Results of the 2000-2001 Coho Salmon (*Oncorhynchus kisutch*) and Steelhead (*Oncorhynchus mykiss*) spawning surveys on the Noyo River, California

Prepared By
Sean P. Gallagher[1]

Abstract

Spawning surveys were conducted in the Noyo River between December 2000 and April 2001 to quantitatively estimate steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) populations. Adult, carcass, redd counts, and redd areas were used to estimate adult populations using the area-under-the-curve (AUC) and two redd-based methods. Physical characteristics of coho salmon and steelhead redds were measured in detail and data analyzed using principle components analysis (PCA) to develop a linear discriminant function that identified redds to species. Information on spawning locations and distributions were collected. Data were examined using stratified index sampling to estimate total populations from AUC and redd based methods. A total of 120 km of the Noyo River was surveyed approximately bi-weekly from December 2000 through April 2001. Steelhead redds were distributed throughout 92.5 km of the Noyo River. A total of 296 steelhead, 113 lamprey, and 377 coho redds were observed. Field uncertainty in redd identification was 23.4%. The PCA discriminant function reduced uncertainty in redd identification to 2.8% 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. Steelhead spawned significantly later and further upstream than coho salmon. The average size of 194 steelhead redds was 1.61 m^2 (S.E.= 0.07) and ranged from 0.11 to 7.56 m^2. The average size of 352 coho redds was 4.76 m^2 (S.E.= 0.21) and ranged from 0.17 to 23.84 m^2. Steelhead redd density was 2.43/km (S.E.= 0.49) and ranged from zero to 9.16/km. Coho redd density was 5.22/km (S.E.= 2.93) and ranged from zero to 74/km. Area-under-the-curve population estimates were similar to redd based estimates for coho salmon and steelhead. Redd based steelhead population estimates ranged from 258 (± 7) to 583 (± 16) and the AUC estimate was 222 (95% CI 127-416). The redd based coho salmon population estimate was 555 (± 16) and the AUC estimate was 592. Steelhead average fork length was 65.8 cm, S.E. = 1.32 and ranged from 32 to 90 cm. Coho salmon fork length averaged 62.2 cm (S.E. = 1.58) and ranged from 30 to 95 cm. Steelhead female to male ratio was 0.97:1.00 (n=27). Coho salmon female to male ratio was 0.65:1.00 (n=58). There was a large overlap in the timing of coho and steelhead spawning. Stratified index sampling population estimates were not significantly different from AUC and redd area methods and may decrease field effort in the future. The PCA discriminant function developed from coho and steelhead redd information is 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.

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[1] Steelhead Research and Monitoring Program Report No. FB-09. August 2001. Philip K. Barrington Senior Biologist Supervisor, California State Department of Fish and Game, 2030 1st Street, Suite 9, Eureka, CA 95501.

This report should be cited as: Gallagher, S. P. 2001. Results of the 2000-2001 Coho Salmon (*Oncorhynchus kitsch*) and Steelhead (*Oncorhynchus mykiss*) spawning surveys on the Noyo River, California. California State Department of Fish and Game, 1031 South Main, Suite A, Fort Bragg, CA 95437. 44pp.

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, Huntington et al. 1996, Federal Register 2000). Responding to a proposal to list steelhead (*Oncorhynchus mykiss*) under the ESA in 1996, the California State 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 of 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 SB 271, 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 rivers and streams and basic life history and biological information is needed to understand the nature and character of populations (McEwan and Jackson 1996). The 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 existing adult steelhead information for coastal Mendocino County. He also presents results of steelhead spawning surveys on the Noyo River during 2000. Previous spawning surveys of Mendocino County rivers and streams assumed all redds found before 1 February were made by coho salmon and those found after this were made by steelhead (Maahs and Gilleard 1993, Maahs 1996, Wehren 1996, Maahs 1997). Thus species identification was based solely on time of year.

The purpose of the 2000-2001 spawning survey on the Noyo River was to quantitatively estimate adult coho salmon and steelhead populations. This report presets findings from the second 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 purpose of this study was to estimate coho salmon and steelhead populations by visually capturing tagged steelhead, collecting information to calculate the area-under-the-curve (AUC- Beidler and Nickelson 1980, English et al. 1992, Irvine et al. 1992), mark-recapture of carcasses, and collection of information to estimate populations using redd based methods Maahs (1997). Physical characteristics of coho salmon and steelhead redds were measured in detail and data analyzed using principle components analysis to develop a linear discriminant function which identified redds to species. Information on spawning timing, locations, and distributions were collected. Data were also collected on Pacific lamprey (*Lamperta tridentata*) redds.

Study Area

The Noyo River watershed (Fig. 1) is a forested, coastal watershed in Mendocino County, California, which drains approximately 260.3 km^2 immediately west of Willits. The Noyo River flows through the coast range and into the Pacific Ocean at Fort Bragg. The Noyo River was selected because, 1) a significant proportion of the watershed is in Jackson State Demonstration Forest, 2) the remainder of the watershed is primarily owned by two timber companies, 3) CDFG operates the Noyo Egg Collecting Station (Noyo-ECS) on the South Fork Noyo River, 4) CDFG has conducted coho studies on the South Fork Noyo since 1986, 5) CDFG has implemented many different types of habitat improvement projects in the South Fork Noyo River, and 6) the Noyo River has a USGS hydrologic gauging station (#11468500). In addition, the Noyo River watershed is subject to several recent changes in fisheries management including no harvest of wild adult steelhead, no artificial propagation of steelhead, and changes in land uses associated with changes in landownership.

The Noyo River watershed is unique in Mendocino County because approximately 19% of the basin is owned and managed by the California Department of Forestry and Fire Protection (the South Fork). Other major landowners in the basin include the Mendocino Redwood Company (the upper watershed) and Campbell Timberland Management (along the main stem).

Survey Segments

The Noyo River was divided into three main areas based on property ownership (Fig. 2) to simplify survey access and presentation of results. The three areas were the South Fork, the Noyo River above Northspur (upper river), and the Noyo River below Northspur (lower river). These segments are similar to the planning area watersheds of the California Regional Water Quality Control Board (CRWQCB-1999) except I combined their headwaters and North Fork into the Noyo River above Northspur and their lower Noyo and middle Noyo into the Noyo River below North Spur.

The South Fork was divided into seven survey segments based on access (Fig. 2, Table 1). The seven segments were: 1. The North Fork South Fork and Brandon Gulch, 2. Parlin Creek, 3. The upper South Fork (above Parlin Creek), 4. The middle South Fork and Bear Gulch (between the North Fork South Fork and Parlin Creek), 5. The lower South Fork (Kass Creek to the North Fork South Fork), 6. The South Fork from the mouth to Kass Creek, and 7. Kass Creek. These segments were similar to those surveyed by Maahs and Gilleard (1993) and Gallagher (2000).

The upper river (Noyo River below Northspur) was divided into eight survey segments based on access (Fig. 2, Table 1). The eight segments were: 1. North Fork to Hayworth Creek including Marble Gulch, 2. North Fork above Hayworth Creek including Dewarren Creek, 3. Middle Fork, 4. Hayworth Creek, 5. Noyo River from Northspur to Redwood Creek, 6. Noyo River above Redwood Creek including Burbeck and McMullen creeks. 7. Olds Creek, and 8. Redwood Creek.

The Noyo River below North Spur was divided into seven survey segments (Fig. 2, Table 1). The seven segments were: 1. Duffy Gulch, 2. Hayshed Gulch, 3. The Little North Fork, 4. The Noyo River from Company Ranch to Grove, 5. The Noyo River from Duffy Gulch to Northspur, 6. The Noyo River from Grove to Duffy Gulch, and 7. The Noyo River from Madsen Hole to Company Ranch.

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) were followed for this study. Crews of two walked or kayaked and snorkeled stream reaches approximately bi-weekly from early-December 2000 to early-April 2001. The main stem Noyo River below Northspur was sampled by kayak. Kayaks were also used to survey the North Fork from Hayworth Creek to Northspur, when stream flows permitted. Tagged and untagged fish were 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. 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, treated as unknown, or test redds under construction, counted, and measured. Test redds were reexamined on consecutive surveys and were reclassified when possible based on apparent completion of the redds. 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, 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 at the upstream left and right of the edge of the pot as the preexisting stream bed substrate following the methods of Gallagher and Gard (1999). All redds were marked with flagging on each visit to avoid double counting. All live fish, carcasses, and redd locations were recorded on field maps and GPS coordinates established for redds in the upper river and the main stem Noyo segments. South Fork observations were not mapped or otherwise geographically referenced. A preliminary attempt to estimate observer efficiency for the AUC method was conducted by electro-fishing behind a survey crew on one survey segment. Adult steelhead where not observed by the surveyors and one fish was captured electro-fishing. Time constraints did not allow a repeat of this process.

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 (7 December 2000) set as day one. The redd data 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. Eleven steelhead redds and 25 coho redds were positively identified. These data were analyzed using principle components analysis (Equations 1-2, Table 3) and a linear discriminant function which identified redds to species was developed. Principle component 1 (PC1) is shown in Equation 1. Principle component 2 (PC2) is shown in Equation 2. The linear discriminant function (Equation 3) was developed using PC1 and PC2. Using the first two principle components, the discriminant function misclassified one redd (steelhead as coho). The first six principle components explained greater than 95% of the variance (Fig. 3) and still misclassified one redd (steelhead as coho).

Equation (1)

$$PC1 = -0.4148PA+0.171*PS-0.288*TL-0.335*TW-0.406*TA-0.490*RA+0.255*km+0.182*FK+0.316*DT$$

Equation (2)

$$PC2 = 0.007*PA-0.192*PS-0.155*TL+0.496*TW+0.276*TA+0.139*RA+0.541*km+0.216*FK+0.508*DT$$

Equation (3)

$D = 0.2318PC1 - 0.069*PC2$, $D>2.874$: Steelhead otherwise coho.

This set of equations (1-3) was applied to all redd data to discriminate redds as coho or steelhead. Test redds without tailspills were not included. The average fork length of all salmonids observed was used in the above equations for redds for which fish were not observed. The sensitivity of equations 1-3 to changes in fork length was examined by randomly selecting 30 redd data sets of each species (coho and steelhead) and changing the fork length in the equations to the extreme edges of the range (31-95cm) observed.

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) and the number and size of redds as described by Nielsen et al. (1990), Maahs and Gilleard (1993), and Maahs (1996, 1997). Carcass counts were used to calculate coho populations using the Peterson method (Brower et al. 1984). Uncertainty in redd counts was derived from the PCA discriminant analysis 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 (Maahs 1996), I divided the range of 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 and Gilleard (1993), and Maahs (1996, 1997). Female steelhead population estimates based on redd numbers and redd area were multiplied by 0.97, the male per female ratio observed this season and summed with female estimates to get a total population estimate. Female coho population estimates based on redd numbers and redd area were multiplied by 1.54, the male per female ratio observed this season and summed with female estimates to get a total population estimate. Carcass-based population estimates were possible only for coho.

The trapezoidal approximation (Equation 4) 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 5 (Hilborn et al. 1999). Steelhead stream residence time (*rt*) estimates for use in Equation 5 were based on observations of tributary spawning in the Noyo River during 2001 and the time between capture and recapture of fished tagged in the Noyo River during 2001 (Neillands, In Preparation). Stream *rt* was estimated for male, female, and unknown sex fish for tributaries and the main stem Noyo River because surveys that cover the whole stream will produce larger estimates of *rt* than those that only cover spawning areas (English et al. 1992). Female steelhead *rt* was estimated as 11 days in tributaries and 46 days in the main stem. Male steelhead *rt* was estimated as 22 days in tributaries and 38 days in the main stem. Unknown sex steelhead *rt* was estimated as 17 days in tributaries and 23 days in the main stem. The average *rt* for all steelhead observed was 36 days (n = 6). 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*) was calculated by dividing the total number of adult steelhead found during spawning surveys by the low, median, and high population estimates from the mark-recapture study (Neillands, In Preparation). No estimate of *v* was made for coho salmon, thus it was assumed to be 1.0.

Equation (4)

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

Equation (5)

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

To test if stratified index sampling (Irvine et al. 1992) would provide reasonable estimates of coho and steelhead populations based on live fish (AUC) and redd based methods, I sub-sampled the original data to produce population estimates using stratified index sampling. I did this by dividing the stream into high, medium, and low density reaches. I then selected three reaches in each category and calculated the average number of redds or adults/km for each density class. The average density for each density category (high, medium, low) was then multiplied by the total length of stream within each category and summed to produce a population estimate.

Physical characteristics of redds were compared using t-tests or Mann-Whitney *U*-test when Standard Kurtosis *p*-values were < 0.05. Redd densities (number per km) between segments 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 *t*-tests 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. Steelhead adults observed during spawning surveys, at the Madsen Hole weir (Neillands In Preparation), or in downstream fyke traps were pooled to examine fork length, sex ratios, and life stage timing during 2000-2001. Male, female, and unidentified fish fork lengths were compared using *t*-tests and Mann-Whitney *U*-test when

Standard Kurtosis *p*-values were < 0.05. Population estimates from AUC and redd area calculations were compared to stratified index sampling population estimates using paired *t*-tests or the Wilcoxon signed rank test when Standard Kurtosis *p*-values were < 0.05. Redd areas, redd locations, and fish fork lengths 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 Madsen Hole weir to estimate the adult population in the Noyo River during 2001. Three steelhead marked at the weir were recaptured during the spawning surveys and were used to estimate the steelhead population in the Noyo River during 2001 (Neillands, In Preparation). Only two steelhead carcass were observed, thus no carcass-based population estimates were made. Coho carcasses provided a population estimate of 267 (S.E. = 41). Of these 181 (S.E. = 28) were estimated to have been in the South Fork. Three hatchery marked coho salmon carcasses were found in the lower river segments and one hatchery marked carcasses was found in the upper river. Hatchery marked coho salmon were not recorded by crews surveying the South Fork. Two female chinook salmon (*Oncorhynchus tshawytscha)* carcasses (fork length 95 and 88cm) were found in the Noyo River between Madsen Hole and Company Ranch in mid-January 2001 and one adult male was captured at the weir. Thus a minimum of two chinook salmon redds may have been identified as coho or steelhead. No chinook salmon redds were identified during the field surveys.

