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DEVELOPMENT AND APPLICATION OF A TECHNIQUE TO DISTINGUISH BETWEEN COHO SALMON (*Oncorhynchus kisutch*) AND STEELHEAD (*Oncorhynchus mykiss*) REDDS AND ESTIMATE ADULT POPULATIONS FROM SPAWNING SURVEYS IN SEVERAL COASTAL MENDOCINO COUNTY STREAMS

PROJECT 1d2

By

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Northern California North Coast Region

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DEVELOPMENT AND APPLICATION OF A TECHNIQUE TO DISTINGUISH BETWEEN COHO SALMON (*Oncorhynchus kisutch*) AND STEELHEAD (*Oncorhynchus mykiss*) REDDS AND ESTIMATE ADULT POPULATION SIZES FROM SPAWNING SURVEYS IN SEVERAL COASTAL MENDOCINO COUNTY STREAMS

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Sean P. Gallagher[1]

ABSTRACT

Spawning surveys were conducted in seven coastal Mendocino County streams between December 2001 and April 2002 to quantitatively estimate steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) populations. Live adult, carcass, and redd areas were used to estimate adult populations using mark-recapture, area-under-the-curve (AUC), and redd area methods. Physical characteristics of positively identified coho salmon and steelhead redds were measured in detail and data analyzed using logistic regression to develop a discriminant function that identified redds to species. Information on spawning locations and distributions were collected. A stratified random block transect sampling design was used to estimate total populations from redd based methods and compared to total estimates. The discriminant function reduced uncertainty in redd identification from 18.4 to 3.9% and was used to differentiate between coho salmon, steelhead, unknown, and test redds when fish were not observed. Steelhead and coho salmon redds were significantly different in redd area and date of spawning. The average size of 331 steelhead redds was 1.51 m^2 (S.E. = 0.49) and ranged from 0.3 to 6.66 m^2. The average size of 261 Coho salmon redds was 5.25 m^2 (S.E. = 0.22) and ranged from 0.69 to 16.37 m^2. Steelhead redd density was not significantly different among streams during 2001-02. Coho redd density was not significantly different among streams during 2001-02. Suggesting that these populations are behaving similarly within this geographic area thus may not be independent populations. Steelhead AUC and redd area population estimates are presented for three and six streams, respectively. Coho salmon population estimates from AUC, caracass mark-recapture, and redd area are reported for six coastal Mendocino County streams. AUC population estimates were similar to redd area estimates for coho salmon and steelhead. Steelhead fork lengths were not different among streams during 2001-02. Coho salmon fork lengths were not different among streams during 2001-02. Steelhead female to male ratio varied slightly among steams. Coho salmon female to male ratio was also varied slightly among streams. There was a large overlap in the timing of coho and steelhead spawning. Stratified random block transect sampling population estimates were not significantly different from redd area population estimates and will decrease field effort in the future. The discriminant function is robust for differentiating between Coho salmon and Steelhead based on physical redd characteristics and may be useful in other rivers where these species co-occur. Future work should employ stratified random block sampling, collect data on redds, carcasses, and adults, and calculate population estimates by redd area.

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[1] Steelhead Research and Monitoring Program Report No. FB-12. 14 September 2011. Philip K. Bairrington Senior Biologist Supervisor, California State Department of Fish and Game, 50 Ericson Court, Arcata, CA 95521.

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INTRODUCTION

In California many populations of salmonids are considered at risk of extinction and are listed or are proposed for listing under the Federal Endangered Species Act (ESA) (Higgins et al. 1992, Nehlsen et al. 1991, Federal Register 1996, 2000, Huntington et al. 1996). Responding to a proposal to list steelhead (*Oncorhynchus mykiss*) under the ESA in 1996, the California Department of Fish and Game (CDFG) entered a Memorandum of Agreement (MOA) with the National Marine Fisheries Service (NMFS) in 1998 to provide improved conservation and management of North Coast steelhead (Federal Register 2000). The MOA, in part, commits CDFG to develop and implement a program directed at monitoring, evaluating, and adaptively managing North Coast (North Coast Evolutionary Significant Unit-ESU) steelhead. Since 1998 CDFG has taken significant steps to implement and expand the steelhead monitoring program (Federal Register 2000) including implementation of the Salmon and Steelhead Restoration Account, changes in harvest regulations and hatchery practices, and development of the North Coast Steelhead Research and Monitoring Program (S-RAMP). The implementation of S-RAMP began in July 1999. In June 2000 NMFS formally listed North Coast ESU steelhead as Threatened Species under the ESA (Federal Register 2000).

Little information exists for steelhead in most California Streams and basic life history and biological information is needed to understand the nature and character of populations (McEwan and Jackson 1996). The South Fork Eel River is the only stream in the North Coast ESU for which recent estimates of winter-run steelhead exist (CDFG 1998). Breeding population size (number of reproductive adults) is an important statistic for assessing population status. Four key parameters for assessing viable salmonid populations are abundance, population growth rate, population spatial structure, and diversity (McElhany et al. 2000). The NMFS focuses on the number of adults escaping to spawn in natural habitat and is mandated by the ESA and internal policy to focus on natural viability of salmon populations (Busby et al. 1996).

Gallagher (2000) summarized most existing adult steelhead information for coastal Mendocino County streams and presented results of steelhead spawning surveys on the Noyo River during 2000. Previous spawning surveys of Mendocino County streams assumed all redds found before 1 February were made by Coho salmon and that those found after this date were made by steelhead (Maahs and Gilleard 1993, Maahs 1996, 1997, Wehren 1996). Thus species redd identification was based solely on time of year. Rieman and Myers (1997) used redd counts to examine trends in bull trout (*Salvelinus confluentus*) populations in Idaho. Zimmerman and Reeves (2002) used stepwise discrimination to differentiate resident and anadromous steelhead redds in the Deschutes River, Oregon. Gallagher (2002a) used Fishers' discrimination analysis (Zar 1984) to differentiate Coho salmon and steelhead redds based on physical redd characteristics simplified by principle components analysis. He applied the results to estimate populations from spawning surveys in the Noyo River, California. Maahs (1997) developed and applied a redd area method to estimate Coho salmon populations in portions of three coastal Mendocino County streams. Gallagher (2001, 2002a) modified and applied this method to steelhead and Coho salmon (2002 only) in the Noyo River.

The area-under-the-curve (AUC- Beidler and Nickelson 1980) method has been used to estimate Coho populations in various rivers over the last 20 years (Beidler and Nickelson 1980, Nielsen et al. 1990, English et al. 1992, Irvine et al. 1992, Maahs and Gilleard 1993, Maahs 1996, 1997, 1999, Hillborn et al. 1999, Gallagher 2002a). The AUC method has not been applied to steelhead until recently in the Noyo River (Gallagher 2002a).

Steelhead populations in the Noyo River estimated from the redd area method did not differ from an independent mark-recapture study (Neillands 2001) in the Noyo River during 1999-2000. Steelhead populations estimated using the redd area method did not differ from the AUC or weir mark-recapture estimates (Neillands 2002) in the Noyo River during 2000-2001 (Gallagher 2002a). Coho salmon AUC and redd area population estimates were similar in the Noyo River during 2000-01 (Gallagher 2002a). To reduce field effort, a stratified index sampling approach (Irvine et al. 1992) was tested using data collected during 200-01 on the Noyo River (Gallagher 2002a). Population estimates did not significantly differ between total counts and those derived from the stratified index approach.

The purpose of the 2001-2002 spawning surveys was to quantitatively estimate adult coho salmon and steelhead populations in the Albion, Noyo, Little, and Ten Mile rivers and Caspar, Hare, and Pudding creeks, California (Figure 1) using the methods developed by Gallagher (2002a). This report presets findings from the third consecutive year of steelhead spawning surveys in the Noyo River. The spawning surveys were intended to assist in the recapture portion of mark-recapture study to estimate adult steelhead populations in the Noyo River. The objectives of this study were to estimate adult Coho salmon and steelhead populations by visually capturing tagged steelhead (Noyo River only), collecting information to calculate the AUC, mark-recapture of carcasses, collection of data on the physical characteristics of Coho salmon and steelhead redds to improve discrimination, and collection of information to estimate populations using the redd area method. Information on spawning timing, locations, and distributions were collected. Data were also collected on Chinook salmon (*O. tshawytscha*) and Pacific lamprey (*Lampetra tridentata*) redds.

STUDY AREA

The Albion River watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 111 km^2 immediately east of Comptche. The Albion River flows through the coast range and into the Pacific Ocean at Albion. The majority of the Albion watershed is owned by the Mendocino Redwood Company (MRC). The main-stem Albion River and the South Fork Albion River make up the two sections surveyed during 2001-02 (Figure 1, Table 1).

The Caspar Creek watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 23 km^2 immediately east of the town of Caspar. Caspar Creek flows into the Pacific Ocean south of the town of Caspar. The majority of the Caspar Creek watershed is owned and managed as an experimental forest by the California Department of Forestry (CDF). There were three stream reaches surveyed during 2001-02 (Figure 2, Table 1) in Caspar Creek.

The Hare Creek watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 24 km^2 immediately south of Fort Bragg. Hare creek flows into the Pacific Ocean south of Fort Bragg. Most of the Hare Creek watershed in owned and managed as an experimental forest by the CDF. There were four stream reaches surveyed during 2001-02 (Figure 3, Table 1) in Caspar Creek.

The Little River watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 13 km^2 immediately east of the town of Little River. The Little River flows through Van Damme State Park and into the Pacific Ocean north of the town of Little River. The entire Little River watershed in owned by the California State Department of Parks and Recreation. There was one stream reach surveyed during 2001-02 (Figure 4, Table 1) in Little River.

The Noyo River watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 260 km^2 immediately west of Willits. The Noyo River flows through the coast range and into the Pacific Ocean at Fort Bragg. Approximately 19% of the Noyo River watershed is owned and managed by the CDF (the South Fork). The other major landowners in the basin are MRC (the upper watershed) and Hawthorne Timber Company (along the main stem). There were 28 stream reaches surveyed during 2001-02 (Figure 5, Table 1) in the Noyo River.

The Pudding Creek watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 48 km^2 immediately north of Fort Bragg. Pudding Creek flows into the Pacific Ocean north of Fort Bragg. Most of the Pudding Creek watershed is owned by Hawthorne Timber Company and is managed by Campbell Timberland Management. There were four stream reaches surveyed during 2001-02 (Figure 6, Table 1) in Pudding Creek.

The Ten Mile River watershed (Figure 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 296 km^2 west of Laytonville. The Ten Mile River flows through the coast range and into the Pacific Ocean north of Fort Bragg. The Hawthorne Timber Company owns the entire Ten Mile River watershed which is managed by Campbell Timberland Management. There were 9 stream reaches (about 30% of the entire river) surveyed during 2001-02 (Figure 7, Table 1) in the Ten Mile River.

METHODS AND MATERIALS

Field Methods

In general, the methods employed by Nielsen et al. (1990) Maahs and Gilleard (1993), Maahs (1996, 1997, 1999), and Gallagher (2000, 2002) were followed for this study. Crews of two walked or kayaked and snorkeled stream reaches approximately bi-weekly from early-December 2001 to mid-April 2002 (Table 1). The main stem Noyo River below Northspur was sampled by kayak. Kayaks were also used to survey the North Fork Noyo River from Hayworth Creek to Northspur and the main stem Noyo from Olds Creek to Northspur, when stream flows permitted. The Albion River was only surveyed between December 2001 and February 2002 (Table 1). The Ten Mile River was only surveyed December 2001 and January 2002. Fish were visually identified to species, counted, sized, and sexed from the banks and/or by snorkeling when observed. Carcasses were identified to species, sex, fork length measured, and inspected for tags, marks, and fin clips. Unmarked carcasses were hog ringed with a uniquely numbered metal tag and put back where they were found. The time of beginning and ending of surveys and driving to and from survey areas was also recorded.

All redds observed were identified to the species assumed to have constructed them, classified as unknown, or test redds under construction, counted, and measured. Test redds were reexamined on subsequent surveys and were reclassified when possible based on apparent completion of the redd. When observed, live (or dead) fish in the vicinity of each redd or redd cluster were noted to help confirm species making redds. All newly constructed redds, those without periphyton or sediment in the pot, were measured during each visit. Redd measurements consisted of area, substrate, and depth. The redd pot was considered the excavated portion. Pot length (usually longitudinally parallel to stream flow), pot width (perpendicular to stream flow or 90^o of the length axis), and pot depth (the maximum depth of the excavation relative to the undisturbed stream bed) were measured and the dominant pot substrate was visually estimated (Table 2). Tail spill length (longitudinally parallel to stream flow) and tail spill width at 1/3 and 2/3 from edge of pot (perpendicular to stream flow or 90^o of the length axis) were measured and the dominant tail spill substrate was visually estimated in the middle of the tail spill. All redds were marked with flagging on each visit to avoid double counting. All redd locations were recorded on field maps, except in the Albion River, and located with handheld GPS units when readings could be made. No estimates of observer efficiency or stream residence time were made during 2001-02 due to time constraints and the inability to operate a weir and capture fish in the Noyo River at Northspur.

Data Analysis

Redd area was calculated by summing calculated pot and tail spill areas. Pot area was calculated by treating the pot as a circle or an ellipse depending on length and width dimensions. Tail spill area was calculated as a triangle or rectangle depending on the length and width dimensions. Redd location was the distance from the river mouth. Date of spawning was changed to days with the first day of surveys (30 November 2001) set as day one. Table 3 shows the variables recorded and calculated for each redd. The redd data from each river was examined and all redds for which the species making it was known, based on observations of one or more fish making or guarding the redd, were identified.

Logistic regression was used to develop a model to differentiate redds by species based on their physical characteristics using both years known species redd data from the Noyo River. Prior to use with logistic regression, all data were checked for correlation as when independent variables are correlated regression models can become unreliable (Agresti 1990, SPSS Inc. 1997). Variables that were found to be highly correlated were not used in logistic regression (Table 3). In the logistic regression analysis the species making the redd was the dependent variable and day, distance from river mouth (LKM), fish fork length (FKL), redd area (RA), and year were independent variables (Table 4). Modeling with logistic regression continued iteratively, removing those variables which were least significantly associated with predicting species and rerunning the regression (C. Gallagher, Perrs. Comm.). The results of the various trials for the

Noyo River data are shown in Table 4. The final trail for these data shows that only redd area and the date redds were observed were significantly associated with predicting species (Table 4).

To examine how predicting species from physical redd data might be influenced by year, river, and increased sample size; I combined the data from both years and all rivers. Because so few steelhead redds were observed, I searched the data set for all rivers and developed a subset which had only redds field identified as steelhead after 16 February (the last date which Coho salmon were observed) such that these could only have been made by steelhead. From this data set, I randomly selected redds from each river each year until I had an equal number of steelhead and Coho salmon redds per river. Steelhead redds were not observed in the Albion and Ten Mile rivers during 2001-02, due to the surveys ending in mid-February. Therefore, I randomly selected late-season field identified steelhead redds from the other rivers in the subset until there were equal numbers of steelhead and Coho salmon redds. This data set was checked for correlation and variables that were found to be highly correlated were not used in logistic regression (Table 3). In the logistic regression analysis the species making the redd was the dependent variable and day, distance from river mouth (LKM), fish fork length (FKL), redd area (RA), river, and year were independent variables. Modeling with logistic regression continued iteratively, removing those variables which were least significantly associated with predicting species and rerunning the regression (C. Gallagher, Perrs. Comm.). The first set of models treated the Noyo River data as one river and all other rivers data as a second river (Table 4). This procedure resulted in a model that suggested that river, date of observation, and redd area were the only variables significantly associated with predicting species (Table 4, all rivers 1-2). To determine if individual rivers were important in predicting species, I ran trails all rivers 3-4, Table 4. The final trial analysis for these data indicated that, similarly to that of the Noyo River data alone, only redd area and the date the redd was observed were significantly associated with predicting species. The result (Equation 1) was applied to all redd data collected during 2001-02 to identify redds as constructed by coho salmon or steelhead. Redds that were field identified as Pacific lamprey were not included in the analysis, as these redds were easily identified in the field. No Chinook salmon redds were positively identified and were therefore not included in logistic regression analysis.

Equation (1)
Logit P = -4.074+(0.13*Day)-(0.918*RA). If inverse log (logitp) >=0.5 steelhead, otherwise Coho.

Spawning population estimates were derived from live fish observations using the AUC method (Beidler and Nickelson 1980, English et al. 1992, Hilborn et al. 1999, Gallagher 2002) and the size of redds as described by Maahs (1996, 1997) and Gallagher (2002a). Carcass counts were used to calculate coho populations using the Jolly-Seber and Schnabel methods (Brower and Zar 1984, Krebs 1989) depending on the number of recaptures. Uncertainty in redd counts was derived from logistic regression and field uncertainty was calculated from observer uncertainty in species making redds as the percentage of redds recorded on data forms as unknown or test and those which the notes stated maybe another species divided by the total number of redds. To estimate steelhead populations based on redd area (Gallagher 2002a), I divided the range of known steelhead redd sizes by four to get one, three quarters, half, and one quarter effort/size estimates for a female steelhead. To estimate coho populations based on redd area I followed

Maahs (1996, 1997). In some instances, redds were identified but not measured because fish were making the redd or time constraints limited field crews during one survey and high flows flattened or obscured redds prior to the following survey. In these cases, I took the percentage of redds reclassified as one species or another by Equation 1 in each stream and changed the classification of the unmeasured redds accordingly. For these redds I used the average size of all redds for each species to estimate populations with the redd area method. Female steelhead population estimates based on redd area were multiplied by the male per female ratio observed this season for each stream and summed with female estimates to get a total population estimate. Female coho population estimates based on redd area were multiplied by the male per female ratio observed this season for each stream and summed with female estimates to get a total population estimate. Carcass-based population estimates were possible only for coho.

The trapezoidal approximation (Equation 2) as described by Hilborn et al. (1999) was used to calculate the AUC. Where t_i is the day of the year and x_i is the number of salmon observed on the *i*th day (English et al. 1992, Bue et al. 1998, Hilborn et al 1999). Population estimates (Ê) were made following Equation 3 (Hilborn et al. 1999). Steelhead stream residence time (*rt*) was set as the average (36 days) of the observations in the Noyo River during 2000-01 (Neillands 2001). Coho *rt* was set at 11.5 days based on estimates from Beidler and Nickelson (1980), English et al. (1992), Irvine et al (1992), and Mackey et al. (2001). Observer efficiency (*v*) for steelhead was assumed to be the same as during 2000-01 (Neillands 2001). The estimates of *v* for Coho salmon of 0.54 and 0.80 were taken from the literature (Shardlow et al. 1987, English et al. 1992).

Equation (2)

$$AUC = \Sigma\ (t_i-t_{i-1})*(x_i+x_{i-1})_{/2}$$

Equation (3)

$$\hat{E} = (AUC/rt)*\ v^{-1}$$

To further examine the utility of stratified index sampling (Krebs 1989, Irvine et al. 1992, Gallagher 2002a) for estimating Coho salmon and steelhead populations based on the redd area method for the Noyo River, I developed a performance curve (Figure 8) to estimate the minimum number of sample reaches after which the variance around the mean does not substantially decrease. Figure 8 indicates that after 9 samples the variance around the mean does not substantially decrease and I used the high, medium, and low density reaches identified during 2000-01 (Gallagher 2002a). The average density was then multiplied by the total length of stream spawning habitat to produce a population estimate and a standard error. To employ this approach on the Little River, Caspar, Hare, and Pudding creeks, I mapped out the redd locations, divided the river into 0.5 km segments, and estimated the number of Coho salmon and steelhead with the redd area method for each 0.5 km segment within each stream. I developed performance curves (Figures 9-12) to estimate the minimum number of samples needed. The stratified index population estimate for each river was calculated by randomly selecting the minimum number of 0.5km sample reaches indicated by the performance curves (generally about 30% of the stream length and number of reaches), estimating the number of steelhead and Coho salmon using the redd area method in each 0.5km reach, calculating the average and standard error, and multiplying this by the total stream length.

Coho salmon and steelhead redd density (#/km) for all rivers surveyed during 2000-01 and from 1989 through 1997 was gleaned from various reports (Nielsen et al. 1990, Maahs and Gilleard 1993, and Maahs 1996, 1997, Harris 1999, Gallagher 2000, 2002a), combined with data collected this year, and compared over the years. Coho salmon AUC population estimates were taken from these reports and compared to data collected during 2001-02.

