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COASTAL MENDOCINO COUNTY SALMONID LIFE CYCLE AND REGIONAL MONITORING: MONITORING STATUS AND TRENDS

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By

Sean P. Gallagher [1]
California Department of Fish and Game
Northern Region
Coastal Watershed Planning and Assessment Program
And
David W. Wright
Campbell Timberlands Management, LLC

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[1] Primary author to whom correspondence should be addressed. This report should be cited as: Gallagher, S. P. and D. W. Wright. 2009. Coastal Mendocino County salmonid life cycle and regional monitoring: monitoring status and trends. California State Department of Fish and Game, Coastal Watershed Planning and Assessment Program, 1487 Sandy Prairie Court, Suite A, Fortuna, CA 95540. 58 pp.

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ABSTRACT

This report documents the results of the first year of a multi-year regional salmonid monitoring program the first implemented part of the California's Coastal Salmonid Monitoring Program (CMP), funded by the Fisheries Restoration Grants Program. The scope of the work was to monitor salmonid (Chinook salmon, Coho salmon, and Steelhead) escapement in all coastal streams in Mendocino County to develop regional and watershed specific population estimates and continue life cycle monitoring in three streams. We used annual spawner: redd ratios from life cycle monitoring streams to calibrate regional redd counts and to ensure sufficient statistical power and adequate precision in the results. We sampled 41 reaches in a Generalized Random Tessellation Stratified (GRTS) design. The purpose of this study was to 1) continue salmon life cycle monitoring (adults in- smolts out) in three life cycle monitoring streams and provide spawner: redd ratios for calibrating regional redd surveys and, 2) conduct regional spawning ground surveys in all coastal Mendocino County streams to estimate escapement and assess sampling rate at this regional scale. Part of this effort included developing and field verifying the sampling frame and subsequently producing a GRTS sample draw for this area. This effort provided multi-species escapement data for six independent and eight potentially independent populations and two Diversity Strata within the CCCESU. During 2008-09 we developed a sampling frame for the Mendocino Coast Hydrologic Unit and made a GRTS ordered sample draw. We field verified and gained access to 41 reaches during summer 2008 and conducted spawning surveys in these reaches during winter 2008-09. We continued operation of three LCS's to monitor populations in Caspar Creek, and Pudding Creek and the South Fork Noyo River. Nine of the first 41 GRTS reaches (22%) were unavailable for sampling because landowners denied access. These reaches were replaced by the next nine on the sample draw list to fill out our required sample size of n = 41 (12% of the reaches in our sample frame). We estimated an average 1.72 coho salmon per redd and 0.32 steelhead per redd. We found no significant trend in coho salmon adult or smolt abundance over the last nine years. However, there were significant negative trends in coho salmon survival and productivity at our life cycle monitoring streams. We found that sampling 41 reaches encompassed the variation in redd density within coastal Mendocino County. Coho salmon redd density (ANOVA H = 11.32, df = 16, p = 0.79) and steelhead redd density was not significantly different among streams we surveyed in coastal Mendocino County (ANOVA H = 16.16, df = 16, p = 0.44) during 2008-09. We estimated 517 (95% CI 212-909) coho salmon redds and 887 (95%CI 415-1545) adult coho salmon and 1143 (95% CI 634-1749) steelhead redds and 442 adult steelhead (95% CI 245-674) in coastal Mendocino County during 2008-09. The precision in our estimates was > 30% and we attribute this to low escapement for the entire region relative to previous years.

INTRODUCTION

Recovery of salmon and steelhead listed under the Federal and California Endangered Species Acts (ESA and CEAS, respectively) primarily depends on increasing the abundance of adults returning to spawn in their freshwater natal habitats (McElhany et al. 2000, Good et al. 2005), and monitoring the trend in spawner escapement is the primary measure of recovery. In California watersheds north of Montery Bay, Chinook (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*) are listed species under the U. S. Endangered Species Act (Federal Register 1999, 2000, 2005). Additionally, coho salmon are also listed under the California Endangered Species Act (CDFG 2004). Delisting criteria will depend on whether important populations have reached abundance thresholds (Spence et al. 2008), one of the four key components of the Viable Salmonid Population concept developed by the National Marine Fisheries Service (McElhany et al. 2000). Both the Recovery Strategy for California Coho Salmon (CDFG 2004) and the Steelhead Restoration and Management Plan for California (McEwan and Jackson 1996) identify population monitoring as critical to assess the effects of recovery actions and to determine if recovery goals have been met.

In 2005, the California Department of Fish and Game (CDFG) and NOAA Fisheries completed an Action Plan for monitoring California's coastal salmonid populations (Boydstun and McDonald 2005). The Action Plan outlines a strategy to monitor salmonid populations status and trends at evolutionarily significant regional spatial scales, while still providing population level estimates. The monitoring plan follows a sampling scheme similar to the adult component of the Oregon Plan (Stevens 2002, Firman and Jacobs 2000), where data to evaluate adult population status at a regional level are collected in a spatially explicit rotating panel design (Overton and McDonald 1998). Crawford and Rumsey (2009) guidance for monitoring recovery of Pacific salmon and steelhead reccomend a robust unbiased spawner abundance sampling design using a spatially balanced probabilistic (e.g. GRTS) approach. Similarly, Boydstun and McDonald (2005) propose using a two-stage approach to estimate regional population status. Under this scheme, first stage sampling is comprised of extensive regional spawning surveys to estimate escapement based on redd counts, which are collected in stream reaches selected under a Generalized Random Tessellation Stratified (GRTS, Larsen et al. 2008) rotating panel design at a survey level of 10% of available habitat each year. Second stage sampling consists of producing escapement estimates in intensively monitored census streams through either total counts of returning adults or capture-recapture studies to estimate total abundance. The second stage estimates are considered to represent true adult escapement and are used to calibrate first stage estimates of regional adult abundance (Boydstun and McDonald 2005) by associating precise redd counts with true fish abundance (Adams et. al. In review).

The Action Plan, described above, was tested and further developed in a three year pilot study (2006-2008) (Gallagher et al. In press a-b, Gallagher and Wright 2008. This pilot study compared abundance estimates derived from a regional GRTS survey design to abundance measured using a more intensive stratified random monitoring approach, evaluated sample size and statistical power of the regional data for trend detection, and evaluated the quality of the stage two data for calibrating regional surveys. Gallagher et al. (In Press a) and Gallagher and Wright (2008) recommended that annual spawner: redd ratios from intensively monitored watersheds be used to calibrate redd counts for regional status and trend monitoring of California's coastal salmonid populations because they were reliable, economical, and less intrusive. Converted redd counts were statistically and operationally similar to live fish capture-recapture estimates, but required fewer resources than the other methods they evaluated. Gallagher et al. (In Press b) and Gallagher and Wright (2008) also found that redd counts and escapement estimates using annual spawner: redd ratios were reliable for regional monitoring using a 10% GRTS sample, and that increasing sample size above 15% did not significantly improve the estimates. Their evaluation of sample size suggested that a sample size of ≥ 41 reaches would have adequate precision and sufficient statistical power to detect regional trends in salmon populations. The pilot study recommended this low impact regional escapement monitoring approach of redd surveys calibrated by spawner: redd ratios be applied at actual regional spatial scales consistent with ESA recovery planning efforts.

The 10% annual GRTS sampling recommended by the Action Plan (Boydstun and McDonald 2005) was provided with little justification. The Mendocino Coast example GRTS sample draw at 10% in the Action Plan resulted in an annual sample of 203 reaches. Although this example sample frame overestimated the amount of available spawning habitat and needs further refinement, a sample draw of 10% of these reaches would likely result in costly over sampling of more reaches than necessary to encompass intra-reach variance (Dana McCain, Institute for River Ecosystems, Arcata, CA, Personal Communication). NOAA (2007) wrote that the issue of sampling intensity for a Coastal Monitoring Plan (CMP) has not yet been resolved. Clearly, the next step in the development and implementation of the CMP in California is to better define the annual regional sampling rate.

The purpose of this study was to 1) continue salmon life cycle monitoring (adults in-smolts out) in three streams (LCS) and provide spawner: redd ratios for calibrating regional redd surveys and, 2) conduct Regional Spawning Ground Surveys in the Mendocino Coast Hydrologic Unit (Figure 1) to estimate Chinook salmon, Coho salmon, and Steelhead escapement and assess sampling size at this regional scale. Part of this effort included development and field verification of the sampling frame and production of a GRTS sample draw for this area. This effort provided escapement data for six independent and eight potentially independent populations and two Diversity Strata within the CCCESU. During 2008-09 we developed a sampling frame for the Mendocino Coast Hydrologic Unit (Figure 1) and made a GRTS ordered sample draw (Table 1). We field verified and gained access to 41 reaches during summer 2008 and conducted spawning surveys in these reaches during winter 2008-09. We operated three LCS's to continue population monitoring on Caspar and Pudding creeks and the South Fork Noyo River.

MATERIALS AND METHODS

Study Area

Life Cycle Monitoring Streams

The three intensively monitored LCS (Figure 2) were selected for a variety of reasons. Pudding Creek has a weir and fish ladder where fish can be marked and released. This ladder was operated as an egg collecting station in the 1950's and 1960's providing historic data for comparison. There are nine consecutive years' adult escapement estimates (2001-2009) in Pudding Creek, and it has been operated as an LCS by Campbell Timberlands Management since 2004-05. The South Fork Noyo River has a long history of coho data relating to the Noyo ECS and known numbers of coho salmon can be marked and released above this structure. There are over ten years data on escapement, redd counts, and smolt abundance above the ECS (2000-2009). Caspar Creek was chosen because there are many years of adult escapement, juvenile rearing, and downstream trapping data available, it is a California Department of Forestry (CDF) experimental watershed, and has a history of monitoring and restoration activities. We constructed and installed a weir in Caspar Creek under Fisheries Restoration Grants Program (FRGP); (grants P0410527 and P0510544) to mark adult fish as they enter the stream. Caspar Creek and the South Fork Noyo River have been operated by CDFG staff as LCS since 2004-05.

Mendocino Coast Regional Sample Frame Development and GRTS Draw

We followed Boydstun and McDonald (2005) to define the sampling universe (e.g. all streams of interest in an area such as an ESU), to create a sample frame (e.g. the sampling universe broken into sampling units), and to produce a GRTS draw (e.g. the spatially balanced random sample). The sampling universe (Figure 3) was defined as all coho, steelhead, and Chinook spawning habitat in coastal Mendocino County (see discussion of species panels). Reaches known to be unavailable to spawning salmonids, such as above barriers and high gradient areas, were removed from a list of all streams in the study area, leaving the sampling universe. To create the sampling frame, all the streams in the sampling universe were divided into one to three kilometer reaches based on tributary junctions or known landmarks. All stream reaches in the sampling frame were numbered recursively from north to south and input into SDraw (MacDonald 2003) to produce the GRTS draw.

To define the sampling universe we started with an Arcview layer of the 1:24,00 (24k) routed hydrography containing the latitude-longitude (LLID) identifiers, stream and tributary names, and stream lengths obtained from Dana McCain (Institute for River Ecosystems, Arcata, CA, Personal Communication) (Figure 4). We then used the barriers layer in Cal-Fish and historical occurrence information in Spence et al. (2005) to delineate coho salmon distribution in the 24 k hydrography layer for all coastal Mendocino County streams from Usal Creek in the North to Schooner Gulch in the South. Only streams given a coho salmon presence certainty of ≤ 2.0 by Spence et al. (2005) were included. Next, we made paper maps of these streams and used the expert opinion of Scott Harris (California Department of Fish and Game), Matt Goldsworthy (Mendocino Redwood Company), Shaun Thompson (California Department of Fish and Game), and Dave Wright (Campbell Timberlands Management) to define the upper and lower limits of coho salmon spawning habitat including all tributaries in each stream (Figure 3). Experts were informed that it was better to exclude areas where spawning occurs and be wrong than to incorrectly include non-spawning areas. As a result of this process a few streams were removed. Whale Gulch and Jackass Creek were removed because they are very remote and have less than 0.2 km of actual spawning habitat. Mitchell and Doyle creeks were removed because the culverts on State Highway One have blocked access to spawning habitat. They are very small streams with < 1 km of spawning habitat, and they are inhabited by ephemeral populations (Bjorkstedt et al. 2005). Jug Handle and Little Juan creeks and Russian Gulch were removed because recent surveys of Jug Handle Creek indicated little to no spawning habitat, both streams are very small, and these streams only support ephemeral populations. Removal of these streams represents, at most, less than 1.6% of the entire length of identified coho spawning habitat in the study area. While it is conceivable that, for example, Russian Gulch has 6 IP-km of juvenile coho habitat it is very unlikely there is more that 1 km of spawning habitat. Thus the percent reduction in spawning habitat by removal of these streams from the sampling universe is closer to 0.20% of the entire area.

A number of streams with historical coho salmon presence (Spence et al. 2005) in which coho have not been observed during annual surveys conducted since 1994, were included in the sampling frame. These streams were identified by expert opinion as open to adult salmon spawning migration and lacking any clear reason why coho should not spawn in them. It was deemed possible that these streams could be recolonized as a result of recovery and should be included in the sample universe. These streams include Juan, Howard, Greenwood, and Alder Creeks which together comprise 2.8% of the entire defined sampling universe (Figure 3). Because steelhead and coho spawning habitat completely overlaps in coastal Mendocino County streams and because the streams listed above were included in the sample universe, the sample frame (Figure 4) was considered complete for both species. Although, steelhead spawn in a number of small coastal Mendocino County streams such as Virgin and Mill creeks and others listed as having historical coho salmon presence certainty of > 2.0 by Spence et al. (2005), we believe that excluding these streams will not affect the power of the process for monitoring steelhead status and trends. The excluded streams are small, have < 1.0 km of potential steelhead spawning habitat, were considered ephemeral populations (e.g. dependent populations) by Bjorkstedt et al. (2005), and comprise < 1% of all potential steelhead spawning habitat in coastal Mendocino County. Our exclusion of any stream does not imply any management prescription other than it was unnecessary for the purpose of this study and not needed for trend analysis. In addition recovery criteria probably will not include ephemeral population units.

Because Chinook salmon spawning habitat overlaps that of coho salmon and steelhead, we defined a subset of the streams delineated as coho and steelhead spawning habitat as Chinook salmon spawning habitat. These streams define the Chinook salmon sampling universe. Chinook salmon are known to spawn in the Ten Mile, Noyo, Big, Albion, Navarro, and Garcia rivers. The National Marine Fisheries Service identified portions of Wages Creek and the Ten Mile, Noyo, Big, Albion, and Garcia rivers as critical habitat for Chinook salmon (Figure 5). Portions of the main stem Navarro and its tributaries should also be included (Scott Harris, Personal Communication). We defined the Chinook salmon spawning universe as the NOAA critical habitat, excluding Wages Creek and including portions of the Navarro River.

We created a sample frame from the resulting three species universe (Figure 6) and used soft stratification of this master sample (Larsen et al. 2008) to associate each reach with one or more of these species (Table 1). The master sample was created by dividing all streams into one to three km segments (average 2.46 ± 0.05 S.E., range 0.10 to 4.20 km) based on tributary confluences or notable landmarks (Figure 6). This resulted in a list of 339 stream reaches. We then used the LLID tool in ArcMap to determine the LLID for the start of each reach, which is the input needed to produce the GRTS sample draw. Streams were numbered recursively north to south (Boydstun and McDonald 2005). To do this we numbered streams starting at the downstream end of spawning habitat working first up the main stem to the top, the next consecutive order number was applied to the first tributary encountered working upstream. Tributaries were numbered to the top and then the first tributary of the tributary was numbered upstream as for the main stem. This was repeated for all streams in a north to south manner. We separated the LLID number for each stream reach into its northing (latitude or x coordinate) and easting (longitude or y coordinate) and created an SDraw input file using the stream order number and the x coordinate. This file was run in SDraw following Boydstun and McDonald (2005) and McDonald (2003) with population structure set at 1 dimensional, coordinates and ID units selected, sample size and population size set to 339 so that all units were assigned a GRTS sample order, and Pixel size was left at one. The resulting GRTS sample output file was imported back into the original metadata file and sorted in ascending GRTS order (Table 1). We selected the first 41 reaches (Figure 7), with an over sample of the following 20 reaches to account for reaches that might be unavailable to sample. Landowners in each reach were identified, contacted, and entry permissions established.

Life Cycle Monitoring

Adult Abundance

To estimate escapement we marked and released fish with weekly time-specific individually numbered bi-colored floy tags (Szerlong and Rundio 2008). Recaptures were live fish observations made during spawning ground surveys. In order to evaluate tag loss, fish were also marked with weekly stream-specific operculum punches. Floy tags on carcasses were recovered and all carcasses inspected for operculum punches (and other marks) to estimate tag loss, residence time, and to calculate capture-recapture estimates from carcass data. Adult fish were captured, marked and released at the following locations: 1) a fish ladder and flashboard dam located 0.25 km from the Pacific Ocean on Pudding Creek, 2) an egg collecting station (ECS) on the South Fork Noyo River, and 3) a floating board resistance weir in Caspar Creek 4.9 km from the Pacific Ocean (Figure 2). Adult steelhead were also captured and marked in screw traps on Pudding Creek and the South Fork Noyo River and in fyke traps on Caspar Creek.

Spawning Ground Redd Survey Abundance Estimation

To estimate escapement we used redd count and measurement data collected during spawning surveys following methods established in previous studies by the primary author of this report (Gallagher and Knechtle 2003, Gallagher et al. 2007). Over and under-counting errors in redd counts (bias corrected) were reduced following Gallagher and Gallagher (2005). These efforts included a formal written protocol, training of field staff, pairing experienced and inexperienced observers, marking and reexamining marked redds, estimating observer efficiency for each reach, measuring redds, using predictive models to determine redd species, having a test category for ambiguous redds (these were removed from further analysis), and surveying biweekly. Surveys were conducted approximately fortnightly from early-December to late-April 2008-09 in all spawning habitat in each stream.

We calculated spawner: redd ratios by dividing capture-recapture abundance estimates for coho and steelhead by the bias corrected redd counts for all available data. These estimates were then used to convert redd counts into fish numbers in each stream.

