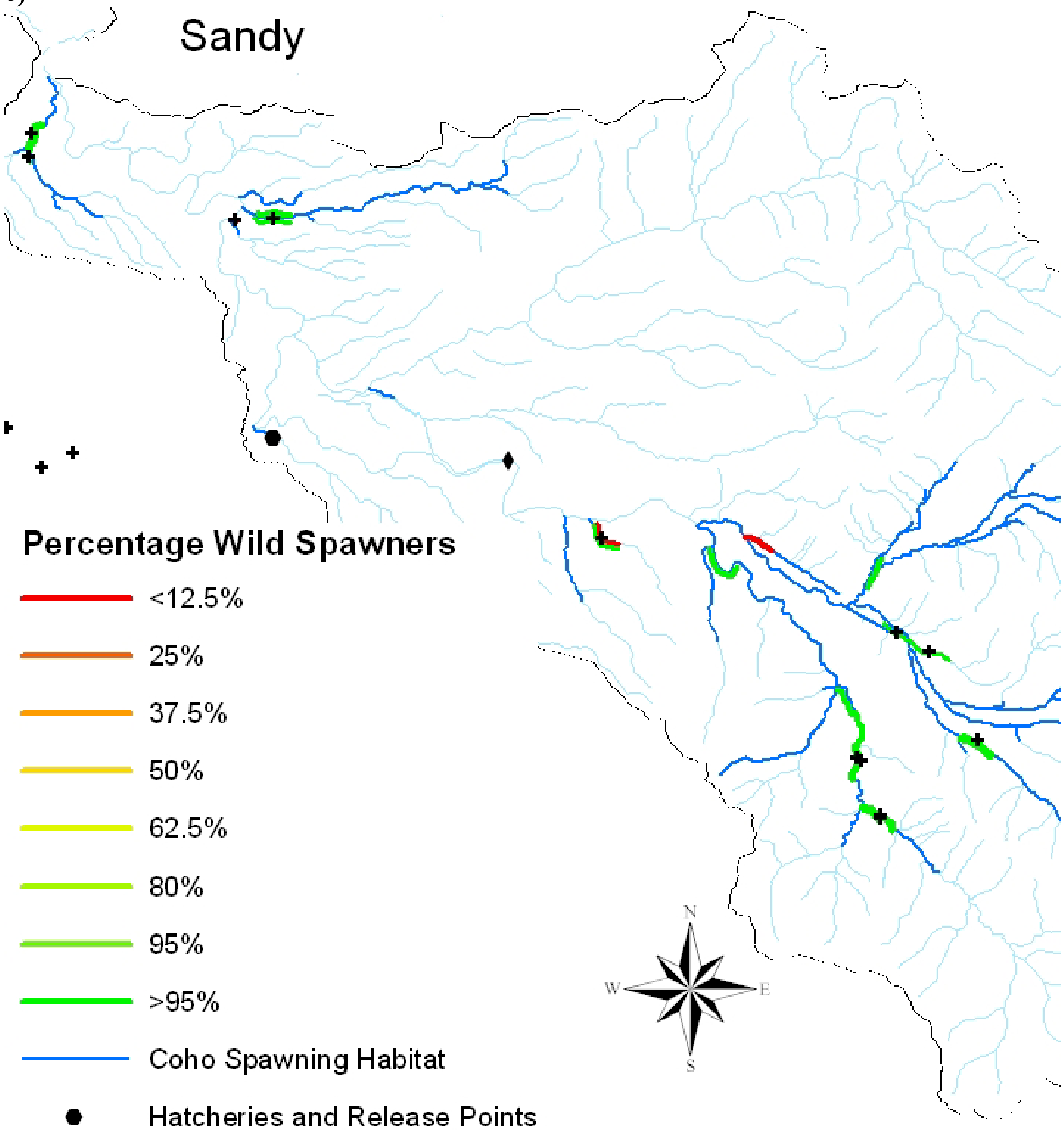


Figure 10. Percentage of wild spawners in surveyed segments in the Lower Columbia River ESU by population complex a) Astoria, b) Clatskanie, c) Scappoose, d) Clackamas, e) Sandy. The percentage is based on recovered carcasses and is adjusted for hatchery release mark rates. In segments where no carcasses were recovered the percentage is based on live observations and denoted with a "+". 2002 surveys are offset to the left of the stream, 2003 surveys are centered on the stream and 2004 surveys are offset to the right of the stream.