Redds

Field uncertainty in redd identification was 23.4%. Uncertainty in redd identification based on the PCA discriminant function was 2.8%. All physical characteristics included in the PCA analysis were significantly different between coho salmon and steelhead redds (Table 4). Of the four physical characteristics not included in the PCA analysis only tail spill substrate was not significantly different between the two species (Table 4). Although the first six principle components explained greater than 95% of the variance and misclassified one redd (steelhead as coho). Using only the first two principle components, the discriminant function still only misclassified one redd (steelhead as coho) and made calculations much less cumbersome. Equations 1-3 were not sensitive to changes in fork length input except at the low end of the range (< 35cm) where four of 60 redd species classifications were changed.

A total of 120 km of the Noyo River was surveyed approximately bi-weekly from 7 December 2001 to 5 April 2001 (Table 1, Table 5). Steelhead redds were found throughout 92.6 km of the Noyo River (Table 6, Fig. 2). The chi-square index of dispersion indicated steelhead redds were distributed in an aggregated pattern in the Noyo River during 2000-01 ($X^2 = 60.36$, n =25). A total of 296 (± 8.3) steelhead redds were identified in the Noyo River between Decmber 2000 and April 2001 (Table 6). The average size of 194 completely measured steelhead redds was 1.61 m^2 (S.E.= 0.07) and ranged from 0.11 to 7.56 m^2.

Coho redds were found throughout 72.3 km of the Noyo River (Table 7, Fig. 4). The chi-square index of dispersion indicated coho redds were distributed in an aggregated pattern in the Noyo

River during 2000-01 (X^2 = 979, n =25). A total of 377 (± 10.5) coho redds were observed between December 2000 and February 2001 (Table7). The average size of 352 coho redds was 4.76 m^2 (S.E.= 0.21) and ranged from 0.17 to 23.84 m^2.

Steelhead redd density was 2.43/km (S.E.= 0.49) and ranged from zero to 9.16/km (Fig. 5 a-c, Table 6). Treating the survey segments as samples, there was a no difference in the number of steelhead redds per km between the upper Noyo River, which averaged 5.41 redds/km (S.E. = 0.57), the South Fork averaged 3.52 redds/km (S.E. = 1.29), and the lower river averaged 1.23 redds/km (S.E. = 0.33) (f = 1.68, p = 0.21). However, the power of this test was low (α = 0.14).

Coho redd density was 5.22/km (S.E.= 2.93) and ranged from zero to 74/km (Fig. 6a-c, Table 7). The highest coho redd density was in the South Fork Noyo River below Kass Creek and was more than14 times as high as any other survey segment (Fig. 5a-c). Treating the survey segments as samples, there was a significant difference in the number of coho redds per km between the upper Noyo River, which averaged 0.56 redds/km (S.E. = 0.29), the South Fork averaged 13.24 redds/km (S.E. = 8.8), and the lower river averaged 2.80 redds/km (S.E. = 0.43) (H = 11.11, p = 0.004). Coho redd density was significantly different between the upper river and the South Fork segments (Q = 2.97, p <0.05) and between the upper river and the lower river segments (Q = 2.57, p < 0.05). Coho redd density was not significantly different between the South Fork and lower river segments (Q = 0.26, p > 0.05).

Steelhead redd area and river location were positively correlated (n = 294, r = 0.121, p = 0.038) while coho salmon redd area and river location were not related (n = 341, r = -0.005, p = 0.918). There was no relationship between steelhead female fork length and redd area (r = 0.41, p = 0.21, n =11). Similarly there was no relationship between coho salmon female fork length and redd area (r = -0.23, p = 0.38, n =17).

A total of 113 Pacific lamprey redds were observed in the Noyo River between 21 March and 4 April 2001. The average size of these redds was 0.211 m^2 (S.E. = 0.04). Pacific lamprey redds were found throughout the Noyo River from Company Ranch to McMullen Creek. Pacific lamprey spawning activity peaked after the end of the spawning surveys this year.

Adult Steelhead

A total of 69 adult steelhead were observed during spawning surveys on the Noyo River between December 2000 and April 2001(Table 6). Observed live steelhead density was 0.56/km (S.E. = 0.13) in the Noyo River during 2000-01. The AUC method steelhead population estimate was 222 (95% CI =128 to 416) in the Noyo River during 2000-01 (Table 8). Steelhead spawning population estimates based on redd information ranged from 258 (± 7.2) to 583 (± 16.3) for the 2000-01 season (Table 8). Steelhead density from the AUC method was 2.04/km (95% CI = 1.38 to 4.49). Steelhead density estimates derived from redd counts ranged from 2.79 ± 0.08 to 6.30 ± 0.18 per km. The AUC and population estimates based on two redds per female and redd area were very similar (Table 8). These estimates are within the range of the mark-recapture estimate of 272 (95% CI = 147-508) (Neillands In Preparation.). The adult population estimate assuming one redd per female is outside this range (Table 8).

The number of redds per female based on AUC population estimates was 2.49 (95% CI = 1.33 to 4.34). For the redd area method the number of redds per female was 2.30 (± □0.06).

A total of 104 adult steelhead (not including 6 recaptures) were observed in the Noyo River between 12 December 2000 and 2 April 2001. Of these, 69 were observed during spawning surveys, 15 (plus one recapture) were captured at the Noyo-ECS, 19 (plus one recapture) were captured at the Madsen Hole weir, and seven (two were recaptures) were captured in a downstream fyke traps. Of these fish 96 were observed in enough detail to estimate fork length. Steelhead average fork length was 65.8 cm, S.E. = 1.32 and ranged from 32 to 90 cm. Average male steelhead fork length was 62.2 cm (n = 35, S.E. = 2.3) (Fig. 7). Female steelhead fork length averaged 70.3 cm (n= 35, S.E.= 1.9) (Fig. 7). The average fork length of 26 unidentified sex steelhead was 70.0 cm, S.E. = 2.61 S.E. (Fig. 7). Male and female fork lengths were significantly different ($t = -2.15$, $p = 0.008$). Female and unidentified sex fish fork lengths were not significantly different ($t = 637$, $p = 0.06$). Male and unidentified sex fish fork lengths were not significantly different ($t = 860$, $p = 0.43$). The female to male ratio of all steelhead identified to sex was 1.03:1.00. The female to male ratio of 31 captured and handled fish was 1.02:1.00.

Adult Coho Salmon

A total of 626 adult coho salmon were observed during spawning surveys on the Noyo River between December 2000 and April 2001(Table 7). One hundred and fifty six coho carcasses were observed between 7 December 2000 and 16 February 2001. Observed live coho density was 18.1/km (S.E. = 16.6) in the Noyo River during 2000-01. Excluding the South Fork the observed live coho density was 1.51/km (S.E. = 0.59) in the Noyo River during 2000-01. The AUC method coho population estimate was 592 in the Noyo River during 2000-01 (Table 7). The coho salmon spawning population estimate based on redd area was 556 (± 16) for the 2000-01 season. Coho density from the AUC method was 6.4/km. Coho salmon density estimated from redd counts was 6.00 ± 0.17 per km. The AUC and redd based coho population estimates were similar (Table 7). A total of 429 coho salmon were observed at the Noyo-ECS, 231 of these were passed through the trap. The AUC population estimate for the South Fork above the Noyo-ECS was 50.6% and the redd area estimate was 68% of number of coho salmon released. The female to male ratio at the Noyo-ECS was 0.79:1.00. The female to male ratio of coho salmon passed through the Noyo-ECS was 0.69:1.00.

The number of coho redds per female based on AUC population estimates was 1.81 (± □0.05). . For the redd area method the number of redds per female was 1.93 (± □0.05). The number of coho redds per female based on carcass mark-recaptures was 2.45 (± □0.01). The number of coho redds per female based on the number of females released above the Noyo-ECS was 1.38 (± □0.01).

A total of 630 adult coho salmon were observed in the Noyo River between 7 December 2000 and 9 February 2001. Of these, 626 were observed during spawning surveys and four were captured during downstream fyke trapping. Of these, 86 were observed in enough detail to estimate fork length. Coho salmon fork length averaged 62.2 cm, S.E. = 1.58 and ranged from 30 to 95 cm. Average male coho fork length was 60.1 cm (n = 23, S.E. = 2.51) (Fig. 8). Female coho fork length averaged 68.1 cm (n= 35, S.E.= 2.54) (Fig. 8). The average fork length of 25 unidentified sex coho was 56.1 cm, S.E. = 2.56 S.E. (Fig. 8). Male and female fork lengths were significantly different ($t = 2.15$, $p = 0.036$). Female and unidentified sex fish fork lengths were significantly different ($t = 3.27$, $p = 0.002$). Male and unidentified sex fish fork lengths were not significantly different ($t = 1.13$, $p = 0.26$). More of the unidentified fish were likely males, which corresponds with the observed male-female ratio.

Adult Migration and Spawning Timing

The observation frequency of adult steelhead in the Noyo River during 2000-01 is shown in Fig. 9a. Steelhead were first observed in the Noyo River on 12 December. The first adult in spent condition was observed on 9 February 2001 when one fish was captured at the Madsen Hole weir (Neillands, In Preparation.). Steelhead were last observed on 2 April 2000, one unknown sex fish was captured in a downstream fyke trap in the South Fork and another was observed in Hayworth Creek. The peak period of steelhead observation in the Noyo River during 2000-01 was between mid-February and mid-March (Fig. 9a). Male steelhead were observed from 11 January to 29 March 2001 (Fig. 9b). Female steelhead were observed from 11 January through late-March 2001. Unidentified sex steelhead were first observed in late-December 2000 and last observed in late-March (Fig. 9b).

A total of eleven steelhead redds were observed with one or more fish guarding or building them. In each case the same section of river was surveyed within 8 days and fish were not observed again on these redds. In one observation, a pair of steelhead (male and female) were observed spawning and six days later the redd was complete and no adults could be found. This suggests the minimum adult stream residency was seven days.

Steelhead spawned in the Noyo River between mid-December and early April 2000-01. Steelhead redds were observed in the Noyo River beginning in late-December 2000 (Fig. 10). The majority (40.9%) of steelhead redds observed in the Noyo River were found during January, 29% were observed in February, and 28.7% of were observed in March. Newly formed redds were found from December to early-April. Redds observed in December and April accounted for 1.1 and 0.2% respectively, of the total found during the entire survey period. During late-April, May, and June, four of the survey segments which had new redds during the last survey period were surveyed again and no new redds were found. Steelhead spawned significantly later and further upstream than did coho salmon in the Noyo River during 2000-01 (Table 4).

The observation frequency of adult Coho salmon in the Noyo River during 2000-01 is shown in Fig. 9c. Coho were first observed holding in the Noyo River estuary on 15 October 2000. The first coho carcass was observed on 7 December 2000, the first day of spawning surveys. Live coho were last observed on 9 February 2001. The peak period of coho observation in the Noyo River was during December 2000 (Fig. 9c). Male coho were observed from late-December 2000 to early-February 2001 (Fig. 9c). Female coho were observed from early December 2000 through early-February 2001. Unidentified sex coho were observed from early December 2000 through early-February 2001 (Fig. 9c).

Newly formed coho salmon redds were found from December to early-February. Coho salmon redds were observed in the Noyo River beginning in early-December 2000 (Fig. 10). The majority (63.0%) of coho redds observed in the Noyo River were found during December, 36.4% were observed in January and 0.6% were found in February. No coho redds were found in March. Coho salmon spawned in the Noyo River between mid-December and early-February 2000-01.

Stratified Index Sampling Population Estimation

The stratified index design (representative reach) approach was based on AUC and redd based population estimates per km (Tables 1 and 8) for each segment. The average number of steelhead and coho by density category for both estimation methods are shown in Table 9. The redd area estimation resulted in a stratified index population estimate of 239 (S. E. = 27) steelhead and 531 (S.E. = 254) coho. The AUC based estimation resulted in a representative reach population estimate of 229 (S. E. = 49) steelhead and 1131 (S.E. = 804) coho. There was no difference in the number of steelhead per segment estimated by AUC and extrapolated from AUC estimates (Table 10). There was no difference in the number of steelhead per segment estimated by the redd area method and extrapolated from these estimates (Table 10). However, the power of this test was low ($\alpha = 0.05$). There was a significant difference in the number of coho per segment estimated by AUC and extrapolated from AUC estimates (Table 10). There was no difference in the number of coho per segment estimated by the redd area method and extrapolated from these estimates (Table 10). Segments selected for extrapolation of redd based and AUC estimations were not always the same. Nor were they the same for steelhead and coho (Appendix A lists the density categories for each segment).