Smolt Abundance

We used downstream migrant traps to estimate smolt abundance using capture-recapture methods in the LCS and Little River. Traps were placed in the streams in mid-March and checked daily until early-June 2009. One fyke trap was located about 5.0 km above the Pacific Ocean in the main stem of Caspar Creek. We deployed a screw trap about 50m below the ECS on the South Fork Noyo River. A fyke trap was fished in Little River about 2.5 km above the Pacific Ocean. Campbell Timberland Management operated a screw trap about 5 km upstream of the ocean in Pudding Creek. To further evaluate migration timing we installed two PIT tag antennae arrays about 0.5km from the ocean in Caspar Creek and one array on the Pudding Creek dam. In addition, Campbell devised and operated a smolt capture trap in the fish ladder during spring 2009.

In general, we followed the methods of Barrineau and Gallagher (2001), except we used PIT tags as the primary mark for fish > 70 mm. One year and older coho and steelhead (> 70 mm FL) were also marked with a maxillary clip to assess PIT tag loss. We measured and weighed all steelhead and coho > 50 mm (FL). Captured fish were marked with a site and week specific mark (pit tag or fin clip) and released upstream of the traps.

All other species captured were identified, counted, and released below the traps. We examined all steelhead and coho >50 mm for marks each day. Those without marks were marked and released at least 150 m above the traps. Recaptured fish were measured and released at least 150 m below the traps. Handled fish were anesthetized using Alka-Seltzer® except in Pudding Creek where MS 222 was used.

To estimate salmonid populations, capture probabilities, and timing for each trap all captures and recaptures were totaled by week and size/age class to create data matrices for input to DARR (Darroch Analysis with Rank Reduction), a software application for estimating abundance from stratified mark-recapture data (Bjorkstedt 2003). These matrices were run in DARR to produce population estimates and capture probabilities for both coho and steelhead. For coho and steelhead, we determined the following classes: < 70 mm (YOY), 71-120 mm (Y+), and > 120 mm (Y++). We developed these age/size classes based on Neillands (2003), Gallagher (2000), Shapovalov and Taft (1954), and through discussion with local biologists. Salmonids < 71 mm captured before fry were first observed in spring were assumed to be Y+. After which fork length frequencies were used to separate year classes.

Late-Summer Juvenile Abundance

We developed a 20 unit GRTS sample draw of 50m reaches in Pudding Creek for estimating summer rearing density following methods described above for regional sampling. Similarly we randomly selected ten 50 m units in Caspar Creek. Salmonid density was estimated in each reach using depletion electro-shocking. All salmonids > 60 mm fork length were given PIT tags and maxillary clips and all captured fish were examined for previously applied marks. We calculated the average and 95% CI density of salmonids by species in each stream and multiplied this by the total length of anadromy to estimate late-summer juvenile abundance.

Survival

We estimated coho smolt to adult survival for the three LCS streams over five years from smolt abundance data from 2000 to 2007 and adult return data from 2000 through 2008-09. Coho spawner/recruit (spawner/spawner) ratios for seven consecutive years were estimated using data from this study. Over winter survival was estimated for Caspar and Pudding Creeks using data collected during summer electro-fishing: summer stream-level population estimates were divided into smolt abundance estimates the following spring and the estimated number of summer PIT tagged fish captured in downstream traps was divided by the total number of PIT tags deployed in summer.

Trends in Coho Salmon Abundance

Trends in coho and steelhead abundance, productivity, and survival over ten years and eight complete coho life cycles were examined following McDonald (et al. 2007) using a trend detection package in R (www.r-project.org) developed for this purpose (Trent McDonald, Personal Communication). Coho salmon population trends and population viability were examined following methods described by Spence et al. (2008). Trends in redd counts and redd densities versus year were examined with t-tests.

Spawning Ground Spawning Survey Abundance Estimation

We conducted biweekly spawning ground surveys in 41 regional GRTS reaches from December 2008 to April 2009. Our methods for redd count and measurement data on spawning surveys followed Gallagher and Knechtle (2003) and Gallagher et al. (2007) as described above for LCS spawning ground surveys. We used the average annual coho salmon and steelhead spawner: redd ratios from our LCS to convert bias corrected redd counts into fish number for each reach. Because we did not capture and tag any Chinook salmon, we used an estimate of 1.01 redds per female (Murdoch et al. 2009) and an assumed 1:1 sex ratio to estimate Chinook salmon numbers for each reach. Reach abundance estimates were divided by reach length to estimate density. We followed Boydstun and McDonald (2005) to estimate regional abundance where the average density in our 41 reaches was multiplied by the total length of stream in our sample frame. The 95% confidence estimates were made using the Bootstrap with replacement and 1000 iterations (Trent McDonald Personal Communication).

Data Analysis

Mark-recapture escapement was estimated using the Schnabel method and confidence intervals were obtained from the Poisson distribution (Krebs 1989). To evaluate precision in our escapement estimates we evaluated confidence interval widths. Narrower 95% confidence intervals (and thus smaller SD) were deemed more precise and reliable than wider bounds. We compared species specific redd densities and reach level abundance with ANOVA or the Kruskal-Wallis ANOVA on ranks when Standard Kurtosis p-values were < 0.05. We evaluated sample size for our regional spawning ground surveys following Equation 1 and graphically with performance curves (Brower and Zar 1987). We examined redd spatial patterns using the Standardized Morisita Index (Krebs 1989). Finally, to further evaluate our regional estimates we compared our LCS redd census data to reach expanded population estimates using pair t-test treating streams as replicates. We accepted statistical significance at $p < 0.05$, although, endangered species management often accepts statistical significance at the $p < 0.10$ level (Good et al. 2005).

Equation 1

$$n \approx \frac{(100 t_{\alpha})^2}{r^2}\left(\frac{1}{\bar{x}} + \frac{1}{k}\right)$$

Where $\bar{x}$ is the mean value expected in data, *k* is the negative binomial exponent, r is the desired level of error- the width of the 95% confidence intervals relative to the point estimates as a percent (10%, 25%, 30%, and 50%), and t_α is the probability of not achieving desired level of error (from Krebs 1989).

RESULTS

Mendocino Coast Sample Frame Development and GRTS Draw

Nine of the first 41 GRTS reaches (22%) were unavailable for sampling because landowners denied us permission to enter. These reaches were replaced by the next nine in the list to fill out our required sample size of n = 41 or a 12% sample size. Sampling the 41 reaches selected for this study resulted in a 9.7% sample of all identified Chinook reaches (n = 11 of 113 Chinook reaches) for evaluating Chinook escapement sampling size and reach variances. The GRTS sample resulted in sampling reaches in all six independent populations in the two coho salmon diversity strata in the CCC ESU (Figure 8).

Life Cycle Monitoring

Adult Escapement

We tagged six coho salmon in Caspar Creek and only observed one tagged fish above the weir. Stream flows during 2008-09 were low and did not overtop the weir; therefore we assumed there were a total of six coho salmon in this stream (Table 2). We tagged and released 19 coho salmon above the Noyo River ECS and observed only three tagged fish during spawning ground surveys. Thus we assume a total 19 coho salmon were above the ECS. Four tagged male coho salmon were recaptured at the ECS suggesting they had dropped below the station sometime after being tagged and released and were roaming . Only three of the 19 fish tagged and released above the ECS were females. In Pudding Creek we estimated there were 50 coho salmon (95% CI 32-96). We only observed five coho salmon carcasses in Pudding Creek and two in the South Fork Noyo River. Therefore we were unable to use this information to estimate escapement.

We captured and tagged seven steelhead in Caspar Creek and only observed one tagged fish above the weir. Stream flows during 2008-09 were low and did not over top the weir, therefore we assume there were seven steelhead in this stream (Table 3). We tagged and released 14 steelhead above the Noyo River ECS and observed one tagged and two unmarked steelhead during spawning ground surveys. We recaptured one steelhead at the ECS. The steelhead escapement estimate above the ECS for 2008-09 (Table 3) is likely biased high because of low flows where fish moved into the ECS but dropped below the station rather than spawning upstream. In Pudding Creek we estimated there were 10 steelhead (95% CI 5-35).

All live coho salmon and steelhead recaptures had both their floy tags and operculum punches, thus this type of tag loss was 0%. Only one floy/ operculum punch marked coho salmon was recovered as a carcass and it only retained its operculum punch. Therefore floy tag loss on carcasses was 100% and operculum punch loss was 0%, based on this one observation. Of the eight coho salmon adults captured with PIT tags (1 in Caspar, 2 in SF Noyo, and 5 in Pudding Creek); only one did not have a maxillary clip. We did not capture any adult salmon with maxillary clips that did not have PIT tags. Thus PIT tag loss was 0% and maxillary clip loss was 12.5%.

All PIT tag recaptured coho salmon adults were originally marked as smolts in spring 2007. These fish were between 93 and 98 mm when captured and tagged as smolts between March and May 2007. Average smolt size in the Noyo River during 2007 was 96 mm (SE = 0.30mm) and in Caspar Creek it was 87 mm (SE = 0.32mm). These fish spent about 20 months in the ocean and returned at between 610mm and 670mm fork length.

We used our LCS redd census and mark-recapture data (Tables 2-3) to calculate average annual spawner: redd ratios for calibrating regional redd counts. We estimated an average 1.72 coho salmon per redd. Because of problems with our mark-recapture estimates for steelhead above the ECS, we did not use this data for calculating spawner: redd ratios for this species. Our estimate of 0.32 steelhead per redd, while accurate for converting redd counts into escapement, appears a bit low. This is likely due to problems capturing and tagging steelhead.

Smolt Abundance

Coho smolt abundance estimates were highest in Pudding Creek and lowest in Little River in spring 2009 (Table 4). We marked 406 coho salmon and 296 steelhead with PIT tags in Caspar Creek and estimated smolt production of 2045 (310 = SD) coho salmon and 1885 (SD = 312) steelhead during spring 2009 (Tables 4 and 5). In Pudding Creek we marked 2916 coho salmon and 591 steelhead with PIT tags and estimated 16309 (SD = 971) coho smolts and 3291 (SD = 511) steelhead smolts. Our smolt estimates for the South Fork Noyo River were 4070 (SD = 231) steelhead and 313 (SD = 13) coho salmon. At a trap installed at the Pudding Creek Dam we PIT tagged 726 coho salmon and only 3 steelhead. We estimated 1860 coho salmon and 8 steelhead passed this trap during spring 2009. There were long periods of time during spring that we weren't able to operate this trap due to flows.

In all three streams where PIT tags were used we captured a number of coho salmon in the traps during spring 2009 that were tagged and classified as year old fish during downstream trapping the year before. The average percentage of total captured fish displaying this two-year stream residency pattern was 0.67% (range 0.30% to 1.50%) 2006 to 2007, 1.00% (range 0.08% to 2.00%) in 2007 to 2008, and 1.96 (range 0.73% to 3.90%) during 2008 to 2009. These estimates differ from our detections of fish at downstream PIT tag antenna placed in Caspar and Pudding creeks during spring 2009 (Tables 6-7). In Caspar Creek 19% (± ~2%) and in Pudding Creek 8% of coho salmon marked during 2008 were detected at the arrays in 2009. The percentage of 2008 marked coho salmon detected in 2009 at the Pudding Creek dam was 0.4%. This number is low because the dam downstream trap was not consistently fished. Steelhead detections of fish marked by year are shown in Tables (6-7) and are lower than those of coho salmon.

Smaller fish took more time to travel to the ocean, presumably because there is a minimum size for ocean entry (>80mm). It addition it appears that coho salmon captured in our downstream traps later in the spring are more likely to rear a second year (Table 6). Coho salmon marked during 2009 at our upstream traps took on average less than 10 days for fish classified as Y++ (> 120 mm) and about 20 days for Y+ (70-119mm) to travel to the ocean in Caspar Creek (Table 8). More than 50% of the coho salmon marked in 2008 and detected at the array in Caspar Creek in 2009 were first marked at our trap in May 2008 (Table 8). In Pudding Creek fish marked at the upstream trap were smaller (average = 88mm) than fish captured at the dam (average = 102mm).

Late-Summer Juvenile Abundance

We PIT tagged 439 coho salmon in Pudding Creek and 7 coho salmon in Caspar Creek during fall 2008 electrofishing operations. The average coho salmon density in Caspar Creek was 0.08 fish per meter, but the data was insufficient to estimate abundance of coho in this stream during fall 2008. The average coho salmon density in Pudding Creek was 1.29 fish/ meter and we estimated there were 11,390 ± 273 coho in this stream during fall 2008.

In fall 2008 we PIT tagged 7 coho salmon in Caspar during electro-fishing operations. One of the seven coho salmon marked during summer electro-fishing in Caspar Creek was recaptured in the fyke trap in spring 2009, as a 2 years old (Table 5). Thus 14% of these fish showed a two-year freshwater rearing life history. During spring out-migrant trapping in Pudding Creek we captured 18 of the fish marked during fall 2008 electro-fishing in Pudding Creek.

Survival

Coho smolt to adult survival was similar among streams over seven years and ranged from 0.002 to 0.17 (Table 9). Treating years as replicates smolt to adult survival was not significantly different among streams (ANOVA $H = 0.55$, $df = 2$, $p = 0.76$). Treating streams as replicates smolt to adult survival was significantly different over eight years (ANOVA $H = 18.31$, $df = 7$, $p = 0.01$). Examined individually there was no difference among years (Dunn's $q < 2.65$, $p > 0.05$). However, it was lower this year than it has been over the past seven years.

Based on our downstream trapping and adult mark-recapture population estimates the 2007 smolt to 2008-09 adult survival was < 1% at all three LCS (Table 9). In the South Fork Noyo River the smolt to adult survival thus estimated was 0.005 (0.50%). Based on the number of PIT tagged fish released and subsequently recaptured as adults, smolt to adult survival in the South Fork Noyo River was 0.0018 (0.18%). At the South Fork Noyo during spring 2007 a total of 1137 smolts were given a right maxillary clip (independent of the PIT tagging and left maxillary marking), two adults with this mark were observed in 2009. This gave a smolt to adult survival estimate of 0.0017 (0.17%). Smolt to adult survival has been low over the past three years and was the lowest on record during 2009 (Figure 9). Smolt to adult survival in Pudding Creek from smolts PIT tagged in 2007 to adult returns in 2008-09 was 0.10%.

Coho salmon recruits per spawner ratios were less than 1.00 for the 2002-03 to 2005-06, 2003-04 to 2006-07, the 2004-05 to 2007-08, and the 2005-06 to 2008-09 cohorts (Table 9). Treating years as replicates, recruits per spawner estimates were not significantly different among streams (ANOVA $F = 0.42$, $df = 24$, $p = 0.74$). The power of this test was low ($ß = 0.05$). When streams were treated as replicates, recruits per spawner estimates were significantly different over seven years (ANOVA $H = 19.95$, $df = 6$, $p = 0.003$). Examined by year recruits per spawner were only significantly different between 2001-04 and 2006-09 (Dunn's $q = 3.05$, $p < 0.05$). There were no other significant differences in recruits per spawner for the other years data (Tukey's $q < 3.00$, $p > 0.05$).

Trends in Coho Salmon Abundance, Productivity, and Survival

Coho salmon and steelhead redd densities did not exhibit significant trends between 2000 and 2009 ($r > 0.40$, $p > 0.06$, $n > 144$, Figure 10). There was no significant regional trend in coho salmon escapement over the last 10 years (Figure 11). When examined by year class, only the 2001 cohort showed a significant negative trend in escapement over three generations (Figure 11a-c). If we lower the acceptance probability to $p < 0.10$ then all three cohorts exhibited significant negative escapement trends (Figure 11a-c). When evaluated by spawners per intrinsic potential-km (Bjorkstedt et al. 2005) and using the geometric mean approach of Spence et al. (2008) there were no significant trends in coho salmon abundance in any of the study streams over eight years (Tables 10-11). Based on risk categories in Spence et al. (2008) extinction risks of these populations were moderate to low (Tables 10-11). There were no significant regional trends in coho salmon smolt abundance over the past ten years (Figure 12). Similarly, there were no significant trends in coho salmon smolt abundance for three cohorts over three to four generations (Figure 12).

Coho salmon productivity (recruits per spawner) showed a significant negative trend over the past 7 years (Figure 13). Examined by year class all three cohorts showed significant negative production trends (Figure 13 a-c). Similarly, coho salmon smolt to adult survival showed a significant negative trend over the past eight years (Figure 9). Only one of three cohorts showed a significant negative trend in smolt to adult survival over three generations (Figure 9). If we lower our acceptance probability to $p < 0.10$ then two of the three cohorts exhibited significant negative trends (Figure 9a-b). There were no statistically significant trends the number of smolts produced per adult (smolts per adult) over the last ten years (Figure 14).

Spawning Ground Spawning Survey Abundance Estimation

Sampling 41 reaches encompassed the variation in redd density within coastal Mendocino County. Coho salmon redd density was not significantly different among the streams we surveyed (ANOVA H = 11.32, df = 16, p = 0.79) during 2008-09 (Figure 15A). Steelhead redd density was not significantly different among streams we surveyed in coastal Mendocino County (ANOVA H = 16.16, df = 16, p = 0.44) during 2008-09 (Figure 15B). Chinook salmon redd density was not significantly different among streams in our study area (ANOVA f = 0.15, df = 5, p = 0.72) (Figure 15C).