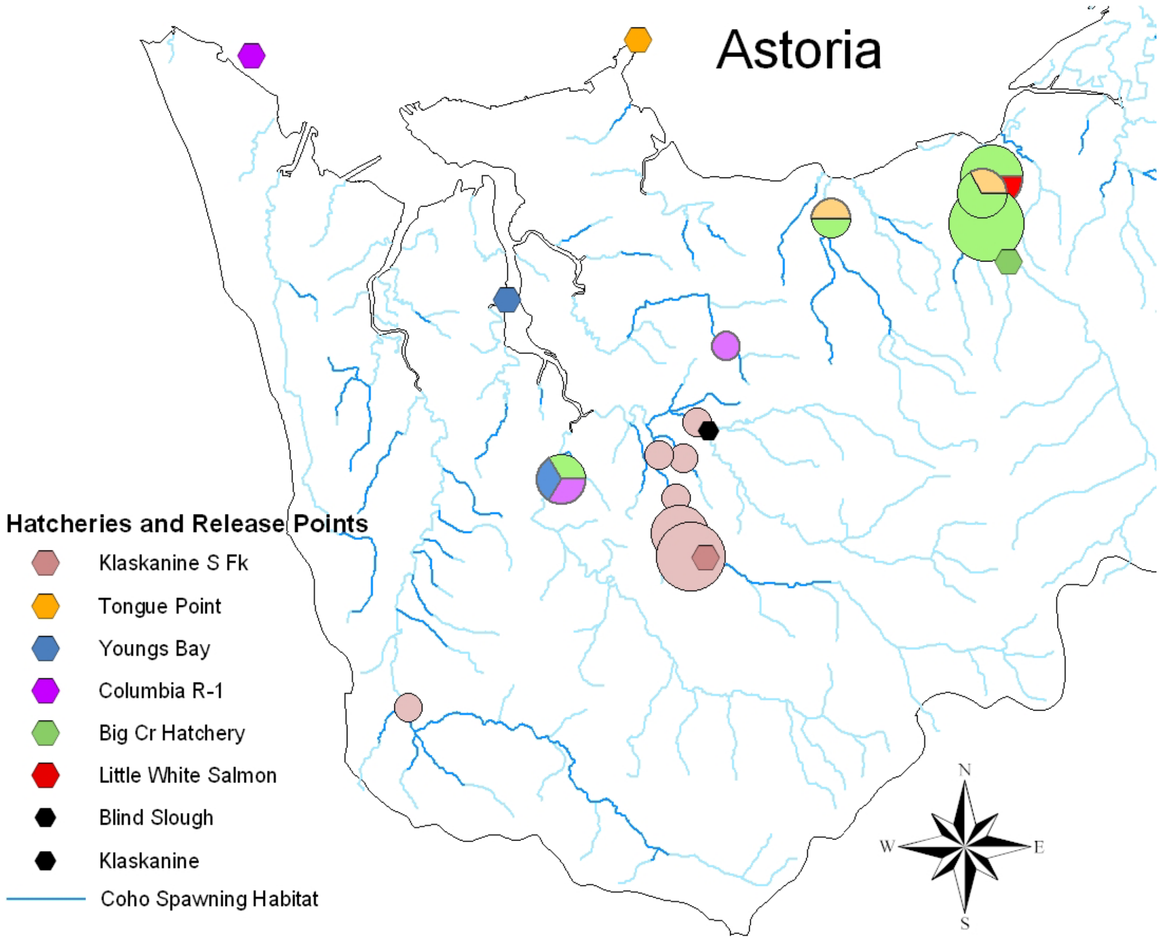


Figure 11. Coded wire tag (CWT) recovery locations in the Astoria complex. Charts indicate the release sites and are sized relative to the number of CWT recovered, the largest circle indicates seven recoveries and the smallest one recovery. Little White Salmon NFH is not shown on the map; it is located on the Columbia River at river mile 162.