Physical characteristics of redds were compared using correlation, logistic regression, and *t*-tests. Redd densities (number per km) were compared using one way analysis of variance (ANOVA) or the Kruskal-Wallis ANOVA on ranks when Standard Kurtosis p-values were < 0.05. To isolate areas which differed in redd density Tukey's or, when Standard Kurtosis p-values were < 0.05, Dunns pair-wise analysis were used. Redd spatial patterns were determined using the chi-square index of dispersion (Krebs 1989) treating the survey segments as samples for the Noyo River and the 0.5 km segments delineated for stratified index sampling as samples for the other streams. Male, female, and unidentified fish fork lengths were compared using one way analysis of variance (ANOVA) or the Kruskal-Wallis ANOVA on ranks when Standard Kurtosis p-values were < 0.05. To isolate fork length differences within and among streams Tukey's or, when Standard Kurtosis p-values were < 0.05, Dunns pair-wise analysis were used. Population estimates from AUC and redd area calculations were compared to stratified index sampling population estimates with ANOVA or the Kruskal-Wallis ANOVA on ranks when Standard Kurtosis p-values were < 0.05. Redd area and associated variables were compared by correlation. Statistical significance was accepted at $p < 0.05$.

RESULTS

One objective of this study was to visually recapture steelhead marked at the Northspur weir to estimate the adult population in the upper Noyo River during 2001-02. No steelhead were captured or marked at the weir (Neillands In Prep.). Only six steelhead carcasses were observed and marked and none were recaptured, thus no carcass-based population estimates were made. Coho salmon carcass population estimates are shown in Table 5. Coho salmon carcass based population estimates differ from other population estimates only in Caspar Creek (Table 5). The Chinook salmon carcass population estimate in the Noyo River was 6 ± 0. All Chinook salmon carcasses in the Noyo River were observed above Northspur. Thus a minimum of three Chinook salmon redds may have been identified as coho or steelhead. No chinook salmon redds were identified during the field surveys. One Chinook salmon carcass was observed in the Albion River. Chinook salmon were not observed in any of the other streams surveyed this season.

Redds

Field uncertainty in redd identification was 18.2%. The apparent error rate from logistic regression was 3.9 %. In the training data set (i.e. known species redds) only eight out of 204 redds were misclassified by logistic regression. When this model (Equation 1) was applied to all redds observed, no redds were identified as Coho after 16 February, the last day live or carcass Coho were observed. Only redd area and the date redds were observed were significantly associated with predicting species (Table 4). Year and river were not significantly associated with predicting species (Table 4). Fish fork length was not significantly associated with pot depth ($r = 0.09$, $p = 0.93$), pot size ($r = 0.05$, $p = 0.62$), or redd size ($r = 0.06$, $p = 0.57$). The average size of 331 steelhead redds completely measured in all rivers was 1.51 m^2 (S.E. = 0.49) and ranged from 0.3 to 6.66 m^2. Steelhead redd length averaged 2.24 (S.E. = 0.06) and width averaged 0.97 (S.E. = 0.20). Tail spill substrate was not significantly different between Coho salmon and steelhead redds during 2001-02 ($T = 1857$, $n = 41:42$, $p = 0.22$). The average size of 261 Coho salmon redds completely measured in all rivers was 5.25 m^2 (S.E. = 0.22) and ranged from 0.69 to 16.37 m^2.

Steelhead redd locations in streams surveyed during 2001-02 are shown in Figures 2-7. Steelhead redds were generally distributed in a random pattern in streams surveyed during 2001-01 (Table 6). The number of steelhead redds and the number of redds/km identified in streams surveyed during 2001-02 are shown Figure 13. Steelhead redd densities were significantly different among rivers and years (Table 7, Figure 14, ANOVA $f = 2.73$, $p = 0.01$). However, the power of this test was low ($\alpha = 0.72$). When examined separately steelhead redd densities did not differ significantly between streams during any one year nor among years in any stream (Figure 14, Tukey's $q < 3.68$, $p > 0.45$).

Coho salmon redd locations in streams surveyed during 2001-02 are shown in Figures 15-20. Coho salmon redds were distributed in an aggregated pattern in streams surveyed during 2001-02 (Table 6). The number of Coho salmon redds observed and redd densities are shown in Figure 21. Coho salmon redd densities were significantly different among rivers and years (Table 8, Figure 22, ANOVA $H = 40.13$, $p = 0.003$). When examined separately, Caspar Creek densities were significantly lower in 1996-97 than in 1991-92 and 2001-02 (Figure 22, Dunn's $q = 2.55$, 2.34 respectively, $p < 0.05$). Coho salmon redd densities did not differ significantly between streams during any one year nor among years in any other stream examined (Dun's $q < 1.44$, $p > 0.05$).

Pacific lamprey redds were only observed in the Noyo River and Hare Creek. A total of 102 Pacific lamprey redds were observed in the Noyo River between 4 March and 27 April 2002. The average size of these redds was 0.13 m^2 (S.E. = 0.01). Pacific lamprey redds were found throughout the Noyo River from Company Ranch to McMullen Creek. A total of 7 Pacific lamprey redds were observed in Hare Creek during April 2002. The average size of these redds was 0.15 m^2 (S.E. = 0.06). Pacific lamprey redd size was not significantly different between the Noyo River and Hare Creek ($T = 360$, $n = 100:7$, $p = 0.82$). Pacific lamprey redds were much smaller than coho salmon and steelhead redds.

Adult Steelhead

The number of adult steelhead observed and the number/km are shown in Table 7. The adult steelhead population estimates based on the AUC and redd area methods for the 2001-02 season are shown in Table 5. Population estimates from the AUC and redd area methods in the Noyo River during 1999-00, 2000-01, and 2001-02 are shown in Figure 23. Population estimates were not different between the two methods over three years. Nor did the estimated populations appear different over three years in the Noyo River. Steelhead density based on AUC and redd area population estimates are shown in Table 9. The number of redds per female based on AUC and redd area population estimates are shown in Table 9. The female to male ratio of all steelhead identified to sex is shown in Table 9.

Average steelhead fork lengths in Hare Creek are shown in Table 10. Steelhead fork length frequencies observed in Hare Creek are shown in Figure 24. The number of steelhead observed in Hare Creek and identified to sex was too small for statistical comparisons. Seventy-nine adult steelhead were observed in the Noyo River between 9 December 2001 and 17 April 2002. Steelhead fork length frequencies observed in the Noyo River during 2001-02 are shown in Figure 25. Male, female, and unknown sex fork lengths were not significantly different in the Noyo River during 2001-02 (ANOVA $H = 4.61$, $p = 0.10$).

Adult Coho Salmon

The number of adult Coho salmon observed during spawning surveys is shown in Table 8. Observed live Coho salmon density is shown in Table 8. The AUC, redd area, and carcass Coho salmon population estimates are shown in Table 5. Coho density from the AUC and redd area methods are shown in Table 11. The AUC and redd based coho population estimates were similar (Table 6). Coho salmon AUC and redd area population estimates for 200-01 and 2001-02 are shown in Figure 26. The female to male ratio is shown in Table 11. The number of coho salmon redds per female based on AUC and redd area population estimates is shown in Table 11. AUC population estimates for streams surveyed between 1989-90 and 2001-02 are shown in Figure 27.

Coho salmon fork lengths were different among streams (Figures 23, 28-33, Table 12). Coho salmon fork length frequencies are shown in Figures 24 and 28-33. Female fork lengths were significantly different between rivers ($H = 52.44$ $p < 0.001$). Dunn's Pair-wise comparisons showed that Coho salmon were larger in Ten Mile River than in all other rivers except Hare Creek. All other comparisons were not significantly different ($Q < 2.45$, $p > 0.05$).

Adult Migration and Spawning Timing

<u>Steelhead</u>

Adult steelhead were observed between December 2001 abd April 2002 (Figure 34a-c). Steelhead were first observed in the Noyo River on 10 December 2001 and last observed on 17 April 2002. Steelhead were only observed in the Ten Mile River during January 2002 because surveys were only conducted in December 2001 and January 2002 in this river. In Hare Creek they were observed in January and February and in Pudding Creek only during January and late-March (Figure 46a). The peak period of steelhead observation in the Noyo River during 2001-02 was between mid-February and mid-March and followed a large flow event (Figure 34b). Male and female steelhead were observed throughout the spawning season in the Noyo River during 2001-02. Observation of steelhead does not appear to be related to water temperature (Figure 34c).

The number of steelhead redds observed by month for streams surveyed during 2001-02 are shown in Figures 35-41. In general most redds were found during March 2002. There was little difference in the timing of steelhead redd observations, and thus perhaps the timing of steelhead spawning, among streams during 2001-02 (Figures 35-41).

A total of nine steelhead redds were observed in the Noyo River during 2001-02 with one or more fish guarding or building them. In all but one case the same section of river was surveyed within 8 days and fish were not observed again on these redds. In one observation, a female was observed spawning and found on the redd 13 days later. This suggests the minimum adult stream residency was between 8 and 13 days.

<u>Coho Salmon</u>
The observation frequency of adult Coho during 2001-02 is shown in Figures 42-48. Coho were observed between 30 November 2001 and 16 February 2002. The first coho carcass was observed on 10 December 2000, the first week of spawning surveys. Live coho were last observed on 16 February 2002. The peak period of coho observation was generally during December 2000 (Figures 41-47), except where survey effort was greater later in the season (Figure 48).

Newly formed coho salmon redds were found from December to early-February (Figures 35-41). The majority of Coho salmon redds were observed in early-December 2001 (Figures 35-41). In four streams surveyed during February, the percentage of Coho salmon redds observed ranged from zero to 11.3%. No Coho redds were found in March.

Stratified Index Sampling Population Estimation

The stratified random block design approach was based on redd area population estimates per ½ km segments for Caspar, Hare, and Pudding creeks and Little River (Figures. 10-12). The stratified index population estimates for the Noyo River were based on redd area population estimates for survey segments (Table 1, Figure 8) following Gallagher (2002a). The redd area stratified index population estimates are shown in Figure 49. There was no difference in the number of steelhead per segment estimated by redd area and extrapolated from these estimates (Tukey's $q < 3.9$, $p > 0.05$). However, the power of the test was low ($\alpha = 0.70$). There was no difference in the number of coho per segment estimated by the redd area method and extrapolated from these estimates (ANOVA $H = 11.74$, $p = 0.11$).

Effort

The extent and number of surveys for each stream is shown in Table 1. Generally, crews of two surveyed two approximately 5 km segments each day. Personnel from Campbell Timberlands Management surveyed the Ten Mile River, and Little North Fork Noyo River, and Duffy and Hayshed gulches in the Noyo River during December 2001 and January 2001. Personnel from CDFG's Central Coast Salmon and Steelhead Resource Assessment Program collected data on the South Fork Noyo and Little rivers and Caspar, Hare, and Pudding creeks. Personnel From CDFG's North Coast Watershed Assessment Program collected data in the Albion River. Generally, two vehicles were used each day. Segments were selected each day to maximize efficiency by coordinating drop off and pick up or vehicle rendezvous points. The effort expended on spawning surveys during 2001-02 is shown in Table 13.

DISCUSSION

Coho salmon population estimates based on carcass mark-recaptures were similar to estimates from the AUC and redd area methods (Table 5). Although, there was a wide range in the confidence levels due to the low numbers of recaptures. Data collection procedures were improved considerably compared to the previous season (Gallagher 2002a) and the Coho salmon population estimates from carcass counts were improved. However, estimates for the Albion River and Caspar Creek were made using the Schnabel method and the assumptions of this method were violated (Krebs 1989). Carcass population estimates require unique individual marks, a short duration between surveys, and that the entire river is surveyed to increase the chance of recapturing marked fish. High flows between surveys can burry, wash away, or otherwise decrease the chance of finding carcasses. Cederholm et al. (1989) found that the distance carcasses drifted was directly related to freshets and that the occurrence of buried carcasses was greatly underestimated. After three years of intensive study on the Noyo River (Gallagher 2000, 2002a), it is clear that using carcass based mark-recapture estimators for steelhead is unfeasible due to low numbers of carcasses observed.

Redds

Previous surveys, which assumed all redds found prior to 1 February were made by Coho salmon (Maahs and Gilleard 1993, Maahs 1996, Wehren 1996, Maahs 1997), potentially misidentified a significant number of early season redds. While time of year is an important factor for discriminating between species, assuming that redds made prior to 1 February are all Coho salmon will bias redd area population estimates.

Logistic regression showed that redd area and the date redds were observed were the only significant variables in predicting species constructing redds. Gallagher (2002a) included these variables in discrimination analysis to differentiate Coho salmon and steelhead redds. Increasing the sample size for the training data set and including more rivers and years might change this relationship. However, the number of known steelhead redds was low as they are rarely observed during spawning. Zimmerman and Reeves (2000) report that most steelhead in the Deschutes River, Oregon spawn at night and were only able to positively identify 28 steelhead redds over three years. Because the other physical redd variables including river were shown not to be significantly associated with predicting species, it appears that Coho salmon and steelhead redds are similar among rivers despite potential differences in watersheds. The stream flow in the Noyo River during 2000-01 was below the 49 year median (Gallagher, 2002b), while the 2001-02 stream flows were consistently above the 49 year median (USGS stream gauge # 11468500). Because year was not shown to be significant in predicting species it is likely that the timing of spawning of the two species is driven more by time of year rather than by differences in stream flow. While distance from the river mouth was not significant in predicting species, Coho salmon appear to have spawned higher in the Noyo River during 2001-02 (Figure 17) than during 2000-01 (Gallagher, 2002, Figure 4). Coho salmon spawned significantly lower than steelhead in the Noyo River during 2000-01 (Gallagher 2002a). However, steelhead spawning distribution in the Noyo River appears to be similar between 2000-01 (Gallagher 2002a, Figure 2) and 2001-02 (Figure 5). Logistic regression did not predict coho redds from those identified as steelhead, test, or unknown in the field after 16 February, the time at which no more live coho were observed.

Field uncertainty in redd identification was 18.2%. The apparent error rate from logistic regression was 3.9%. Zimmerman and Reeves (2000) report apparent error rates of 28-36% for classification of anadromous and resident steelhead redds in Oregon. Logistic regression greatly increased confidence in redd identification. However, chinook salmon and Pacific lamprey redds were not included in this analysis. Chinook salmon were not observed on any redds and no redds were identified in the field during 2001-02 as being constructed by chinook salmon. Burner (1951) found fall-run chinook salmon redds averaged 4.9 m^2 and range from 0.83 to 13.4 m^2 in Columbia River tributaries. This size range is closer to redds of Coho salmon (average = 5.22 m^2, S. E. = 0.22) than steelhead (average = 1.51 m^2, S. E. = 0.49) during 2001-02. The last Chinook salmon carcass found in the Noyo River was on 13 February 2002. Thus it is more likely that any Chinook salmon redds in the Noyo River during 2001-02 were identified as coho salmon rather than steelhead. The study plan included Chinook salmon and Pacific lamprey redds in discrimination analysis, yet no positive identifications were made for Chinook salmon and lamprey redds were so distinct in the field that they were not included in the analysis.

Data used in the discrimination was easy to collect, added little extra effort in the field, and was necessary to estimate populations using the redd area method. Crisp and Carling (1989) used logistic transformations to develop linear regressions that predict female fish fork length from redd dimensions. Berghe and Gross (1984, as cited in Crisp and Carling 1989) found a positive correlation between pot depth and female Coho size with 71% of the variance being explained by fish size and 5% by gravel size. There was no relationship between redd area and female fork length for coho salmon and steelhead in the Noyo River during 2001-02. This could be due to the small sample size. Zimmerman and Reeves (2000) used step-wise discrimination to differentiate between anadromous and resident steelhead redds in the Deschutes River, Oregon and found water depth and substrate size significant in classifying anadromous and resident steelhead. They used redd total length and maximum width, tailspill substrate, and water depth and velocity to discriminate between the two life history forms. Length and width were used to calculate redd area and this was found important in discriminating between steelhead and Coho salmon redds. Because the Noyo River is an unregulated river, stream flows and thus depths and velocities can vary widely from survey to survey and were not included in the analysis. Tailspill substrate was measured differently during 2000-01 and was therefore not included in the analysis. Tail spill substrate was not significantly different between Coho salmon and steelhead redds during 2001-02. Gallagher (2002a) used PCA to reduce nine of 13 redd variables and applied the results using Fishers discriminant analysis. This method successfully classified the training data set and worked well to differentiate between Coho salmon and steelhead redds. This method is more cumbersome than logistic regression and is more difficult to add variables for multiple years and rivers, therefore logistic regression was used this year. In addition, multiple species can more easily be included with logistic regression. The discrimination function developed from coho and steelhead redd area and date of spawning using logistic regression appears to be robust for differentiating between these two species based on physical characteristics of the nests and may be useful in other rivers where these species co-occur.

The average size of steelhead redds observed during 2001-02 was smaller than the estimate of 5.4 m^2 from Shapovalov and Taft (1954). However, they only report information for one redd and provide no estimate of the variation in redd size. Orcutt et al. (1968) found that steelhead redds in Idaho streams averaged 5.4 m^2 and ranged from 2.4-11.2 m^2. Steelhead redds in coastal Mendocino County streams during 2001-02 were smaller on average but within the size range reported by Orcutt et al. (1968). Maahs (1996) reports that redds found in some Mendocino County streams after 1 February (assumed to be steelhead) averaged 3.4 m^2 and ranged in size from < 1 to 9 m^2. Maahs (1996) calculated redd area as a square, which might explain why his estimates are slightly higher. The average size of steelhead redds during 2001-02 was smaller than the estimate of Gallagher (2000), but similar to that of Gallagher (2002a). This is likely due to differences in field measurements and calculations of redd area. Gallagher (2000) treated redds as squares whereas Gallagher (2002a), and in this report, the pot was treated as an ellipse or circle and the tail spill as a triangle or square. Zimmerman and Reeves (2000) report anadromous and resident steelhead redd lengths and widths from the Deshutes River in Oregon. Steelhead redds were slightly longer and thinner in coastal Mendocino County streams than those for anadromous steelhead reported by Zimmerman and Reeves (2000). However, the difference is small and likely insignificant. Steelhead redds were longer and wider in coastal Mendocino County streams than those for resident steelhead reported by Zimmerman and Reeves (2000). They also report that resident steelhead spawn from mid-April through early-August with the majority of spawning occurring after mid-May and that anadromous and resident fish segregate spawning habitat. Thus it is likely that few if any resident steelhead redds were observed during 2001-02. However, one pair of anadromous sized steelhead was observed spawning accompanied by three resident sized fish. Whether or not these fish were interbreeding was unknown.

Burner (1951) reports that Coho salmon redds ranged from 1.51 tot 2.85 m^2 in tributaries to the Columbia River. This is much smaller, but within the range, of Coho salmon redds observed in coastal Mendocino County during 2001-02. Maahs (1996) reports that redds found in some Mendocino County streams before 1 February (assumed to be coho) averaged 4.45 m^2 and ranged in size from < 1 to 20 m^2. This is similar to coho redd sizes observed during 2001-02. The slightly larger redd sizes reported by Maahs (1996) may be because only lengths and widths were measured and redd area was calculated as a square. Coho salmon redds were larger and were generally found earlier in the year than steelhead redds (Table 4).

Average steelhead redd densities observed during 2001-02 was not significantly different than previously reported for coastal Mendocino County streams. However, survey duration and intensity was different over the years and early season steelhead were potentially misidentified as Coho salmon in earlier surveys. If redd density is an indication of population abundance, it appears that steelhead populations have been relatively constant over the last 12 years. Shapovalov and Taft (1954) found adult steelhead counts relatively stable between 1933 and 1942 in Waddell Creek, California. Noyo River redd densities were similar over the last three years (Figure 14) when survey methods, duration, and intensity were similar. Steelhead population estimates were similar over the last three years in the Noyo River (Figure 23). Therefore, redd densities may be a reasonable metric for long term monitoring of population trends. Although it may take large changes in abundance to detect significant changes in redd densities. Using a stratified index approach will increase the sample size for calculating stream specific redd densities and should increase the power of this type of data for trend detection.