Effort

The entire Noyo River, excluding some smaller tributaries and some gulches was surveyed between six and 12 times during 2000-01 (Tables 1, 5). Generally, two crews of two surveyed two approximately 5 km segments of the Noyo River each day. The South Fork survey segments, the Little North Fork, and Duffy and Hayshed gulches were surveyed weekly from December 2000 through mid-February 2001 and biweekly from mid-February to April 2001. Personnel from Campbell Timberlands Management surveyed the Little North Fork and Duffy and Hayshed gulches from December 2000 to late-February 2001. 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 entire spawning survey, excluding data entry, analysis, and reporting totaled about 30 days, 738 field hours, and 316 hours of driving. This totals about 2100 person hours.

Discussion

The coho salmon population estimate based on carcass mark-recaptures was much lower than estimates from the AUC and redd area method. Maahs and Gilleard (1993) used a carcass retention model to estimate coho salmon populations in the South Fork Noyo River. This model only accounted for 7.4% of the known number of coho salmon in the stream in their study. Therefore I did not use this model to estimate coho populations. Many of the assumptions of the Peterson method (Brower and Zar 1984)) are violated when estimating populations from carcass mark-recaptures (Krebs 1989). I would have preferred to use a Jolly-Seber (Krebs 1989) approach to calculate coho salmon populations from the carcass data, however most of the marked and recaptured fish were found in the South Fork and, as crews working there did not individually mark carcasses, this was not possible. Improving data collection and marking procedures may improve coho salmon population estimates from carcass counts. Carcass mark-recapture for steelhead in the Noyo River appears to be unfeasible due to low numbers of carcasses.

Redds

The one redd misclassified by the PCA discriminant function was located in Hayshed Gulch and was found in early January. The crew conducting this survey was uncertain of their identification of coho and steelhead at that time (D. Wright Pers. Comm.) and it is quite possible that this was a coho rather than a steelhead. If this is the case then the discriminant function correctly identified all redds to species. If this is not the case uncertainty in redd identification using the discriminant function was 2.8% compared to field uncertainty of 23.4%. This function did not predict coho redds from those identified as steelhead, test, or unknown in the field after 9 February, the time at which no more live coho were observed.

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 up 20% of early season redds . About a third of the adult steelhead (Fig. 9) and 42.5% of the steelhead redds (Fig. 10) were observed in the Noyo River before 1 February 2001. While time of year is an important factor for discriminating between species, assuming that redds made prior to 1 February are all coho will bias population estimates.

The discriminant function 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 redds and their redds were not identified in the field during 2000-01. Prior to January 2001 chinook salmon had not been observed in the Noyo River and therefore survey crews were not looking for redds of this species. 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 = 4.76 m^2, S. E. = 0.21) than steelhead (average = 1.61 m^2, S. E. = 0.07) in the Noyo River during 2000-01. Only 9 steelhead redds were identified in the Madsen Hole to Company Ranch reach whereas 40 coho redds were found in this reach (Tables 6 and 7). Thus it is more likely that the few possible chinook salmon redds in the Noyo River during 2000-01 were identified as coho salmon rather than steelhead. The initial study plan included Pacific lamprey redds in the PCA analysis, yet very few lamprey redds (n = 113) were observed prior to the end of steelhead spawning during 2000-01 and were therefore not included.

Data used in the discrimiant function was easy to collect, added little extra effort in the field, and was necessary to estimate populations using the redd area method. Two of the variables used in the principle components analysis (tail spill area and redd area) were calculated from other variables used in the analysis. However, variables resulting from principle components analysis are uncorrelated (C. Gallagher, Pers. Comm.). Date, river location, and fish fork length were included in the PCA analysis to help differentiate redds by species because if larger fish spawn earlier, lower in the river, or make bigger redds this would confound discrimination of redds. These three factors were significantly different between species (Table 4) and aided in differentiating redds by species. In the data use to calculate the principle components, steelhead and coho salmon fork lengths did not differ ($t = -2.03$, $p = 0.05$). However, the power of the test was low ($\alpha = 0.40$). If coho and steelhead fork lengths differed, using the average of the two as input into equations 1-3 for redds where fish were not observed might cause discrimination of species to be incorrect. Equations 1-3 used to discriminate species were not sensitive to changes of fork length inputs except at the low end of the observed range of both species (< 35 cm). Average fork length for both species in the Noyo River during 2000-01 was 64.2 cm (S.E. = 1.01 cm) and it is unlikely that the average of all species in other years would be < 40 cm. Crisp and Carling (1989) used logistic transformations to develop linear regressions that predict female fish fork length from redd dimensions. There was no relationship between redd area and female fork length for coho salmon and steelhead in the Noyo River during 2000-01. This could be due to the small sample size. The PCA discriminat function developed from coho and steelhead redd information 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.

Tail spill substrate was the only physical factor that was not different between the coho salmon and steelhead. This is likely a result of the substrate being estimated as the existing bed material above the red pot rather than from within the tail spill itself. Coho salmon redds were larger and had deeper pots than steelhead (Table 4). However, steelhead pot substrate was larger than that of coho salmon. This may be because steelhead spawned further upstream (Table 4) where streams are generally steeper and appear to have larger substrates overall due to stream power and parent material characteristics. 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. In the Noyo River during 2000-01, steelhead were larger than coho but coho redd pots where deeper and larger (Table 4). This may be because steelhead are iteroparous and they must maintain energy reserves after spawning to survive the journey back to the ocean. This might also be a result of the substrate being smaller and flows larger lower in the river such that coho can move more gravel and thus make larger redds. However, steelhead redd area and spawning locations were positively correlated rather than negatively correlated, the latter would be expected if larger redds were located lower in the river. Coho salmon redd area and spawning locations were not related. Thus the difference in redd area between the species is likely a result of species differences in spawning habitat preferences.

The average size of steelhead redds in the Noyo River during 2000-01 was smaller than the estimate of Gallagher (2000). This is likely due to differences in field measurements and calculations of redd area. Gallagher (2000) treated redds as squares where in this report I treated the pot as an ellipse or circle and the tail spill as a triangle or square. 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 the Noyo River were smaller on average but the range of sizes overlapped with those of Orcutt et al. (1968). Maahs (1996) reports that redds found in some Mendocino County rivers and 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 were slightly higher. The average size of steelhead redds observed during 2000-01 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.

Maahs (1996) reports that redds found in some Mendocino County rivers and 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 found in the Noyo River during 2000-01. 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.

Almost twice as many steelhead and many times more coho redds were observed during 2000-01 (Tables 6 and 7) than during 2000 (Gallagher 2000). This seasons surveys covered the entire spawning period for coho and steelhead and surveyed the entire river. Gallagher (2000) did not start surveys until late-February and was not able to survey the entire river. Steelhead redds were found to be distributed randomly in the Noyo River during 2000, whereas during 2000-01 they were found to be distributed in an aggregated pattern. This is also likely a result of the 2000-01 surveys covering the entire river and spawning period.

Maahs and Gilleard (1993) report February redd (assumed to be mostly steelhead) densities ranging from 0.18 to 8.01 redds/km for eight coastal Mendocino County streams. The average steelhead redd density observed during 2000-01 in the Noyo River was within the range previously reported for coastal Mendocino County. The South Fork mouth to Kass Creek segment steelhead redd density (Table 6) was slightly higher than previously reported. Steelhead redd density in the Noyo River during 2000-01 was higher than reported by Gallagher (2000). This is probably because the entire river and spawning period was covered during 2000-01, whereas in 2000 the earlier portion of the season and many parts of the lower river were not surveyed. Maahs (1996) reports late season redd (assumed to be steelhead) densities ranging from 0.87 to 6.33 redds/km for Caspar Creek and portions of the Ten Mile River over three seasons. Maahs (1999) reports late season average redd density during 1998-99 in the Garcia River was 3.91 redds/km. Late season redd densities ranged from 0 to 3.21 redds/km in the Garcia River over four years of survey data (Maahs 1999). The average steelhead redd densitiy observed during 2000-01 in the Noyo River was within this range.

Nielsen et al. (1990) state that November to February 1989-90 redd densities in the South Fork Noyo River range between 1.01 and 11.85/km. They state the South Fork Noyo River had the highest density of 82 streams surveyed and attribute this to coho returning to the Noyo-ECS. Coho salmon redd densities during 2000-01 in the Noyo River were within this range except for the South Fork mouth to Kass Creek segment. Similar to Nielsen et al. (1990) coho salmon redd densities were highest in the South Fork which was likely due to to coho returning to Noyo-ECS. Coho salmon returns to the Noyo-ECS during 2000-01 were much higher than in recent years (M. Knechtle, Pers. Comm.). Maahs (1996) reports early season redd (assumed to be coho) densities ranging from 11.2 to 16.8 redds/km for Casper Creek and 2.4 to 4.7 redds/km portions of the Ten Mile River). Maahs (1997) reports early season redd (assumed to be coho) densities ranging from 0 to 5.9 redds/km for Casper Creek, 0 to 1.04 redds/km for portions of the Garcia River, and 1.7 to 1.8 redds/km portions of the Ten Mile River. Maahs (1999) reports late season average redd density during 1998-99 in the Garcia River as 2.3/km. Coho salmon redd densities were on average higher in the Noyo River during 2000-01 than in all streams previously surveyed except for Caspar Creek in 1995-96. This is likely due to large numbers of hatchery reared coho salmon returning to the South Fork Noyo River. Coho densities in Noyo River excluding the South Fork averaged 1.8/km. These densities are lower than previously reported probably because the entire Noyo River was surveyed in 2000-01 whereas previous surveys concentrated on known spawning areas and only surveyed portions of rivers and streams. Harris (1999) provides results of spawning surveys from 1990 through 1999 for Caspar Creek and Little River. Timing of surveys, length of survey segments, and survey methods are not reported and only total numbers of adults, carcasses, and redds are presented so no comparison to results reported here for the Noyo River during 2000-01 were made.

Adult Steelhead

Observed live steelhead density in the Noyo River during 2000-01 was within the range reported recently for other nearby streams. Live steelhead density was higher than reported by Gallagher (2000) because the entire stream and spawning period was not covered during 2000. Maahs and Gilleard (1993) report observed February steelhead densities of 0.44 and 1.11/ km in Pudding Creek. Maahs (1996) reports observed steelhead density in the Ten Mile River at 0.99/km and in Caspar Creek at 0.50/km. Over the years 1995-96, 1996-97, and 1998-99 observed steelhead per km ranged from 0 to 0.31 in Caspar Creek and from 0.68 to 2.6 in portions of the Garcia River (Maahs 1999). The observed live steelhead density for the Noyo River during 2000-01 was for the entire river whereas previous studies focused on portions of streams known to have high spawning potential. The time between surveys, annual stream flow, and differences in water visibility likely influence the number of live fish observed.

The adult steelhead population estimates for all methods, except for that assuming one redd per female, overlapped with the population estimate from a mark-recapture study (Neillands, In Preparation.). The close correspondence in the estimate of the number of redds per female between the AUC and redd area methods add confidence in these estimates. 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. The estimate of 2.4 redds/female in the Noyo River during 2000-01 is not unrealistic. Of all the methods, the AUC had the lowest median estimate and largest confidence levels. This may be due to using the mark-recapture population estimate to develop estimates of *v*, uncertainty in *rt*, and higher than anticipated interval between surveys due to lack of personnel and high stream flows. Beidler and Nickelson (1980) found the AUC to have a downward bias because observation efficiency changes with changes in stream flow and fish maturity. Maahs and Gilleard (1993) found that live fish estimates using AUC dramatically underestimated spawning populations and are very sensitive to *rt* for adult coho. 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. Shardlow et al. (1987) found that observation efficiency depended on the method of observation. In this study *v* was set as a constant because there were no independent estimates for rafting, snorkeling, and walking. 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. In approximately 20% of the cases the number of fish seen was greater than that captured. Needham and Taft (1934) observed one pair of steelhead to spawn in 12 hours, but speculate that spawning could take up to a week. Shapovalov and Taft (1954) estimate that steelhead spawning (*rt*) takes 14 days. I estimated *rt* separately for main stem and tributaries and for each sex based on field observations and recaptures of marked fish during 2000-01. Hilborn et al. (1999) developed a maximum-likely-hood model to estimate salmon populations that incorporates changes in stream residence time and observer efficiency, however this model deviated up to 40% from known populations sizes. Improved estimates of *rt* and *v* will likely improve population estimates using the AUC method. Using a Bayesian based model (Gazey and Staley 1986) may also improve population estimates derived from spawning surveys.

The adult steelhead population estimates for the Noyo River during 2000-01 were almost twice those presented by Gallagher (2000). It is likely that the difference was due to differences in the timing and duration of surveys rather than because there were more steelhead in the Noyo River during 2000-01. Shapovalov and Taft (1954) found adult steelhead counts relatively stable between 1933 and 1942 in Waddell Creek, California. However, 2000-01 was an exceptional year for chinook salmon returns to the Klamath-Trinity system and coho returns to the Noyo-ECS (M. Knechtle, Pers. Comm.). Thus it is possible that 2000-01 was also a good year for steelhead and the differences between 2000 and 2000-01 were due to increased steelhead in the Noyo River.

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 258 (± 7.2) adult steelhead in the Noyo River during 2000 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 2000-01.

Redd-based steelhead population estimates for streams surveyed during the 1990's were not possible due to the timing of the surveys and lack of information on steelhead mating systems (Maahs 1996). I used the female to male ratio observed during 2000-01 in the Noyo River to calculate the number of males and females present from the number of redds observed based on one and two redds/female and the redd area method (Maahs 1996). The steelhead population estimates from these methods, except for that assuming one redd/female, are within the range of the mark-recapture estimate and indicate that incorporation of refinements in methods suggested by Gallagher (2000) has improved steelhead population estimates. Use of the PCA discriminant function to differentiate redds by species also improved redd based population estimates.