Appendix I. Oregon smolt release information for the 2002 - 2004 spawning years (1999 - 2001 brood years).

Population Complex	Release Site	Stock	Hatchery	Total Released	Mark Rate
2002 Spawning Year					
Astoria	Youngs Bay	Tanner Cr	CEDC	1,042,767	98.2%
Astoria	Youngs Bay	Clackamas R Early	CEDC	502,077	95.5%
Astoria	Tongue Pt	Tanner Cr	CEDC	179,199	99.6%
Astoria	Tongue Pt	Clackamas R Early	CEDC	482,414	98.4%
Astoria	Blind Slough	Sandy R	CEDC	299,411	91.0%
Astoria	Columbia R-1	Tanner Cr	CEDC	179,187	98.9%
Astoria	Klaskanine R, S Fk	Klaskanine R	CEDC	344,738	99.1%
Astoria	Klaskanine R, S Fk	Klaskanine R	Klaskanine Pond	365,341	99.2%
Astoria	Big Cr	Big Cr	Big Creek	537,185	99.2%
			Astoria Total	**3,932,319**	**97.7%**
Clackamas	Clackamas R	Clackamas R Early	Sandy	69,188	0.0%
Clackamas	Eagle Cr	Clackamas R Early	Eagle Creek NFH	711,927	96.4%
Sandy	Cedar Cr	Sandy R	Cedar Cr	718,155	96.1%
Bonneville	Tanner Cr	Tanner Cr	Bonneville	1,249,655	98.9%
2003 Spawning Year					
Astoria	Youngs Bay	Tanner Cr	CEDC	1,206,039	99.3%
Astoria	Youngs Bay	Clackamas R Early	CEDC	482,657	98.2%
Astoria	Tongue Pt	Tanner Cr	CEDC	178,892	99.3%
Astoria	Tongue Pt	Clackamas R Early	CEDC	488,866	93.5%
Astoria	Blind Slough	Sandy R	CEDC	343,842	91.1%
Astoria	Klaskanine R, S Fk	Klaskanine R	Klaskanine Pond	583,248	97.9%
Astoria	Big Cr	Big Cr	Big Creek	540,898	98.9%
			Astoria Total	**3,824,442**	**97.4%**
Clackamas	Eagle Cr	Clackamas R Early	Eagle Cr NFH	862,729	97.1%
Sandy	Cedar Cr	Sandy R	Cedar Cr	862,729	96.2%
Bonneville	Tanner Cr	Tanner Cr	Bonneville	1,198,209	99.6%
2004 Spawning Year					
Astoria	Youngs Bay	Tanner Cr	CEDC	1,003,129	97.9%
Astoria	Youngs Bay	Clackamas R Early	CEDC	512,549	98.3%
Astoria	Tongue Pt	Tanner Cr	CEDC	197,794	98.1%
Astoria	Tongue Pt	Clackamas R Early	CEDC	477,918	97.4%
Astoria	Blind Slough	Sandy R	CEDC	316,804	90.4%
Astoria	Columbia R-1	Tanner Cr	CEDC	171,033	97.0%
Astoria	Klaskanine R, S Fk	Klaskanine R	Klaskanine Pond	641,555	98.4%
Astoria	Big Cr	Big Cr	Big Creek	537,086	99.8%
			Astoria Total	**3,857,868**	**97.6%**
Clackamas	Eagle Cr	Clackamas R Early	Eagle Cr NFH	505,400	95.0%
Sandy	Cedar Cr	Sandy R	Cedar Cr	772,939	95.5%
Bonneville	Tanner Cr	Tanner Cr	Bonneville	1,243,477	100.0%