Steelhead redds were found to be distributed randomly in the Noyo River during 1999-00 (Gallagher 2000) and aggregated during 2000-01 (Gallagher 2002a). Survey period and intensity was less during 1999-00 than in 2000-01 and similar between 2000-01 and 2001-02. Thus differences in effort are likely not responsible for the difference. Water years were more similar between 1999-00 and 2001-02 than during 2000-01. Thus stream flow might explain the different distributions.

Coho salmon populations appear to have varied over the last 12 years in coastal Mendocino County (Figure 27). However, coho salmon redd densities were not different between streams or among years over the last 12 years except in Caspar Creek where densities were significantly lower in 1996-97 than in 1991-92 and 2001-02. The difference in Coho salmon redd densities in Caspar Creek may be real or due to differences in effort. If redd density is an indication of population abundance it appears that Coho salmon populations have been relatively constant over the last 12 years. Shapovalov and Taft (1954) found adult Coho salmon counts to be variable between 1933 and 1942 in Waddell Creek, California ranging from 84 to 583. However, these were assumed to be total counts without confidence bounds in their counts. Except for Caspar Creek during 2001-02 compared to 1996-97, Coho salmon populations appear to be similar over the period 1989-90 to 2001-02. Therefore, redd densities may be a reasonable metric for long term monitoring of population trends. Using a stratified index approach will increase the sample size for calculating stream specific redd densities and should increase the power of this type of data for trend detection.

Adult Steelhead

Observed live steelhead density during 2001-02 was within the range reported recently for other nearby streams. However, live steelhead were not observed in all streams surveyed during 2001-02 (Table 7), even though steelhead redds were observed in all streams except the Albion River. The time between surveys, annual stream flow, and differences in water visibility and fish behavior influence the number of live fish observed. Live fish densities are likely not a reliable metric for long term monitoring.

The AUC confidence levels for 2001-02 were based on estimates of *v* from Gallagher (2002a) and was not estimated during this season. The *rt* used in the AUC to estimate steelhead populations during 2001-02 was the average estimate of 36 days from Gallagher (2002a) and was not estimated during this season. English et al. (1992) state that *v* and *rt* should be estimated annually for each stream because the AUC method is sensitive to these variables. English et al. (1992) found the AUC method sensitive to variability in survey time and observer efficiency and that estimates based on total residency time more closely predicted known population values. AUC estimates during 2001-02 were similar to redd area methods indicating that using *rt* and *v* values estimated on the Noyo River during 2000-01 were not entirely unreliable and that the timing between surveys was sufficient. However, AUC population estimates were not made for some streams during 2001-02 because fish were not observed, indicating that the periodicity of surveys should be increased. Also using Noyo River 2000-01 *rt* and *v* values for other streams or other years may be unrealistic. The overlap between AUC and redd area estimates may be because the *v* values from the Noyo River were based on rather large mark-recapture confidence intervals (Neillands 2002).

Estimates of *rt* and *v* strongly influence AUC population estimates (Beidler and Nickelson 1980, English et al. 1992, Irvine et al. 1992, Maahs and Gilleard 1993, Hilborn et al. 1999). Estimates of *rt* and *v* change from year to year and should be made each year (English et al. 1992) and estimated throughout each season (English et al 1992, Manske and Schwarz 2000). Estimates of *rt* and *v* are realistically only possible using independent mark-recapture estimates (from which populations estimates can be made using standard techniques). Shardlow et al. (1987) found that observation efficiency depended on the method of observation. Irvine et al. (1992) did not find a relationship between fish density and the number sampled by electro-fishing to estimate *v* for Coho salmon in Vancouver, British Columbia. Maahs and Gilleard (1993), Irvine et al. (1992), English et al. (1992), and Hilborn et al. (1999) produced estimates *rt* and/or *v* using independent mark-recapture or weir counts. Manske and Schwarz (2000) developed a technique to use mark-recapture to estimate *rt* and the AUC. Mark-recapture population estimates require physical structures or active capture techniques which are highly susceptible to failure due to high flows. Shapovalov and Taft (1954) could not operate traps on Waddell Creek during high flows. Neillands (2000, 2002, In prep.) caught very few steelhead during 1999-00 with gill nets, had difficulty maintaining a weir during 2000-01 (which was more successful than gill netting), and did not catch any steelhead in a weir prior to it being destroyed by high flows during 2001-02. Zuspan and Sparkman (2002) were successful in capturing steelhead with seines and estimating populations by mark-recapture in the Mad River, California during 2000-01. However, they were unable to use this technique during 2001-02 due to high stream flows (Sparkman Perrs. Comm.). It appears that the AUC method for estimating steelhead populations is not reliable because it is labor intensive, requires a mark-recapture method which is subject to failure during moderate and high water years, observer efficiency is difficult to estimate, and requires mark-recapture of fish which can estimate populations without the AUC. Improved estimates of *rt* and *v* will likely improve population estimates using the AUC method, but are likely to be very costly and labor intensive to obtain for each stream each year.

Redd-based steelhead population estimates for streams surveyed during the 1990's were not made due to the timing of the surveys and lack of information on steelhead mating systems (Maahs 1996). Using mark-recapture, Boydstun (1977) estimated the steelhead population in the Gualala River to be between 3508 and 5654 adults in 1976-77. The Gualala River drains approximately 777 km^2 and has 286 km of steelhead habitat (Higgins 1998), thus it is about three times as large as the Noyo River. The redd area population estimate of 163 (± 6) adult steelhead in the Noyo River during 2001-02 is, considering relative stream size, still much lower than the Gualala River estimate in the 1970's. The CDFG (1965 as cited in Busby et al. 1996) estimated steelhead populations in the Gualala River at 16,000 and for the Noyo River at 8,000. This estimate is more than three times the number estimated in the 1970's for the Gualala. The CDFG 1965 estimate for the Noyo is more than 13 times the high estimate for 2001-02. The Noyo River steelhead population estimate for 2001-02 is less than that of 2000-01 (Gallagher 2002a) and similar to that of 1999-00 (Gallagher 2000).

Adult steelhead population estimates from the AUC and redd area methods were similar during 2001-02 (Figure 23, Table 5). Gallagher (2001, 2002) found that redd area population estimates from 1999-00 and 2000-01and the AUC estimate during 2000-01 were similar to independent mark-recapture population estimates. The close correspondence in the estimate of the number of redds per female between the AUC and redd area methods adds confidence to these estimates (Table 9). Gallagher (2002a) had similar results. The estimate of numbers of redds/female during 2001-02 were not unrealistic. Riengold (1965) recorded an example of a female steelhead building two redds in different locations. Crisp and Carling (1989) found that 51% of rainbow trout redds had eggs. Two or three redds per female, especially if distributed widely, decreases the chance of loss from high flow scour, sedimentation, or other catastrophic event and increases survival and the likelihood of successful spawning with more than one male.

The redd area method assumes that all redds are counted throughout a season and that there is a relationship between redd size and the number of redds a female steelhead makes. Repeated surveys throughout the season, conducting surveys between high turbidity events, and having two people observing during each survey increases the chances all redds are counted and measured. Taking the above into account redd area population estimates should be considered as minimum estimates. This methodology is potentially sensitive to estimates of the relationship between redd size and the number of redds a female steelhead makes. I used the average known redd size and divided by ¾, ½, and ¼ to estimate the number of females from redd areas and this appears to have worked well. More information on the number and size of redds made by one female and mating behavior may help better define this relationship. The redd area method appears to be a useful and reliable technique for estimating steelhead populations. It has shown to produce population estimates within the confidence bounds of other independent estimation methods over three years in the Noyo River and when applied to five coastal streams during 2000-01 and 2001-02. This methodology is not susceptible to mechanical failure, can have an relatively large interval between surveys (as long as high flows do not obscure redds between surveys), does not require independent mark-recapture data, has been demonstrated to produce estimates within the confidence bounds of independent estimates, does not require tagging or handling fish, is technically and conceptually straightforward, and appears to be a technique which can be employed consistently and reliably over many different water year types.

The redd area method assumes that all redds are counted throughout each season and that there is a relationship between redd size and the number of redds a female coho or steelhead makes. Repeated surveys throughout the season, conducting surveys between high turbidity events, and having two people observing during each survey increases the chances all redds are counted and measured. Evaluation of observer efficiency for redd surveys will improve estimates for this method. Jacobs et al (2001) found steelhead redds to be recognizable on average after 41 ± 17 days, that < 8% were missed if surveys were conducted biweekly, and that they would only miss about 26% if they only surveyed monthly. Taking the above into account, redd area population estimates should be considered as minimum estimates. This methodology is potentially sensitive to estimates of the relationship between redd size and the number of redds a female salmonid makes. We used the maximum known steelhead redd size multiplied by 0.75, 0.5, and 0.25, and information from Maahs (1997) for coho to estimate the number of females from redd areas. This approach produced population estimates within the range produced by two independent methods. More information on the number and size of redds made by one female and mating behavior may help better define this relationship.

Steelhead observed during 2001-02 were within the size range reported previously for nearby streams. Boydstun (1977) reports the mean fork length for steelhead captured in the Gualala River during 1976-77 was 71.3 cm. Steelhead captured in the Gualala River during 1975-76 ranged from 30 to 90 cm fork length (Boydstun 1976). Steelhead captured in the Garcia River during 1972-73 ranged from 13 to 85 cm fork length (CDFG 1973).

The adult steelhead sex ratio observed in the Noyo River during 2001-02 was different from, and in Hare Creek the same, as reported by Withler (1966) where steelhead sex ratios were nearly 1:1 along the Pacific Coast from California to British Columbia. Erman and Hawthorne (1976) and Everest (1973) found that steelhead sex ratios had higher proportions of males in Sagehen Creek, California and the Rouge River, Oregon, respectively. Boydstun (1976) found that un-spawned steelhead showed no trend in sex ratio, while females dominated spent fish catches in the Garcia River during 1975. Boydstun (1977) found that females vastly outnumbered males in the Garcia River during 1976 and attributed this to capture methods. Everest (1973) attributes the difference in sex ratio to the fact that females generally complete spawning and leave streams more rapidly than males. The Noyo River steelhead sex ratio during 2001-02 was different than during 1999-00 and 2000-01 (Gallagher 2000, 2002). The difference in sex ratio among years maybe due to sampling methods where all fish were visibly identified during 2001-02 and some fish were captured and handled during 1999-00 and 2000-01.

Steelhead Migration and Spawning Timing

Steelhead spawning began in mid-December 2001 and extended through mid-April 2002. There was some difference in the beginning, ending, and peak dates of spawning among rivers during 2001-02. This may be due to differences in survey periodicity and intensity. There was a large overlap in the spawning of coho salmon and steelhead during 2001-02. This is apparent in the larger uncertainty of field identified redds. When both species were in the river discrimination analysis was necessary to distinguish redds by species. The migration timing of adult steelhead and spawning activity during 2001-02 was similar to most previous reports for nearby streams. Shapovalov and Taft (1954) found steelhead first entered Waddell Creek between October and December, peaked in March, and left the creek between March and July with a peak in mid-April. Boydstun (1976) reported that steelhead spawning occurred between February and April, peaked in mid-February, and that fish entered the Gualala River between December and April 1975-76. He states that steelhead spawning in the Garcia occurs between February and March. Nielsen et al. (1990) reported that steelhead spawning began in early January and continued past the end of their survey in the South Fork Noyo during 1989-90. Maahs and Gilleard (1993) observed few steelhead before February in seven coastal Mendocino County streams they studied during 1990-92. Maahs (1996, 1997) found steelhead spawning began in early January 1995 and in mid- March 1996 and peaked in mid-March during both years in portions of the Garcia and Ten Mile rivers and Caspar Creek. Spawning activity continued through mid April both years. Maahs (1999) found a similar pattern in the Garcia River during 1998-99. Steelhead begin their spawning run in early-January and are found through April during most years in coastal Mendocino County streams. However, Busby et al. (1996) state that steelhead enter Pudding

Creek in November and spawn between December and March. They show spawning and migration timing for Caspar Creek and Gualala River similar to that described above.

Adult Coho Salmon

Observed live coho salmon density during 2001-02 was generally higher than the range reported recently for other nearby streams. Live coho salmon density was lower than reported by Gallagher (2002) in the Noyo River because there was a hatchery component to the run in 2000-01 and not in 2001-02 (M. Knechtle, Perrs. Comm.). Nielsen et al. (1990) report observed December-January (assumed to be coho) densities in 11 coastal Mendocino County Streams ranged from 0 to 11.86/ km with the highest density in the South Fork Noyo River. They found the highest density of coho salmon in the South Fork Noyo River was in the segment below the Noyo-ECS. Maahs and Gilleard (1993) report observed December-January (assumed to be coho) for eight coastal Mendocino County streams densities ranged from 0 to 0.31/ km and the highest density was in the South Fork Noyo River at 7.8/km. Maahs (1996) reports observed coho density in the Ten Mile River was 0.56/km, in the Garcia River was 0.56/km, and in Caspar Creek was 1.43/km. Live coho density in the Garcia River during 1998-99 was 0.31/km (Maahs 1999). Annual and watershed differences in water visibility likely influence the number of live fish observed. Live fish densities are likely not a reliable metric for long term monitoring.

The carcass based mark-recapture, AUC, and redd area population estimates during 2001-02 were very similar. However, redd area population estimates were outside the AUC confidence bounds in four out of seven streams. Redd area estimates were within the carcass mark-recapture confidence bounds in five of six cases. The AUC *rt* and *v* were taken from the literature and not developed from local rivers. Thus these estimates should be viewed with caution. Also there was a period of about two and one half weeks in late-December 2001 and early-January 2002 when stream flows were high and turbid such that surveys could not be conducted. It is possible that a large number of fish were missed during this period and contributed to the differences in population estimates from redd areas and AUC. However, based on the discussion above for adult steelhead and the AUC, this method, while capable of producing population estimates, may prove too cumbersome and costly to estimate Coho populations over the long term. Some Coho salmon redds may have been missed or obscured by high flows. Thus the estimate from the redd area method should be treated as a minimum estimate.

Coho salmon observed during 2001-02 were within the size range reported previously for nearby streams. Gallagher (2002a) found Coho salmon to range from 35 to 90 cm in the Noyo River. Nielsen et al. (1990) found coho salmon to range from 38 to 78 cm. Maahs and Gilleard (1993) report that two year old male coho salmon were 47.1 cm (range 42-50), two year old females were 48 cm (range 46-50), three year old males were 64.5 cm and ranged from 45-71cm, and three year old females were 63.8 cm (range 49-73). Maahs (1996) found coho salmon in the Ten Mile and Garcia rivers and Caspar Creek ranged of 41 to 70 cm. Maahs (1997) found coho salmon to range between 50 and 65 cm.

Coho Salmon Migration and Spawning Timing

Coho salmon observations during 2001-02 generally peaked in late-December 2000, except where survey intensity was concentrated in January 2002. There was a large overlap in the spawning of coho salmon and steelhead during 2001-02. This caused uncertainty in field identification of redds. Discrimination analysis was necessary to distinguish redds when both species were in the river and lowered uncertainty in redd identification. The migration timing of adult coho salmon and spawning activity during 2001-02 was similar to most previous reports for nearby streams. Nielsen et al. (1990) and Maahs and Gilleard (1993) reported that coho spawned between December 1989 and February 1990 in the South Fork Noyo River during 1991-92. Maahs (1996, 1997) found coho spawned between December and January 1996 and peaked in January during both years in portions of the Garcia and Ten Mile rivers and Caspar Creek. Coho salmon begin their spawning run between November and February in most years in coastal Mendocino County streams (Nielsen et al. 1990).

Stratified Index Sampling Population Estimation

This type of sampling can be viewed as a specialized form of stratified random blocked transect sampling were the stream segments are blocks and the entire length of stream spawning habitat is the census zone. The mean number of fish and variance is calculated from the blocks and multiplied by the census zone (Krebs 1989). This methodology is preferable to total count censuses because population estimates have associated variance estimates (Krebs 1989). Because redds are flagged the chance of double counting is reduced. Although Coho salmon redds are aggregated, the use performance curves to set the minimum number of samples needed reduced sampling error.

Irvine et al. (1992) found that stratified index estimates were always similar to mark-recapture estimates. Gallagher (2002a) found stratified index population estimates within the range of those derived from mark-recapture and not significantly different from AUC and redd area estimates for steelhead in the Noyo River. Coho salmon redd area population estimates using stratified index sampling design were not significantly different from actual estimates in the Noyo River during 2001-02 (Gallagher 2002a). The redd area estimates from stratified random block sampling were not significantly different for steelhead and Coho in all streams during 2001-02. Using a stratified random blocked transect sampling design for small streams based on 0.5 km segments and estimating populations with the redd area method resulted in reasonable population estimates with variance estimates for Coho salmon and steelhead when 33% of the stream spawning habitat length and 33% of segments were sampled. For larger streams a stratified random blocked transect sampling design which estimated populations with the redd area method, based on the results from the Noyo River over two years, that sampled 33% of the sample reaches and 45% of the stream spawning habitat length resulted in reasonable population estimates with estimates of variance.

Coho salmon and steelhead populations were best estimated by the redd area method, with uncertainty in redd identification reduced by discrimination, in a stratified random blocked transect sampling design during 2000-01 and 2001-02.

Effort

The entire spawning survey, excluding data entry, analysis, and reporting totaled about 1222 field hours, 488 hours of driving, and 3421 person hours. This resulted in redd distribution, redd density, redd number, adult population estimates, and provided information on adult coho salmon and steelhead migration and spawning timing in seven coastal Mendocino County streams. A stratified random blocked transect design appears to provide reasonable population estimates for Coho salmon and steelhead and can reduce field effort in individual streams allowing increased coverage of this geographic area.

RECOMMENDATIONS

There was a wide range in the estimate of adult numbers based on the AUC method due to a lack of stream and year specific estimates of *rt* and *v* and because some streams were surveyed less intensively than others. More information on steelhead mating systems, length of stream residency, and estimates of observer efficiency may improve AUC population estimates, but may be very costly and time consuming. Starting surveys earlier, reducing the time between surveys, and conducting studies directed at understanding mating systems, the number and size of redds produced per female, and estimating observer efficiency in redd counts will help reduce the uncertainty in redd based population estimates. A study to examine mating systems using remote sensing (i.e. video equipment) is planned for the Noyo River during 2002-03.

A stratified random blocked transect design appears to provide reasonable population estimates with the redd area method for Coho salmon and steelhead and can reduce field effort in individual streams allowing increased coverage within this geographic area. This method should be employed and tested in other rivers in the NCESU. Spawning surveys should be conducted on multiple streams in the future using a stratified random block design which samples 30 to 45% of spawning habitat per stream depending on total stream size. Spawning surveys should begin in late-November next year. This will require working around large flow events and will require a larger crew. Carcasses should be individually marked and mark-recapture used with the stratified random block design. Coordination with timber companies (i.e. Campbell Timberland Management and The Mendocino Redwood Company) and other CDFG programs greatly increased coverage in coastal Mendocino County streams during 2001-02. This should be encouraged for 2002-03. Chinook salmon and Pacific lamprey redd data should be collected and included in discrimination analysis to further refine discrimination of redds. Streams in which no redds were observed this season should be visited at least once each season. Those streams found not to have redds again next season should be re-surveyed intensively every five years.

ACKNOWLEDGEMENTS

Thanks to the Mendocino Redwood Company for allowing access to their property and the use of their roads. Charles Bellow ungraciously disallowed access to the North Fork and roads to the upper North Fork. Tamara Camper, Scott Fullerton, Merrin Siavage, Fred Schuler, Jeremy Wright , Dave Wright, John Yanez of the Campbell Timberland Management Company assisted with data collection on the Ten Mile River and lower Noyo River segments and shared their data. Marisa Calloway, Scott Harris, Andy Hepokoski, Kristi Knechtle, Morgan Knechtle, Mike

McNeal, Debra Parthree, and Emma Womack of the CDFG Central Coast Salmon and Steelhead Resource Assessment program and Heidi Fish and Steve Gough of the NMFS Santa Cruz laboratory surveyed Caspar, Hare, and Pudding creeks and the Little and South Fork Noyo rivers. Sarah Greene, Cynthia LeDoux, Alan Palacios, Andy Pothast, John Richardson of CDFG's North Coast Watershed Assesment Program surveyed the Albion River. Brigette Bondoux, Matt Coleman, Craig Comen, Forrest Cottrell, Natalie Lohi, George Neillands, and Chris Szejk helped conduct this survey on the Noyo and Ten Mile rivers. Colin Gallagher, Department of Statistics, Clemson University, Clemson SC assisted with discrimination analysis. George Neillands, Matt Coleman, Morgan Knechtle, and Adam Wagshagel provided helpful comments on the manuscript.