Because redd density was not different among streams, indicating we captured landscape variation in this metric, we were able to use the average of all reaches to estimate total redd counts and escapement for the region and for individual populations within the region. We estimated 517 (95% CI 212-909) coho salmon redds and 887 (95%CI 415-1545) adult coho salmon in coastal Mendocino County during 2008-09 (Figure 16a, Table 2). Coho salmon confidence limit widths were 64% with n = 41 and decreased to 45% when we included reaches from the LCS's (n =77). Decomposing the data to estimate escapement for the two diversity strata and for individual streams increased the confidence limit widths due to smaller sample sizes (Table 2). Individual stream estimated confidence limit widths ranged from 76% to 145% for coho salmon, 69% to 150% for steelhead, and 107% to 150% for Chinook salmon. There were a number of streams where we did not observe any coho salmon redds and thus did not estimate escapement for these streams. Similarly, we estimated steelhead redds and adult escapement for the Mendocino coast region (Table 3). With a sample size of n = 37 reaches the confidence limit widths were 49%, including all reaches (n=77) surveyed during 2008-09 the confidence limit widths narrowed to 30% (Figure 16b). As the data were decomposed to individual stream estimates the confidence limit widths increased. We estimated 53 (95%CI 13-126) Chinook salmon redds and 133 (95% CI 33-315) adult Chinook salmon in this region during 2008-09 (Table 12). Due to the small sample size and the low number of redds observed, the confidence limit widths were wide. We did not observe any Chinook salmon redds in survey reaches in the Central Coast diversity strata and did not estimate escapement for this species in this area.

We evaluated the use of the regional average redd density from our GRTS sampling to determine if we could use it to estimate redd abundance for streams we did not survey within the region. We assumed if the regional average density multiplied by survey length gave an estimate that was not different from our census redd counts at the LCS we might use the average density to estimate abundance for streams we did not survey. Coho salmon census redd counts were not significantly different than estimates made by multiplying regional redd density by stream length ($t = 0.59$, $df = 2$, $p = 0.06$, $\alpha = 0.06$, Figure 17a). Similarly, steelhead census redd counts and estimates made by multiplying regional redd density by stream length were not significantly different ($t = -0.22$, $df = 2$, $p = 0.84$, $\alpha = 0.06$, Figure 17b).

Although redd density was not significantly different among streams, Chinook and coho salmon and steelhead redds were distributed in a clumped spatial pattern (Standardized Morasita Index = 0.12, 0.51, and 0.52, respectively). We found Chinook salmon redds in 33% of the reaches surveyed for this species and did not observe dead or alive Chinook salmon in any reaches during 2008-09. We observed coho salmon redds in 49% and adult coho in 19.5% of the survey reaches. We observed steelhead redds in 61% and adult steelhead in 24% of the survey reaches.

The confidence limit widths for our regional sampling were greater than 30% (Tables 2-3, 12). Using data collected for this region during 2008-09, it appears to attain confidence limits with 30% precision and 90% certainty we need to sample 103 coho salmon reaches, 241 Chinook salmon reaches, and 117 steelhead reaches (Table 13). This level of sampling would require sampling more than a third of the entire region for coho salmon and steelhead and would necessitate sampling double the total amount of Chinook habitat in the entire region. However, variation around the mean coho salmon redd density did not substantially decrease after 58 reaches (Figure 18a). The coefficient of variation in mean coho salmon redd density was 1.87 at $n = 41$ and did not improve with continued sampling ($cv = 2.02$ at $n = 77$). For steelhead the variation about mean redd density did not substantially decrease after 38 reaches (Figure 18b) and coefficient of variation was 1.48 at $n = 37$ and did not improve with continued sampling ($cv = 1.43$ at $n = 77$). Examination of decrease in variation about the mean Chinook salmon suggests sampling more than nine reaches will not improve the precision of the estimates (Figure 18c). However, the sample size was small.

DISCUSSION

Mendocino Coast Regional Sample Frame Development and GRTS Draw

Frame Refinement and Species Panels

The Action Plan (Boydstun and McDonald 2005, Page 50) states that frame refinement will include frame refinement (redundant?), species estimates and stratifications, and examining sample methods, variances, and statistical power. It seems by refinement the authors meant to take the list of all fourth order streams (page 44) and remove those that fish don't inhabit. The document states that refinement may reduce the sample frame by 30-40%. Our refinement reduced a list of 2033 stream reaches to 339 which is an 83% reduction. The sample frame we produced is for Chinook, steelhead, and coho, with species designation for each reach (e.g. soft stratification, Larsen et al. 2008). This is the same approach Gallagher and Wright (2008) used for assigning species use to reaches in their five stream pilot study. Soft stratification is simpler and cheaper than having one sample frame for each species because each reach covers multiple species and thus reduces logistics and field time. We identified all coho streams for this area using historical and current records (Spence et al. 2005) and local experts. We believe there is complete overlap in spawning areas for coho and steelhead. Therefore, by including all historic coho streams (those that we found suitable for coho but their presence has not been documented in the past 15 years) we also have a complete steelhead frame. Including all steelhead spawning streams in this area for a steelhead only frame might add approximately five to eight small coastal streams (possibly 10 reaches) but would not have add any more tributaries or additional reaches to our coho/steelhead frame. Excluding these few small streams should have no effect on our ability to monitor steelhead population status and trends. The Chinook reaches are simply a subset of the coho/steelhead streams we know Chinook presently inhabit. The Action Plan states that the second area of frame refinement is species based estimates and that the initial samples should be drawn from one Chinook, coho, and steelhead frame. In addition, if estimates are judged unstable or unrepresentative then the frame will have to be stratified into single species stratum, which will potentially add considerable cost. Evaluation of the data collected for this sample frame will determine if a three species frame with soft stratification is sufficient (see further discussion of this initial analysis below).

The Action Plan suggests a 3, 12, 30 year revisit design with rotations based on resident salmonid life cycles. In 2007, based on advise from Trent McDonald, we used a simple three year rotation where 33% of the 10% GRTS draw (the first 3 of 8, increased 9 for evenness, of 76) were sampled every year, and the next 6 GRTS samples were sampled in year 1 (GRTS reaches 4-9), the next 6 were sampled year 2 (reaches 10-15), the next 6 (13-21) sampled year 3 (Gallagher and Wright 2007). The Action Plan states that 40% of the GRTS sample reaches should be assigned as annual samples. For this study 40% (16) of the 41 reaches we sampled in 2008-09 will be sampled every year, and the rest of the 339 will be sampled following our 2008-09 study (Gallagher and Wright, 2008). However it is possible that the temporal panels (rotating panel design) are unnecessary. Spence et al. (2008) recommend using the geometric mean as a running average for trend detection because it can use annual escapement numbers without assigning fish to age cohorts. Thus we don't need to account for different life histories in the temporal sampling frame scheme (it’s dealt with at the analysis side). If we sample 40% of the GRTS draw every year as proposed in the Action Plan, and we move through the list for the other 60% each year as year’s progress, we would sample all the reaches in nine years.

Sample Frame Development for Other Areas

A document presenting the historical occurrence of coho salmon in the Northern California/Southern Oregon ESU similar to Spence et al. (2005) has not been produced. Consequently, a different method is needed to define spawning habitat in this ESU. The IP-km produced by NOAA Fisheries (Agrawal et al. 2005, Bjorkstedt et al. 2005) was made to provide an index of potential historic habitat carrying capacity for juvenile salmonids and thus is not a refined tool for determining spawning habitat in streams where we lack empirical information (Agrawal et al. 2005). It should be noted that the IP-km data and information in Spence et al. (2005) was very useful as a starting point for frame development in coastal Mendocino County. Ricker (Personal Communication) used the output of the work of Agrawal et al. (2005): the 10 DEM measures of slope, valley constraint, and discharge, to develop a predictive model or set of criteria curves to adapt the IP-km data to help define spawning habitat for areas where data are lacking. This approach should be tested with data from another area and once validated used to help develop a coast wide master sample (Larsen et al. 2008).

Life Cycle Monitoring

Adult Abundance

Precision in our adult mark-recapture escapement estimate for coho salmon in two of three streams was ± 0%, because flows never overtopped the traps. Thus the coho salmon counts in Caspar Creek and the South Fork Noyo River were censuses this year. In Pudding Creek our precision was above the 30% recommended by Jacobs and Nickelson (1998) for monitoring coho salmon. This is likely the result of too few observations of marked fish. We only observed a total of 10 (7 marked and 3 unmarked) coho salmon in the creek during spawning ground surveys this year. Coho escapement to our LCS's during 2008-09 was the lowest we have observed over ten years (Figure 19). Compared to previous years where we tagged over 100 fish at Pudding Creek; we only tagged 41 coho salmon this year. This also influenced the precision of our estimates. In addition, an unknown number of fish got through the fish ladder early in the season because extremely high tides and flooded lagoon allowed fish to bypass the trap. This was discovered and corrected within the first week of trap operation.

Except for Caspar Creek, where we believe that only marked steelhead were above our weir, our mark-recapture escapement estimates were very imprecise. Jacobs et al. (2001) defined ± 30% as target precision levels for steelhead redd count estimates in Oregon. Gallagher et al. (In Press b) state that for steelhead, managers may have to except lower precision in steelhead estimates or use redd areas. We attributed this to difficulties capturing and observing steelhead. Over the past six years precision in our steelhead escapement estimates has ranged from 40% to 221%, we have never seen precision ≤ 30%.

Krebs (1989) states that population estimates for management should be accurate to ± 25% and preliminary surveys should be ± 50%. Jacobs and Nickelson (1998) suggest that ± 30% should be the target precision level for monitoring coho salmon. Jacobs et al. (2001) also defined ± 30% as target precision levels for steelhead redd count estimates in Oregon. Over four years the precision in the live coho capture-recapture estimates for Pudding Creek was < 30% and in two of these years it was ≤ 25%. Jacobs and Nickelson

(1998) had basin level precision in escapement estimates between 80% and 99%. Korman et al. (2002) suggest that precision in tagging studies can be improved by selecting survey dates with the best possible survey conditions and by increasing the number of tags present (i.e. marking more fish). Despite our continued efforts, steelhead prove difficult to capture, tag, and re-observe. For this species, managers may have to accept larger uncertainties in escapement estimates. This may be the case for both species in some years.

Smolt Abundance

Low flows in late-spring 2009 required the use of a motor on both the Pudding Creek and South Fork Noyo River Screw traps. PIT tags allowed us to mark individual fish and collect fish specific data during multiple recaptures. We found only a small proportion of fish were captured multiple times or showed delayed migration (Appendix 1). Because the PIT tags provide unique individual marks, we were able to account for multiple recaptures when developing input matrices for Darr and thus reduced this potential source of error. In 2010-11, pit tagged smolts returning as adults should provide useful information on ocean survival.

Bell and Duffy (2007) document a two-year freshwater life history of coho salmon for the first time in California. Bell (2001) states that 28% of coho captured during the second year of his study were age two. We documented two-year old coho salmon smolts in coastal Mendocino County, California by using PIT tags to mark fish during spring downstream trapping and fall electro-fishing - beginning in 2006. We have observed this life history each year since we initiated PIT tag operations. In spring 2009 we deployed PIT tag antennae arrays in Caspar and Pudding creeks. Our estimates of two-year-old coho salmon smolts from these arrays during 2009 are slightly less than observed by Bell (2001). Our array estimated proportion of two-rear-old coho salmon was considerably higher than the proportion of this aged fish captured in our downstream migrant traps. This difference is likely a result of fish rearing below the traps sites during their second year. Our 2006 over-summer data for Pudding Creek 2006 to smolts 2007 suggested that about 20% of the year old coho tagged in spring 2006 remained in Pudding Creek an additional year (Gallagher and Wright 2007). The proportion of coho showing the two year rearing life history was less (15%) from fall 2008 to spring 2009. According to ODFW (1996) coho smolts remain in streams for two or three years in British Columbia, the coldest part of their range. Water temperatures in these creeks are similar to those of the other coastal California streams where this life history has not been observed. It appears there is a threshold size of > 88mm necessary for coho migration to the ocean. Fish that fail to meet this size by the end of spring hold over a second year. At the time of migration to the ocean in their second spring these fish are generally larger than this minimum size. In fact most two year rearing coho salmon are much larger than the one year-old fish. This suggests fish marked later in the spring are likely to hold a second year, probably because they had yet reached a sufficient size for migrating to the ocean.

Survival

Coho smolt to adult survival over seven smolt-to-adult return cycles was similar to that reported by Bradford (1999), Logerwell et al. (2003), and Shapovolov and Taft (1954) between 2002 and 2005, but has been considerably lower since 2006 (Figure 9). Coho adult-to-adult survival was much lower in 2008-09 than the average value of 0.13 reported by Shapovalov and Taft (1954). Both smolt to adult and recruits per spawner were significantly lower over the last three years compared to the previous three (Table 9). Coho smolt to adult (and adult-to-adult) survival is influenced by ocean conditions at the time of ocean entry. These conditions were generally favorable from 1999 to 2004 (Kudela et al. 2006). Ocean productivity was poor during the time of salmonid ocean entry in 2007 (www.nwfsc.noaa.gov/research/divisions/fed/oeip/g-forecast.cfm) and adult-to-adult and smolt to adult survival during this period were likely negatively influenced by these conditions.

Our estimates of coho salmon smolt to adult survival from PIT tag numbers and our independent max clip only study on the South Fork Noyo were essentially the same (0.18% versus 0.17%). This suggests that PIT tags were not lost nor did they influence survival differently than clipping the maxillary bone only. This is contrary to Knudsen et al. (2009) where Yakima River hatchery Chinook salmon had 18% pit tag loss and significantly lower smolt-to-adult survival than fish marked with coded wire tags. We speculate this is due to species, location, size of marked fish (>70 mm), life history, and procedural differences.

Trends in Coho Salmon Abundance, Productivity, and Survival

We did not find significant trends in coho escapement over nine years in four streams. This may be a result of the length of the time series or due to the three-year coho salmon life cycle. However, all populations showed moderate extinction risk and population sizes < 500 (Tables 10-11). When we examined escapement trends by cohort one of three cohorts showed a significant negative trend. If we increase the p-value for accepting statistical significance to $p \leq 0.10$, all three cohorts showed significant negative trends in escapement over the last nine years. However, there were no trends when the data was examined using the harmonic mean and the geometric mean approaches of Spence et al. (2008). Both of these approaches are designed to incorporate the three-year life history of coho salmon. Thus the difference between the regional model results by cohort and methods suggested by Spence et al. (2008) may be a result of small sample size in the former. Trend detection may be more appropriate over a longer time series (Spence et al. 2008), with additional covariates such as mean December to January stream flow, an index of the Pacific decadal oscillation or ocean survival, annual precipitation, March to June stream flow two years previous, and perhaps other values. Larsen et al. (2004) found that trend detection increased markedly with increased time series and Shea and Mangel (2001) state that statistical uncertainty in trend detection for modeled coho populations increased with shorter time series. There is increasing evidence that Pacific salmonid populations follow a decadal cycle in abundance that is related to large-scale climate cycles (Smith and Ward 2000, Smith et al. 2000). If salmonid population abundance fluctuates on decadal or longer periods, this nine-year dataset could be too short to detect these long-term trends. However, Bradford et al. (2000) suggest their results, and others they cite, argue against the idea that regional climate variation affect coho freshwater survival. When we examined coho salmon trends by cohort we found that the 2000-01 adults showed a significant negative trend whereas their smolt progeny did not, furthering the notion that poor ocean conditions was the cause. Furthermore, productivity in terms of recruits per spawner showed significant negative trends whereas smolts per adult, which can be viewed as freshwater survival, did not, suggesting ocean rather than freshwater conditions may be responsible. These data may also prove useful for population viability analyses (Legault 2005) such as done by Chilcote (2001) for steelhead in Oregon.

We did not examine steelhead trends due to the short time series in the data (only eight years). Steelhead can live up to seven years and spawn as many as four times (Shapovolov and Taft 1954). Thus we only have data for one generation. Continued monitoring of these streams is necessary to provide this type of data as well as information needed for population viability assessments as recommended by Spence et al. (2008).

Abundance Estimation derived from Spawning Ground Spawning Surveys

We produced escapement estimates for Chinook salmon, coho salmon, and steelhead for the entire coast of Mendocino county consisting of two diversity strata within the CCC Coho salmon ESU, five dependent populations, and seven potentially independent populations. While the precision of these estimates (95% confidence half widths) was lower than expected, this is the first time anyone has produced estimates with statistical certainty on how many salmon returned to spawn in this large geographic area. We believe, given the variance in redd density we observed, if we are confident in our regional estimates (i.e. the entire Mendocino coast) we can have confidence in individual population estimates despite the large confidence widths. Our evaluation of sample size and effort generally supports findings of other researchers, and also supports the contention that monitoring at greater than a 15% GRTS does not provide any substantial improvement in either the ability to detect differences in abundance estimates (true positive rate) or the ability to identify estimates as the same (true negative rate).

In our earlier studies we suggested (Gallagher et al. In Press b, Gallagher and Wright 2008) if redd density variation in their pilot study area was representative of coastal California as a whole, a sample size > 41 reaches for coho salmon and > 37 reaches for steelhead should have confidence interval widths of 30%. In addition we found that sampling >25 reaches should have sufficient statistical power for monitoring escapement trends. Our present application of these sample sizes to the entire area of coastal Mendocino County resulted in escapement estimates with larger confidence widths than we expected. When we included all reaches surveyed during 2008-09, a systematic rather than design based GRTS sample, precision in our estimates improved for coho salmon (45% versus 64%) and steelhead (30% versus 49%). However, the coefficient of variation did not improve with increased sample size for both species and variation about the mean (Figure 18) did not substantially decrease after 55 reaches (~15%) for coho salmon and 37 reaches (11%) for steelhead. We attribute this in large part to low abundance. Redd density (an index of abundance) in five intensively monitored streams was the lowest observed since 2000 (Figure 10) and was outside the range of data we used earlier (Gallagher et al. In Press b) to develop sample size estimates. Other observers (Courbios et al. 2008) found that a larger sampling fraction and higher redd abundance resulted in better accuracy for GRTS sampling Chinook salmon redds in Washington. At low redd abundance none of their sampling designs were accurate. In a GRTS sampling design for bull trout in the Columbia Basin, Jacobs et al. (2009) used a sample size on average of 38% with a target sample size of 50 sites per basin. They found that accuracy ranged from 15% to 35% and was dependent on redd distributions within basins and that there was no reduction in accuracy with sample sizes between 10 and 50 sites. Our results are similar in that increased sample size appears to only marginally improve the precision of our estimates.