Steelhead captured during 2000-01 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).

In general the adult steelhead sex ratios observed in the Noyo River during 2000 were similar to those 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. Males recaptured in the Noyo River during 2000-01 averaged 38 Days in the river and ranged from 22 to 50 days. Only one female was recaptured in the Noyo River during 2000-01 and had been in the river for 46 days. Late season observations in the Noyo River during 2000-01 (Fig. 9b) were equal in male and females. This is different than during 2000 (Gallagher 2000) when more males were observed late in the season. This could be due to differences in stream flows between years or from misidentification of fish sex in the field.

Steelhead Migration and Spawning Timing

Steelhead observations in the Noyo River peaked in February 2001. Steelhead spawning in the Noyo River began in mid-December 2000 and extended through early-April 2001. Spawning activity peaked in late-January 2001. There was a large overlap in the spawning of coho salmon and steelhead in the Noyo River during 2000-01. This is apparent in the larger uncertainty of field identified redds. The PCA discriminant function was necessary to tell redds apart when both species were in the river. The migration timing of adult steelhead and spawning activity in the Noyo River 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 in 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 in the Noyo River during 2000-01 was generally higher than the range reported recently for other nearby streams. Live coho salmon density was higher than reported by Gallagher (2000) because the entire stream and spawning period was not covered during 2000. Nielsen et al. (1990) report observed December-January (assumed to be coho) densities in 11 coastal Mendocino County Rivers and 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 rivers and 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). The observed live coho density for the Noyo River during 2000-01 is for the entire river whereas previous studies focused on portions of streams known to have high spawning potential. Live coho observations during 2000-01 in the South Fork Noyo River were heavily influenced by salmon returning to the Noyo-ECS. The high density of 417/km was after a storm caused freshet and were salmon observed holding in a pools in the lower South Fork. Annual and watershed differences in water visibility likely influence the number of live fish observed.

The AUC and redd area population estimates for coho salmon in the Noyo River during 2000-01 were very similar. However, the AUC and redd based population estimates appear to underestimate the known number of fish released above the Noyo-ECS. Maahs and Gilleard (1993) found that their population estimates did not correspond with known populations and attributed this in part to fish moving downstream and back over the Noyo-ECS. The number of coho released during 2000-01 that went back downstream is unknown. However, 3.1% of the 65 released fish found as carcasses were below the Noyo-ECS (M. Kncettle. Pers. Comm.). These fish could have swam down to spawn or drifted down while dying or after death. Although carcass surveys generally underestimate salmon populations (Maahs and Gilleard 1993), assuming 25% of live coho were observed as carcasses (626/156) during 2000-01, the AUC underestimated the coho population by 32.1% and the redd area by 9.1%. Beidler and Nickelson's (1980) desired level of resolution in escapement estimates is 25% for comparison of harvest strategies. The redd area method appears to be well within this range for coho salmon. Better estimates of *v* and *rt* might improve AUC estimates. Use of the PCA discriminant function to differentiate redds by species improved redd based population estimates.

Gallagher (2000) did not report adult coho population estimates. Nielsen et al. 1990 estimated the population of coho salmon in the South Fork Noyo River using the AUC method to be 904 adults (95% CI = 904-930). This population estimate is much higher than that estimated for 2000-01 for the entire Noyo River. However, the number of coho returning to the Noyo-ECS was 2.3 times higher in 1989-90 (Jones, 1999) than during 2000-01 (M. Knectchl, Perrs. Com). Redd-based coho salmon population estimates were made for sections of the Ten Mile River and Caspar Creek in 1991-91 and 1995-96 (Maahs 1996). Because only portions of the rivers were surveyed and estimates per km were not made, no comparisons to this seasons survey can be made.

Coho salmon observed in the Noyo River during 2000-01 were within the size range reported previously for nearby streams. 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. Similar to results of this study, Maahs (1997) found coho to be generally smaller in size than steelhead.

Coho Salmon Migration and Spawning Timing

Coho salmon observations in the Noyo River peaked in late-December 2000 and early-January 2001. Coho salmon spawning in the Noyo River peaked in mid-December 2000 and extended through early-February 2001. There was a large overlap in the spawning of coho salmon and steelhead in the Noyo River during 2000-01. This caused uncertainty in field identification of redds. The PCA discriminant function was necessary to distinguish redds when both species were in the river. The migration timing of adult coho salmon and spawning activity in the Noyo River 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 in between November and February in most years in coastal Mendocino County streams (Nielsen et al. 1990).

Stratified Index Sampling Population Estimation

The stratified index population estimates were within the range of those derived from mark-recapture (Neillands, In Preparation), AUC, and redd based estimates for steelhead. The redd area and AUC method and estimates based on the stratified index design are very similar for steelhead. Irvine et al. (1992) found that stratified index estimates were always similar to mark-recapture estimates. There was no independent estimation of population size for coho salmon for comparison and information on *rt* and *v* is needed to improve AUC estimates. The wide range in coho salmon population estimates from the stratified index design is probably because coho and their redds were highly aggregated due to high redd and adult densities in the South Fork that likely resulted from hatchery fish. For steelhead the stratified index design appears to be a reasonable approximation and would reduce field effort in the future. If wide confidence bounds are acceptable the stratified index design could be applied to spawning surveys to estimate coho salmon populations as well. Or surveys in the South Fork could be limited to above the Noyo-ECS to reduce the influence of hatchery returns on population estimates.

Effort

The entire spawning survey, excluding data entry, analysis, and reporting totaled about 30 days, 738 field hours, and 316 hours of driving. Some tributaries and gulches were only surveyed once or twice due to limited personnel, turbidity, or lack of observed redds and adults. 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. A stratified index design appears to provide reasonable population estimates for steelhead and would reduce field effort in the future. Recaptures of weir marked fish will likely be lower if only index reaches are surveyed.

Recommendations for Further Study

There was a wide range in the estimate of adult numbers based on the AUC method. More information on steelhead mating systems, length of stream residency, and estimates of observer efficiency will further improve AUC population estimates. Starting surveys earlier, surveying the entire Noyo River, reducing the time between surveys, and conducting studies directed at understanding mating systems and the number and size of redds produced per female will help reduce the variability 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 20001-02. Setting up a time lapse video system focused on known spawning areas should help increase our knowledge of how many redds a female builds, how many males accompany each female, and how long fish remain on a redd and in the river. There are a few riffles in the lower North Fork that are extensively used by steelhead for spawning that would provide a good setting for such a study. Having more than one weir or multiple weirs and running them the entire spawning season would help better define residency time and decrease confidence levels in mark-recapture population estimates. Applying Bayesian models to spawning survey data may also increase confidence in adult population estimates.

Spawning surveys on the Noyo River should be continued in 2001-02. The surveys should be conducted in conjunction with a mark-recapture study using several Alaskan weirs. More tagged fish were observed in 2000-01 than in 2000 because spawning surveys began earlier and the entire river was surveyed. Spawning surveys should begin in late-December or early-January next year and should cover coho spawning because of the high overlap with steelhead spawning observed this season. If a stratified index design is employed, the interval between surveys should be decreased to one week or less. This will require working around large flow events and may require a larger crew. Coordination with timber companies (i.e. Campbell Timberland Management and The Mendocino Redwood Company) and other CDFG programs greatly increased coverage in the Noyo River during 2000-01 spawning surveys. This should be encouraged for 2001-02. Redd substrate data should be collected in the tail spill rather than above the redd pot. Chinook salmon and Pacific lamprey redd data should be collected and included in PCA 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.

Acknowledgments

Thanks to the Mendocino Redwood Company for allowing us access to the river and the use of their roads. Charles Bellow graciously allowed access to the North Fork and roads to the upper North Fork. Tammy Swindle, Mitch Stalfis, Alison Wrongly, and Dave Wright of the Campbell Timberland Management Company assisted with data collection on lower river segments and shared their data. Morgan Knechtle, Andy Hepokoski, Mike McNeal, and Jeromy Neal of the

CDFG Central Coast Salmon and Steelhead Resource Assessment program and Hedi Fish and Steve Gough of the NMFS Santa Cruz laboratory surveyed the South Fork Noyo River. Christina Barrineau, Mellisa Berry, Matt Coleman, Derik Lanuette, George Niellands, Alexander Pappas, and John Richardson helped conduct this survey. Colin Gallagher, Department of Statistics, Clemson University, Clemson SC conducted PCA analysis and helped develop the discriminant function used to differentiate redds. Matt Coleman, George Niellands, and Dave Wright provided helpful comments on the manuscript.

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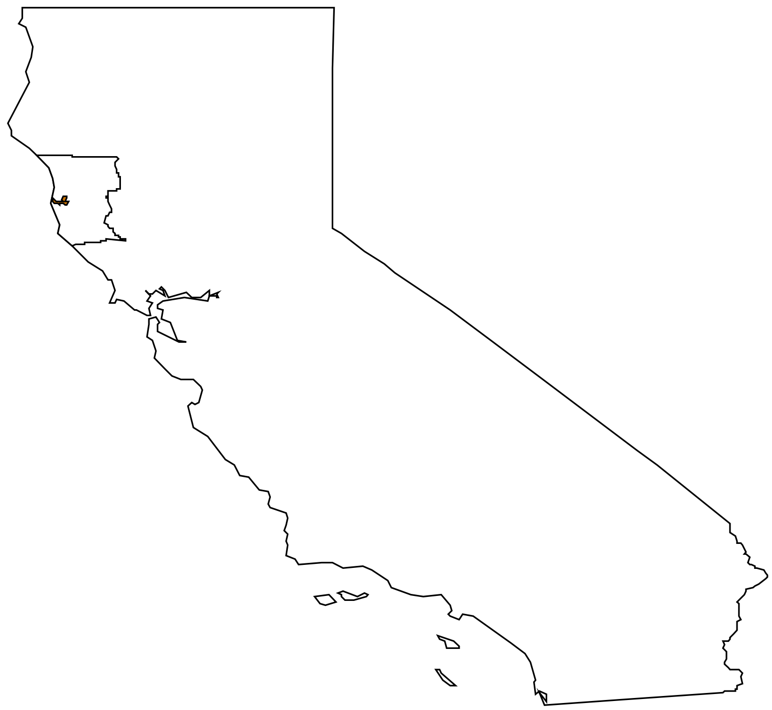

Fig. 1. Location of Mendocino County and the Noyo River watershed in California.

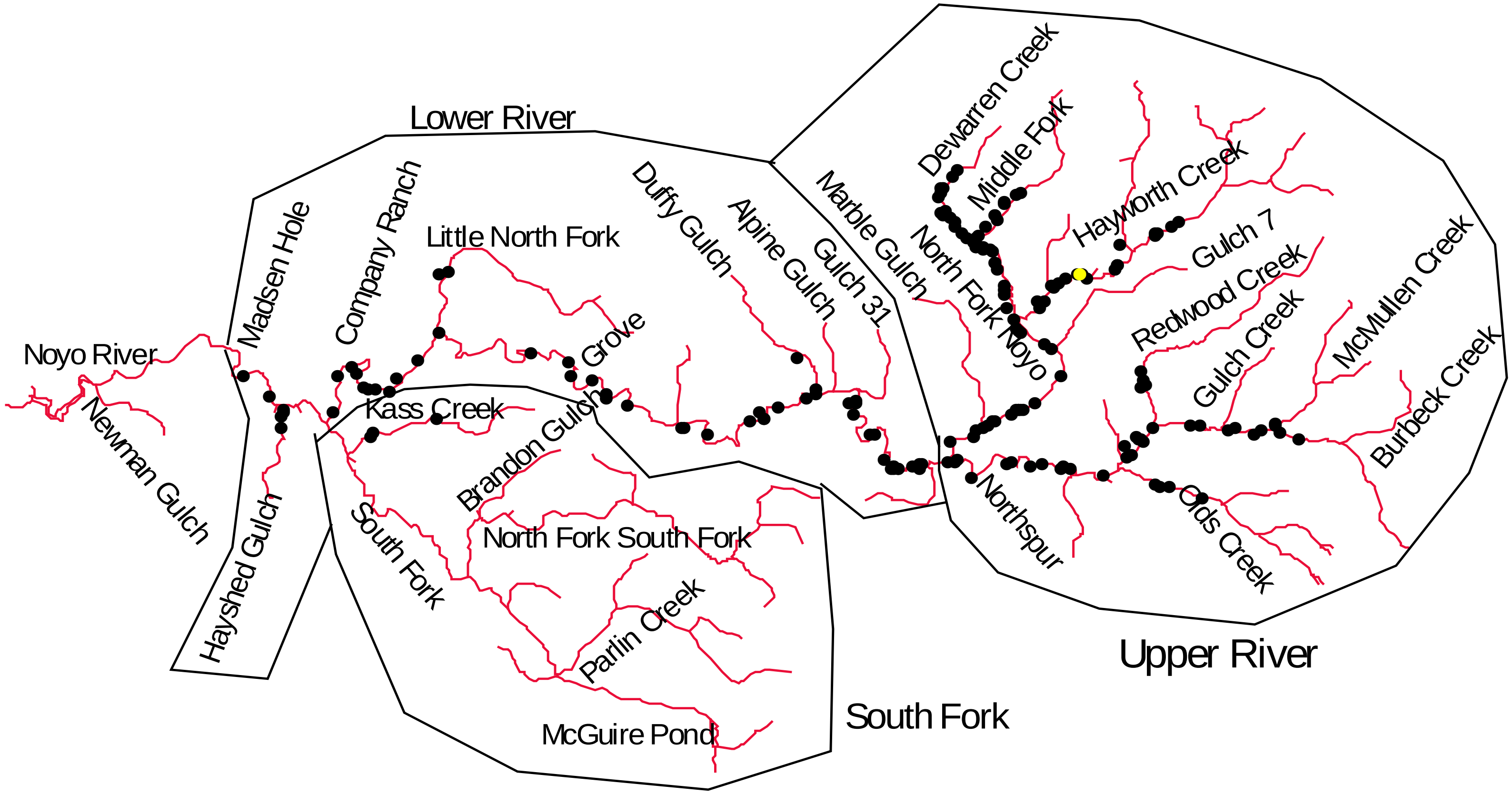

Fig. 2. Stream survey areas, stream segments, and steelhead redd distribution in the upper and lower Noyo River during 2000. Circles indicate individual steelhead redds. **Note**: Steelhad redds were not mapped on the South Fork Noyo River.