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PERSONAL COMMUNICATIONS

Colin Gallagher. June 2002. Department of Mathematics, California State University, Chico, Chico, CA.

Morgan Knechtle. July 2002. California Department of Fish and Game, Fort Bragg, CA.

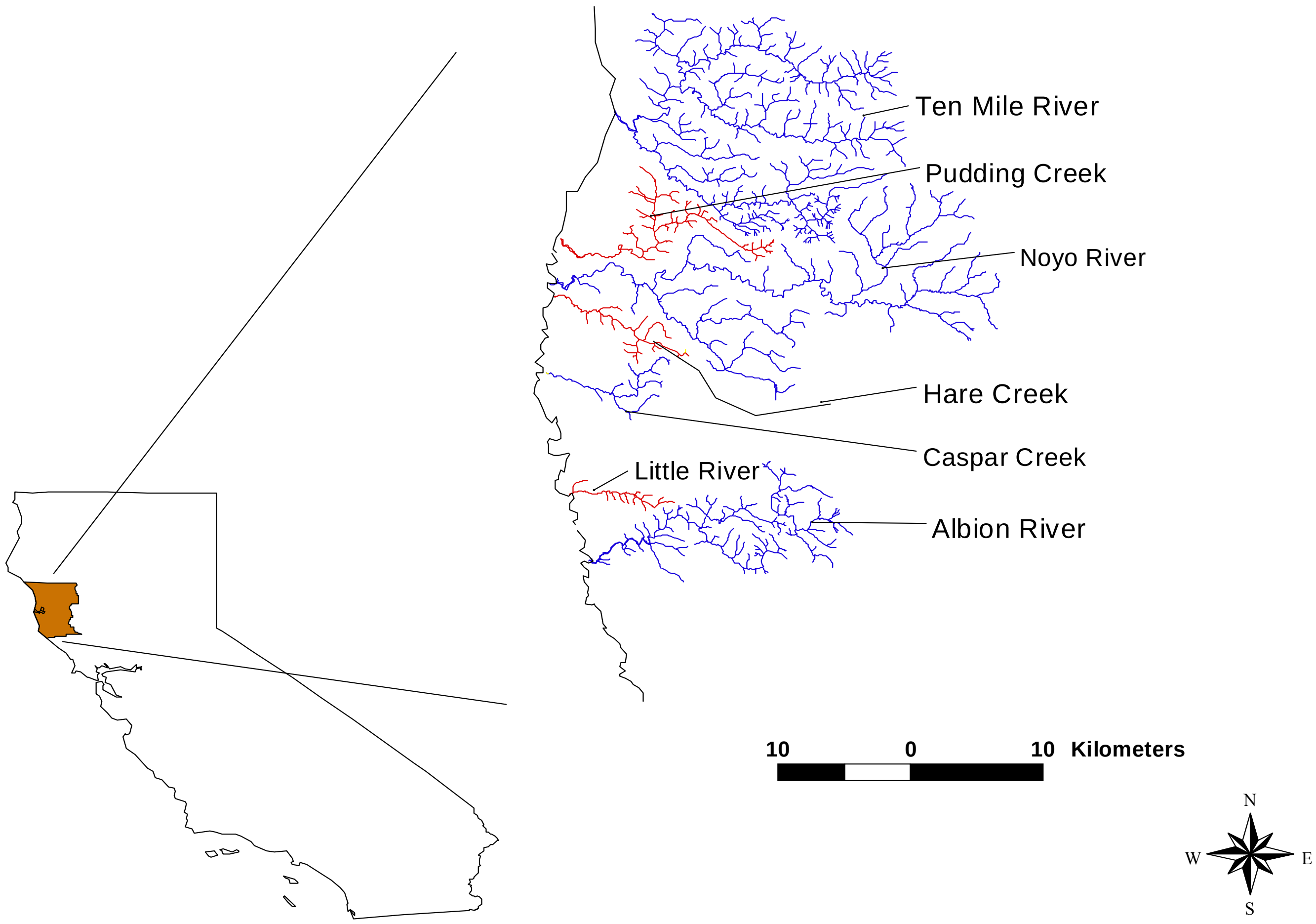


Figure 1. Location of Mendocino County in California and seven streams surveyed during 2001-02.

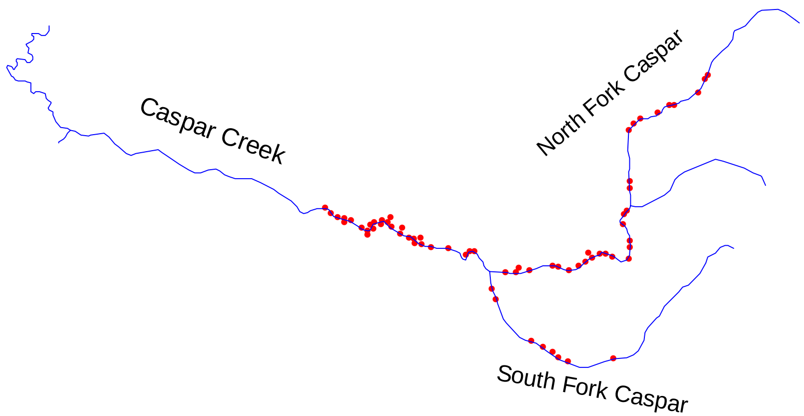


Figure 2. Location of steelhead redds observed in Caspar Creek during 2001-02.

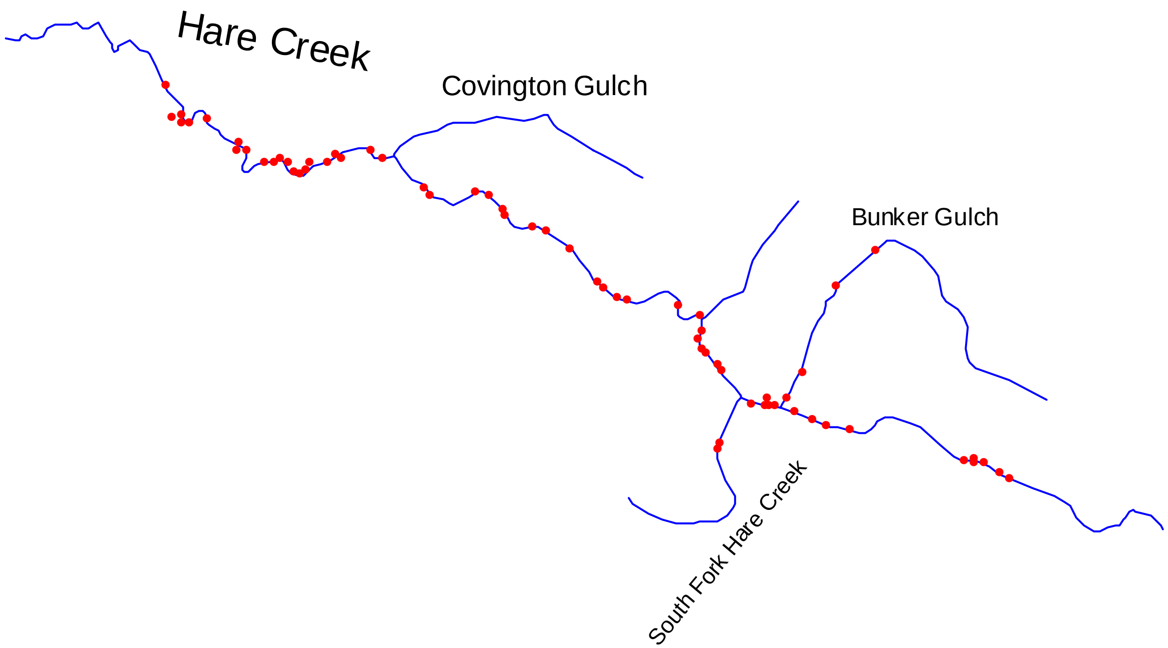


Figure 3. Location of steelhead redds observed in Hare Creek during 2001-02.

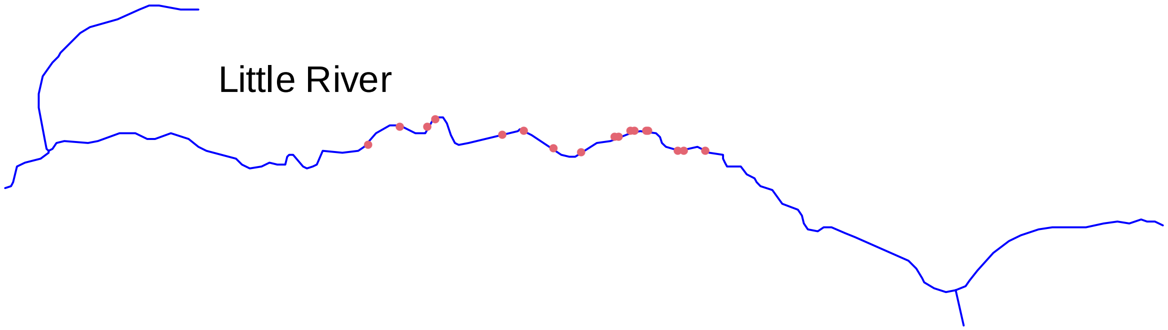


Figure 4. Location of steelhead redds observed in the Little River during 2001-02.

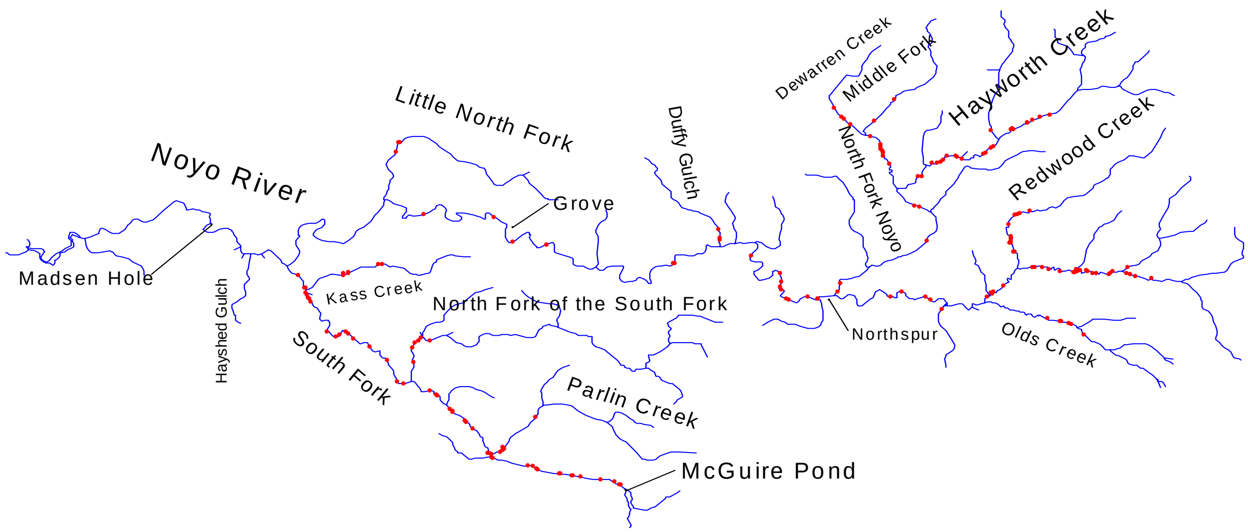


Figure 5. Location of steelhead redds observed in the Noyo River during 2001-02.

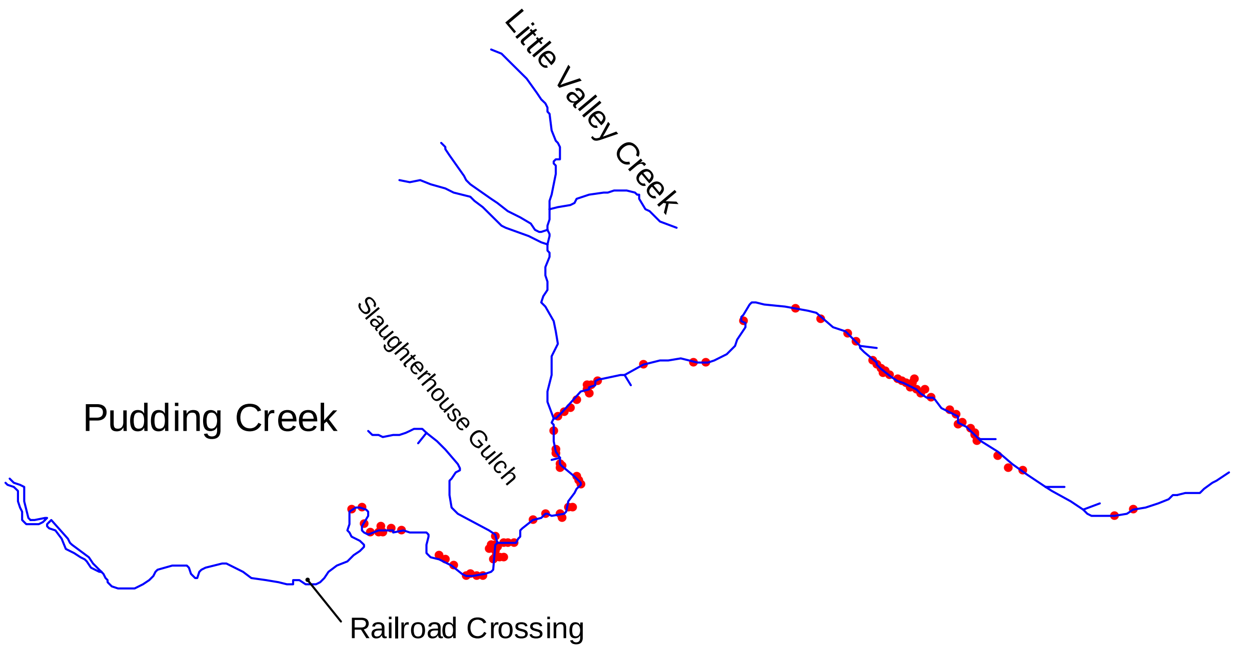


Figure 6. Location of steelhead redds observed in Pudding Creek during 2001-02.

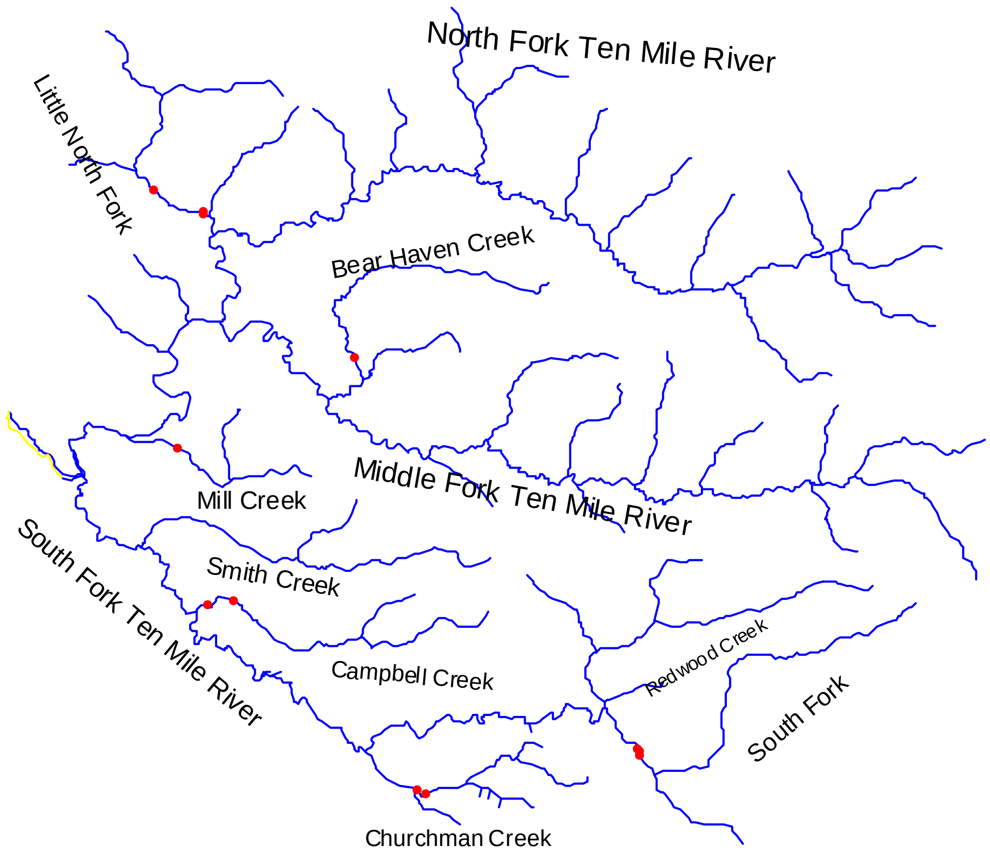
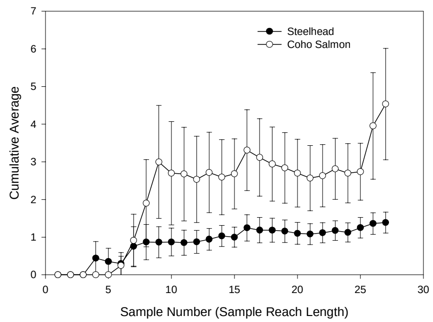
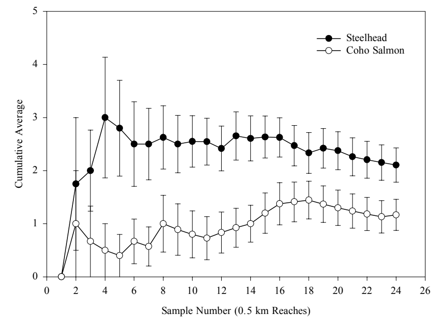


Figure 7. Location of steelhead redds observed in the Ten Mile River during 2001-02.





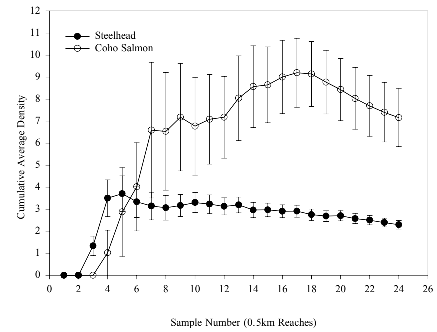
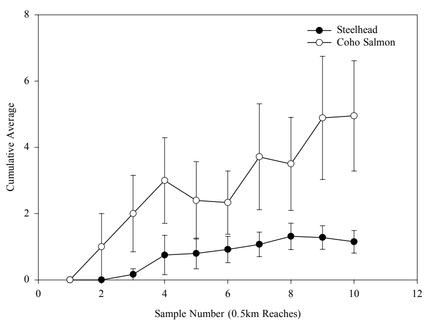


Figure 8. Cumulative mean density of Coho salmon and steelhead ± SE by sample reach in the Noyo River.

Figure 9. Cumulative mean density of Coho salmon and steelhead ± SE by 0.5 km sample reach in Hare Creek.

Figure 10. Cumulative mean density of Coho salmon and steelhead ± SE by 0.5 km sample reach in Caspar Creek.



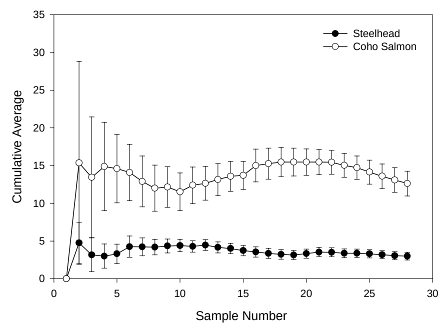


Figure 11. Cumulative mean density of Coho salmon and steelhead ± SE by sample reach in the Little River.

Figure 12. Cumulative mean density of Coho salmon and steelhead ± SE by 0.5 km sample reach in Pudding Creek.