Crawford and Rumsey (2009) suggest that salmon monitoring programs strive for estimates that have a coefficient of variation (CV) of ± 15% as a measure of accuracy. Our CV's were 148% to 202% and increased sample size did not improve them. The accuracy of our LCS escapement estimates was also lower than we expected and this was due to low abundance. It appears that in some years it will not be possible to produce escapement estimates with high precision. Ocean conditions at time of out-migration for the 2010-11 adult returns were very good and returns are predicted to be above average. We recommend increasing the sampling fraction to 15%. However, given the cost to survey one reach for a season ($3,000/ reach, Gallagher et al. In Press b) and the fact that increasing our sampling fraction to 30% would result in sampling 112 reaches ($336,000/year), which appears would not greatly improve our CV estimates, we recommend continued evaluation of smaller sampling fractions. However, Gallagher and Gallagher (2005) found that increasing sample size above 30% did not improve estimates and 30% is the target size used in Oregon. Using the neighborhood variance estimator (Stevens 2002) to estimate confidence bounds relative to cost and sample size should be evaluated. Finally, the use of standardized data collection procedures and well trained staff (Gallagher et al. 2007) will also contribute to increased precision in regional escapement monitoring.

RECOMMENDATIONS

The life cycle monitoring portion of this study should be continued into perpetuity to gather data on multiple generations of salmonids and increase the data set for trend detection. After 2009, these streams should be included in a larger coast-wide monitoring effort. Increase capture and marking of steelhead by better operation of the Pudding Creek flashboard dam and the Noyo ECS. Bootstrap simulations should be used to calculate 95% confidence bounds for regional population estimates. Coordination with others collecting this type of data should continue and a standardized database should be constructed for use at the regional level for both LCS streams and regional GRTS sampling. Access agreements with landowners should be established prior to November 1st each season.

Capture-recapture at LCS streams should use weekly specific colored floy tags and operculum punches with recaptures made during spawning ground surveys. Smolt abundance should be estimated annually at LCS streams using downstream migrant traps and PIT tag capture-recapture. The effect of using the neighborhood variance estimator (Stevens 2002) to estimate confidence bounds on sample size should be evaluated. All coastal salmon monitoring should be included in a master sample and use of standardized data collection procedures and well trained staff (Gallagher et al. 2007).

ACKNOWLEDGEMENTS

This work was funded by the California Department of Fish and Game's Fisheries Restoration Grant Program. Peter Adams, Barry Collins, Seth Ricker (California Fish and Game), and Danna McCain (Humboldt State University), helped to develop this study. Shaun Thompson provided critical review of this manuscript. Too many individuals to mention by name from the following agencies helped with this study: California Department of Fish and Game, Campbell Timberlands Management, NOAA Fisheries Santa Cruz, and the Pacific States Marine Fisheries Commission. Be assured we value your help. A few we are compelled to mention by name include: Stan Allen for administrative support, Shaun Thompson, Wendy Holloway, Chris Hannon, and Katie Webster for many long hours in the field. Thanks to Matt Goldsworthy and the Mendocino Redwood Company for granting access to streams on their property. And special thanks to Big Wave Dave for his surfing artistry.

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PERSONAL COMMUNICATIONS

Trent McDonald, West Inc., Laramie Wyoming, November 2006.
Dana McCain, Institute for River Ecosystems, Arcata, CA August 2005.
Glen Szerlong, NOAA Fisheries Santa Cruz, August 2004.

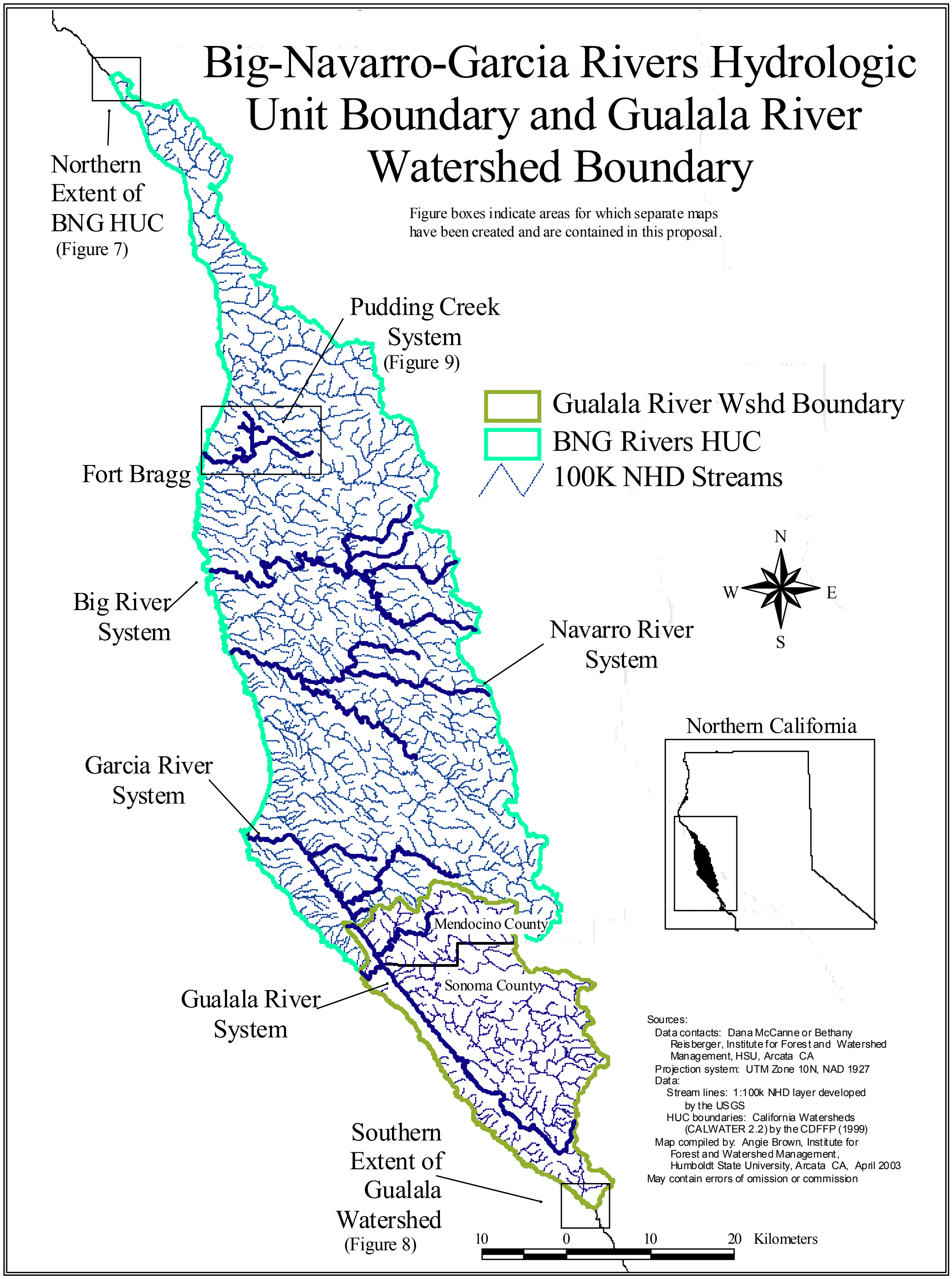

Figure 1. The Big-Navarro-Garcia hydrologic unit (green outlines the area of the phase II pilot study).

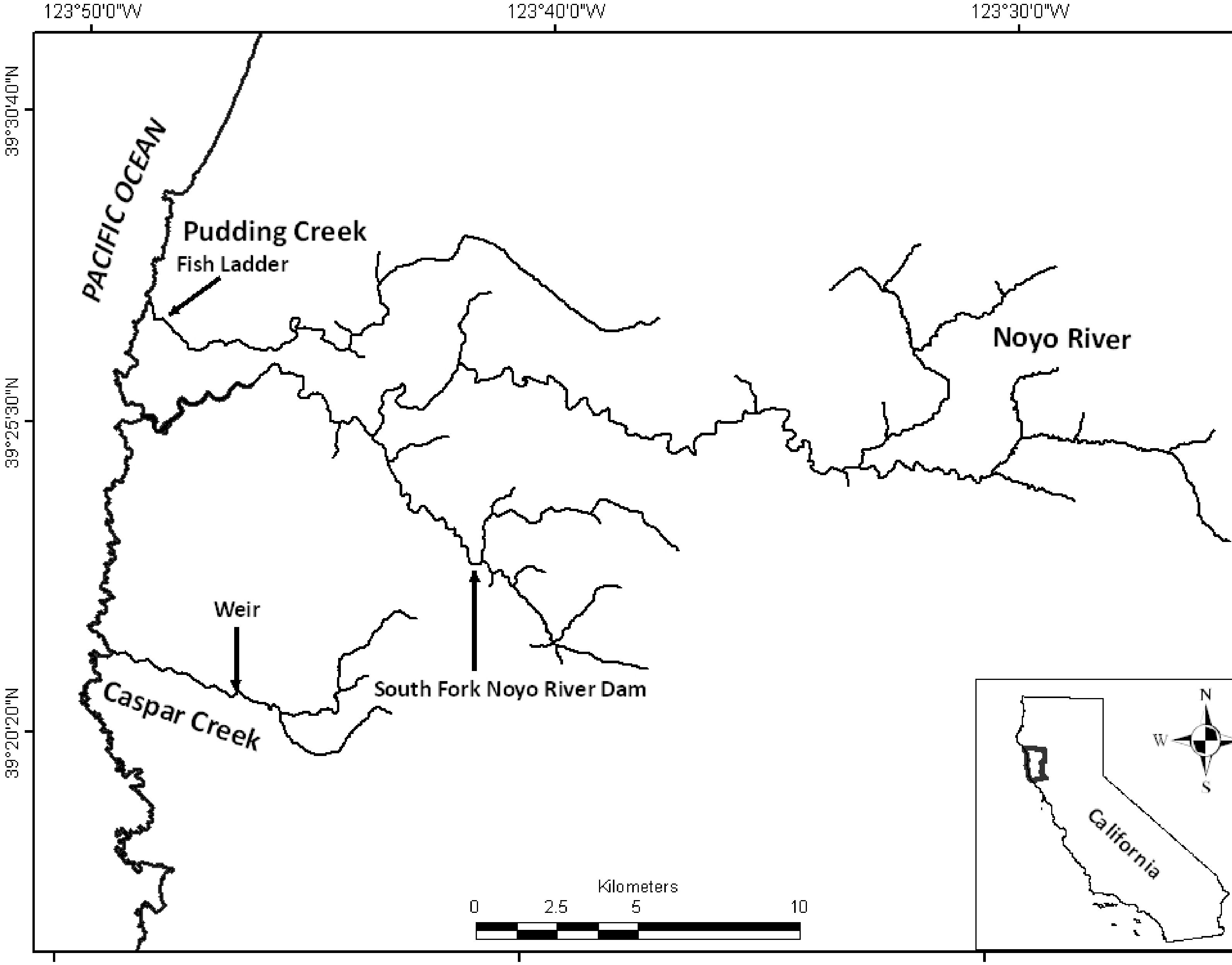

Figure 2. Location of the life cycle monitoring streams in Mendocino County, California. South Fork Noyo River Dam is the South Fork Noyo River Egg Collecting Station.

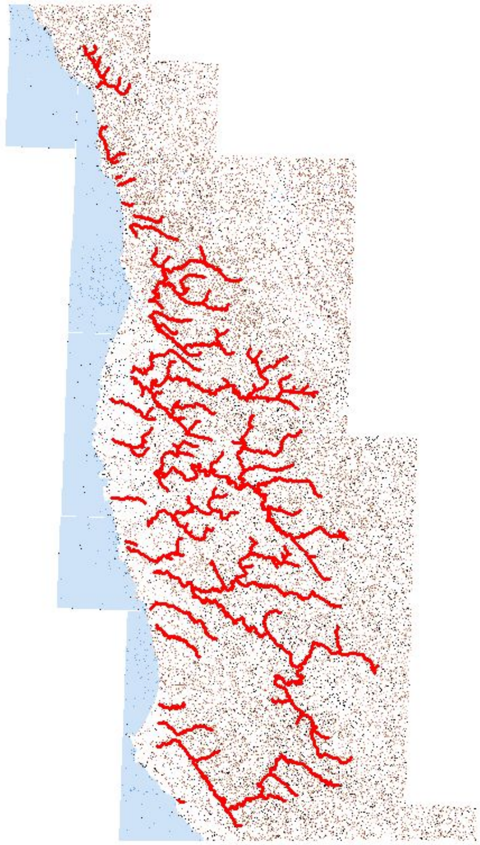

Figure 3. Sample universe for Chinook and coho salmon and steelhead spawning habitat in coastal Mendocino County.

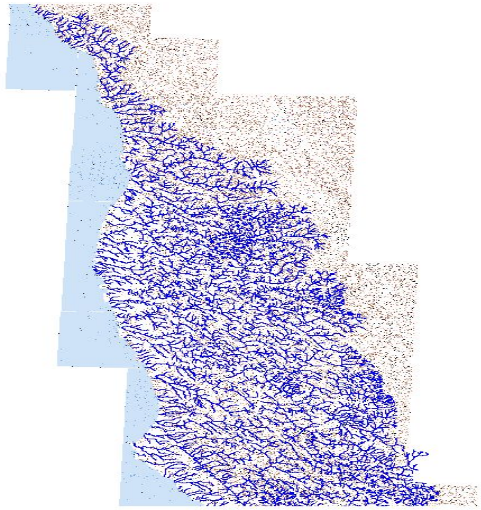

Figure 4. Routed hydrography for coastal Mendocino County.

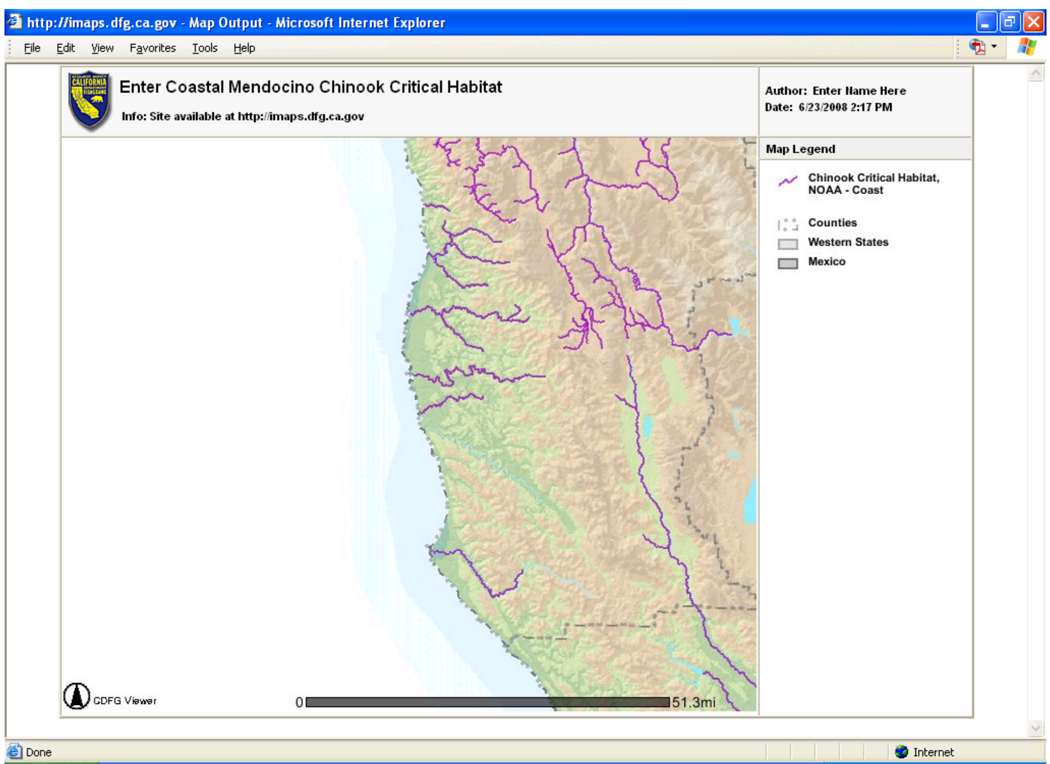

Figure 5. Critical habitat for coastal Chinook salmon in Mendocino County. From Cal-Fish (http://dnn.calfish.org/).

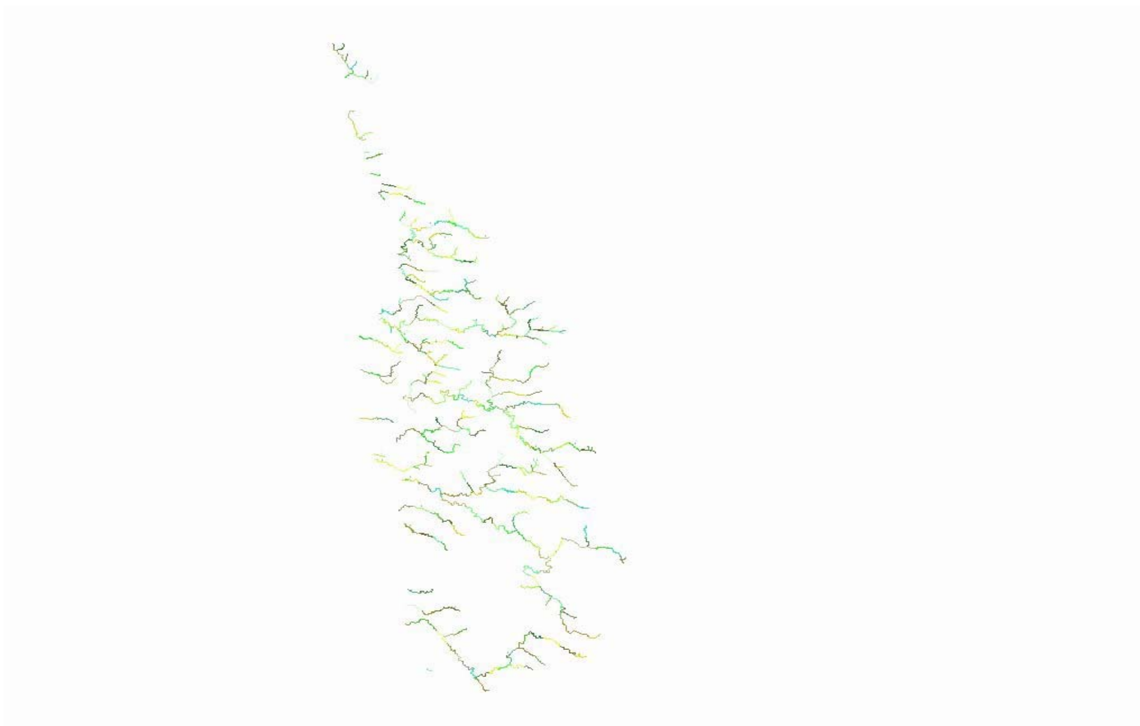

Figure 6. Sampling frame for coastal Mendocino County salmon regional CMP monitoring.