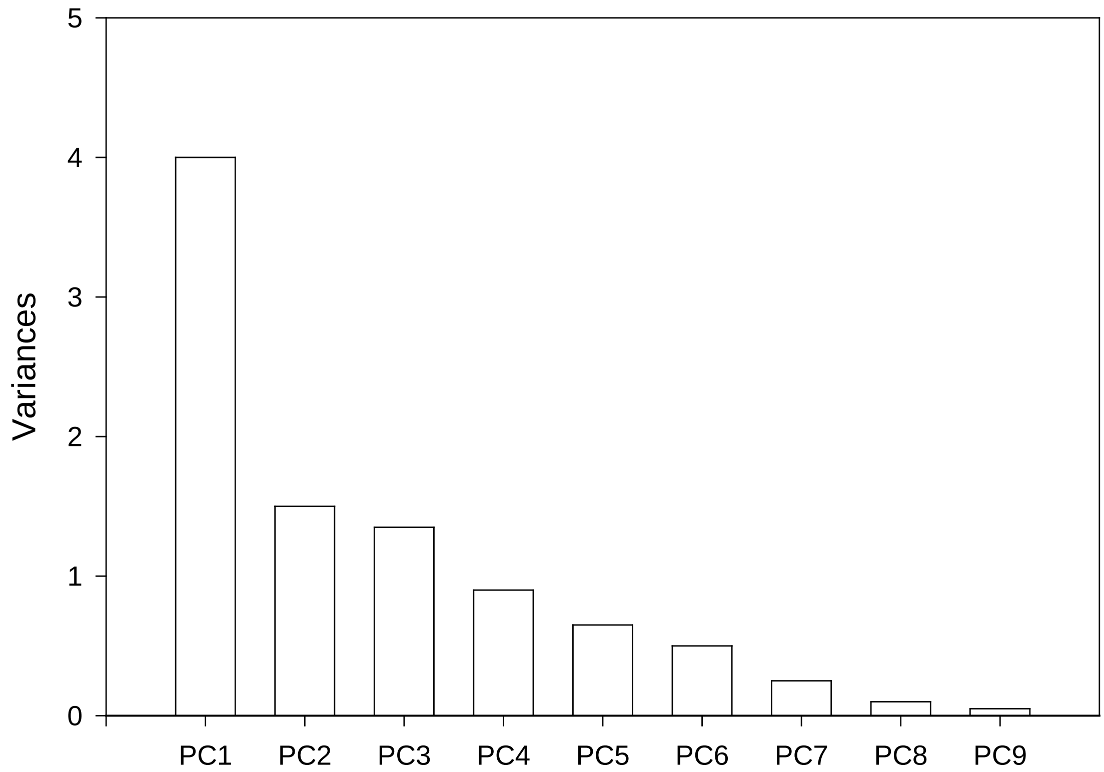

Fig. 3. Variance of each principle component from the correlation matrix of coho and steelhead redd data.

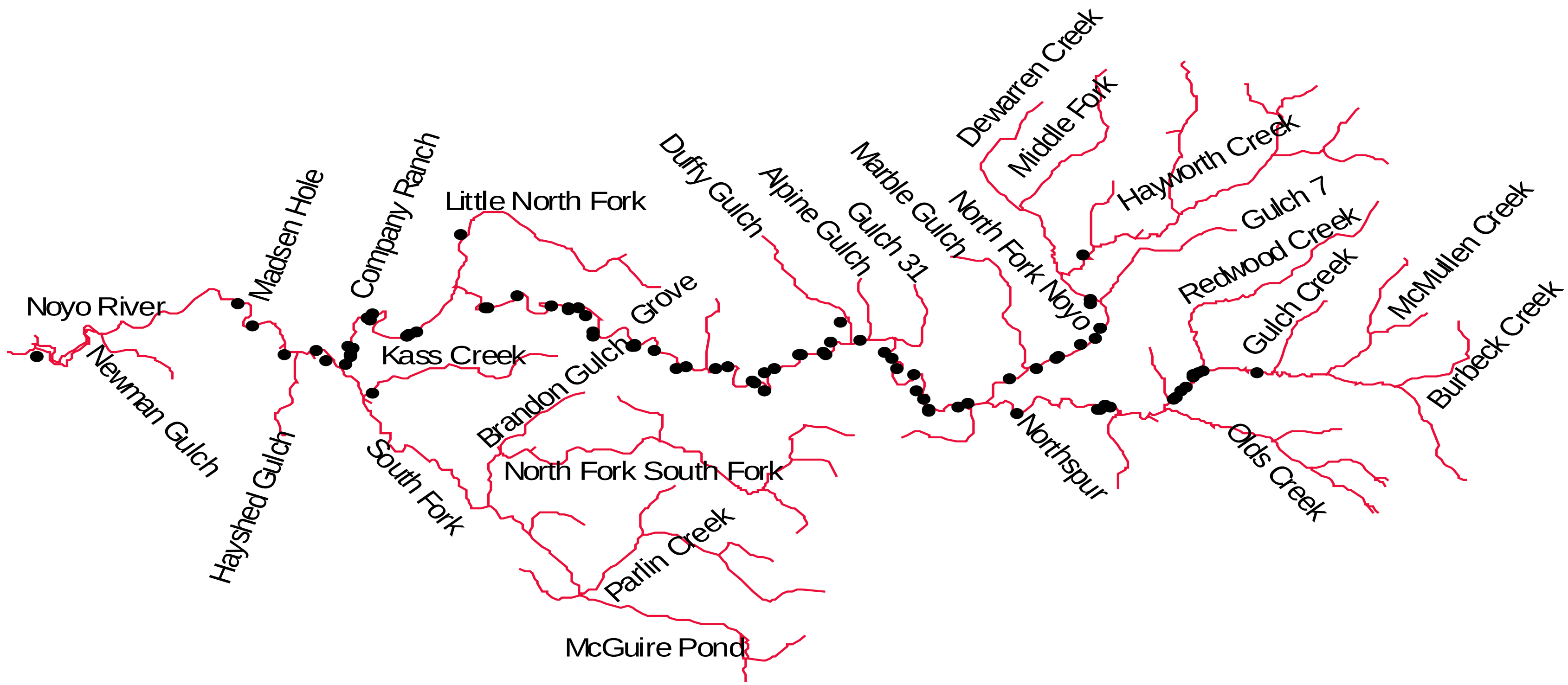

Fig. 4. Stream survey areas, stream segments, and coho salmon redd distribution in the lower and upper Noyo River during 2000. Circles indicate individual coho salmon redds. **Note**: coho salmon redds were not mapped in the South Fork Noyo River.

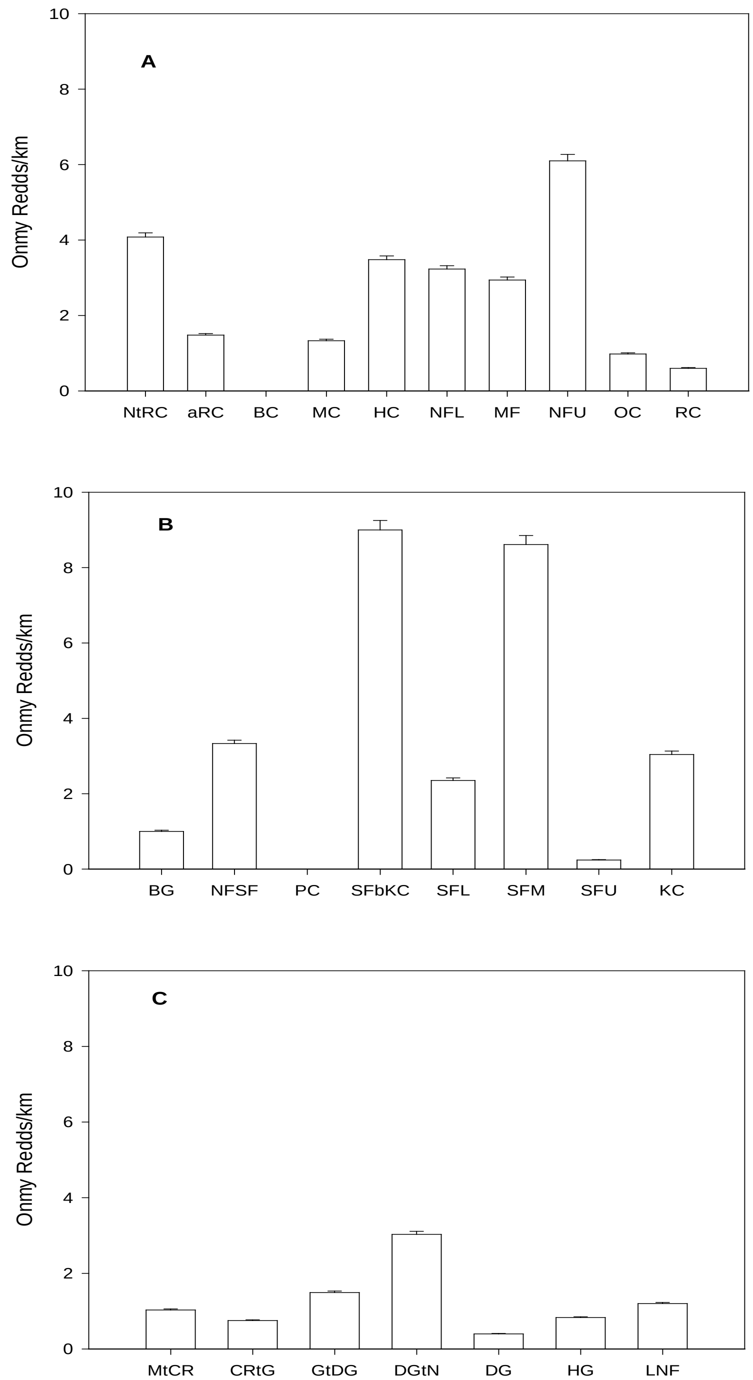

Fig. 5. Number of steelhead (Onmy) redds observed/km in the Noyo River during 2000-01. A). Upper river segments. B). South Fork segments. C). Lower river segments. Segment abbreviations are the same as in Table 1. Note scale is different in panel B.

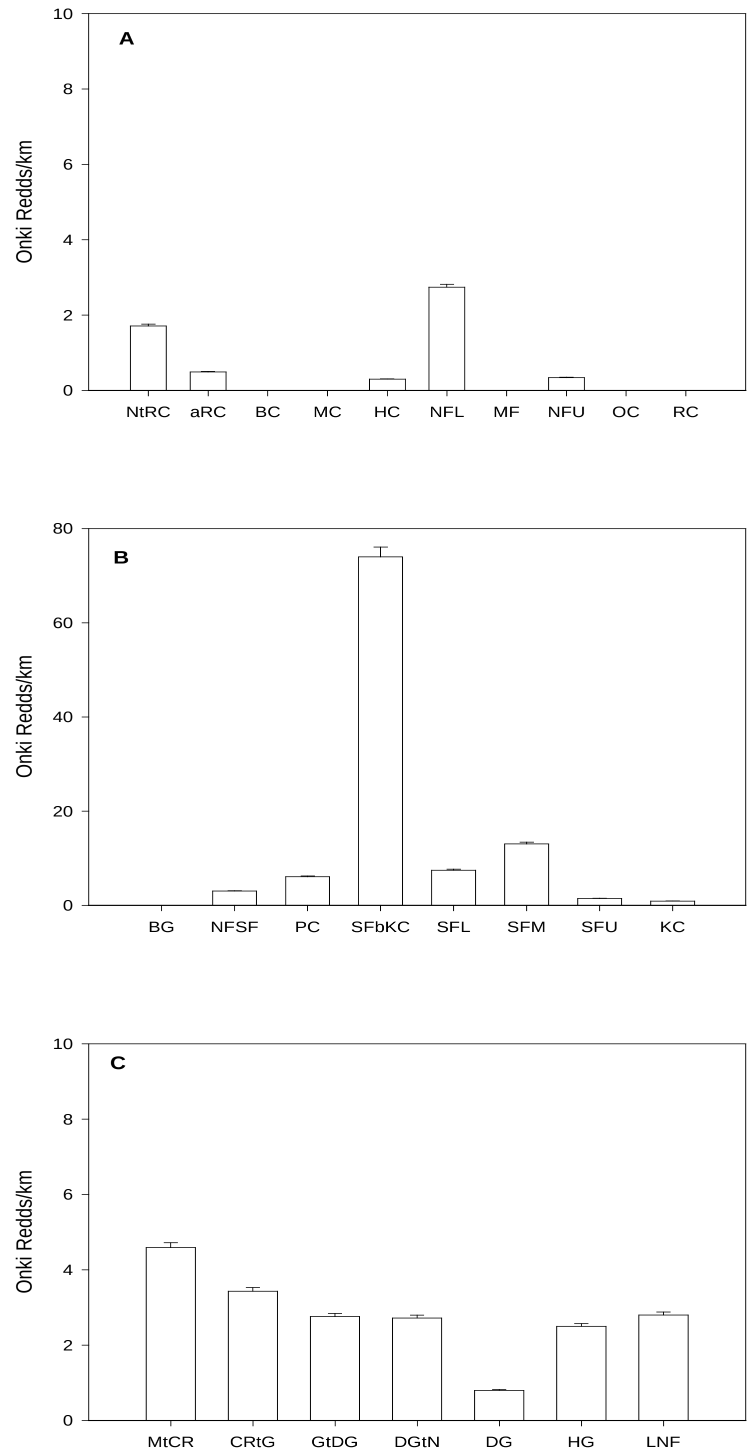

Fig. 6. Number of coho salmon (Onki) redds observed/km in the Noyo River during 2000-01. A). Upper river segments. B). South Fork segments. C). Lower river segments. Segment abbreviations are the same as in Table 1.