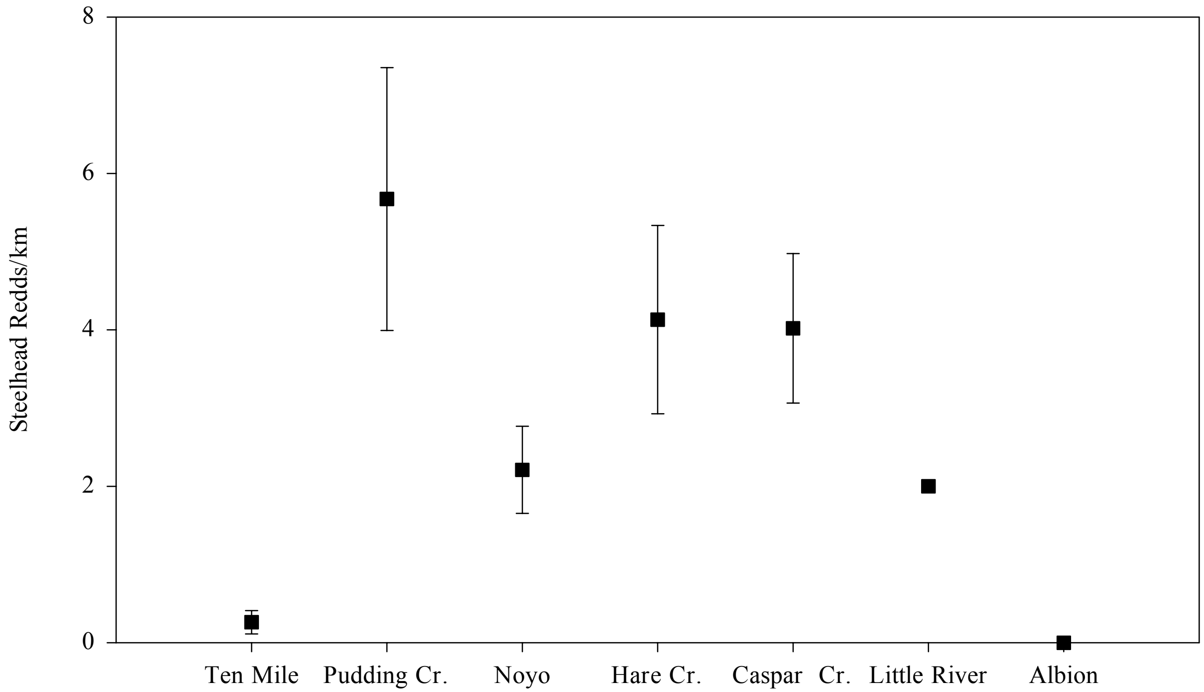


Figure 13. Average steelhead redd density (#/km) in seven coastal Mendocino County streams 2001-02. Streams are arranged north to south. Note: Ten Mile and Albion rivers were not surveyed after mid-February. Thin lines are ± 1 SE. Note: Stream segments were treated as samples to calculate averages. No redds were observed in the Albion River and Little River had only one segment.

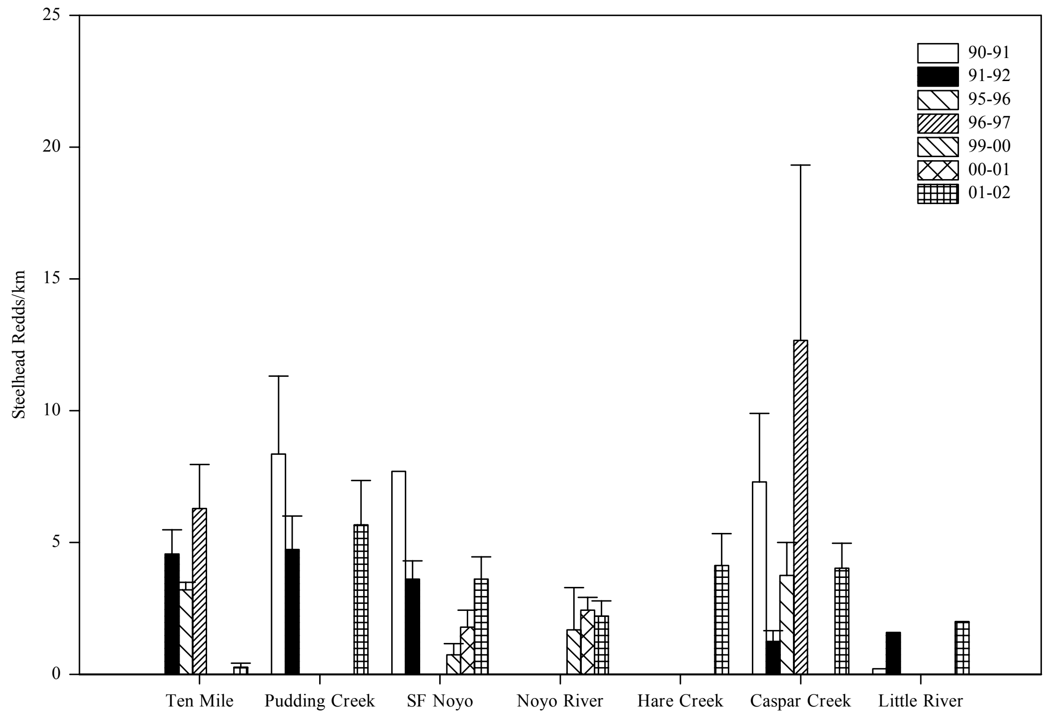


Figure 14. Steelhead redds/km for six coastal Mendocino County streams 1989-90 to 2001-02. Streams are arranged north to south. Thin lines are ± 1 SE. See text for data sources.

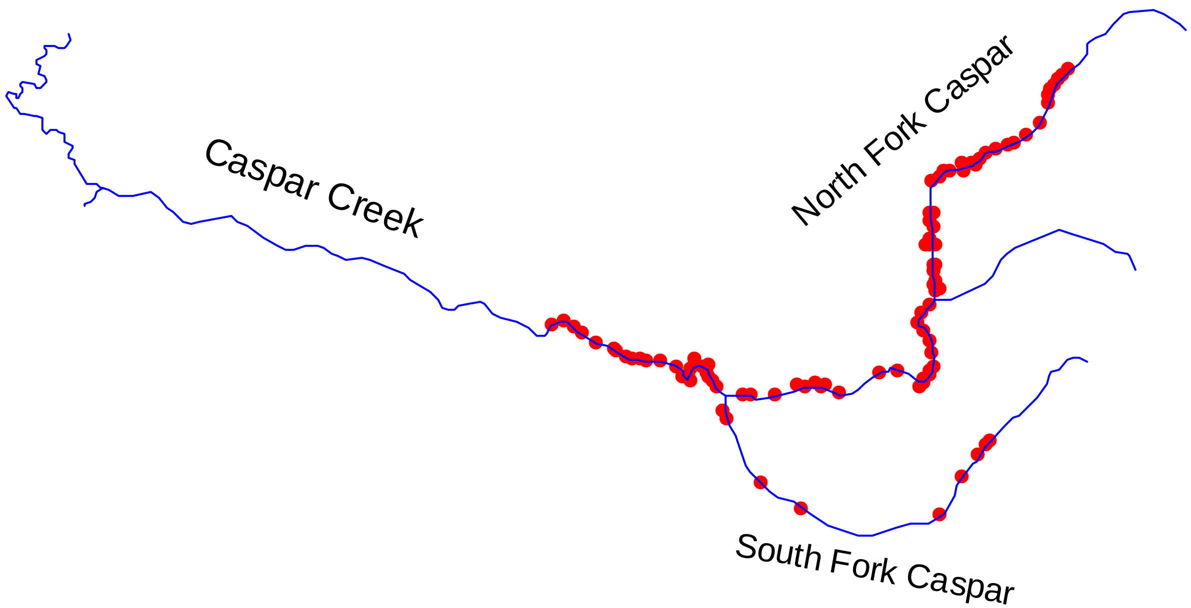


Fig 15. Coho salmon redd locations observed in Caspar Creek during 2001-02.

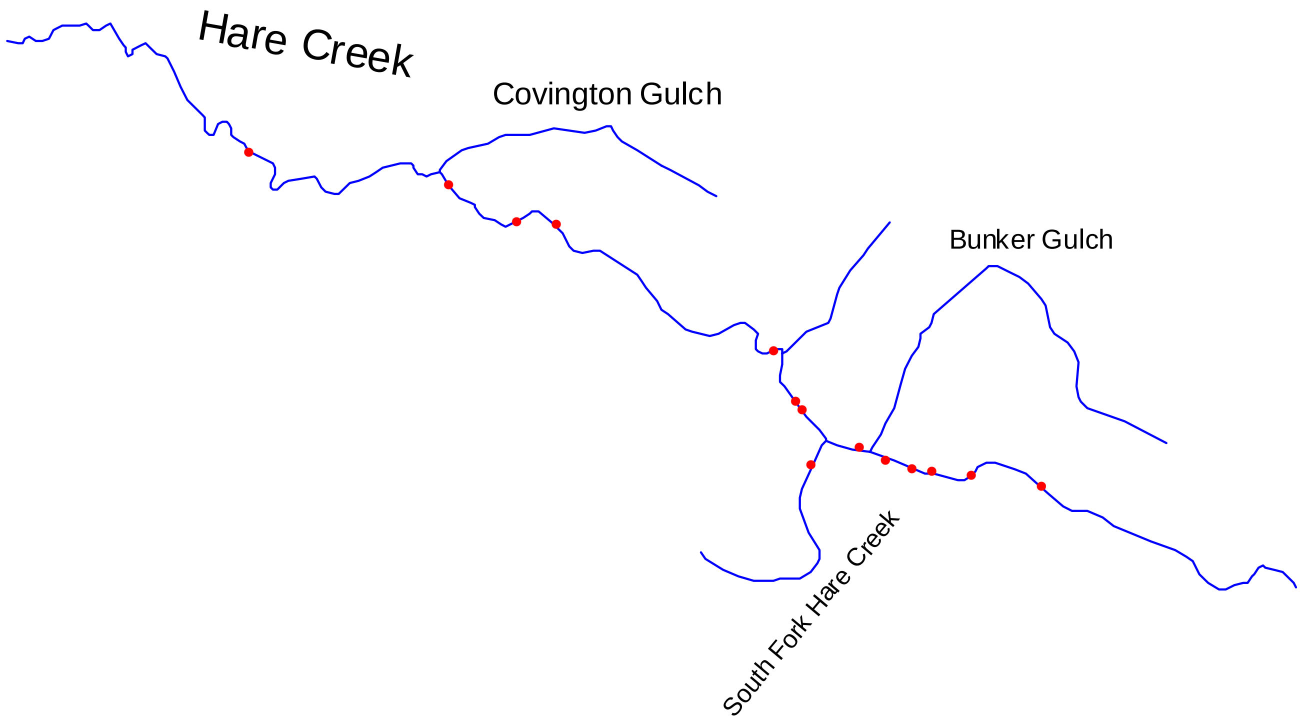


Figure 16. Coho salmon redd locations observed in Hare Creek during 2001-02.

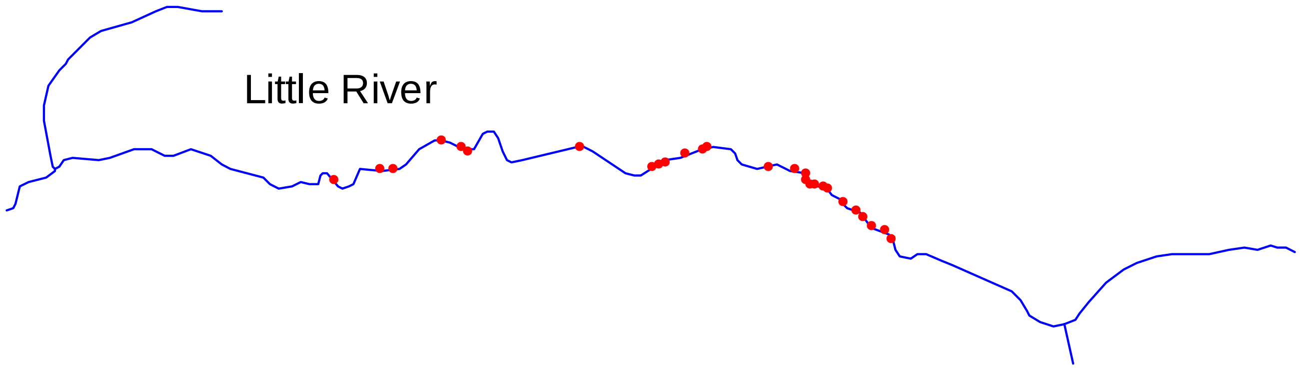


Figure 17. Coho salmon redd locations observed in the Little River during 2001-02.

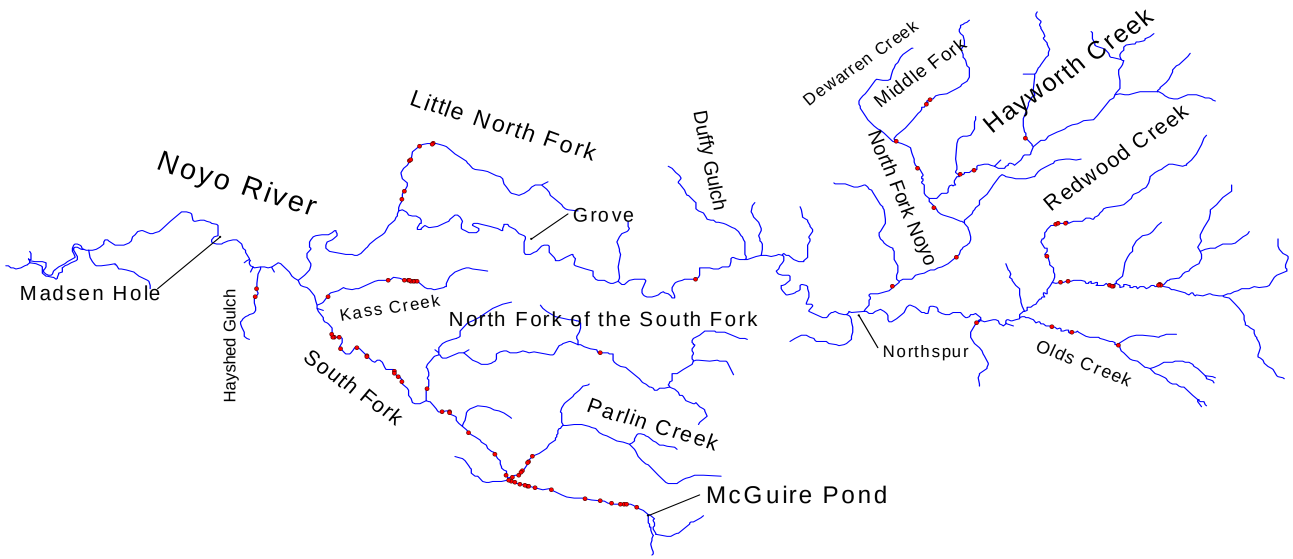


Figure 18. Coho salmon redd locations observed in the Noyo River during 2001-02.

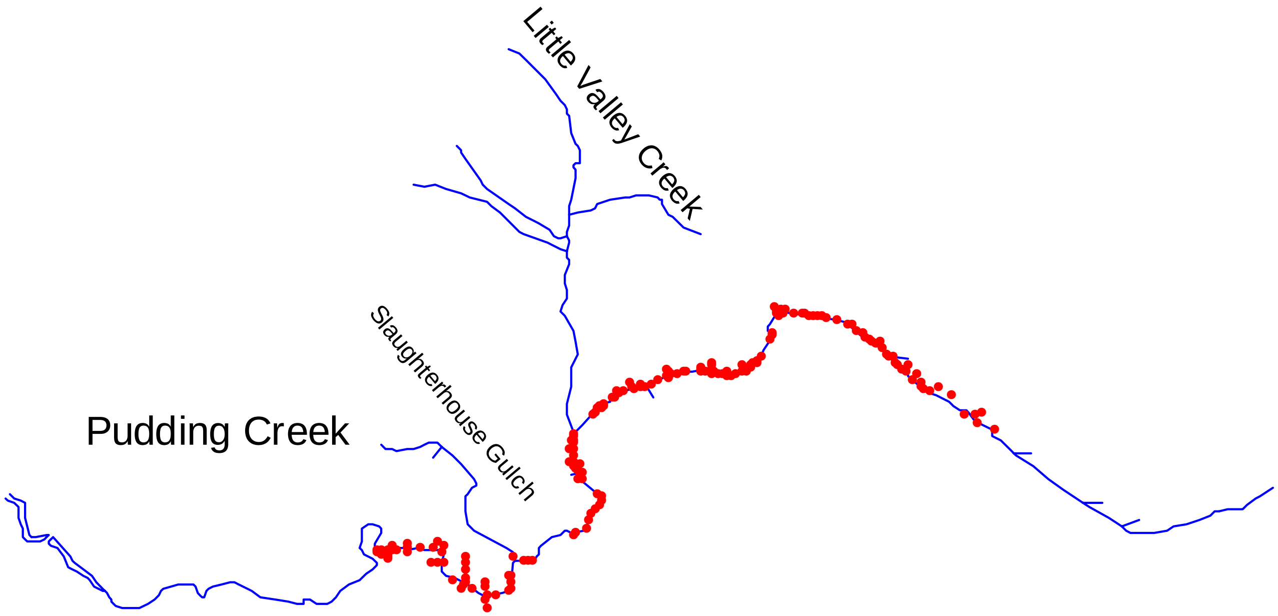


Figure 19. Coho salmon redd locations observed in Pudding Creek during 2001-02.

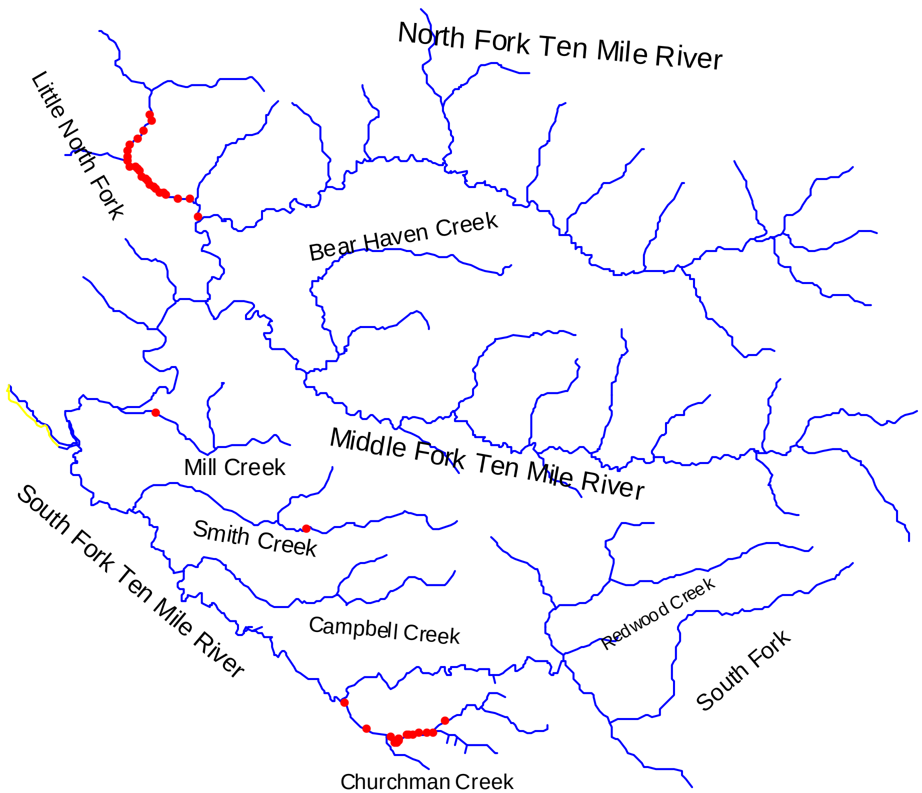


Figure 20. Coho salmon redd locations observed in the Ten Mile River during 2001-02.