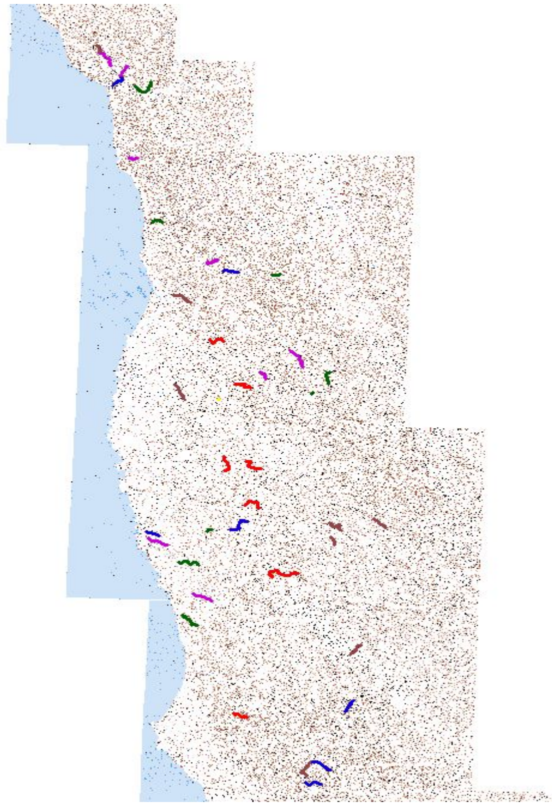

Figure 7. The spatial sample (GRTS) of the first 40 reaches for the Mendocino Coast regional CMP monitoring.

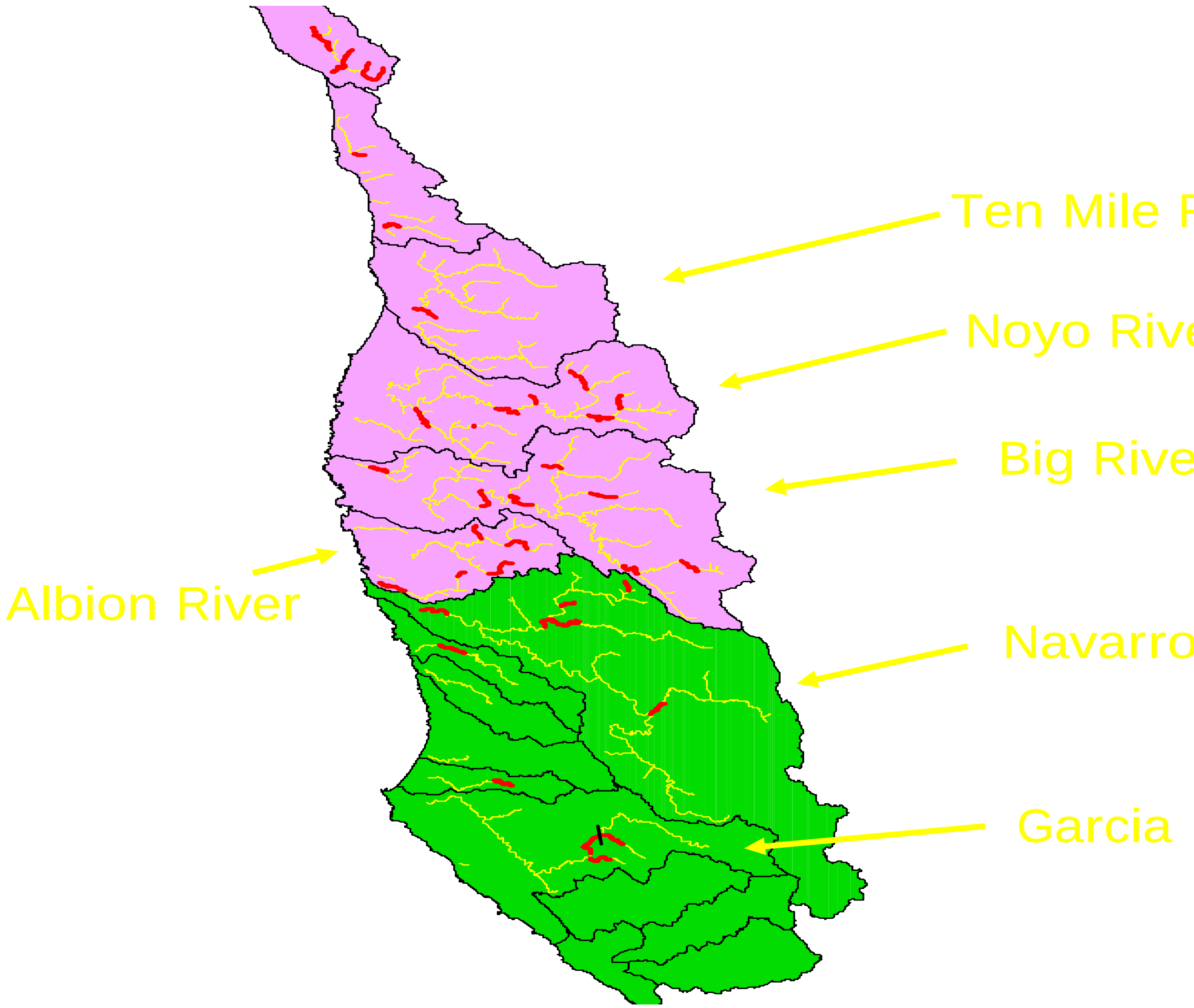

Figure 8. Selected sampling reaches and populations within two CCC coho salmon ESU diversity Strata. Pink is the Lost Coast and green is the Navarro.

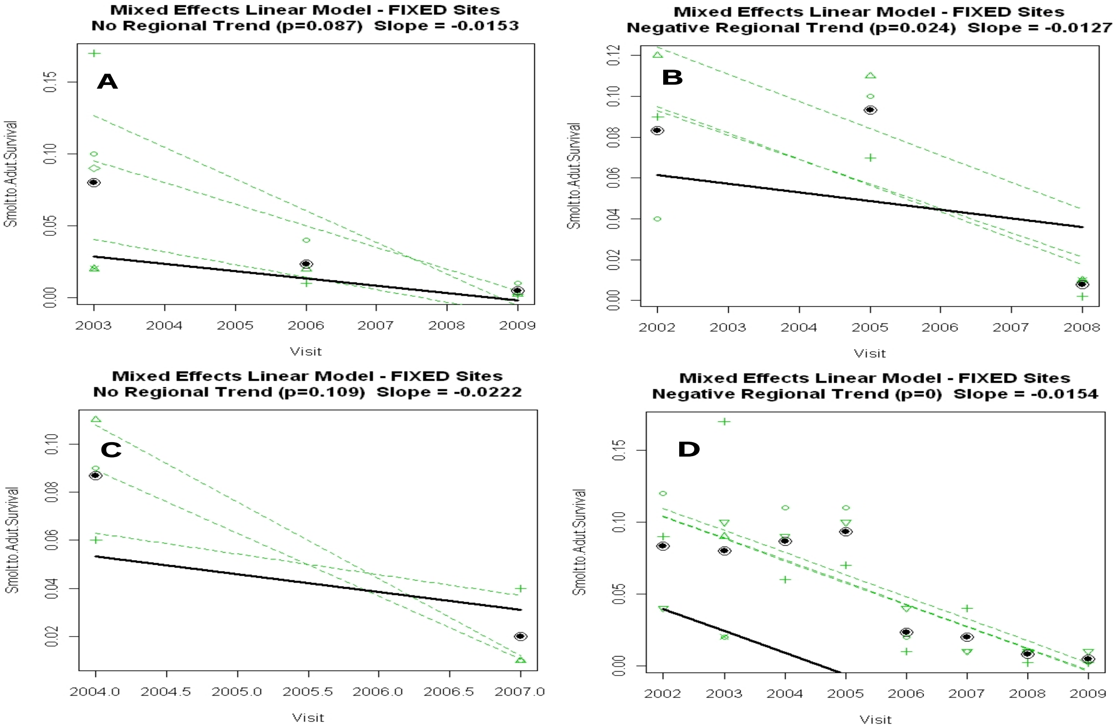

Figure 9. Coho salmon smolt to adult survival trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2003 to 2009. A. Cohort 1 2003, 2006, 2009. B. Cohort 2 2005 and 2008. C. Cohort 3 2004 and 2007. D. All years combined.

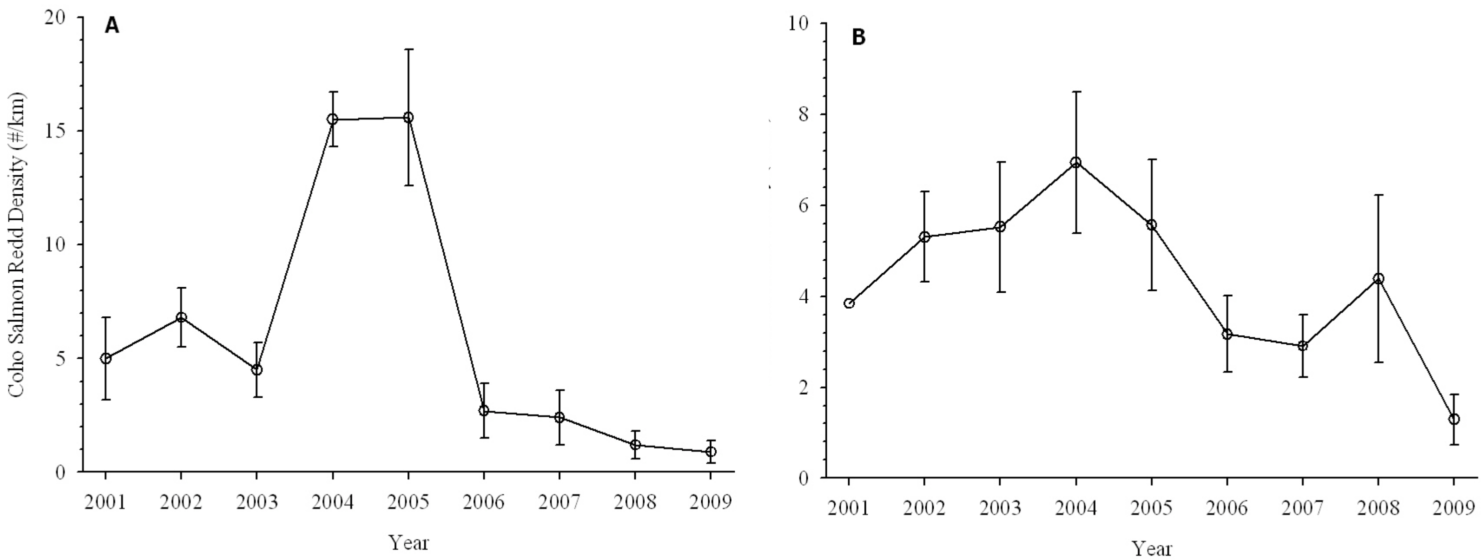

Figure 10. Average coho salmon (A) and steelhead (B) redd densities from 2001 through 2009 from reaches in Caspar and Pudding creeks and the South Fork Noyo and Little rivers. Thin lines are SE.

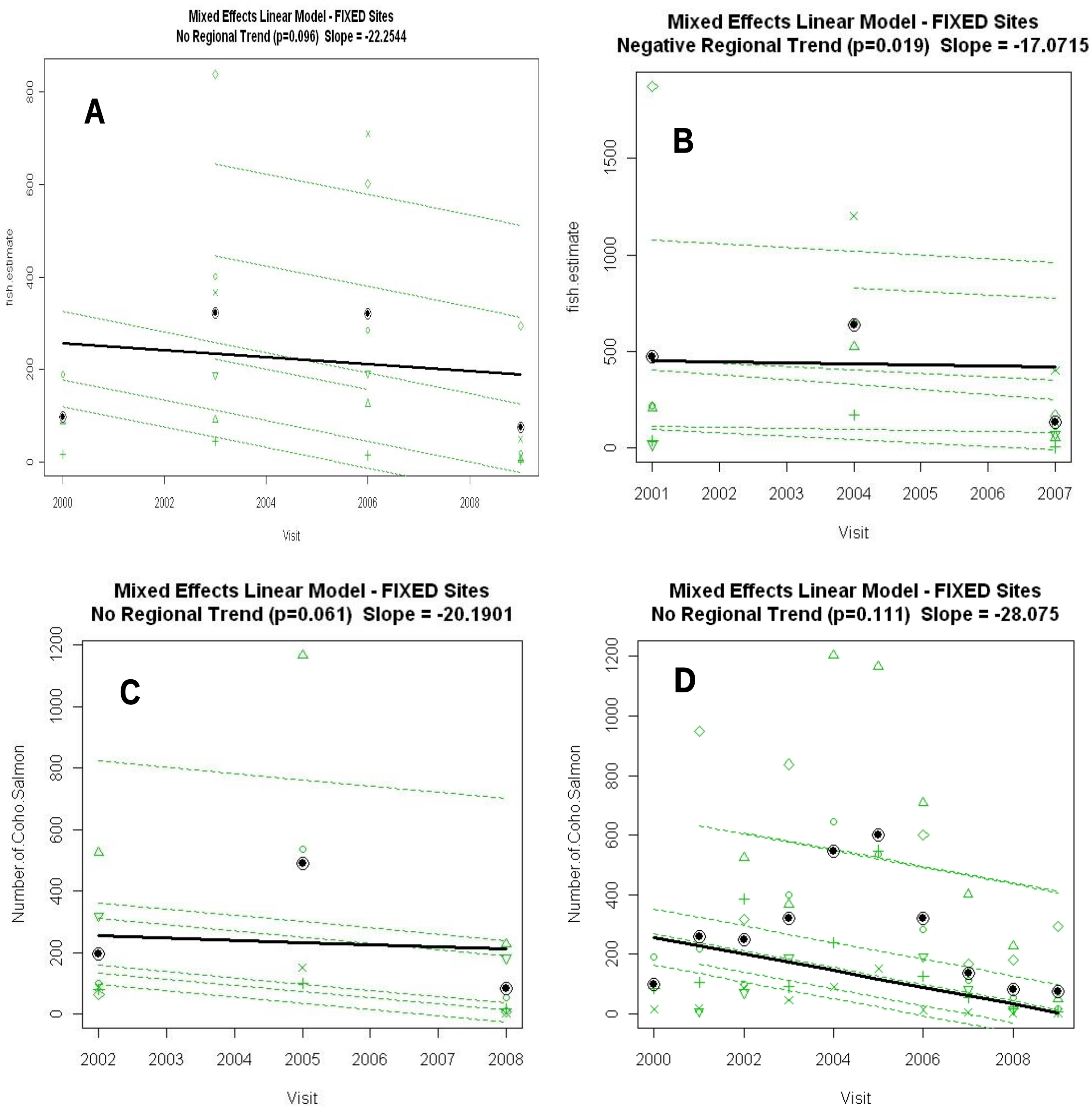

Figure 11. Coho salmon escapement trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2003 to 2009. A. Cohort 1 2003, 2006, 2009. B. Cohort 2 2005 and 2008. C. Cohort 3 2004 and 2007. D. All years combined.

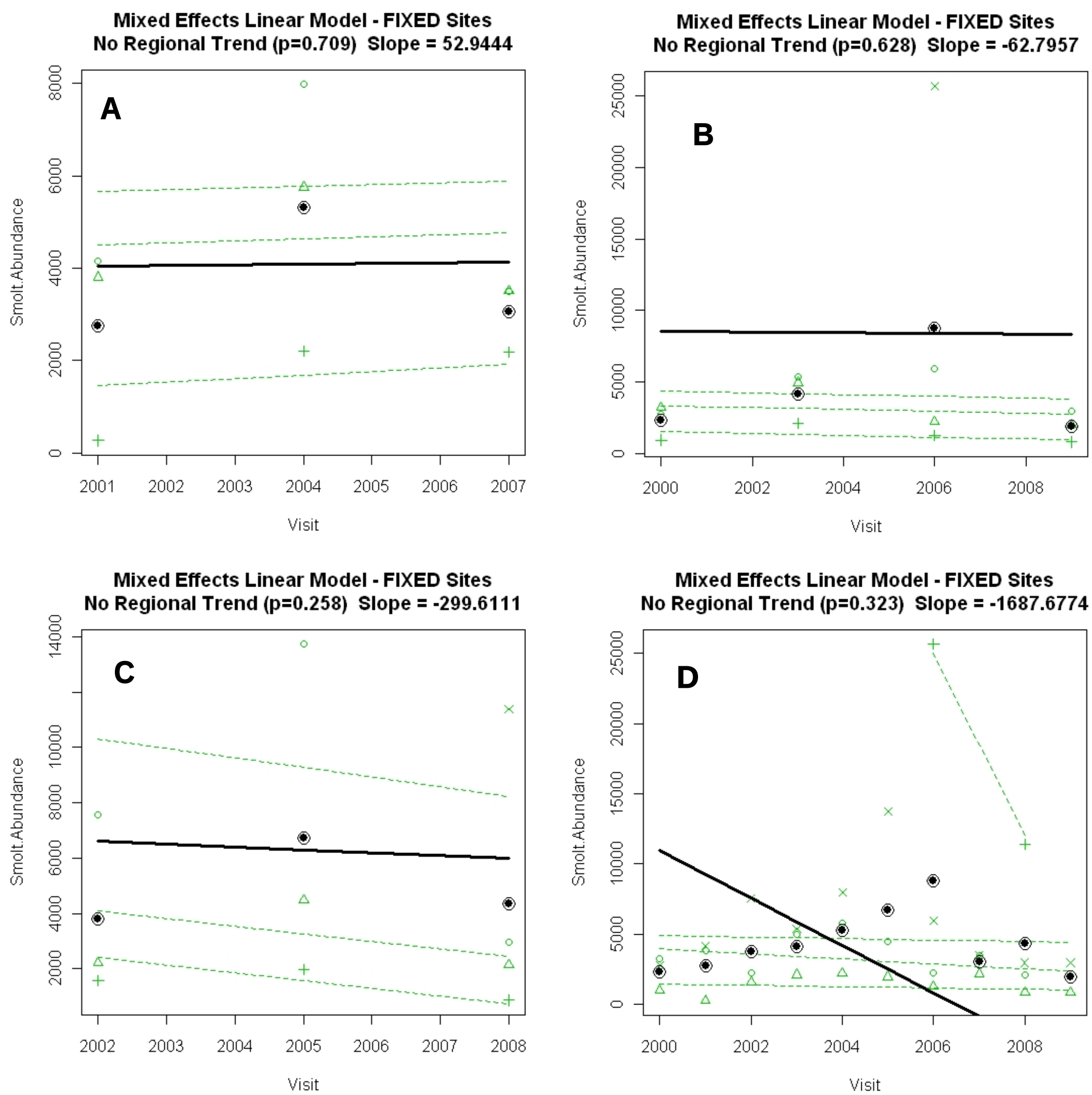

Figure 12. Coho salmon smolt abundance trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2003 to 2009. A. Cohort 1 2003, 2006, 2009. B. Cohort 2 2005 and 2008. C. Cohort 3 2004 and 2007. D. All years combined.