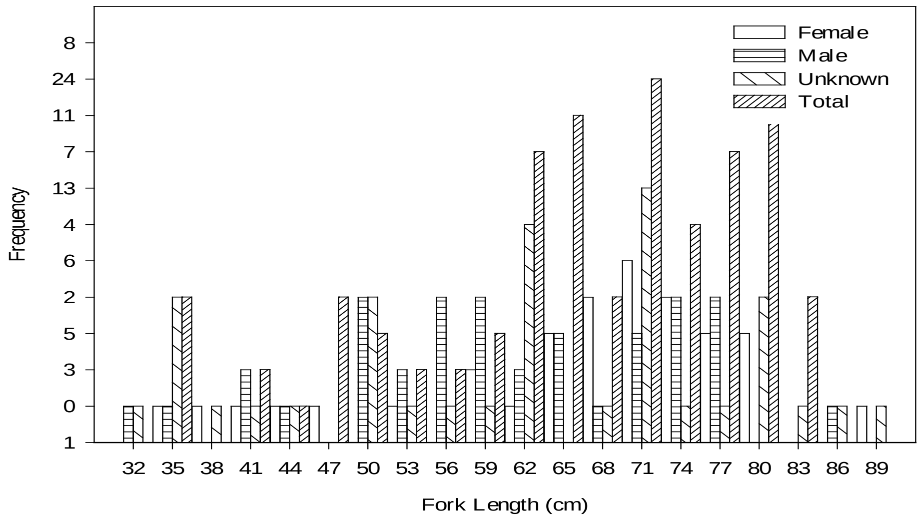

Fig. 7. Steelhead fork length frequencies observed in the Noyo River, California during 2000-01.

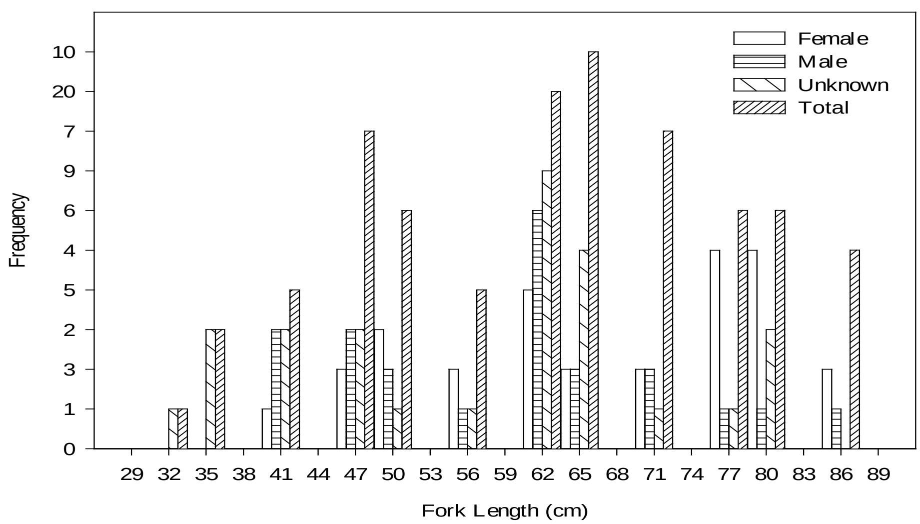

Fig.8. Coho salmon fork length frequencies observed in the Noyo River, California during 2000-01.

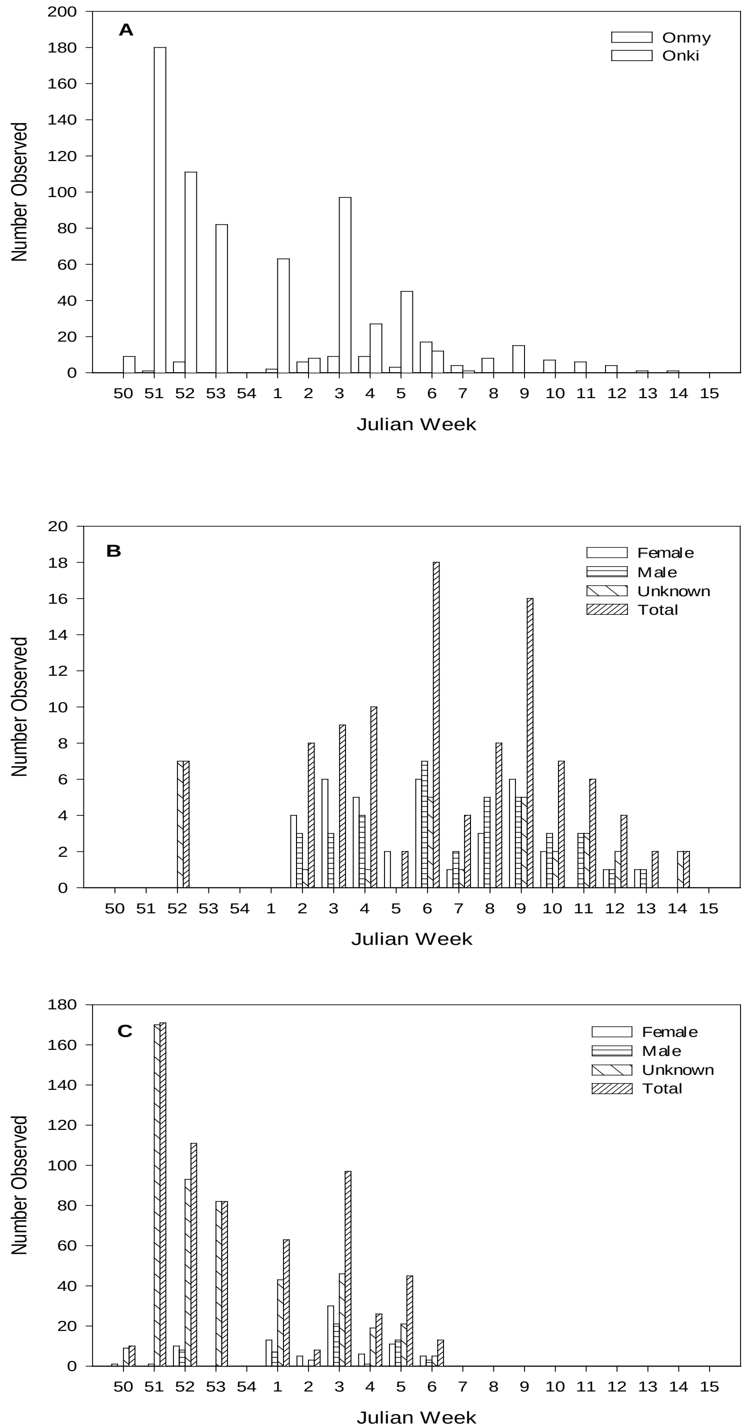

Fig. 9. Number of steelhed (Onmy) and coho salmon (Onki) observed by week during 2001-01. A. Total number of Onmy and Onki observed. B. Onmy by sex. C. Onki by sex. Week 1 is the first week in January.

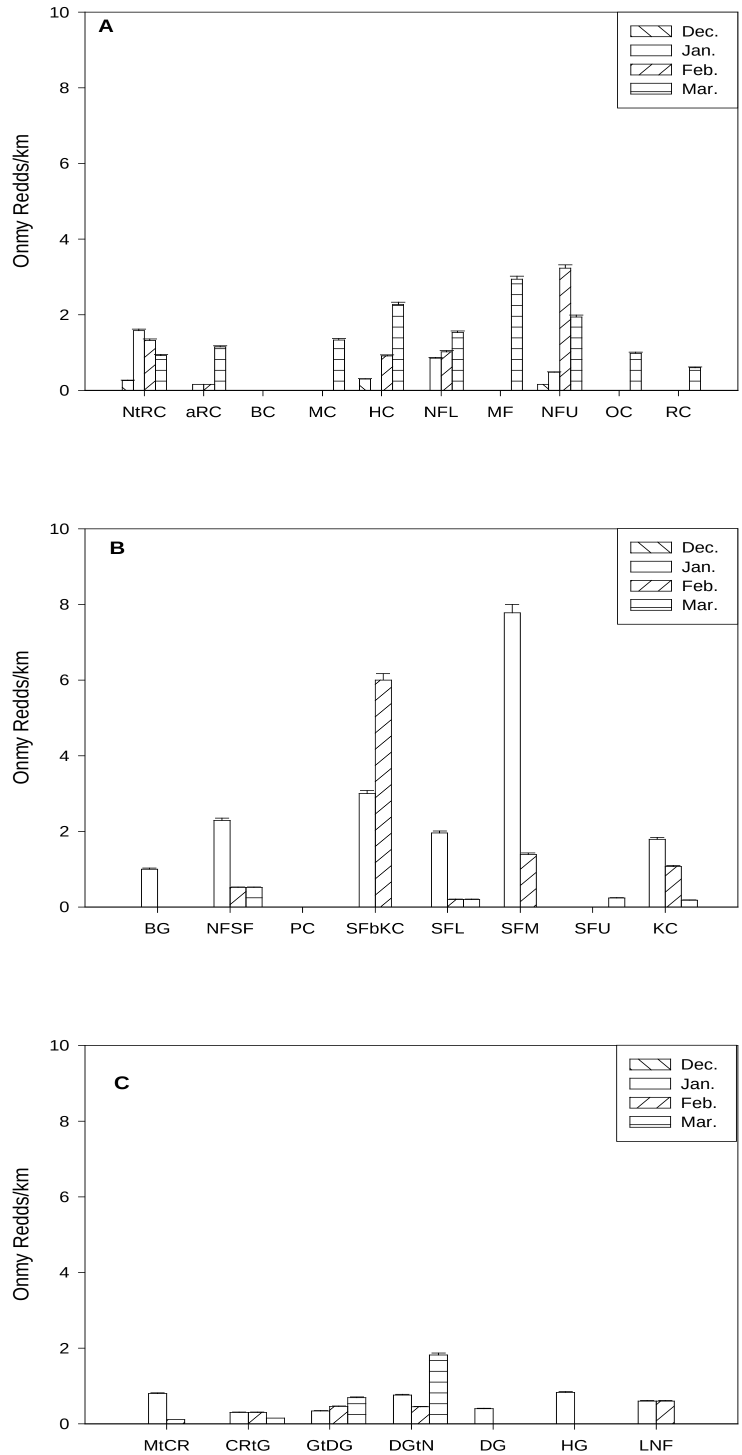

Fig. 10. Number of steelhead (Onmy) redds observed/km each month in the Noyo River during 2000-01. A). Upper river segments. B). South Fork segments. C). Lower river segments. Segment abbreviations are the same as in Table 1.

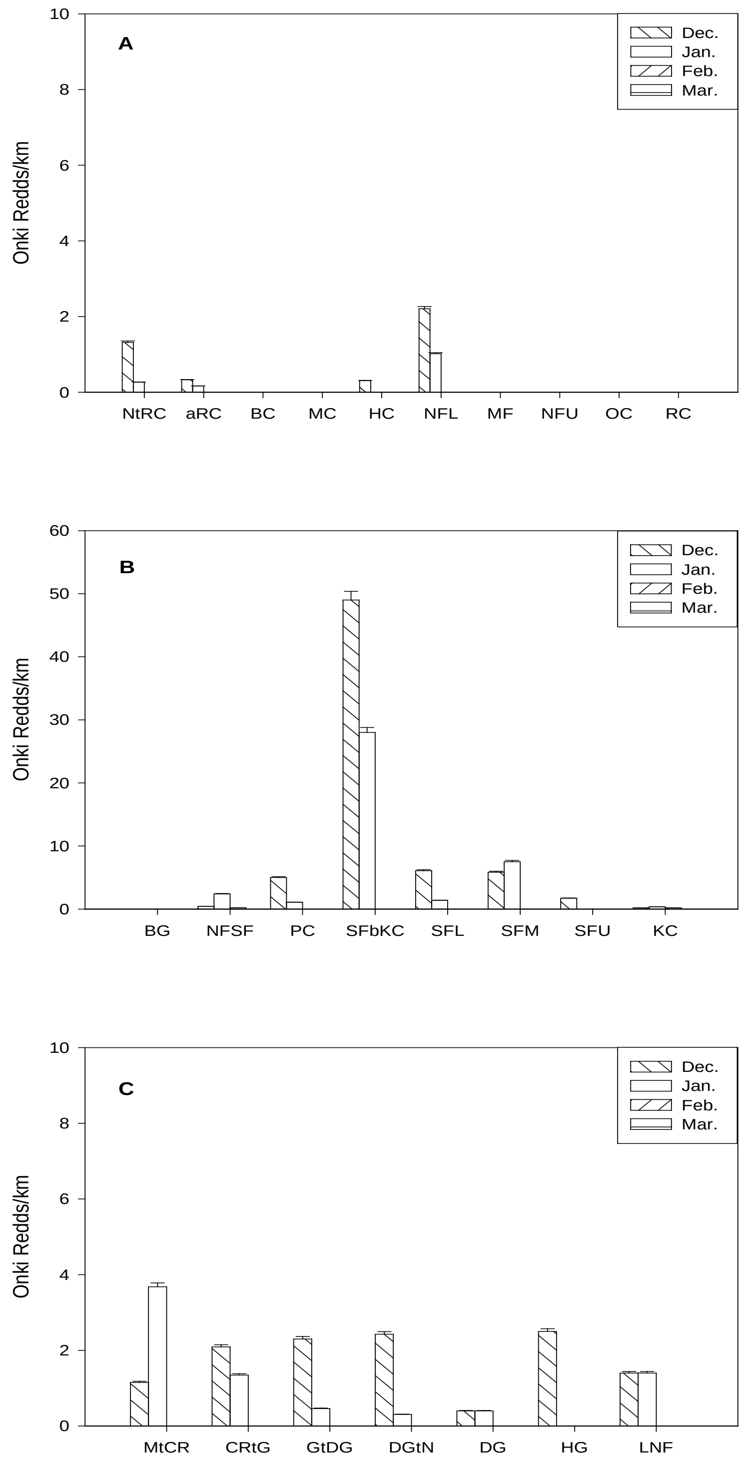

Fig. 11. Number of coho salmon (Onmy) redds observed/km each month in the Noyo River during 2000-01. A). Upper river segments. B). South Fork segments. C). Lower river segments. Segment abbreviations are the same as in Table 1.