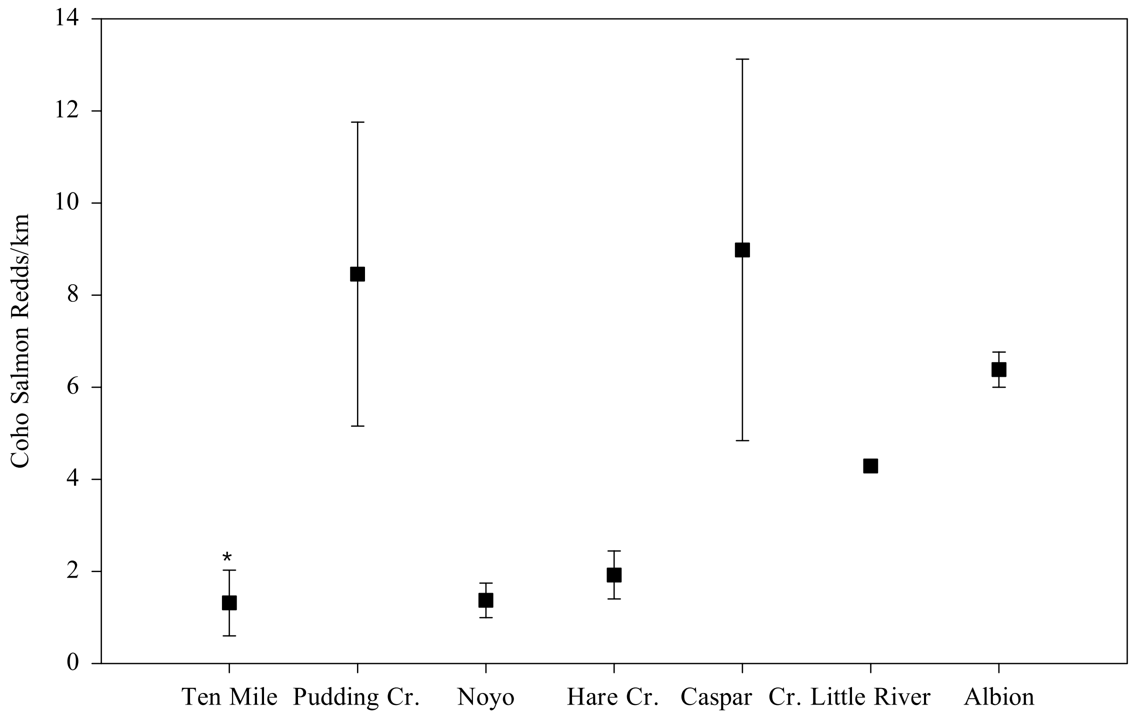


Figure 21. Coho salmon redds/km in seven coastal Mendocino County streams during 2001-02. Streams are arranged north to south. Thin bars are ± 1SE. Note: Stream segments were treated as samples to calculate averages. Little River had only one segment.

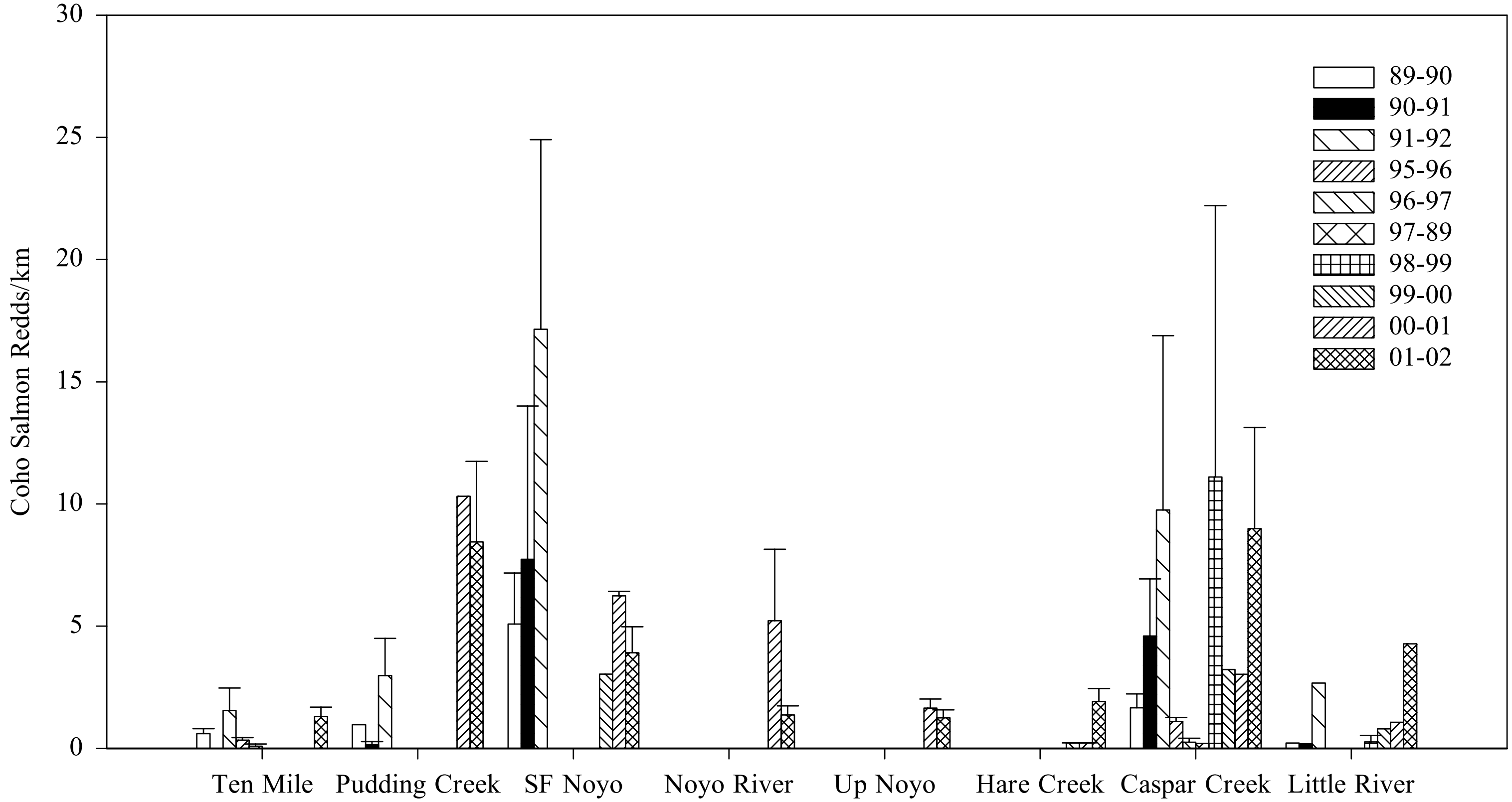


Figure 22. Coho salmon redds/km six coastal Mendocino County rivers s and streams 1989-90 to 2001-02. The South Fork Noyo and upper Noyo are separated to show potential influence of fish returning to the Noyo Egg Collecting Station. Thin lines area ± 1 SE.

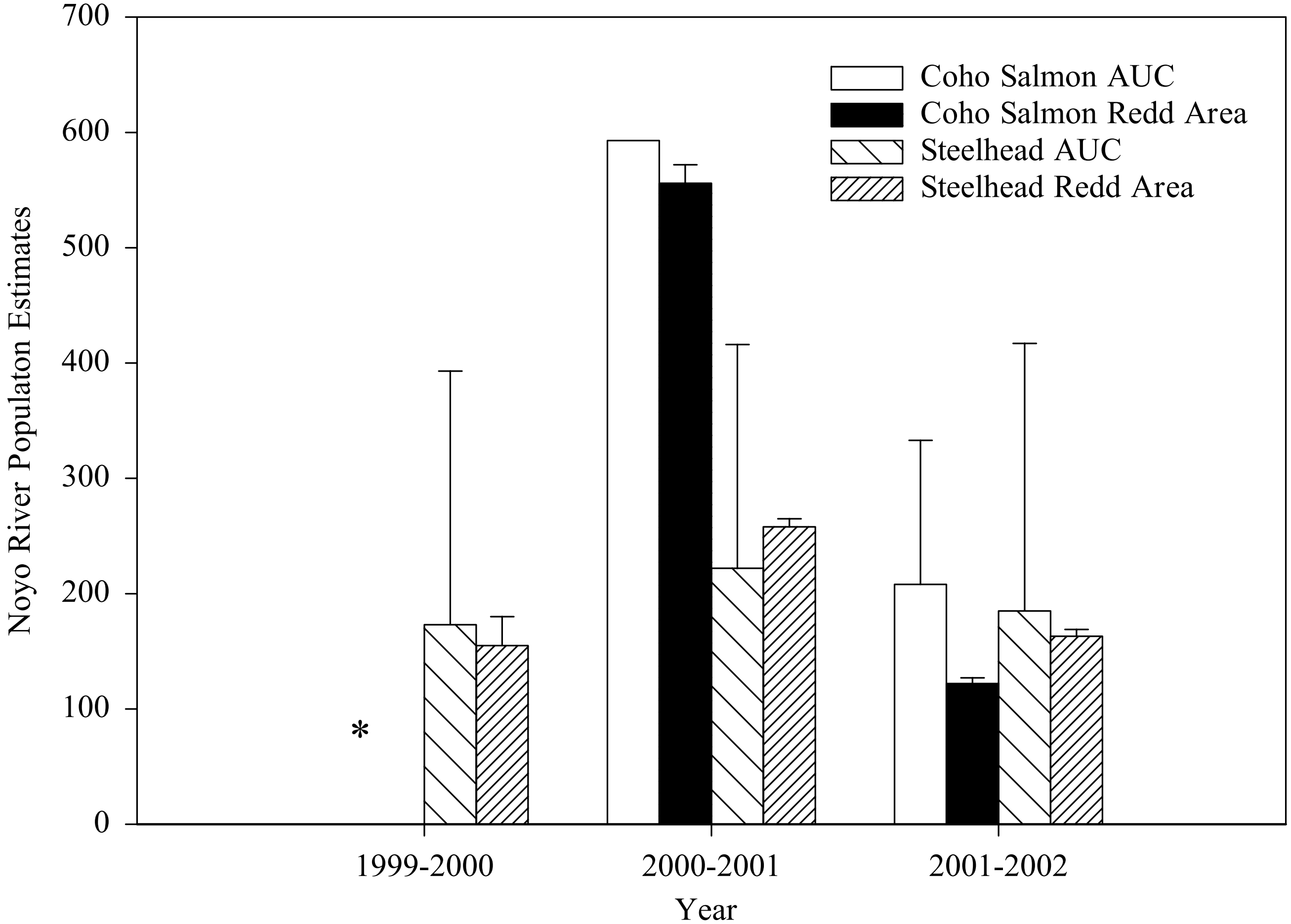


Figure 23. Redd area and AUC population estimates for Coho salmon and steelhead in the Noyo River during 1999-00, 2000-01, and 2001-02. Thin lines area 95% are uncertainty. * Coho salmon not estimated.

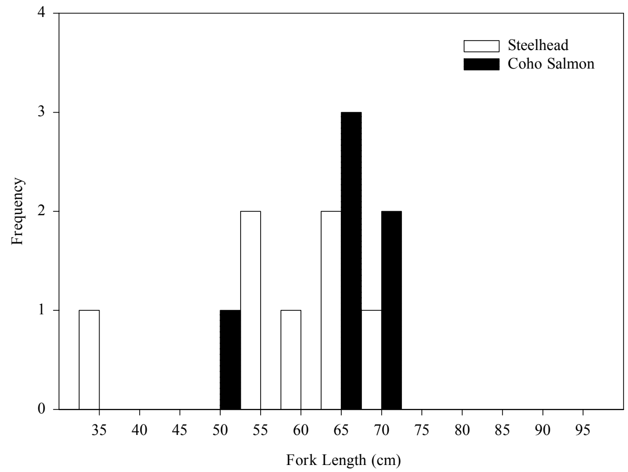


Figure 24. Steelhead and Coho salmon fork length frequencies in Hare Creek 2001-02.

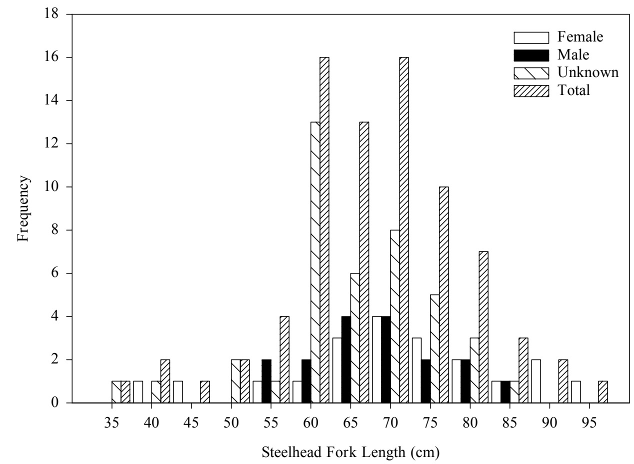


Figure 25. Steelhead fork length frequencies in the Noyo River during 2001-02

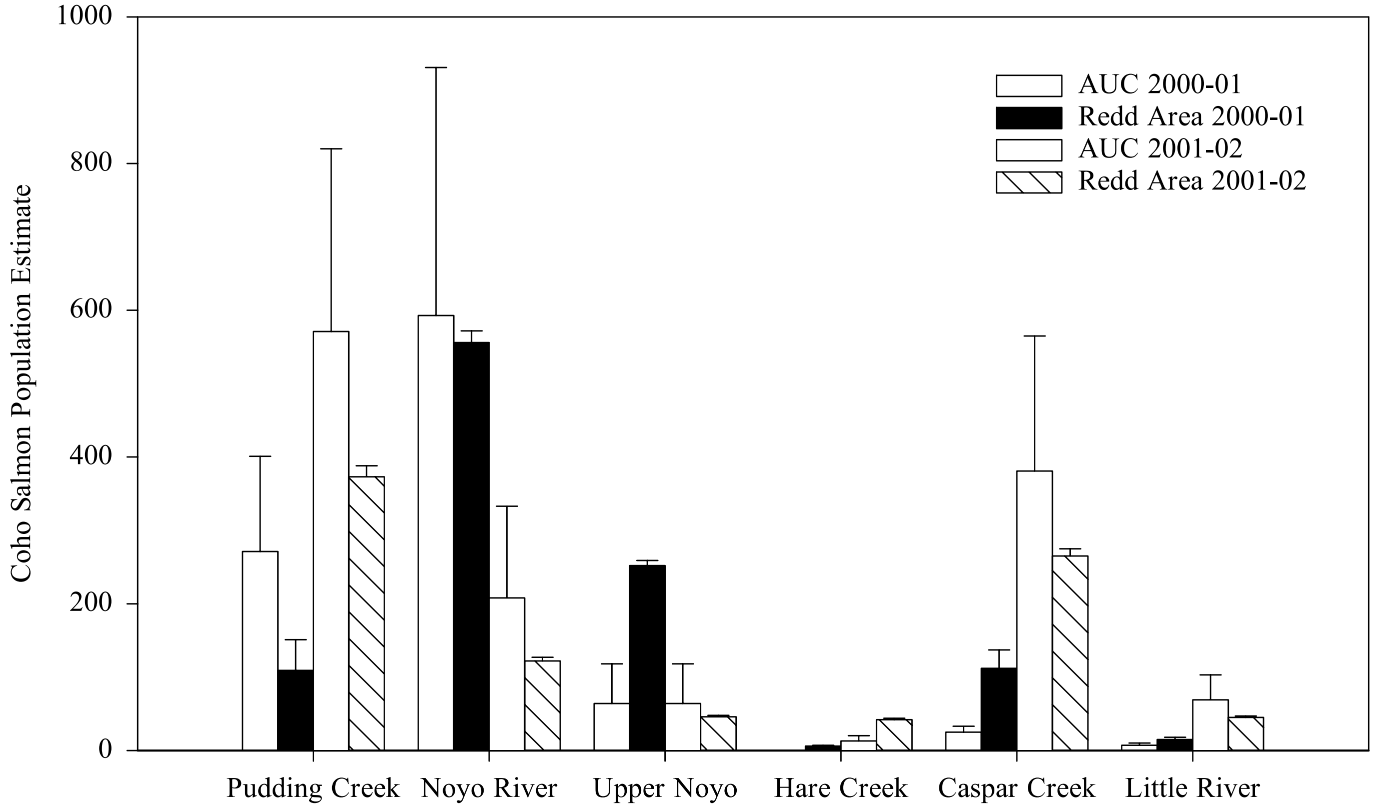


Figure 26. Coho salmon redd area and area-under-the-curve population estimates for five coastal Mendocino County streams during 200-01 and 2001-02. The upper Noyo is separated to show the population without the potential influence of hatchery fish in the South Fork. Thin lines are observer uncertainty.

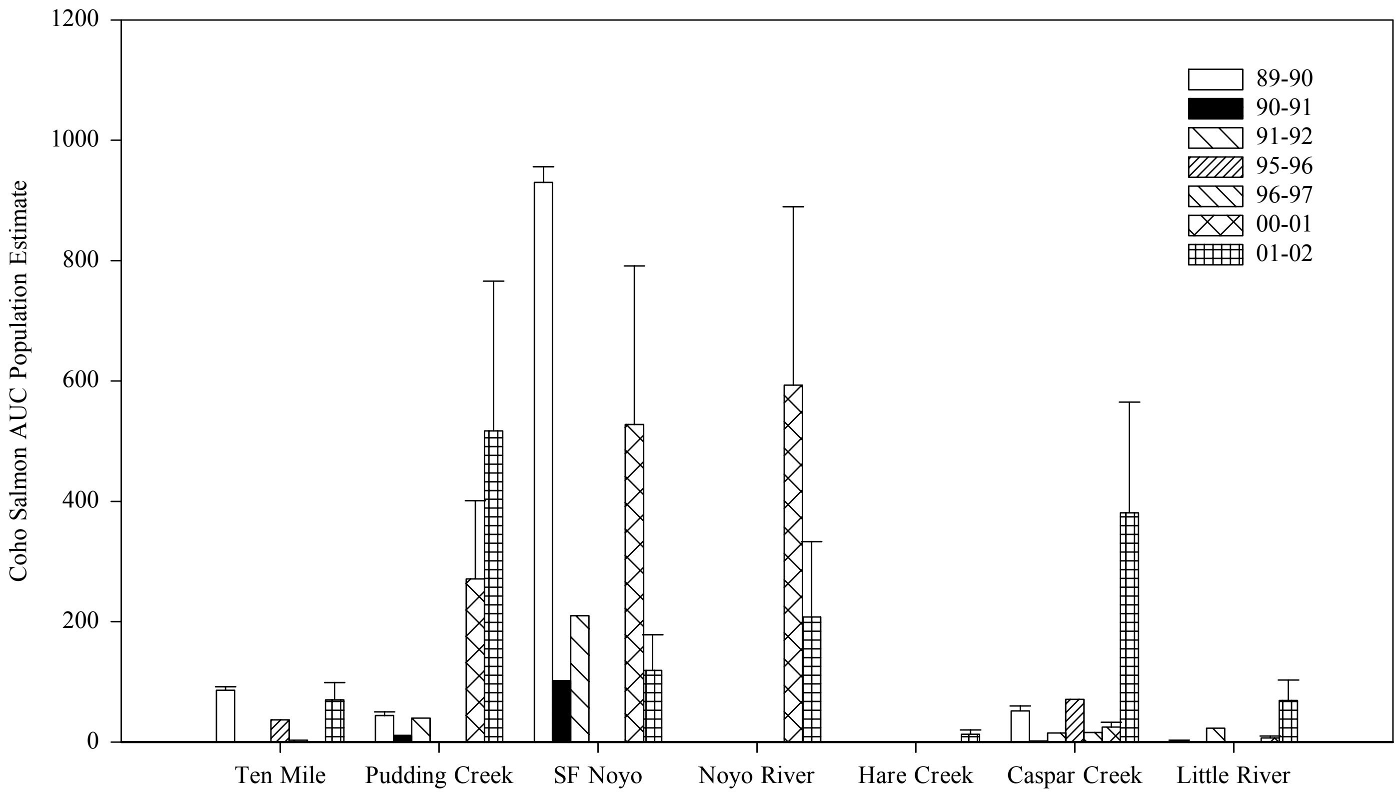


Figure 27. Coho salmon area-under-the-curve population estimates for six coastal Mendocino County streams 1989-90 to 2001-02. Thin lines are observer uncertainty.

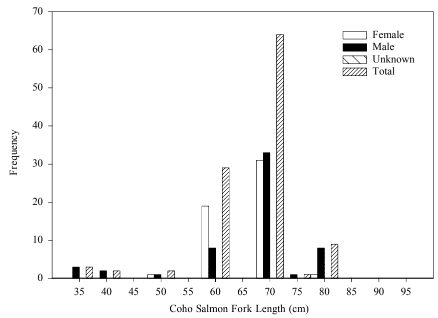


Figure 28. Coho salmon fork lengths in the Albion River during 2001-02.