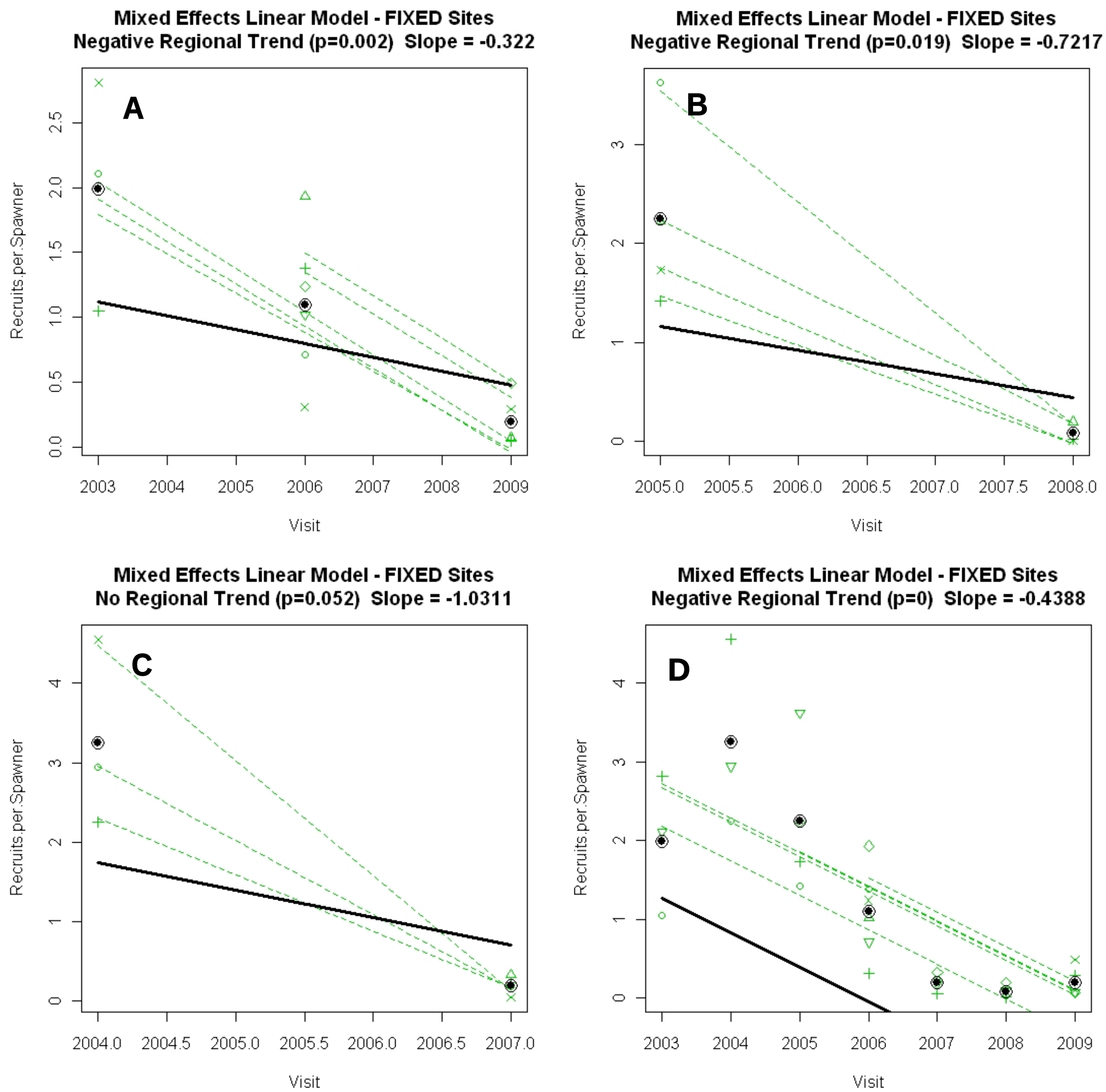

Figure 13. Coho salmon recruits per spawner trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2003 to 2009. A. Cohort 1 2003, 2006, 2009. B. Cohort 2 2005 and 2008. C. Cohort 3 2004 and 2007. D. All years combined.

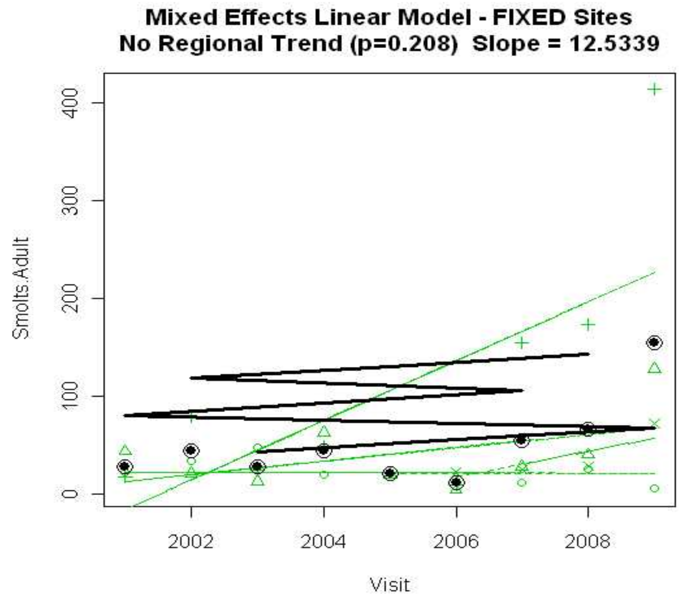

Figure 14. Coho salmon smolt per adult trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2003 to 2009.

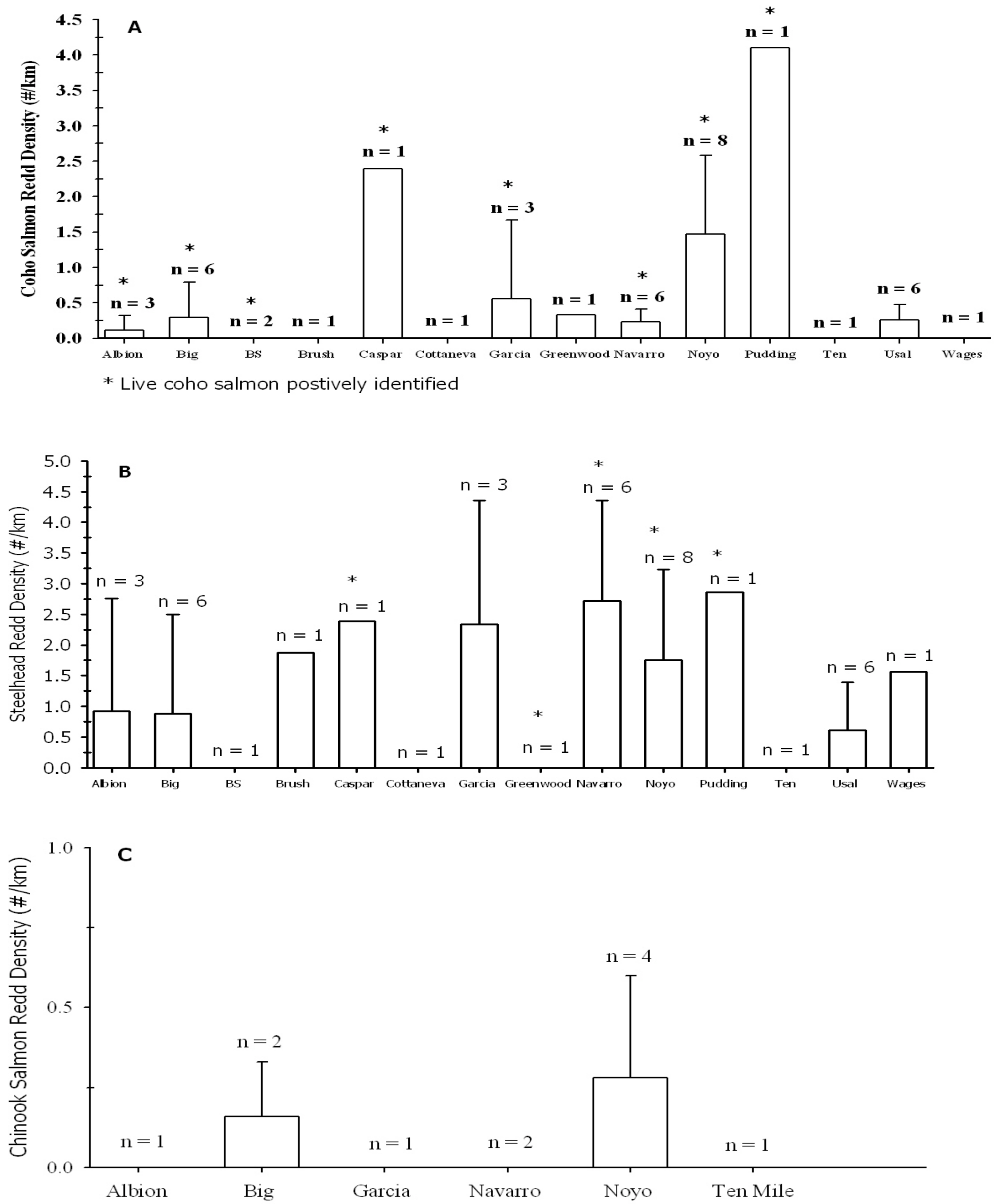

Figure 15. Redd density in coastal Mendocino streams surveyed during 2008-09. A. Coho salmon. B. Steelhead. C. Chinook salmon. Numbers indicate the number of GRTS reaches surveyed in each stream. Thin lines are 95% confidence limits. BS in panels a and b is Brush Creek.

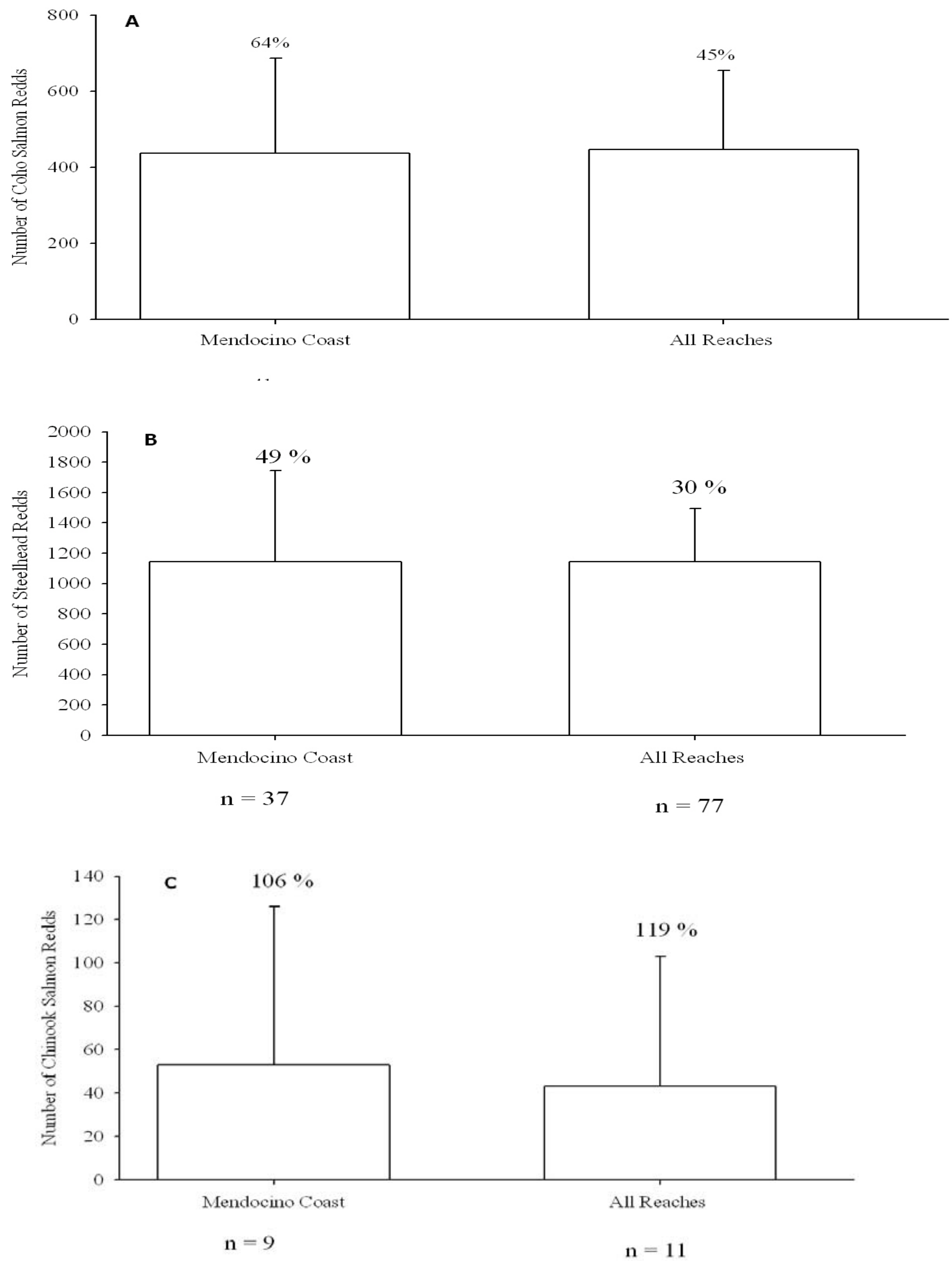

Figure 16. Regional redd count estimates from a GRTS design (n = 41, 37, 9 in panels A-C respectively) and from systematic sampling (n = 77 and 11, panels A-B, and C respectively) in coastal Mendocino during 2008-09. A. Coho salmon. B. Steelhead. C. Chinook salmon. Thin lines are 95% confidence intervals; percentages show the width of the 95% confidence intervals relative to the point estimates.

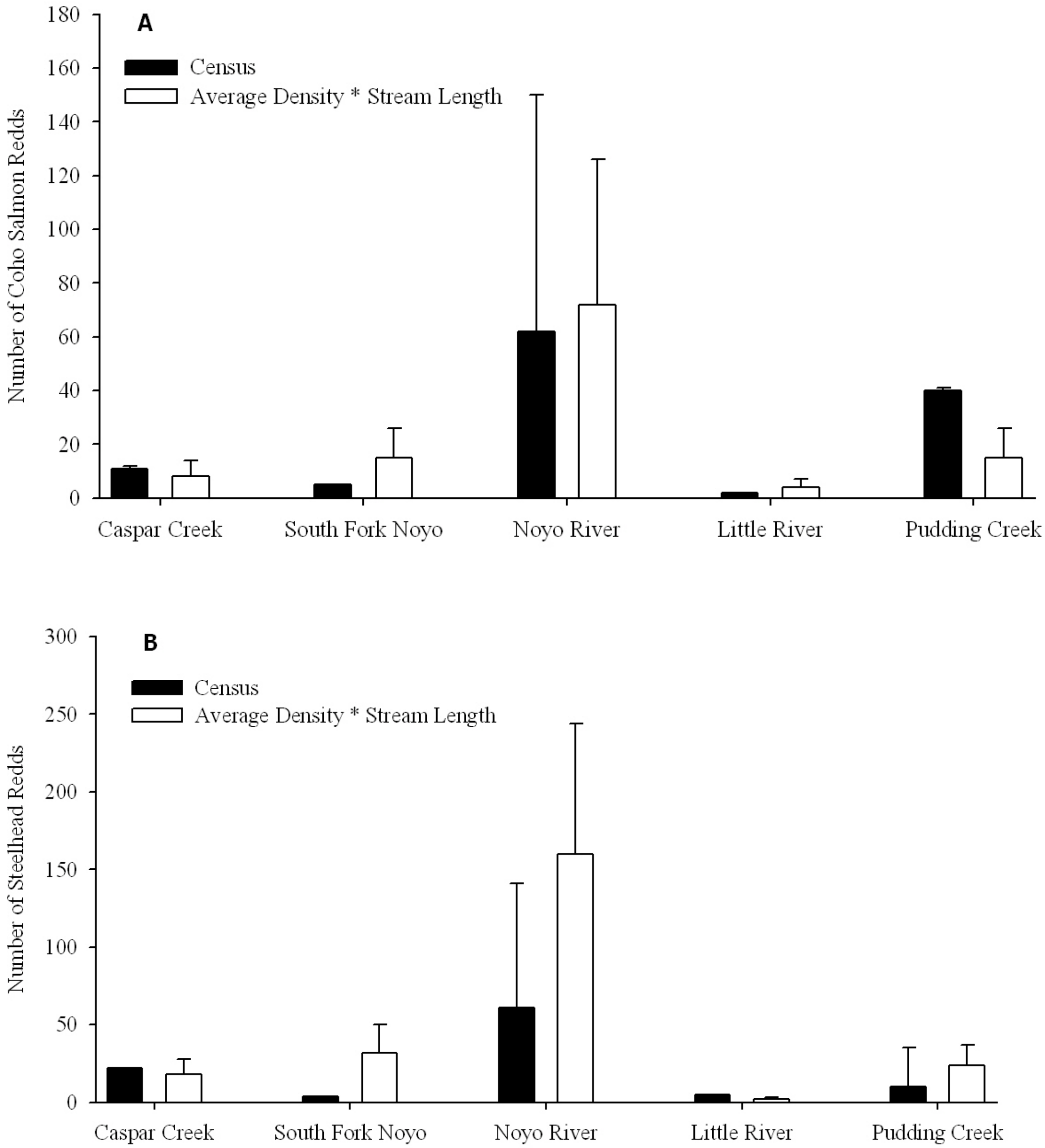

Figure 17. Coho salmon (A) and steelhead (B) redd census counts versus average regional density multiplied by stream length redd estimates for five streams during 2008-09. Caspar and Pudding creeks and the South Fork Noyo and Little rivers are census counts, Noyo River is a systematic sample estimate rather than a total census count. Thin lines are 95% confidence limits.