Table 1. Stream name, segment name, survey length, and extent of steelhead spawning observed during spawning surveys on the Noyo River, California during 2000-01. Letters in parentheses are stream segment abbreviations.

Stream Name	Section	Survey Length (km)	Extent of S
Bear Gulch (BG)	Mouth Up	1	
Burbeck Cr. (BC)	Mouth Up	1	
Duffy Gulch (DG)	Mouth Up	2.5	
Hayshed Gulch (HG)	Mouth Up	1.2	
Hayworth Cr. (HC)	Mouth Up	6.6	
Kass Cr. (KC)	Mouth Up	5.6	
Little North Fork (LNF)	Mouth Up	5	
McMullen Cr. (MC)	Mouth Up	1.5	
Middle Fork (MF)	Mouth Up	3.4	
North Fork (NFL)	Below HC	6.2	
North Fork (NFU)	Above HC	5.9	
North Fork South Fork (NFSF)	Mouth Up	9.6	
Noyo River (aRC)	RC to MC	6.1	
Noyo River (CRtG)	Company Ranch to Grove	6.7	
Noyo River (DGtN)	DG to NorthSpur	6.6	
Noyo River (GtDG)	Grove to DG	8.7	
Noyo River (MtCR)	Madsen Hole to Company Ranch	8.7	
Noyo River (NtRC)	NorthSpur to RC	7.6	
Olds Cr. (OC)	Mouth Up	4.1	
Parlin Cr. (PC)	Mouth Up	2.8	
Redwood Cr. (RC)	Mouth Up	5	
South Fork (SFbKC)	Mouth to KC	1	
South Fork (SFM)	NFSF to PC	3.6	
South Fork (SFU)	PC to Pond	4.1	
South Fork(SFL)	KC to NFSF	5.1	
Totals		119.6	

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. Coho salmon and steelhead redd variables and principle components used to develop a discriminat function to distinguish redds.

Variable	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6	Comp. 7	Comp. 8	Comp. 9
Pot Area (PA)	-0.41500	0.00681	-0.33944	0.00107	-0.13540	-0.53487	0.34043	0.07383	0.53550
Pot Substrate (PS)	0.17074	-0.19252	0.61008	-0.08561	-0.65871	-0.34024	0.03673	-0.05704	0.00022
Tail Spil Length (TL)	-0.28792	-0.15464	0.53836	-0.26044	0.53161	-0.12406	0.10308	0.47634	-0.00044
Tail Spill Width (TW)	-0.33521	0.49588	0.06433	0.19457	-0.40797	0.29422	-0.17572	0.56201	-0.00048
Tail Spill Area (TA)	-0.40616	0.27611	0.38263	-0.03828	0.09540	0.23845	-0.15420	-0.61990	0.37002
Redd Area (RA)	-0.49034	0.13911	-0.53131	-0.01776	-0.04898	-0.26138	0.16509	-0.25073	-0.75910
Location (km)	0.25520	0.54123	-0.04873	-0.34333	0.14138	-0.50844	-0.49296	0.01378	-0.00002
Fork Length (FK)	0.18225	0.21562	0.24167	0.83504	0.25914	-0.29389	0.10236	-0.02433	0.00011
Date (DT)	0.31563	0.50800	0.09277	-0.26464	0.01317	0.16166	0.73263	-0.02497	-0.00002

Table 4. Results of t-test comparisons of coho salmon (Onki) and steelhead (Onmy) redd physical factors. ^ Indicates variable not included in PCA analysis.

Variable	Species	n	Median	25%	75%	t-value	P-value
Pot Depth m (PD)	Onmy	237	0.1	0.08	0.15	44326	< 0.001
	Onki	183	0.14	0.1	0.17		
Pot Length m (PL)	Onmy	293	0.9	0.7	1.1	64049	< 0.001
	Onki	253	1.5	1.1	2.1		
Pot Width m (PW)	Onmy	293	0.8	0.6	1.2	67509	< 0.001
	Onki	253	1.4	1	2.1		
Pot Area m^2 (PA)	Onmy	293	0.56	0.38	0.95	63314	< 0.001
	Onki	253	1.77	0.85	3.46		
Pot Substrate (PS)^	Onmy	295	3	2	3	102524	0.008
	Onki	359	2	2	3		
Tail Spill Length m (TL)	Onmy	291	1.3	0.9	2	65918	< 0.001
	Onki	342	2.5	1.7	4		
Tail Spill Width m (TW)	Onmy	291	0.9	0.7	1.1	64585	< 0.001
	Onki	341	1.3	1	1.7		
Tail Spill Area m^2 (TA)	Onmy	291	0.56	0.32	1.1	63204	< 0.001
	Onki	340	1.7	0.95	3.1		
Tail Spill Substrate (TS)^	Onmy	392	2	2	3	92525	0.318
	Onki	357	2	2	3		
Redd Area m^2 (RA)	Onmy	295	1.23	0.69	2.09	62545	< 0.001
	Onki	315	3.51	1.72	6.97		
Location km (rkm)	Onmy	295	32.5	13.9	41.3	127967	< 0.001
	Onki	377	13.9	9.03	17.9		
Date days (DS)	Onmy	295	63	60	90	147493	< 0.001
	Onki	377	13	11	42		
Fork Length cm (FL)	Onmy	96	70	59	73	6787	0.048
	Onki	83	60	51	70		

Table 5. Stream name, segment name, beginning date, ending date, and number of steelhead spawning surveys conducted on the Noyo River, California during 2000-01. Letters in parentheses are stream segment abbreviations.

Stream Name	Section	Beginning Date	Ending Date	Number of Surveys
Bear Gulch (BG)	Mouth Up	01/17/2001	04/10/2001	2
Burbeck Cr. (BC)	Mouth Up	04/10/2001	04/10/2001	1
Duffy Gulch (DG)	Mouth Up	12/12/2001	04/02/2001	9
Hayshed Gulch (HG)	Mouth Up	12/14/2000	03/22/2001	10
Hayworth Cr. (HC)	Mouth Up	12/12/2001	03/22/2001	10
Kass Cr. (KC)	Mouth Up	12/08/2000	04/11/2001	10
Little North Fork (LNF)	Mouth Up	12/11/2000	04/03/2001	8
McMullen Cr. (MC)	Mouth Up	03/21/2001	03/21/2001	1
Middle Fork (MF)	Mouth Up	03/09/2001	04/09/2001	3
North Fork (NFL)	Below HC	12/12/2000	04/05/2001	11
North Fork (NFU)	Above HC	12/14/2000	03/12/2001	13
North Fork South Fork (NFSF)	Mouth Up	12/07/2000	03/28/2001	18
Noyo River (aRC)	RC to MC	12/11/2000	04/10/2001	11
Noyo River (CRtG)	Company Ranch to Grove	12/20/2000	04/03/2001	6
Noyo River (DGtN)	DG to NorthSpur	12/07/2000	03/14/2001	7
Noyo River (GtDG)	Grove to DG	12/20/2000	04/02/2001	6
Noyo River (MtCR)	Madsen Hole to Company Ranch	12/11/2000	03/22/2001	9
Noyo River (NtRC)	NorthSpur to RC	12/07/2000	04/05/2001	9
Olds Cr. (OC)	Mouth Up	02/08/2001	03/13/2001	2
Parlin Cr. (PC)	Mouth Up	12/07/2000	04/04/2001	7
Redwood Cr. (RC)	Mouth Up	12/06/2000	03/14/2001	6
South Fork (SFbKC)	Mouth to KC	12/08/2000	02/09/2001	11
South Fork (SFM)	NFSF to PC	12/07/2000	02/16/2001	9
South Fork (SFU)	PC to Pond	12/28/2000	04/02/2001	2
South Fork(SFL)	KC to NFSF	12/07/2000	03/29/2001	12

Table 6. Number of stelhead redds, redds/km, adults, and adults/km observed during spawning surveys on the Noyo River, California during 2000-01. Numbers in parentheses are 2.8% uncertainty.

Stream Name	Section	Number of Redds Observed		Number of O. m. Adults Observed				
		Total	Redds/km	Females	Males	Unknown	Total	Number/km
Bear Gulch (BG)	Mouth Up	1	1.00	0	0	0	0	0.00
		(0.03)	(0.03)					
Burbeck Cr. (BC)	Mouth Up	0	0.00	0	0	0	0	0.00
		-	-					
Duffy Gulch (DG)	Mouth Up	1	0.40	0	0	1	1	0.40
		(0.03)	(0.01)					
Hayshed Gulch (HG)	Mouth Up	1	0.83	1	1	0	2	1.67
		(0.03)	(0.02)					
Hayworth Cr. (HC)	Mouth Up	23	3.48	4	5	2	11	1.67
		(0.64)	(0.10)					
Kass Cr. (KC)	Mouth Up	17	3.04	1	0	1	1	0.18
		(0.48)	(0.09)					
Little North Fork (LNF)	Mouth Up	6	1.20	0	1	0	1	0.20
		(0.17)	(0.03)					
McMullen Cr. (MC)	Mouth Up	2	1.33	0	0	0	0	0.00
		(0.06)	(0.04)					
Middle Fork (MF)	Mouth Up	10	2.94	0	0	0	0	0.00
		(0.28)	(0.08)					
North Fork (NFL)	Below HC	20	3.23	3	3	5	11	1.77
		(0.56)	(0.09)					
North Fork (NFU)	Above HC	36	6.10	4	4	1	9	1.53
		(1.01)	(0.17)					
North Fork South Fork (NFSF)	Mouth Up	32	3.33	0	0	1	1	0.10
		(0.90)	(0.09)					
Noyo River (aRC)	RC to MC	9	1.48	1	1	2	4	0.66
		(0.25)	(0.04)					
Noyo River (CRtG)	Company Ranch to Grove	5	0.75	0	0	7	7	1.04
		(0.14)	(0.02)					
Noyo River (DGtN)	DG to NorthSpur	20	3.03	1	0	2	3	0.45
		(0.56)	(0.08)					
Noyo River (GtDG)	Grove to DG	13	1.49	2	1	1	4	0.46
		(0.36)	(0.04)					
Noyo River (MtCR)	Madsen Hole to Company Ranch	9	1.03	0	0	3	3	0.34
		(0.25)	(0.03)					
Noyo River (NtRC)	NorthSpur to RC	31	4.08	4	1	1	6	0.79
		(0.87)	(0.11)					
Olds Cr. (OC)	Mouth Up	4	0.98	0	0	0	0	0.00
		(0.11)	(0.03)					
Parlin Cr. (PC)	Mouth Up	0	0.00	0	0	0	0	0.00
		-	-					
Redwood Cr. (RC)	Mouth Up	3	0.60	0	0	0	0	0.00
		(0.08)	(0.02)					
South Fork (SFbKC)	Mouth to KC	9	9.00	0	1	1	2	2.00
		(0.25)	(0.25)					
South Fork (SFM)	NFSF to PC	31	8.61	0	1	2	2	0.56
		(0.87)	(0.24)					
South Fork (SFU)	PC to Pond	1	0.24	0	0	0	0	0.00
		(0.03)	(0.01)					
South Fork(SFL)	KC to NFSF	12	2.35	0	1	0	1	0.20
		(0.34)	(0.07)					
Total December to Arpil 2001		296	-	21	20	30	69	-
		(8.29)						

Table 7. Number of coho salmon redds, redds/km, adults, and adults/km observed and population estimates by redd area and AUC from spawning surveys in the Noyo River, California during 2000-01. Numbers in parentheses are 2.8% uncertainty.