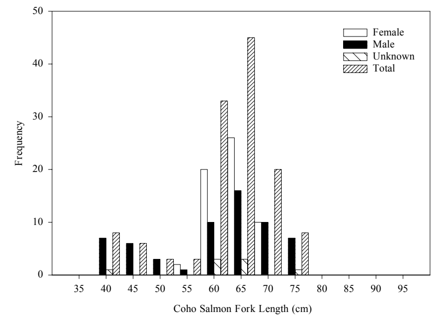


Figure 29. Coho Salmon fork lengths in Caspar Creek during 2001-02.

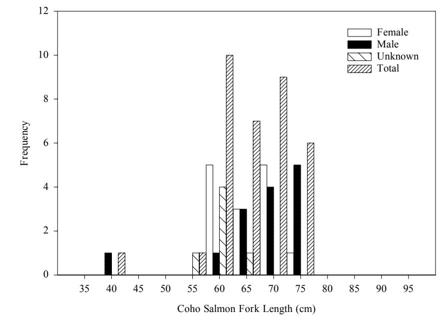


Figure 30 Coho salmon fork lengths in Little River during 2001-02

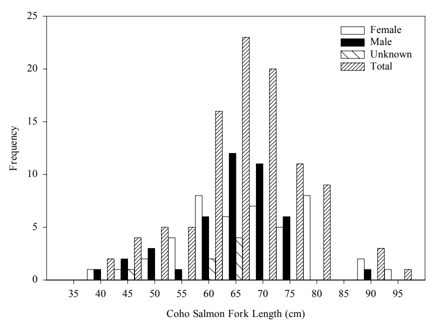


Figure 31. Coho Salmon fork lengths in the Noyo River during 2001-02

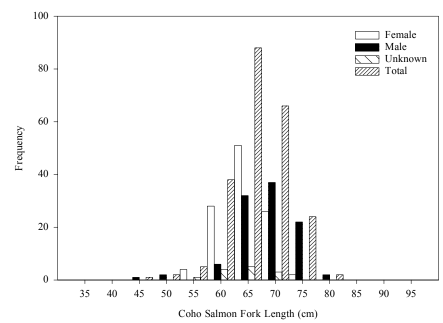


Figure 32. Coho salmon fork lengths in Pudding Creek during 2001-02.

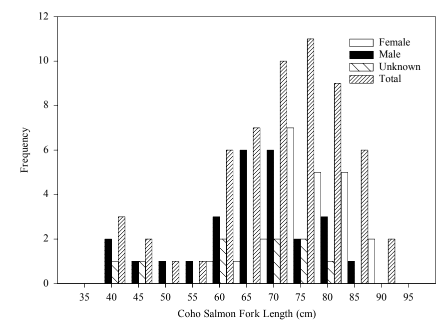


Figure 33. Coho salmon fork lengths in the Ten Mile River during 2001-02.

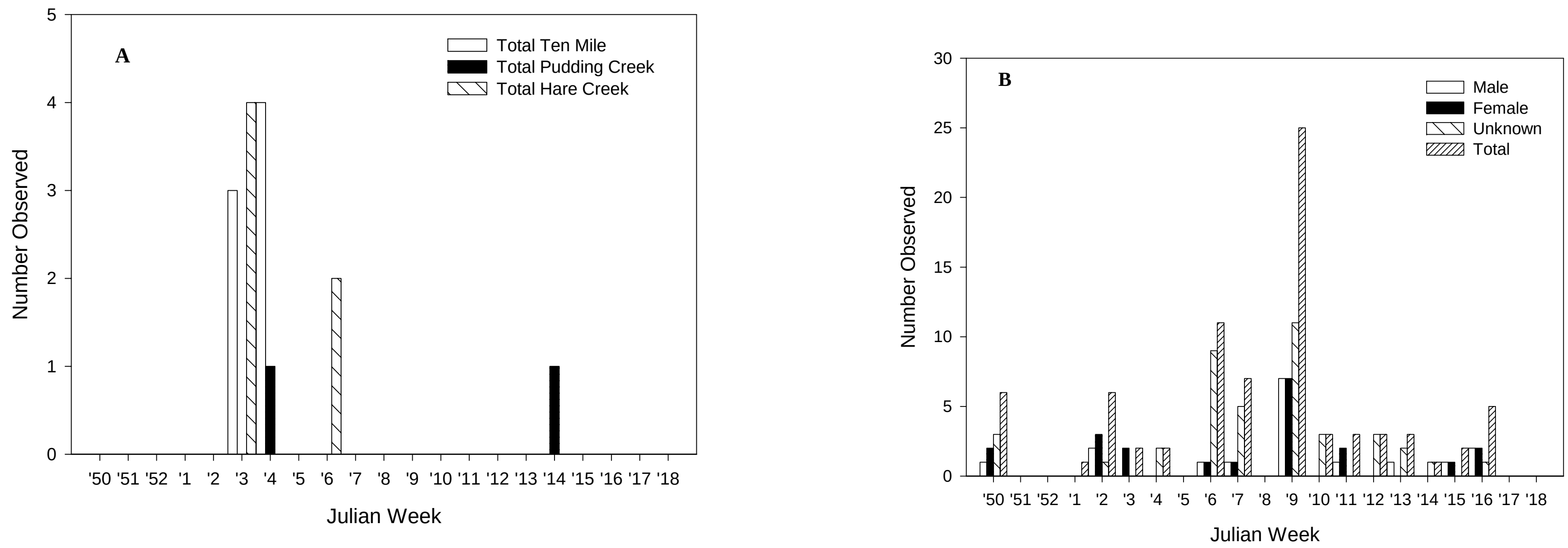


Figure 34. The number of steelhead observed by week during 2001-02. A). Hare and Pudding creeks and the Ten Mile River. B). Noyo River.

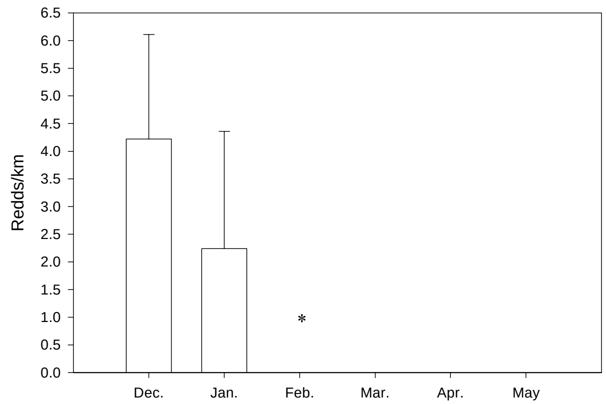
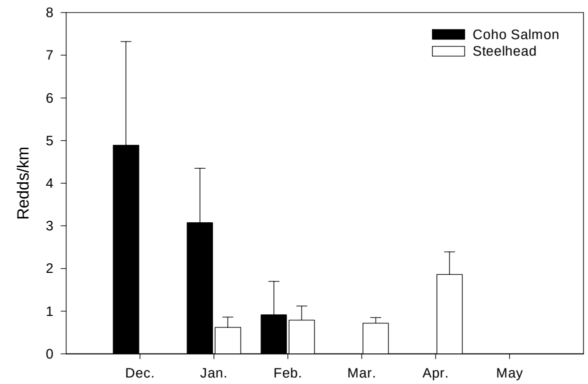


Figure 35. Coho salmon redd density by month the Albion River during 2001-02. * Not surveyed
Thin lines are ± 1SE.



Fug. 36. Coho salmon and steelhead density by month in Caspar Creek during 2001-02.
Thin lines are ± 1SE.

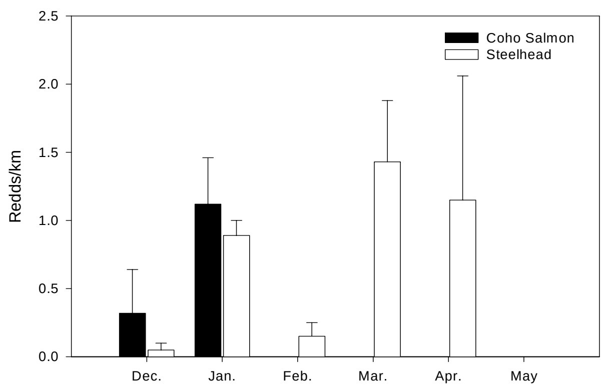


Figure 37. Coho salmon and steelhead redd density by month in Hare Creek during 2001-02.
Thin lines are ± 1 SE.

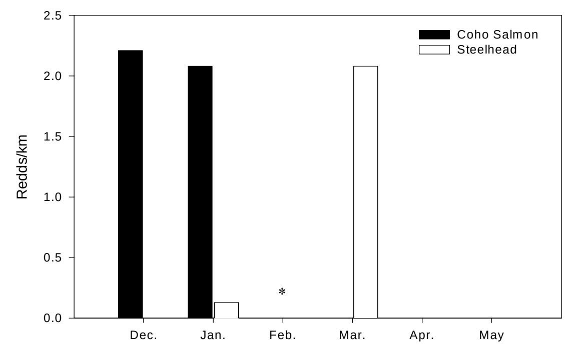


Figure 38. Coho salmon and steelhead redd density by month in the Little River. Thin lines are ± 1 SE.

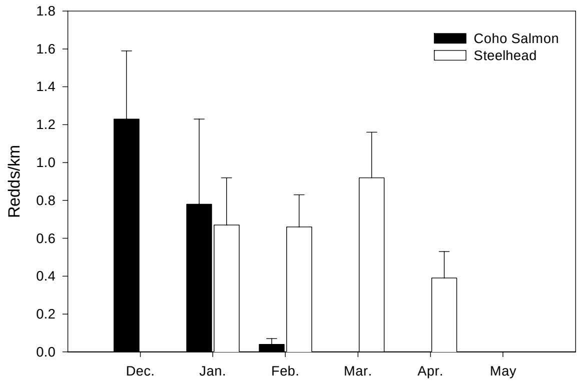


Figure 39. Coho salmon and steelhead redd density by month in the Noyo River during 2001-02. Thin Lines are ± 1 SE.

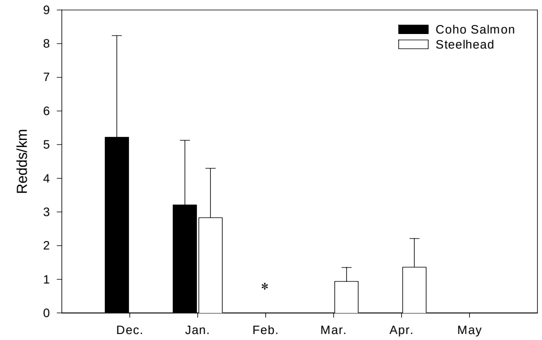


Figure 40. Coho salmon and steelhead redd density by month in Pudding Creek during 2001-02. Thin Lines are ± 1 SE.

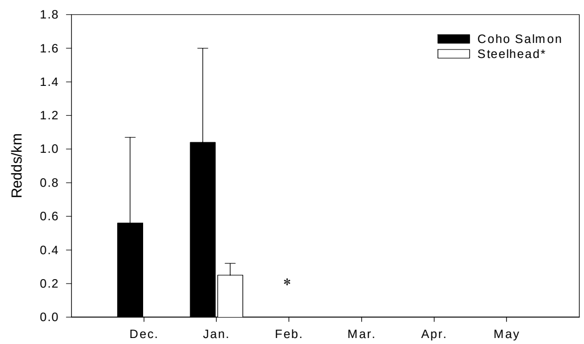


Figure 41. Coho salmon and steelhead redd density by month in the Ten Mile River during 2001-02 * Not surveyed after January 2002. Thin lines are ± 1 SE.

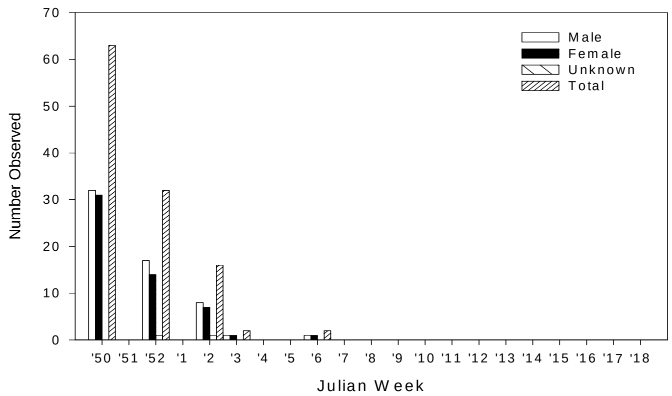


Figure 42. Coho salmon observations by week. in the Albion River during 2001-02.

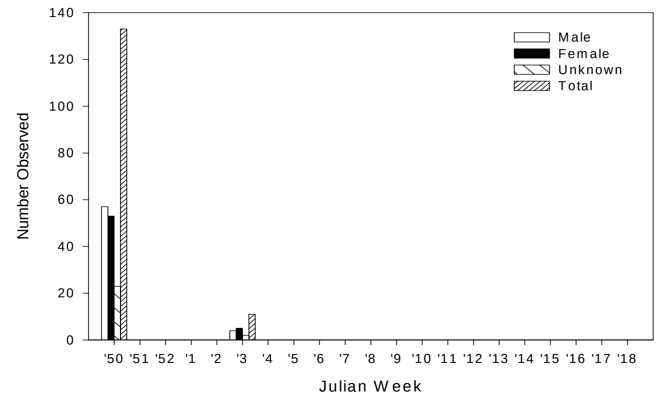


Figure 43. Coho salmon observations by week in Caspar Creek during 2001-02.

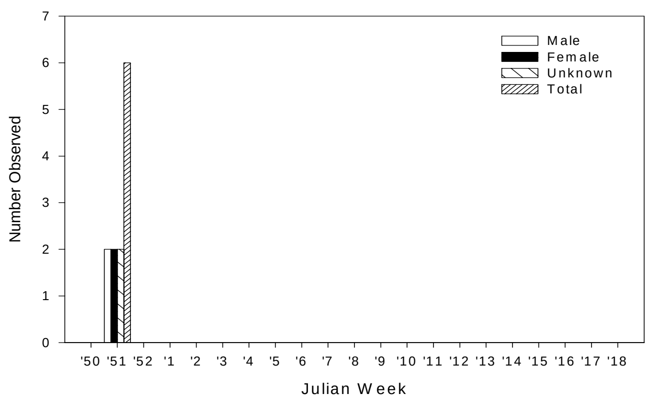


Figure 44. Coho salmon observations by week in Hare Creek during 2001-02.

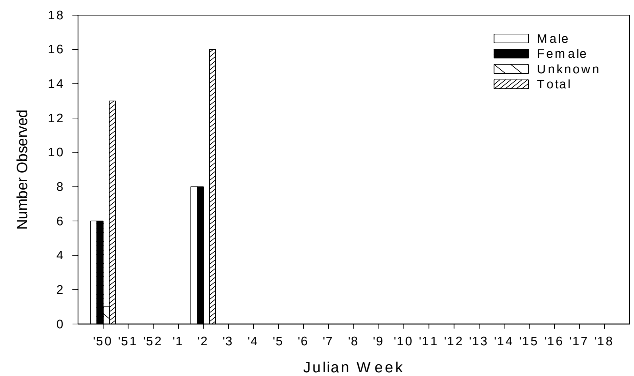


Figure 45. Coho salmon observations by week in the Little River during 2001-02.

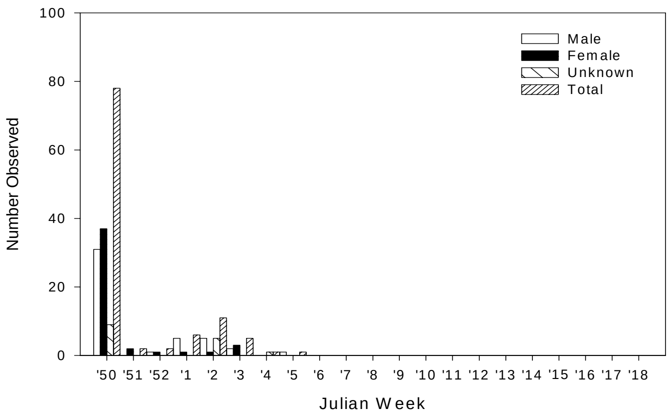


Figure 46. Coho salmon observations by week in the Noyo River. during 2001-02.

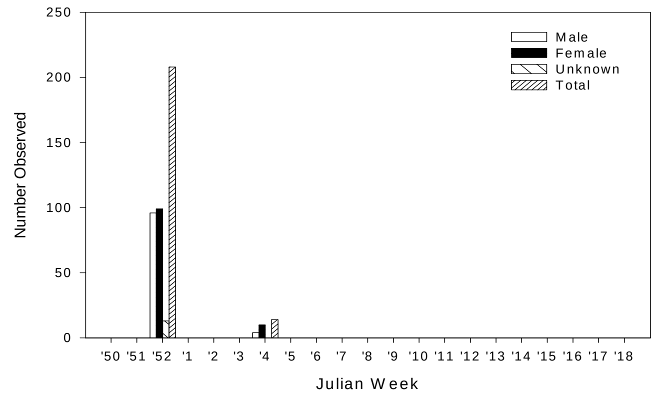


Figure 47. Coho salmon observations by week in Pudding Creek during 2001-02.

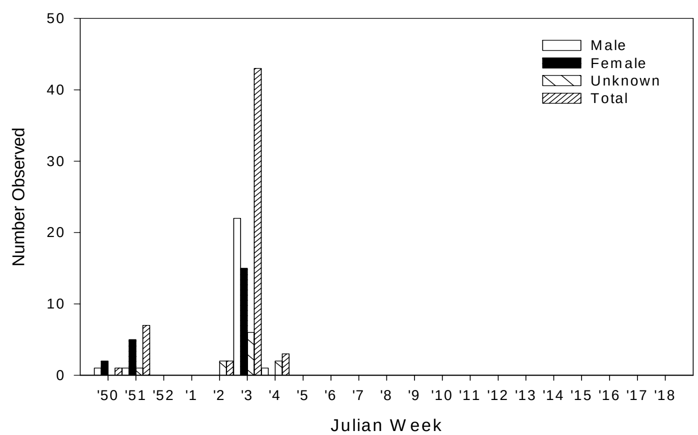


Figure 48. Coho salmon observations by week in the Ten Mile River during 2001-02.

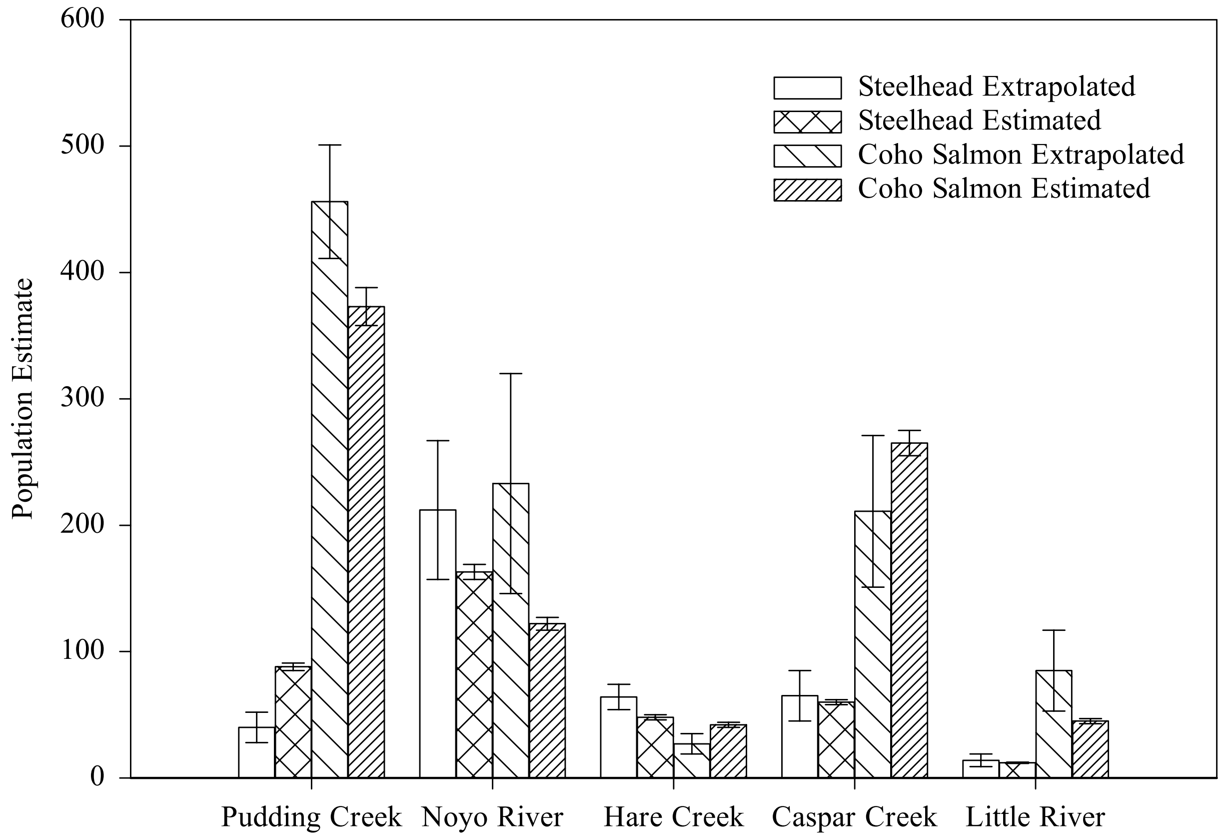


Figure 49. Coho salmon and steelhead stratified redd area population estimates for five coastal Mendocino County streams during 2001-02. Thin lines indicate uncertainty in redd identification for estimates and standard errors for extrapolated estimates.