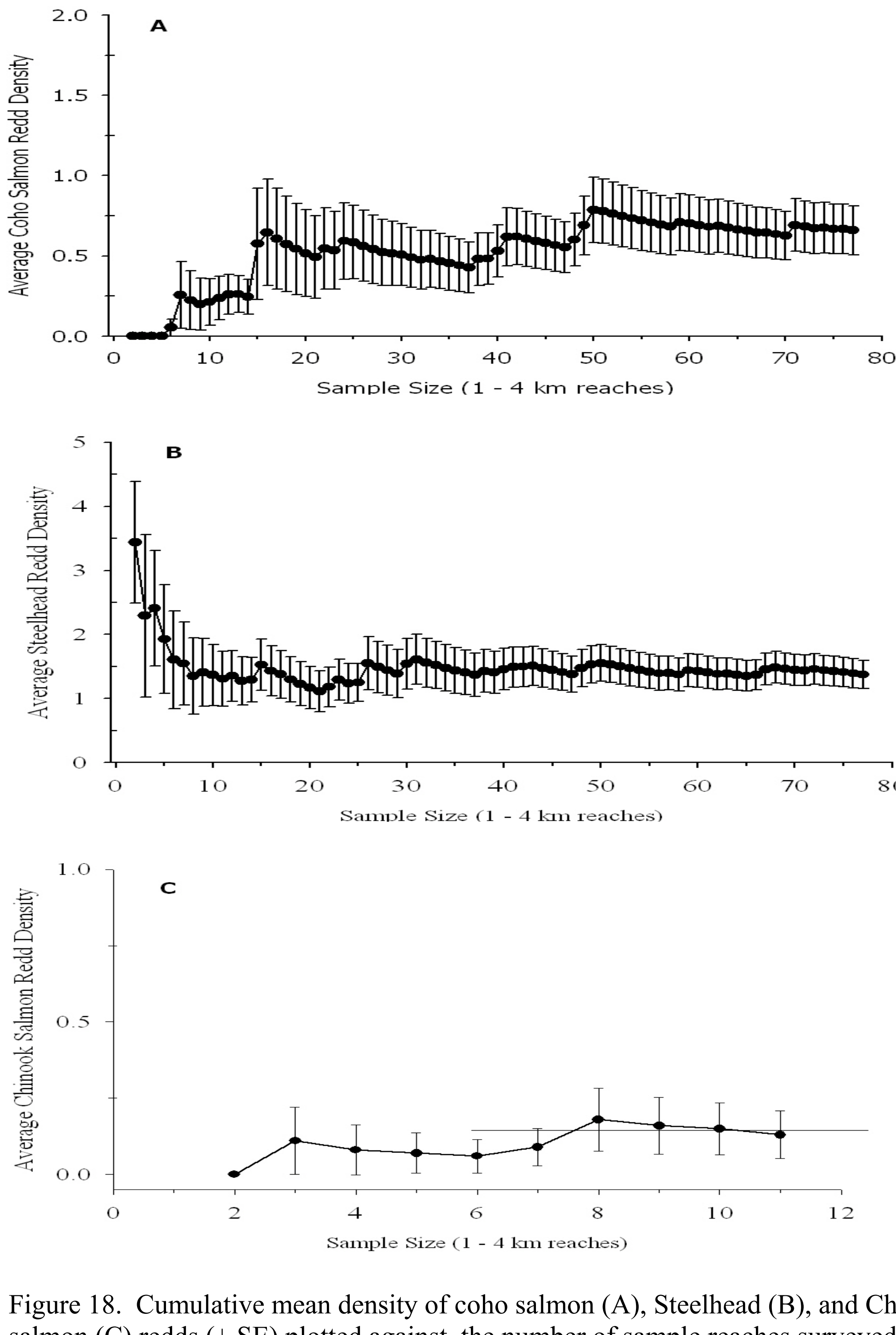

Figure 18. Cumulative mean density of coho salmon (A), Steelhead (B), and Chinook salmon (C) redds (± SE) plotted against the number of sample reaches surveyed during 2008-09 in coastal Mendocino County, California.

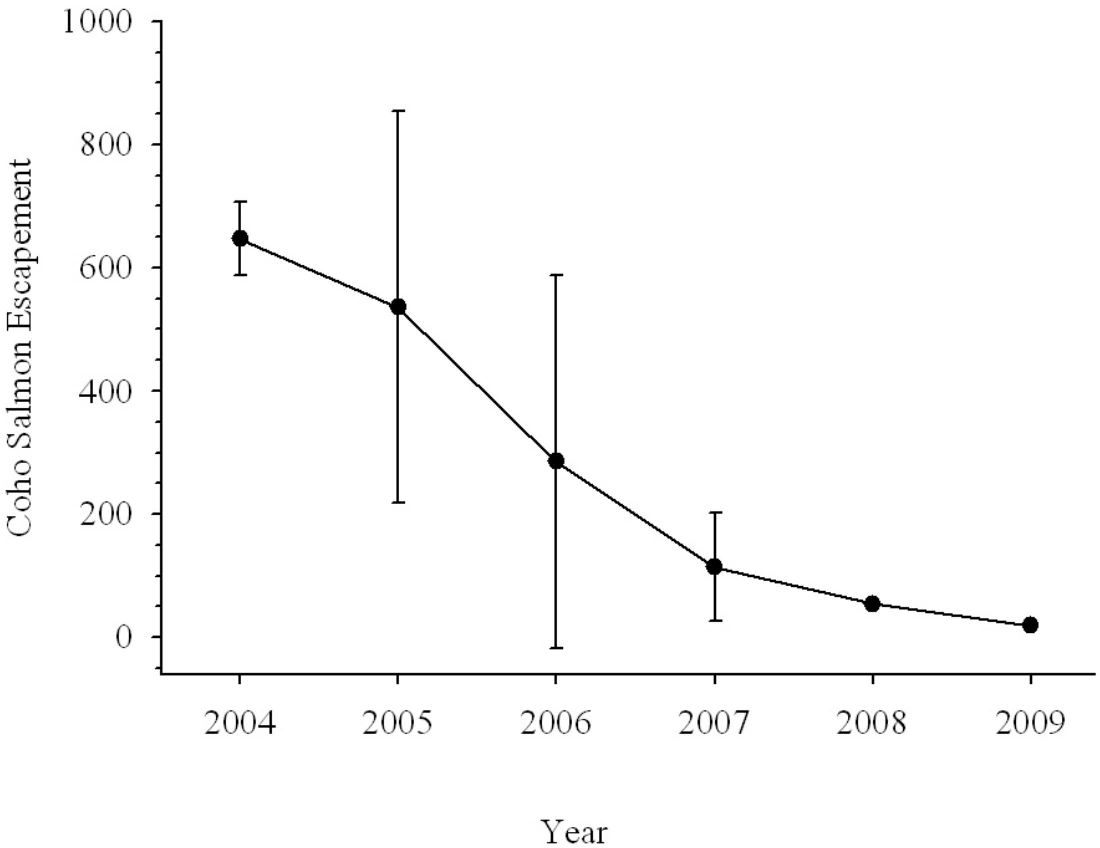

Figure 19. Coho salmon escapement above the South Fork Noyo Egg Collecting station 2004 trough 2009. Thin lines are 95% confidence limits.

Table 1. Grts order sample reaches and addition reaches (GRTS numbers >57 are from the LCS streams and represent a systematic sample), species designations and sample rotation for spawning survey reaches in coastal Mendocino County during 2008-09.

Stream Name	Tributary Name	GRTS Order	Stream Length	Species [1]			Sample Rotation
Garcia River	Inman Creek	2	3.11	coho	steelhead		every year
Usal Creek	mainstem	3	2.4137	coho	steelhead		every year
Noyo River	culi gulch	5	0.1	coho	steelhead		every year
Albion River	South Fork Albion River	7	3.62	coho	steelhead		every year
Garcia River	Signal Creek	8	2.71	coho	steelhead		every year
Albion River	mainstem	9	3.12	coho	steelhead	Chinook	every year
Big River	mainstem	10	3.4	coho	steelhead	Chinook	every year
Big River	mainstem	12	3.02	coho	steelhead	Chinook	every year
Brush Creek	mainstem	13	2.68	coho	steelhead		every year
Noyo River	mainstem	14	3.03	coho	steelhead	Chinook	every year
Navarro River	South Branch North Fork Navarro River	15	4.2	coho	steelhead	Chinook	every year
Navarro River	North Fork Navarro River	16	1.89	coho	steelhead		every year
Usal Creek	South Fork Usal Creek	17	3.53	coho	steelhead		year 1
Wages Creek	mainstem	18	2.56	coho	steelhead		year 1
Noyo River	Redwood Creek	19	2.49	coho	steelhead	Chinook	year 1
Noyo River	no name	20	0.59	coho	steelhead		year 1
Navarro River	mainstem	22	2.17	coho	steelhead	Chinook	year 1
Big Salmon Creek	Hazel Gulch	24	1	coho	steelhead		year 1
Usal Creek	mainstem	25	1.36	coho	steelhead		year 1
Big River	South Fork Big River	26	2.433	coho	steelhead		year 1
Ten Mile River	Mill Creek	27	2.66	coho	steelhead	Chinook	year 1
Garcia River	mainstem	28	3.59	coho	steelhead	Chinook	year 1
Big River	South Fork Big River	29	3.23	coho	steelhead		year 1
Noyo River	South Fork Noyo River	30	3.13	coho	steelhead		year 1
Navarro River	Indian Creek	31	2.58	coho	steelhead		year 1
Navarro River	Spooner Creek	32	1.44	coho	steelhead		year 1
Usal Creek	Soldier Creek	33	1.91	coho	steelhead		year 1
Cottaneva Creek	Rockport Creek	34	1.22	coho	steelhead		year 1
Greenwood Creek	mainstem	35	2.99	coho	steelhead		year 1
Noyo River	North Fork Noyo River	36	3.86	coho	steelhead	Chinook	year 1
Big Salmon Creek	mainstem	37	3.02	coho	steelhead		year 1
Noyo River	Duffy Gulch	38	1.53	coho	steelhead		year 1
Usal Creek	mainstem	39	3.087	coho	steelhead		year 1
Big River	Water Gulch	41	1.98	coho	steelhead		year 2
Albion River	Tom Bell Creek	42	2.07	coho	steelhead		year 2
Big River	East Branch North Fork Big River	45	2.61	coho	steelhead		year 2
Navarro River	Cook Creek	46	1.55	coho	steelhead		year 2
Noyo River	mainstem	47	2.95	coho	steelhead	Chinook	year 2
Usal Creek	Julias Creek	48	1.67	coho	steelhead		year 2
Caspar Creek	mainstem	49	2.09	coho	steelhead		year 2
Pudding Creek	mainstem	56	3.84	coho	steelhead		year 2
Little River	mainstem	57	2.83	coho	steelhead		year 2
Noyo River	Kass Creek	63	1.53	coho	steelhead		year 2
Noyo River	Bear Gulch	68	1.32	coho	steelhead		year 3
Noyo River	Pipe Gulch	89	0.18	coho	steelhead		year 3
Noyo River	Peterson Gulch	91	0.24	coho	steelhead		year 4
Pudding Creek	big wave daves gulch	94	0.2	coho	steelhead		year 4
Albion River	South Fork Albion River	95	2.84	coho	steelhead		year 4
Noyo River	South Fork Noyo River	117	3.54	coho	steelhead	Chinook	year 5
Pudding Creek	Little Valley Creek	130	1.08	coho	steelhead		year 5
Noyo River	South Fork Noyo River	137	3.21	coho	steelhead		year 5
Pudding Creek	Slaughter House Gulch	147	0.49	coho	steelhead		year 6
Caspar Creek	Middle Fork Caspar Creek	158	0.57	coho	steelhead		year 6
Pudding Creek	mainstem	161	2.54	coho	steelhead		year 6
Little River	mainstem	166	3.33	coho	steelhead		year 7
Noyo River	North Fork South Fork Noyo River	168	3.18	coho	steelhead		year 7
Navarro River	Little North Fork Navarro River	173	3.04	coho	steelhead		year 7
Caspar Creek	South Fork Caspar Creek	177	3.86	coho	steelhead		year 7
Caspar Creek	north fork	181	2.8	coho	steelhead		year 7
Pudding Creek	mainstem	184	2.57	coho	steelhead		year 7
Noyo River	North Fork South Fork Noyo River	192	3.29	coho	steelhead		year 8
Noyo River	Gulch 320	197	0.28	coho	steelhead		year 8
Noyo River	mainstem	206	2.84	coho	steelhead	Chinook	year 8
Caspar Creek	mainstem	211	1.61	coho	steelhead		year 8
Noyo River	South Fork Noyo River	222	3.13	coho	steelhead		year 10
Navarro River	Sawyer Creek	236	0.76	coho	steelhead		year 10
Navarro River	Bottom Creek	242	1.83	coho	steelhead		year 11
Pudding Creek	mainstem	248	1.73	coho	steelhead		year 11
Albion River	South Fork Albion River	249	2.81	coho	steelhead		year 11
Noyo River	Brandon Gulch	256	1.13	coho	steelhead		year 11
Pudding Creek	mainstem	271	3.09	coho	steelhead		year 12
Navarro River	Little North Fork Navarro River	272	3.21	coho	steelhead		year 12
Caspar Creek	north fork	273	2.95	coho	steelhead		year 12
Noyo River	North Fork South Fork Noyo River	274	3.11	coho	steelhead		year 12
Noyo River	Parlin Creek	277	3.06	coho	steelhead		year 12
Noyo River	South Fork Noyo River	304	1.48	coho	steelhead	Chinook	year 13
Pudding Creek	mainstem	336	2.31	coho	steelhead		year 14

[1] Chinook reaches are based on NOAA critical habitat and experience. Steelhead and coho are based on Spence et al. (2005) refined by professional experience.

Table 2. Coho salmon redd count and escapement estimates for regional monitoring of coastal Mendocino County's streams during 2008-09.

Stream	Number of Reaches	Number of Coho Salmon Redds			Number of Coho Salmon Adults			Confidence Width
		Low 95% CI	Point Estimate	High 95% CI	Low 95% CI	Point Estimate	High 95% CI	
Mencodino Coast	41	212	517	909	415	887	1545	64%
Lost Coast Diversity Strata	32	172	392	633	295	672	1083	59%
Navarro Point Diversity Strata	9	24	92	199	41	158	342	95%
Albion River	3	0	4	13	0	8	22	145%
Big River	6	0	47	123	0	80	210	132%
Big Salmon Creek [1]	2	-	0	-	-	0	-	na
Brush Creek [1]	1	-	0	-	-	0	-	na
Caspar Creek [2]	6	-	11	-	-	6	-	na
Cottenteva Creek [1]	1	-	0	-	-	0	-	na
Garcia River	3	0	40	120	0	69	206	149%
Greenwood Creek [1]	1	-	5	-	-	9	-	na
Little River [2]	2	-	2	-	-	4	-	na
Navarro River	6	11	41	73	18	70	124	76%
Noyo River	10	48	172	313	82	294	573	77%
South Fork Noyo River [2, 3]	12	-	5	-	-	19	-	na
Pudding Creek [2]	9	-	40	-	32	50	96	65%
Ten Mile River [1]	1	-	0	-	-	0	-	na
Usal Creek	6	1	6	11	2	10	18	83%
Wages Creek [1]	1	-	0	-	-	0	-	na

[1] Only one reach was surveyed in this stream so confidence bounds can not be calculated. When redds were not observed estimates are not possible.
[2] Life cycle monitoring station complete census
[3] Low flows limited the number of fish that passed the wier and spawned above the egg collecting station. There were 23 redds belwo the ECS and only five above.

Table 3. Steelhead redd count and escapement estimates for regional monitoring of coastal Mendocino County's streams during 2008-09.

Stream	Number of Reaches	Number of Steelhead Redds			Number of Steelhead Adults			Confidence Width
		Low 95% CI	Point Estimate	High 95% CI	Low 95% CI	Point Estimate	High 95% CI	
Mencodino Coast	37	634	1143	1749	245	442	674	49%
Lost Coast Diversity Strata	32	392	709	1041	151	274	402	46%
Navarro Point Diversity Strata	5	155	524	937	60	202	362	75%
Albion River	3	0	37	111	0	14	43	150%
Big River	6	9	137	318	4	52	123	113%
Big Salmon Creek [1]	2	0	27	53	0	10	21	99%
Brush Creek [1]	1	-	22	-	-	8	-	na
Caspar Creek [2]	6	-	22	-	-	7	-	na
Cottenteva Creek [1]	1	-	0	-	-	0	-	na
Garcia River	3	0	169	314	0	65	121	93%
Greenwood Creek [1]	1	-	0	-	-	0	-	na
Little River [2]	2	-	5	-	-	2	-	na
Navarro River	6	156	482	819	60	186	316	69%
Noyo River	10	67	206	378	26	79	145	76%
South Fork Noyo River [2, 3]	12	-	4	-	20	45 [4]	280	na
Pudding Creek [2]	9	-	25	-	5	10	35	157%
Ten Mile River [1]	1	-	0	-	-	0	-	na
Usal Creek	6	2	13	31	1	5	12	105%
Wages Creek [1]	1	-	17	-	-	7	-	na

[1] Only one reach was surveyed in this stream so confidence bounds can not be calculated. When redds were not observed estimates are not possible.
[2] Life cycle monitoring station complete census
[3] Low flows limited the number of fish that passed the wier and spawned above the egg collecting station.
[4] Estimate is likely biased high due to low flows and the nature of the ECS where fish moved in but did not continue or remain above it.