Stream Name	Section	Number of O.k. Redds Observed		Number of O.k. Adults Observed		Estimated Number of O.k. Adults	
		Total	Redds/km	Total	Number/km	AUC	Redd Area
Bear Gulch (BG)	Mouth Up	0.0 -	0.0 -	0.0	0.0	0.0	0.0 -
Burbeck Cr. (BC)	Mouth Up	0.0 -	0.0 -	0.0	0.0	0.0	0.0 -
Duffy Gulch (DG)	Mouth Up	2.0 (0.06)	0.8 (0.02)	0.0	0.0	0.0	1.9 (0.05)
Hayshed Gulch (HG)	Mouth Up	3.0 (0.08)	2.5 (0.07)	1.0	0.8	0.4	5.1 (0.14)
Hayworth Cr. (HC)	Mouth Up	2.0 (0.06)	0.3 (0.01)	0.0	0.0	0.0	1.9 (0.05)
Kass Cr. (KC)	Mouth Up	5.0 (0.14)	0.9 (0.02)	1.0	0.2	1.1	11.4 (0.32)
Little North Fork (LNF)	Mouth Up	14.0 (0.39)	2.8 (0.08)	13.0	2.6	14.7	24.1 (0.67)
McMullen Cr. (MC)	Mouth Up	0.0 -	0.0 -	0.0	0.0	0.0	0.0 -
Middle Fork (MF)	Mouth Up	0.0 -	0.0 -	0.0	0.0	0.0	0.0 -
North Fork (NFL)	Below HC	2.0 (0.06)	0.3 (0.01)	0.0	0.0	0.0	3.2 (0.09)
North Fork (NFU)	Above HC	17.0 (0.48)	2.7 (0.08)	10.0	1.6	9.4	27.3 (0.76)
North Fork South Fork (NFSF)	Mouth Up	29.0 (0.81)	3.0 (0.08)	70.0	7.3	51.4	37.4 (1.05)
Noyo River (aRC)	RC to MC	3.0 (0.08)	0.5 (0.01)	0.0	0.0	0.0	3.2 (0.09)
Noyo River (CRtG)	Company Ranch to Grove	23.0 (0.64)	3.4 (0.10)	4.0	0.6	5.1	44.4 (1.24)
Noyo River (DGtN)	DG to NorthSpur	18.0 (0.50)	2.7 (0.08)	2.0	0.3	2.8	24.7 (0.69)
Noyo River (GtDG)	Grove to DG	24.0 (0.67)	2.8 (0.08)	7.0	0.8	7.0	37.4 (1.05)
Noyo River (MtCR)	Madsen Hole to Company Ranch	40.0 (1.12)	4.6 (0.13)	14.0	1.6	24.6	62.8 (1.76)
Noyo River (NtRC)	NorthSpur to RC	13.0 (0.36)	1.7 (0.05)	0.0	0.0	0.0	15.9 (0.44)
Olds Cr. (OC)	Mouth Up	0.0 -	0.0 -	0.0	0.0	0.0	0.0 -
Parlin Cr. (PC)	Mouth Up	17.0 (0.48)	6.1 (0.17)	5.0	1.8	5.7	30.5 (0.85)
Redwood Cr. (RC)	Mouth Up	0.0 -	0.0 -	0.0	0.0	0.0	0.0 -
South Fork (SFbKC)	Mouth to KC	74.0 (2.07)	74.0 (2.07)	417.0	417.0	262.5	83.1 (2.33)
South Fork (SFM)	NFSF to PC	47.0 (1.32)	13.1 (0.35)	35.0	9.7	59.3	81.2 (2.27)
South Fork (SFU)	PC to Pond	6.0 (0.17)	1.5 (0.04)	0.0	0.0	0.0	7.6 (0.21)
South Fork(SFL)	KC to NFSF	38.0 (1.06)	7.5 (0.21)	47.0	9.2	148.5	52.7 (1.47)
Total		377.0 (10.55)		626.0	453.6	592.6	555.8 (15.6)

Table 8. Steelhead population estimates by segment from spawning surveys in the Noyo River during 2000-01. Numbers in parentheses are 2.8% uncertainty.

Stream Name	Section	Estimated Number of O.m. Adults						
		One Redd Per Female	Two Redds Per Female	Estimated By Redd Area	Area Under the Curve Estimates			
					Female	Male	Unknown	Total
Bear Gulch (BG)	Mouth Up	2.0	1.0	0.5	0.0	0.0	0.0	0.0
		(0.05)	(0.03)	(0.01)	-	-	-	-
Burbeck Cr. (BC)	Mouth Up	0.0	0.0	0.0	0	0	0	0
		-	-	-	-	-	-	-
Duffy Gulch (DG)	Mouth Up	2.0	1.0	0.5	0.0	0.0	1.5	1.5
		(0.05)	(0.03)	(0.01)	-	-	(0.9-2.9)	(0.9-2.9)
Hayshed Gulch (HG)	Mouth Up	2.0	1.0	0.9	2.7	1.4	0.0	4.1
		(0.05)	(0.03)	(0.03)	(1.6-5.1)	(0.8-2.5)	-	(2.3-7.6)
Hayworth Cr. (HC)	Mouth Up	45.3	22.6	25.1	12.7	7.6	3.3	23.7
		(1.27)	(0.63)	(0.70)	(7.3-23.8)	(4.4-14.3)	91.9-6.2)	(13.6-44.2)
Kass Cr. (KC)	Mouth Up	33.5	16.7	13.3	2.4	0.0	1.5	3.9
		(0.94)	(0.47)	(0.37)	(1.4-4.4)	-	(0.9-2.9)	(2.2-7.3)
Little North Fork (LNF)	Mouth Up	11.8	5.9	5.9	0.0	2.6	0.0	2.6
		(0.33)	(0.17)	(0.17)	-	(1.5-4.9)	-	(1.5-4.9)
McMullen Cr. (MC)	Mouth Up	3.9	2.0	1.5	0.0	0.0	0.0	0.0
		(0.11)	(0.06)	(0.04)	-	-	-	-
Middle Fork (MF)	Mouth Up	19.7	9.9	7.9	0.0	0.0	0.0	0.0
		(0.55)	(0.28)	(0.22)	-	-	-	-
North Fork (NFL)	Below HC	39.4	19.7	17.2	16.4	7.2	14.9	38.5
		(1.10)	(0.55)	(0.48)	(9.4-30.6)	(4.1-13.4)	(8.6-27.9)	(22.1-71.9)
North Fork (NFU)	Above HC	70.9	35.5	31.5	14.2	7.1	2.5	23.7
		(1.99)	(0.99)	(0.88)	(8.1-26.5)	(4.1-13.2)	(1.4-4.6)	(13.6-44.4)
North Fork South Fork (NFSF)	Mouth Up	63.0	31.5	29.6	0.0	0.0	1.9	1.9
		(1.76)	(0.88)	(0.83)	-	-	(1.1-3.5)	(1.1-3.5)
Noyo River (aRC)	RC to MC	17.7	8.9	6.4	4.4	1.7	5.5	11.6
		(0.50)	(0.25)	(0.18)	(2.5-8.2)	(1.0-3.2)	(3.2-10.3)	(6.7-21.7)
Noyo River (CRtG)	Company Ranch to Grove	9.9	4.9	4.9	0.0	0.0	17.9	17.9
		(0.28)	(0.14)	(0.14)	-	-	(10.3-33.5)	(10.03-33.5)
Noyo River (DGtN)	DG to NorthSpur	39.4	19.7	20.7	2.6	0.0	8.1	10.7
		(1.10)	(0.55)	(0.58)	(1.5-4.8)	-	(4.6-15.1)	(6.1-19.9)
Noyo River (GtDG)	Grove to DG	25.6	12.8	14.8	3.6	2.9	4.8	11.2
		(0.72)	(0.36)	(0.41)	(2.0-6.7)	(1.7-5.4)	(2.7-8.9)	(6.4-21.0)
Noyo River (MtCR)	Madsen Hole to Company Ranch	17.7	8.9	5.4	0.0	0.0	9.1	9.1
		(0.50)	(0.25)	(0.15)	-	-	(5.2-17.1)	(5.2-17.1)
Noyo River (NtRC)	NorthSpur to RC	61.1	30.5	26.6	19.5	2.1	4.9	26.5
		(1.71)	(0.85)	(0.74)	(11.2-36.4)	(1.2-3.9)	(2.8-9.2)	(15.2-49.5)
Olds Cr. (OC)	Mouth Up	7.9	3.9	4.4	0.0	0.0	0.0	0.0
		(0.22)	(0.11)	(0.12)	-	-	-	-
Parlin Cr. (PC)	Mouth Up	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		-	-	-	-	-	-	-
Redwood Cr. (RC)	Mouth Up	5.9	3.0	3.0	0.0	0.0	0.0	0.0
		(0.16)	(0.08)	(0.08)	-	-	-	-
South Fork (SFbKC)	Mouth to KC	17.7	8.9	9.9	0.0	24.5	1.7	26.2
		(0.50)	(0.25)	(0.28)	-	(14.1-45.9)	(0.9-3.1)	(15.0-48.9)
South Fork (SFM)	NFSF to PC	61.1	30.5	18.8	0.0	1.5	3.2	4.7
		(1.71)	(0.85)	(0.53)	-	(0.9-2.9)	(1.8-5.9)	(2.7-8.8)
South Fork (SFU)	PC to Pond	2.0	1.0	0.5	0.0	0.0	0.0	0.0
		(0.05)	(0.03)	(0.01)	-	-	-	-
South Fork(SFL)	KC to NFSF	23.6	11.8	9.4	0.0	4.5	0.0	4.5
		(0.66)	(0.33)	(0.26)	-	(2.6-8.5)	-	(2.6-8.5)
Total		583.0	291.4	258.4	78.3	63.3	80.9	222.4
		(16.32)	(8.16)	(7.24)	(44.9-146.3)	(36.3-118.2)	(46.4-151.1)	(127.5-415.6)

Table 9. Average number of coho salmon (Onki) and steelhead (Onmy) by density class used to estimate populations for stratified index sampling. Numbers in parentheses are standard errors.

		Number per km		
Treatment	Species	Low	Medium	High
AUC	Onmy	0.54	1.52	4.43
		(0.31)	(0.34)	(1.80)
	Onki	0.51	2.43	102.7
		(1.2)	(0.48)	(5.86)
Redd Area	Onmy	0.79	2.66	3.9
		(0.13)	(0.19)	(0.46)
	Onki	1.47	5.28	12.26
		(0.73)	(1.21)	(6.82)

Table 10. Comparisons between extrapolated stratified reach estimates and AUC and redd area estimates of coho salmon (Onki) and steelhead (Onmy) populations by segment. Numbers in parentheses are standard errors.

		Average Population Estimate				
Species	Treatment	Median	25%	75%	Test Statistic	*p*-Value
Onmy	Extrapolated AUC	3.02	1.75	13.22	W = -111	0.139
	Estimated AUC	4.09	0	13.19		
	Extrapolated Redd Area	9.96	(2.13)	-	t = 0.26	0.79
	Estimated by Redd Area	10.18	(1.93)	-		
Onki	Extrapolated AUC	3.37	2.09	18.1	W = -142	0.044
	Estimated AUC	0.78	0	12.04		
	Extrapolated Redd Area	10.44	6.18	35.11	W = -58	0.415
	Estimated by Redd Area	13.46	1.9	37.43		

pendix A. Density categories by stream reach used in the stratified index sampling. Bold Indicates reaches used each species and estimation method. Onki is coho salmon Onmy is steelhead.

Stream Name	Section	Adult Desnity Categories			
		AUC		Redd Area	
		Onmy	Onki	Onmy	Onki
Bear Gulch (BG)	Mouth Up	Low	Low	Low	Low
Burbeck Cr. (BC)	Mouth Up	Low	Low	Low	Low
Duffy Gulch (DG)	Mouth Up	Low	Low	Low	Low
Hayshed Gulch (HG)	Mouth Up	Low	Low	Low	Medium
Hayworth Cr. (HC)	Mouth Up	**High**	**Low**	**High**	**Low**
Kass Cr. (KC)	Mouth Up	Low	Low	Medium	**Low**
Little North Fork (LNF)	Mouth Up	**Low**	**Medium**	**Low**	**Medium**
McMullen Cr. (MC)	Mouth Up	Low	Low	Low	Low
Middle Fork (MF)	Mouth Up	Low	Low	Medium	Low
North Fork (NFL)	Below HC	**High**	**Low**	**High**	**Medium**
North Fork (NFU)	Above HC	High	Low	**Medium**	Low
North Fork South Fork (NFSF)	Mouth Up	**Low**	**Medium**	Medium	Medium
Noyo River (aRC)	RC to MC	**Medium**	**Low**	**Medium**	Low
Noyo River (CRtG)	Company Ranch to Grove	High	Low	**Medium**	**Medium**
Noyo River (DGtNRS)	DG to NorthSpur	**Medium**	Low	Low	Low
Noyo River (GtDG)	Grove to DG	Medium	Low	**Low**	Medium
Noyo River (MtCR)	Madsen Hole to Company Ranch	**Medium**	**Medium**	Low	**High**
Noyo River (NtRC)	NorthSpur to RC	**High**	Low	High	**Low**
Olds Cr. (OC)	Mouth Up	Low	Low	Low	Low
Parlin Cr. (PC)	Mouth Up	Low	Low	Low	High
Redwood Cr. (RC)	Mouth Up	Low	Low	**Low**	Low
South Fork (SFbKC)	Mouth to KC	High	**High**	High	High
South Fork (SFM)	NFSF to PC	Medium	**High**	**High**	**High**
South Fork (SFU)	PC to Pond	Low	Low	Low	Low
South Fork(SFL)	KC to NFSF	**Low**	**High**	Medium	**High**