Table 1. Stream name, survey section, beginning and ending date of surveys, segment length, and extent of spawning.

River	Stream Name	Section	Beginning Date	Ending Date	Number of Surveys	Survey Length (km)	Extent of Spawning (km)
Albion	Albion River	Main Stem	12/12/2001	2/7/2002	4	8.5	8.5
Albion	South Fork	Mouth Up	12/27/2001	1/17/2002	3	7.1	7.1
Caspar Creek	Caspar Creek	Below Forks	12/10/2001	4/9/2002	6	6.5	6.5
Caspar Creek	Caspar Creek	North Fork	12/10/2002	4/23/2002	6	5.6	5.6
Caspar Creek	Caspar Creek	South Fork	12/11/2002	4/9/2002	5	3.75	3.75
Hare Creek	Hare Creek	Bunker Gulch	1/9/2002	3/21/2002	4	2.65	2.65
Hare Creek	Hare Creek	Below Covington Gulch	1/17/2002	4/25/2002	5	5.1	5.1
Hare Creek	Hare Creek	Covington Gulch to Bunker Gulch	12/18/2001	4/24/2002	6	4.75	4.75
Hare Creek	South Fork	Mouth Up	1/17/2002	321/02	2	1	1
Little River	Little River	Mouth Up	12/11/2001	3/26/2002	5	7.7	7.7
Noyo	Bear Gulch (BG)	Mouth Up	12/13/2001	12/13/02001	1	1	0.5
Noyo	Brandon Gulch	Mouth Up	1/8/2002	1/8/2002	1	0.5	0
Noyo	Burbeck Cr. (BC)	Mouth Up	12/11/2001	4/10/2002	5	1	0
Noyo	Dewarren Creek	Mouth Up	4/23/2002	4/23/2002	1	1.5	0
Noyo	Duffy Gulch (DG)	Mouth Up	12/12/2001	3/21/2002	5	2.5	1.5
Noyo	Gulch 7	Mouth Up	4/23/2002	4/23/2002	1	1	0
Noyo	Hayshed Gulch (HG)	Mouth Up	11/30/2001	3/6/2002	3	1.2	0.6
Noyo	Hayworth Cr. (HC)	Mouth Up	12/11/2001	4/15/2002	15	6.6	5.4
Noyo	Kass Cr. (KC)	Mouth Up	1/8/2002	3/29/2002	3	5.6	0.5
Noyo	Little North Fork (LNF)	Mouth Up	12/11/2001	3/5/2002	5	5	2.2
Noyo	McMullen Cr. (MC)	Mouth Up	12/11/2001	4/10/2002	5	1.5	0.5
Noyo	Middle Fork (MF)	Mouth Up	12/13/2001	3/28/2002	9	3.4	2
Noyo	No Name 0.5km DS Olds	Mouth Up	1/10/2002	1/10/2002	1	0.5	0.4
Noyo	North Fork (NFL)	Below HC	11/30/2001	4/22/2002	10	6.2	6.2
Noyo	North Fork (NFU)	Above HC	12/10/2001	4/9/2002	11	5.9	5
Noyo	North Fork South Fork (NFSF)	Mouth Up	12/13/2001	4/30/2002	8	9.6	8.4
Noyo	Noyo River (aOC)	OC to MC	12/11/2001	4/16/2002	16	6.1	5.1
Noyo	Noyo River (CRtG)	Company Ranch to Grove	12/13/2001	4/18/2002	8	6.7	6.7
Noyo	Noyo River (DGtN)	DG to NorthSpur	12/12/2001	4/17/2002	8	6.6	6.6
Noyo	Noyo River (GtDG)	Grove to DG	1/14/2002	4/17/2002	7	8.7	8.7
Noyo	Noyo River (MtCR)	Madsen Hole to Company Ranch	11/30/2001	2/15/2002	4	8.7	8.7
Noyo	Noyo River (NtOC)	NorthSpur to RC	11/30/2001	4/11/2002	10	5.8	5.8
Noyo	Olds Cr. (OC)	Mouth Up	1/8/2002	4/10/2002	9	4.1	3.5
Noyo	Parlin Cr. (PC)	Mouth Up	12/13/2001	4/18/2002	7	2.8	2.4
Noyo	Peterson Gulch	Mouth Up	4/8/2002	4/8/2002	1	0.5	0
Noyo	Redwood Cr. (RC)	Mouth Up	12/12/2001	4/3/2002	10	5	1.7
Noyo	South Fork (SFL)	Mouth to NFSF	12/13/2001	4/27/2002	7	6.1	6.1
Noyo	South Fork (SFU)	NFSF to Pond	12/13/2001	4/26/2002	7	7.7	5.1
Pudding Creek	Pudding Creek	Little Valley to Water Hole	12/26/2001	4/19/2002	4	6.6	6.6
Pudding Creek	Pudding Creek	Rail Road Crossing to Little Valley	12/27/2001	4/22/2002	4	7.05	7.05
Pudding Creek	Pudding Creek	Water Hole to Barrier	1/23/2002	4/4/2002	2	2.6	2.6
Pudding Creek	Slaughter House Gulch	Mouth Up	3/26/2002	na	1	1	1
Ten Mile	Bearhaven Creek	Mouth Up	12/13/2001	1/24/2002	2	4.6	4.6
Ten Mile	Campbell Creek	Mouth Up	1/11/2001	1/29/2002	2	4.5	4.5
Ten Mile	Churchman Creek	Mouth Up	12/11/2001	1/15/2002	2	3.8	3.8
Ten Mile	Little North Fork	Barlow to Blair	1/17/2002	na	1	1.6	3.2
Ten Mile	Little North Fork	Mouth to Barlow	1/16/2002	na	1	3	3
Ten Mile	Mill Creek	Mouth Up	1/24/2002	na	1	2.6	2.6
Ten Mile	North Fork	Gulch 2 up	1/18/2002	na	1	5.3	5.3
Ten Mile	Redwood Creek	Mouth Up	1/11/2002	na	1	5.6	5.6
Ten Mile	Smith Creek	Mouth Up	12/11/2001	1/15/2002	2	9	9
Ten Mile	South Fork	Bridge to Gravel Pit	1/24/2002	na	1	5.2	5.2
Ten Mile	South Fork	Camp 28 to Gulch 12	1/24/2002	na	1	5.3	5.3

Table 2. Substrate sizes and substrate codes.

Substrate Size	Substrate code
< 0.5 cm	1
0.5-2.5 cm	2
2.5-5.0 cm	3
5.0-10.0 cm	4
10.0-15.0 cm	5
15.0-20 cm	6
> 20.0 cm	7
Aquatic Veg.	8

Table 3. Physical redds variables and results of correlation tests with redd area from known Coho salmon and steelhead redds.

Variable	Description	Redd Area Correlations					
		Noyo Only			All Rivers		
		r^2	*p*-value	n	r^2	*p*-value	n
Pot Length	Distance Parrell to Stream Flow (cm)	0.69	< 0.00001	50	0.68	< 0.00001	107
Pot Width	Distance Perpendicular to PL (cm)	0.81	< 0.00001	50	0.75	< 0.00001	107
Pot Depth	Depth of Excavated Pot (cm)	0.42	0.002	50	0.27	0.004	107
Pot Substrate	Size of Dominant Material in Pot[1]	-0.28	0.04	50	-0.21	0.03	107
Pot Area	Calculated From PL and PW (m^2)	0.90	< 0.00001	50	0.87	< 0.00001	107
Tail Spill Length	Distance Parrell to Stream Flow (cm)	0.56	< 0.00001	50	0.69	< 0.00001	107
Tail Spill Width 1	Distance Perpendicular to PL 1/3 of Length (cm)	0.72	< 0.00001	50	0.78	< 0.00001	107
Tail Spill Width 2	Distance Perpendicular to PL 2/3 of Length (cm)	na	-	-	na	-	-
Tail Spill Substrate	Size of Dominant Material in Tail Spill[1]	na*	-	-	-0.02	0.815*	107
Tail Spill Area	Calculated From TL and TW1/TW2 (m^2)	0.78	< 0.00001	50	0.86	< 0.00001	107
Redd Area	Pot Area Plus Tail Spill Area (m^2)	na	-	-	na	-	-
Date in Days	Date Observed. Date of First Redd = Day 1	na	-	-	na	-	-
Fish Fork Length	Length of Fish Observed (cm)	na	-	-	na	-	-
Distance	Distance Redd was From River Mouth (km)	na	-	-	na	-	-
Year	Year Redd was Obsevred	na	-	-	na	-	-

1 See Table 2 for substrate size categories.
* Not included data not measured similarly in both years
na: Not applicable as not included in calculation of redd area

Table 4. Details of logistic regression training data set modeling for discrimination of Coho salmon and steelhead redds.

Model Trial	Logistic Equation	Test Statistic			Apparent Error	Logistic Regression Details		
	Logitp =	Pearson Chi-square	Likelihood Ratio	Homer-Lemeshow		Variables	Wald Statistic	p-value
Noyo 1	-3.77-(3.019*year)+ (0.162*day)-(2.099*redd area)+ (0.376*lkm)+ (0.0464*fkl)	11.44 (p = 1.00)	56.57 (p < 0.001)	1.59 (p = 0.99)	0.02	Constant	0.33	0.56
						Year	0.93	0.33
						Day	1.53	0.22
						Redd Area	2.45	0.12
						Lkm	0.06	0.80
						fkl	0.13	0.72
Noyo 2	-1.79-(2.942*year)+ (0.19*day)-(2.04*redd area	11.71 (p = 1.00)	56.5 (< 0.001)	0.47 (p = 1.00)	0.02	Constant	0.31	0.58
						Year	0.97	0.32
						Day	4.15	0.04
						Redd Area	2.99	0.08
Noyo 3	-3.331+ (0.165*day)-(1.407*redd area)	15.14 (p = 1.00)	55.16 (p < 0.001)	0.67 (p= 1.00)	0.04	Constant	1.3	0.25
						Day	5.34	0.02
						Redd Area	4.3	0.04
All Rivers 1	-14.812-(1.124*year)+ (5.245*r1andall)+ (0.21*day)-(1.844*redd area)+ (0.049*lkm)+ (0.085*fkl)	20.11(p= 1.00)	126.69 (p< 0.001)	0.292 (p= 1.00)	0.17	Constant	3.18	0.07
						Year	0.15	0.70
						r1 and all	1.85	0.17
						Day	3.62	0.06
						Redd Area	2.69	0.10
						lkm	0.13	0.72
						fkl	0.4	0.40
All Rivers 2	-4.028+ (2.401*r1andall)+ (0.114*day)-(1.039*redd area)	57.0 (p= 1.00)	24.06 (p< 0.001)	0.65 (p= 1.00)	0.50	Constant	7.52	0.01
						r1 and all	6.47	0.01
						day	14.55	< 0.001
						Redd Area	10.75	0.00
All Rivers 3	-9.873-(0.203*year)+ (6.407*river1)-(14.93*river2)+(7.813*river3)-(3.253*river4)+ (7.444*river5)-(0.3528river6)+ (0.197*day)-(1.602*redd area)	19.12 (p= 1.00)	264.54 (p< 0.001)	0.12 (p= 1.00)	0.02	Constant	0.01	0.91
						Year	0.02	0.88
						River 1	0.005	0.94
						River 2	0.00001	1.00
						River 3	0.008	0.93
						River 4	0.001	0.97
						River 5	0.006	0.93
						River 6	0.000001	1.00
						Day	7.69	0.01
						Redd Area	6.01	0.01
All Rivers 4	-4.074+ (0.13*day)-(0.918*redd area)	55.54 (p= 1.00)	237.35 (p< 0.001)	3.31 (p= 1.00)	0.04	Constant	8.6	0.00
						Day	18.09	< 0.001
						Redd Area	11.19	< 0.001

Table 5. Redd area, live fish area-under-the-curve, and carcass mark-recapture population estimates for Coho salmon and steelhead in seven coastal Mendocino County streams during 2001-02.

River	Steelhead					Coho Salmon						
	Redd Area		AUC			Redd Area		AUC			Carcass Mark/Recapture	
	Estimate	% Uncertainty	Trapaziodal	AUC^e	95% CI	Estimate	% Uncertainty	Trapeziodal	AUC^e	95% CI	Estimate	95% CI
Albion River	nd	nd	nd	nd	nd	181	7	101	126	101-187	1138	1064
Caspar Creek	60	2	nd	nd	nd	265	10	305	381	305-565	95	40
Hare Creek	48	2	3.4	31	20-71	42	2	11	13	11-20	9	5-78
Little River	12	0.5	nd	nd	nd	45	2	56	69	56-103	13	7-75
Noyo River	163	6	42	185	119-417	122	5	166	208	166-333	216	30-4947
Pudding Creek	88	3	6	24	16-56	373	15	414	517	414-766	816	205-10490
Ten Mile River	8*	0.3	3*	15	10-35	68	3	56	70	56-104	nd	nd

Table 6. Results of Chi-Square index of dispersion tests showing the pattern of Coho salmon and steelhead spawning distributions for five coastal Mendocino County streams during 2001-02.

River	Species	Chi-Square	n	Pattern
Caspar Creek	Coho Salmon	55.9	24	Aggregated
	Steelhead	22.7		Random
Hare Creek	Coho Salmon	47.3	24	Aggregated
	Steelhead	24.4		Random
Little River	Coho Salmon	45.3	10	Aggregated
	Steelhead	11.7		Random
Noyo River	Coho Salmon	117.4	27	Aggregated
	Steelhead	13.4		Random
Pudding Creek	Coho Salmon	155	27	Aggregated
	Steelhead	130		Aggregated

Table 7. Number of steelhead redds, redds/km, adult steelhead, and adults/km observed in seven coastal Mendocino County streams during 2001-02.

River	Steelhead Redds		Steelhead Adults				
	Number Observed	Redds/km	Females	Males	Unkown	Total	Number/km
Albion	nd	nd	0	0	0	0	0.00
Caspar Creek	68	4.29	0	0	0	0	0.00
Hare Creek	67	4.96	1	1	4	6	0.44
Little River	17	2.21	0	0	0	0	0.00
Noyo River	202	2.16	21	17	41	79	0.51
Pudding Creek	93	5.96	0	0	2	2	0.19
Ten Mile	12	0.26	0	0	7	7	0.15

Table 8. Number of Coho salmon redds, redds/km, adult Coho salmon, and adults/km observed in seven coastal Mendocino County streams during 2001-02.

River	Coho Salmon Redds		Coho Salmon Adults				
	Number Observed	Redds/km	Females	Males	Unkown	Total	Number/km
Albion	99	6.38	54	59	2	115	7.37
Caspar Creek	145	8.99	59	61	25	145	9.15
Hare Creek	27	1.92	2	2	2	6	0.44
Little River	33	4.29	14	14	1	29	3.77
Noyo River	120	1.37	46	44	16	106	1.13
Pudding Creek	197	8.45	109	100	13	222	20.85
Ten Mile	44	1.31	22	25	11	58	1.24

Table 9. Number of steelhead adults/km and redds per female estimated by the redd area and area-under-the-curve methods and the observed female to male ratio in seven coastal Mendocino County streams during 2001-02. SE is standard error.

River	Area Under the Curve				Redd Area				
	Number/km	SE	Redds/Female	SE	Female:Male	Number/km	SE	Redds/Female	SE
Albion	-	-	-	-	-	-	-	-	-
Caspar Creek	-	-	-	-	1.00:1.00*	3.53	1.05	2.42	0.25
Hare Creek	1.11	-	3.07	-	1.00:1.00	3.28	0.85	3.13	0.54
Little River	-	-	-	-	1.00:1.00*	1.56	-	2.83	-
Noyo River	1.19	0.33	2.36	0.63	1.23:1.00	1.63	0.41	2.63	0.16
Pudding Creek	0.79	-	3.57	-	1.00:1.00*	5.05	1.38	2.23	0.11
Ten Mile	-	-	-	-	1.00:1.00*	0.34	0.07	3.50	0.97

Table 10. Average steelhead fork lengths observed in seven coastal Mendocino County streams during 2001-02.

River	Female	SE	Male	SE	Unknown	SE	Total	SE
	-	-	-	-	-	-	-	-
Albion	-	-	-	-	-	-	-	-
Caspar Creek	-	-	-	-	-	-	-	-
Hare Creek	-	-	-	-	57.9	4.1	-	-
Little River	-	-	-	-	-	-	-	-
Noyo River	70.9	1.6	68.5	1.0	64.6	1.1	67.1	1.3
Pudding Creek	-	-	-	-	55.0	-	-	-

Table 11. Number of Coho salmon adults/km and redds per female estimated by the redd area and area-under-the-curve methods and the observed female to male ratio in seven coastal Mendocino County streams during 2001-02. SE is standard error.

River	Area Under the Curve					Redd Area			
	Number/km	SE	Redds/Female	SE	Female:Male	Number/km	SE	Redds/Female	SE
Albion	7.70	4.18	4.67	2.80	0.91:1.00	6.87	0.87	1.96	0.12
Caspar Creek	21.91	14.06	6.62	5.47	0.98:1.00	8.60	4.43	2.23	0.13
Hare Creek	1.23	1.23	0.40	-	1.00:1.00	1.82	0.53	2.16	0.09
Little River	8.96	-	8.96	-	1.00:1.00	8.96	-	8.96	
Noyo River	2.59	0.84	0.89	0.12	1.04:1.00	1.36	0.35	1.94	0.09
Pudding Creek	18.95	10.95	3.08	0.47	0.97:1.00	13.74	9.31	3.28	1.55
Ten Mile	2.06	1.00	1.17	0.50	0.90:1.00	0.27	0.09	1.87	0.06

Table 12. Average Coho salmon fork lengths observed in seven coastal Mendocino County streams during 2001-02.

River	Female	SE	Male	SE	Unknown	SE	Total	SE
Albion	66.2	0.8	66.5	1.6	60.0	-	66.2	0.9
Caspar Creek	63.8	0.5	60.3	1.4	61.1	3.7	61.9	0.8
Hare Creek	67.5	2.5	65.0	0.0	60.0	10.0	64.2	3.0
Little River	65.7	1.4	67.9	2.6	60.0	1.4	65.6	1.3
Noyo River	67.8	1.8	65.0	1.5	64.5	1.3	66.1	1.0
Pudding Creek	64.7	0.4	68.5	0.6	63.8	1.3	66.4	0.4
Ten Mile River	77.0	1.5	64.4	2.3	63.2	4.7	69.3	12.1

Table 13. Field survey, drive time, total time, and estimated person hours used during spawning surveys 2001-02.

River	Field Time	Drive Time	Total Time	Person Hours
Albion	75.0	27.3	102.2	204.5
Caspar Creek	68.2	22.0	90.2	180.4
Hare Creek	45.1	19.6	64.7	129.4
Little River	17.7	12.6	30.3	60.5
Noyo River	872.5	370.4	1242.9	2485.7
Pudding Creek	63.0	15.0	78.0	156.0
Ten Mile River	80.5	21.6	102.1	204.2
Total	1222.0	488.4	1710.4	3420.8