Table 4. Coho salmon smolt traps estimates for life cycle monitoring streams in coastal Mendocino County 2008-09.

Trap Location	YOY			Y+		
COHO	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability
Caspar Mainstem	ND	ND	ND	443	2045	0.30
					310	
Little River	ND	ND	ND	340	836	0.52
					69	
SF Noyo	695	ND	ND	202	313	0.63
					13	
Pudding Creek	311	ND	ND	3885	16309	0.33
					971	

Table 5. Steelhead smolt traps estimates for life cycle monitoring streams in coastal Mendocino County 2008-09. Number under estimates are standard deviations, double these for 95% confidence limits.

Trap Location	YOY			Y+ < 120			Y++			Y+ and Y++			Y++ >135mm		
STHD	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability
Caspar Mainstem	655	ND	ND	296	1716	0.28	27	198	0.14	323	1885	0.25	ND	ND	ND
					293			150			312				
Little River	96	ND	ND	491	1993	0.41	42	224	0.19	533	2221	0.35	ND	ND	ND
					218			81			242				
SF Noyo	187	ND	ND	1006	3442	0.35	149	842	0.23	1155	4070	0.32			
					208			181			231				
Pudding Creek	69	ND	ND	554	2538	0.34				748	3291	0.27	ND	ND	ND
					523						511				

Table 6. PIT tag detections at the Caspar Creek Antennae Arrays during spring 2009. DSMT is the fyke trap located 4.6 km above the array.

Array Detections by Mark Year							
Marked At DSMT		Coho			Steelhead		
	Total	All	Y+	Y++	All	Y+	Y++
Reads From DSMT 09	386	313	289	24	73	64	10
Fish Marked DSMT 09		406	375	31	296	275	22
Fish Read / Fish Marked		0.77	0.77	0.77	0.25	0.23	0.45
Reads from DSMT 08	83	77	77	0	6	6	0
Fish Marked DSMT 08		414	412	2	26	20	6
Fish Read / Fish Marked		0.19	0.19	0.00	0.23	0.30	0.00
Reads from DSMT 07	3	0	0	0	3		
Fish Marked DSMT 07					84		
Fish Read / Fish Marked					0.04		

Marked At EFISH		Coho			Steelhead		
	Total	All	Y+	YOY	All	Y+	Y++
Reads from EFISH 08	18	12	7	5	6	4	2
Fish Marked EFISH 08		50	35	15	89	76	13
Fish Read / Fish Marked		0.24	0.20	0.33	0.07	0.05	0.15
Reads from EFISH 07	0	0	0	0	0	0	0
Fish Marked EFISH 07	82	38			44		
Fish Read / Fish Marked	0	0			0		

DSMT Age class is simply: >120mm = Y++
EFISH Age class interpreted by fork length frequency

Marked DSMT 2008, Detected at Array				
	Coho		Steelhead	
	Count		Count	
Marked in March	15	19%	1	17%
Marked in April	22	29%	2	33%
Marked in May	40	52%	3	50%

Table 7. PIT tag detections at the Pudding Creek antennae arrays during spring 2009.

Array Detections by Mark Year							
Marked At DSMT		Coho			Steelhead		
	Total	All	Y+	Y++	All	Y+	Y++
Reads from DSMT 09	1109	1092	1060	32	17	12	5
Fish Marked DSMT 09	3487	2896	2833	63	591	442	149
Fish Read/ Fish Marked	0.318038	0.377072	0.374162	0.507937	0.028765	0.027149	0.033557
Reads from DSMT 08	166	163	163	0	3	2	1
Fish Marked DSMT 08	5482	5003	4687	316	479	261	218
Fish Read/ Fish Marked	0.030281	0.03258	0.034777	0	0.006263	0.007663	0.004587
Reads from DSMT 07	3	2	2	0	1	1	0
Fish Marked DSMT 07	5234	4397	4130	267	837	615	222
Fish Read/ Fish Marked	0.000573	0.000455	0.000484	0	0.001195	0.001626	0

Marked At EFISH		Coho			Steelhead		
	Total	All	Y+	Y++	All	Y+	Y++
Reads from EFISH 08	66	64	64	0	2	2	0
Fish Marked EFISH 08	744	439	439	0	305	256	49
Fish Read/ Fish Marked	0.08871	0.145786	0.145786		0.006557	0.007813	0
Reads from EFISH 07	9	9	9	0	0	0	0
Fish Marked EFISH 07	1072	698	698	0	374	354	20
Fish Read/ Fish Marked	0.008396	0.012894	0.012894		0	0	0

Table 8. Coho and steelhead smolt travel time between our downstream trap sites and the ocean during spring 2009. Caspar trap is located about 4.5 km from the ocean and the PIT tag antennae arrays are located about 0.20 km from the ocean. The Pudding Creek trap is located about 4.5 km from the ocean and the PIT tag antennae arrays are located about 0.20 km from the ocean.

Travel Time: Days from DSMT (2009 Only) to Array								
	Coho Y++		Coho Y+			Steelhead Y+		Steelhead Y++
	Marked	Recaptured	Marked	Recaptured		Marked	Recaptured	Marked or Recaptured
Mean	9.6	4.8	20.0	14.7		28.7	30.6	26.5
Min	2	2	1	1		2	6	3
Max	23	12	80	63		76	51	50

There is a 300m distance between "mark" and "recapture" release sites.
2.7 miles from DSMT to Array

Travel time (days) screw trap to Pudding Creek Dam.

	Y+		Y++	
COHO	2009	EF08	2008	EF07
Mean	27.88	220.27	379.93	575.44
Minimum	1	163	315	558
Maximum	96	243	441	602
Count	1306	85	163	9
Confidence Level(95.0%)	1.364	3.198	4.828	11.815

Steelhead	2009	EF08	2008	EF07
Mean	18.83	193.50	296.33	0
Minimum	1	187	282	0
Maximum	66	200	319	0
Count	18	2	3	0
Confidence Level(95.0%)	9.14	82.59	49.33	0

Table 9. Coho salmon survival and productivity for several Mendocino County streams 2000 to 2009.

	Variable	Noyo Ecs			Pudding Creek			Caspar Creek			Little River			Noyo River			Hare Creek		
		Low ^	Estimate	High	Low ^	Estimate	High	Low ^	Estimate	High	Low ^	Estimate	High	Low ^	Estimate	High	Low ^	Estimate	High
chrt 1	1999-2000 Adults	-	190	-	nd	nd	nd	0	87	186	0	16	67	nd	nd	nd	nd	nd	nd
	2001 Smolts	1596	4152	6708	nd	nd	nd	3355	3799	4243	259	264	280	16307	26765	37223	1763	2193	2623
	2001 Smolts/ 2000 Adults	-	22	-	-	-	-	-	44	23	-	17	4						
	2002-2003 Adults	-	401	-	333	367	401	70	91	112	42	45	48	84	487	890	163	188	213
	Survival 01 Smolt to 03 Adult	0.06	0.10	0.25	nd	nd	nd	0.02	0.02	0.03	0.16	0.17	0.17	0.01	0.02	0.02	0.08	0.09	0.10
	Recruits/Spawner (03/00)	-	2.11	-	nd	nd	nd	na	1.05	0.60	nd	2.81	0.72	nd	nd	nd	nd	nd	nd
	2004 Smolts	7289	7975	8661	nd	nd	nd	4371	5753	7135	2038	2202	2366	nd	nd	nd	nd	nd	nd
	2004 Smolts / 2003 Adults	-	20	-	-	-	-	62	63	64	49	49	49						
	2005-2006 Adults	178	285	588	588	709	888	48	126	4961	1	14	27	512	602	692	183	192	201
	Survival 04 Smolt to 06 Adult	0.02	0.04	0.07	nd	nd	nd	0.01	0.02	0.70	0.00	0.01	0.01	nd	nd	nd	nd	nd	nd
	Recruits/Spawner (06/03)	0.44	0.71	1.47	1.77	1.93	2.21	0.69	1.38	44.29	0.02	0.31	0.56	6.10	1.24	0.78	1.12	1.02	0.94
	2007 Smolts	3212	3488	3764	15313	17609	19905	2843	3505	4167	1855	2175	2495	nd	nd	nd	nd	nd	nd
	2007 Smolts / 2006 Adults	18	12	6	26	25	22	59	28	1	1855	155	92						
	2008-2009 Adults	-	19	-	32	50	96	-	6	-	-	4	-	82	294	537	nd	nd	nd
	Survival 07 Smolt to 09 Adult	-	0.01	-	0.002	0.003	0.005		0.002	- -	-	0.002	-	nd	nd	nd	nd	nd	nd
	Recruits/Spawner (09/06)	-	0.07	-	0.05	0.07	0.11		0.05	- -	-	0.29	-	0.16	0.49	0.78	nd	nd	nd
chrt 2	2000-2001 Adults [9]	-	220	-	nd	279	nd	97	106	115	6	20	33	nd	nd	nd	nd	nd	nd
	2002 Smolts	5994	7562	9130	nd	nd	nd	1922	2224	2526	1441	1575	1709	nd	nd	nd	nd	nd	nd
	2002 Smolts/2001 Adults		34						21			79							
	2003-2004 Adults	530	647	706	1067	1204	1600	178	238	298	28	91	154	nd	nd	nd	nd	nd	nd
	Survival 02 Smolt to 04 Adult	0.09	0.09	0.08	nd	nd	nd	0.09	0.11	0.12	0.02	0.06	0.09	nd	nd	nd	nd	nd	nd
	Recruits/Spawner (04/01)	2.41	2.94	3.21	nd	nd	nd	1.84	2.25	2.59	4.67	4.55	4.67	nd	nd	nd	nd	nd	nd
	2005 Smolts	9261	13727	18193	-	-	-	3792	4482	5172	1834	1974	2114	nd	nd	nd	nd	nd	nd
	2005 Smolts / 2004 Adults	17	21	26	-	-	-	21	19	17	66	22	14						
	2006-2007 Adults	76	114	202	295	401	601	28	54	196	3	5	6	nd	nd	nd	nd	nd	nd
	Survival 05 Smolt to 07 Adult	0.01	0.01	0.01	-	-	-	0.01	0.01	0.04	0.002	0.003	0.003	nd	nd	nd	nd	nd	nd
	Recruits/Spawner (07/04)	0.14	0.18	0.29	0.28	0.33	0.38	0.16	0.23	0.66	0.11	0.05	0.04	nd	nd	nd	nd	nd	nd
	2008 Smolts	2829	2971	3113	10842	11390	11938	1786	2134	2491	800	863	923	nd	nd	nd	nd	nd	nd
	2008 Smolts / 2007 Adults	37	26	15	37	28	20	64	40	13	267	173	154						
chrt 3	2000 Smolts	2102	2763	3424	nd	nd	nd	2889	3259	3629	917	975	1033	nd	nd	nd	820	1128	1436
	2001-2002 Adults	76	112	148	438	524	610	352	386	420	50	88	126	nd	nd	nd	nd	nd	nd
	Survival 00 Smolt to 02 Adult	0.04	0.04	0.04	nd	nd	nd	0.12	0.12	0.12	0.05	0.09	0.12	nd	nd	nd	nd	nd	nd
	2003 Smolts	4789	5357	5925	nd	nd	nd	4258	4976	5694	1885	2115	2345	nd	nd	nd	nd	nd	nd
	2003 Smolts / 2002 Adults	63	48	40				12	13	14	38	24	19						
	2004-2005 Adults	-	536	-	899	1167	1773	298	548	798	0	152	535	nd	nd	nd	nd	nd	nd
	Survival 03 Smolt to 05 Adult	0.09	0.10	0.11	nd	nd	nd	0.07	0.11	0.14	0.00	0.07	0.23	nd	nd	nd	nd	nd	nd
	Recruits/Spawner (05/02)	7.05	4.79	3.62	2.05	2.23	2.91	0.85	1.42	1.90	0.00	1.73	4.25	nd	nd	nd	nd	nd	nd
	2006 Smolts	4760	5980	7200	21862	25656	29450	1893	2253	2613	1176	1294	1412	nd	nd	nd	nd	nd	nd
	2006 Smolts / 2005 Adults		11		24	22	17	6	4	3	-	9	3						
	2007-2008 Adults [8]	16	54	∞	153	228	450	6	16	∞	1	2	4	109	259	697	0	16	64
	Survival 06 Smolt to 08 Adult	0.003	0.01	na	0.01	0.01	0.02	0.00	0.01	na	0.001	0.002	0.003	nd	nd	nd	nd	nd	nd
	Recruits/Spawner (08/05)	0.03	0.10	na	0.17	0.20	0.25	0.02	0.03	na	0.00	0.01	0.01	nd	nd	nd	nd	nd	nd
	2009 Smolts	287	313	339	14367	16309	18251	1424	2044	2664	698	836	974	nd	nd	nd	nd	nd	nd
	2009 Smolts / 2008 Adults	18	6		94	72	41	237	128	-	517	414	245						

^ Adult and smolt data ranges are 95% ci's.
ECS adult escapement from carcass capture-recapture 2001-02, live fish mark-recaptue for 2004-2006, and relase counts other years. Smolt estimates are from Harris 2000 to 2009. I believe that hatchery numbers
Pudding Creek adult escapement from live fish mark-recapture for 2004-2009 and 1 redd per female for other years (95%ci based on redd count SE and n = 3 reaches). 2010 is guess as of 2/8/10
Caspar from live fish capture-recapture for 2005-06 and 1 redd per female for other years (95%ci based on redd count SE and n = 3 reaches).
Little River adult escapement from 1 redd per female (95%ci based on redd count SE and n = 2 reaches).
Hare Creek adult escapement from 1 redd per female (95%ci based on redd count SE and n = 4 reaches 2002-03 and 5 reaches 2005-06 and 2007-08).
Noyo River adult escapement from live fish caprure-recapture 2002-03 and1 redd per female for other years (95%ci based on redd count SE and n = 9 reaches).
[8] Ecs and caspar mark-recapture from Schnabel method without recaptures so upper 96% confidence bounds are infinite.
[9] Pudding adult estimate from Harris 2001 raw redd count of 138 times 2.

Table 10. Coho salmon viability based on Spence et al. (in prep.) for several coastal Mendocino County streams 2000 through 2009.

Stream	Harmonic Mean (per generation)		Number of Years	Extinction Risk [1]	Spawners/ IP-KM
	Population Size	Effective Population Size [2]			
South Fork Noyo River	566	113	8	Moderate	10
Pudding Creek	1568	314	6	Moderate/Low	20
Caspar Creek	302	60	7	Moderate	13
Little River	47	9	8	High [3]	7
Noyo River	975	195	3	Moderate/Low	4

[1] Spence et al. (2008) suggests a minimum of four generations of data. These data are from one to three generations.

[2] Harmonic mean times 0.20.

[3] Spence et al. (2008) state that small stable populations are exempt. Little River shows no trend over years t = -1.06, p = 0.34, slope = -1.04. The same may apply to Caspar and Hare creeks.

[4] Spawners / IP-KM > 40 low risk (Spence et al. 2008).

Table 11. Coho salmon trends based on Spence et al. (in prep.) for several coastal Mendocino County streams 2000 through 2009.

Stream	Geometric Mean [1]	Number of Years	Slope	Negative Trend	Population Size ≤ 500
	Population Size				
South Fork Noyo River	169	8	-1.4	No	Yes
Pudding Creek	415	6	-2.56	No	Yes
Caspar Creek	88	8	-0.23	No	Yes
Little River	20	8	-0.33	No	Yes
Noyo River	409	3	nd	nd	Yes

[1] Spence et al. (2008) suggests a minimum of four generations of data. These data are from one to three generations.

[2] $r^2 < 0.76$, $p > 0.0.07$, $t < -2.40$. Slope not siginificant.

Table 12. Chinook salmon redd count and escapement estimates for regional monitoring of coastal Mendocino County's streams during 2008-09.

Stream	Number of Reaches	Number of Chinook Salmon Redds			Number of Chinook Salmon Adults [1]			Confidence Width
		Low 95% CI	Point Estimate	High 95% CI	Low 95% CI	Point Estimate	High 95% CI	
Mencodino Coast	9	13	53	126	33	133	315	119%
Lost Coast Diversity Strata	8	0	41	87	0	102	217	106%
Navarro Point Diversity Strata	1	-	0	-	-	0	-	na
Albion River [2]	1	0	37	111	0	14	43	150%
Big River	2	0	15	31	0	30	61	113%
Garcia River [2]	1	-	0	-	-	0	-	na
Navarro River [2]	2	-	0	-	-	0	-	na
Noyo River	4	0	14	30	0	35	74	107%
Ten Mile River [2]	1	-	0	-	-	0	-	na

[1] Escapement estimate assumes 2.5 fish per redd.

[2] Only one reach was surveyed in this stream so confidence bounds can not be calculated. When redds were not observed estimates are not possible.

Table 13. Estimated sample sizes (number of reaches) for five desired levels of precision (width of the 95% confidence limits relative to the mean) in redd densities for regional surveys of coastal Mendocino County streams from data colleted during 2008-09.

Precision	Confidence Limits			
	90%		95%	
	Steelhead	Coho	Steelhead	Coho
10%	1049	927	1505	1329
20%	262	232	376	332
30%	177	103	167	148
40%	66	58	94	83
50%	42	37	60	53