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COASTAL MENDOCINO COUNTY SALMONID LIFE CYCLE AND REGIONAL MONITORING: MONITORING STATUS AND TRENDS 2010

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Coastal Mendocino County Salmonid Monitoring Project

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ABSTRACT

This report documents the results of the second year of a multi-year regional salmonid monitoring program implemented as part of the California's Coastal Salmonid Monitoring Program (CMP). This project was funded by the Fisheries Restoration Grants Program. The purpose of this study was to 1) continue salmon life cycle monitoring (adults in- smolts out) in three life cycle monitoring streams (LCS) and provide spawner: redd ratios for calibrating regional redd survey data to regional fish abundance estimates and, 2) conduct regional spawning ground surveys throughout coastal Mendocino County streams to estimate escapement and assess sampling rates at this regional scale. This effort provided multi-species escapement data for six independent and eight potentially independent populations and two Diversity Strata within the CCCESU. We selected 41 reaches in a Generalized Random Tessellation Stratified (GRTS) design. During summer 2009 we field verified and gained access to these reaches, and then conducted spawning surveys during winter 2009-10. We continued operation of three LCS's to monitor populations in Caspar Creek, Pudding Creek, and the South Fork Noyo River- constituting an 11 year continuous data set We used annual spawner: redd ratios from life cycle monitoring streams to calibrate regional redd counts. Nine of 41 selected GRTS reaches (21%) 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 0.79 coho salmon per redd and 1.17 steelhead per redd. Over the last nine years, we found a significant negative trend in coho salmon escapement, but not in smolt abundance. There were also significant negative trends in coho salmon marine 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 and steelhead redd density was not significantly different among streams we surveyed in the coastal Mendocino County region during 2009-10. We estimated 1,135 (95% CI 701-1,352) coho salmon redds, 1,050 (95%CI 515-1,711) adult coho salmon, 1,769 (95% CI 976-2,720) steelhead redds and 2,073 adult steelhead (95% CI 1,144-1,308) in coastal Mendocino County during 2009-10. The precision in our estimates was > 30% due 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 CESA, 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). The criteria for delisting these fish will depend on whether important populations have reached abundance thresholds (Spence et al. 2008), which is one of the four key components of the Viable Salmonid Population concept developed by the National Marine Fisheries Service (McElhany et al. 2000). The recovery strategies for both coho and steelhead (CDFG 2004, McEwan and Jackson 1996) identify population monitoring as critical to assess the effectiveness of recovery actions and 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). This 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 regional adult population are collected in a spatially explicit rotating panel design (Overton and McDonald 1998). Crawford and Rumsey's (2009) guidance for monitoring the recovery of Pacific salmon and steelhead and the Salmon Monitoring Advisor (see https://salmonmonitoringadvisor.org/) reccomend a robust unbiased spawner abundance sampling design using a spatially balanced probabilistic approach (e.g. Generalized Random Tessellation Stratified -GRTS, Larsen et al. 2008). Similarly, Boydstun and McDonald (2005) and Adams et al. (2010) 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 GRTS 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. 2010).

The Action Plan, described above, was tested and further developed in a three year pilot study (2006-2008) (Gallagher et al. 2010 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. (2010 a) 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. (2010 b) 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 or 15%, whichever resulted in fewer 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 implementation of the CMP 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. This effort provided a second year (2009-10) of escapement data for six independent and eight potentially independent populations and two Diversity Strata within the CCCESU. And this work also increased the time series of smolt and adult data for the LCS streams to 11 years. We field verified and gained access to 41 reaches during summer 2009 and conducted spawning surveys in these reaches during winter 2009-10. 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 (2001-2010) in Pudding Creek, and it has been operated as an LCS by Campbell Timberlands Management since 2006. The South Fork Noyo River has a long history of coho data relating to the Noyo Egg Collecting Station (ECS) and known numbers of coho salmon can be marked and released above this structure. There are over 11 years data on escapement, redd counts, and smolt abundance above the ECS (2000-2010). 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 4.9 km from the ocean with funding from the 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 an LCS since 2004-05.

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 17.5 km from the ocean, 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.

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 2009 to late-April 2010 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. The average of these estimates were then used to convert regional redd counts into fish numbers.

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 early-March and checked daily until early-June 2010. 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 tried to operate a smolt capture trap in the fish ladder during spring 2010.

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). To further examine tag loss and survival during spring 2010 every other salmonid > 60 mm captured in Pudding Creek was given only a maxillary clip (on the opposite side of the fish relative to those given both mark types. 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 our methods for regional sampling. Similarly we randomly selected four 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 apparent coho egg to smolt and smolt to adult survival for the three LCS streams over six years from smolt abundance data from 2000 to 2009 and adult return data from 2000 through 2009-10. To estimate egg abundance we used the relationship between fecundity and fork length from Shapovalov and Taft (1954) and the average length and the total number of females observed in each stream each year. Coho spawner/recruit (spawner/spawner) ratios for eight 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 and detected in our arrays was divided by the total number of PIT tags deployed in summer.

We used key-factor analysis following Guy and Brown (2007) and our estimates of marine (smolt to adult) and freshwater (egg to smolt) survival to determine which factor was more important in the observed variability in population abundance over our time series. Key-factor analysis is based on the idea that there is variation in survival at different life stages and variation in one life stage can affect abundance in later stages, with the most influential potentially driving overall population dynamics (Guy and Brown 2007). We also used the key-factor data to examine density dependence in the freshwater and marine environments by regressing each life stage k-value (k values = log of stage specific survival value * -1) against the number of individuals entering that life stage. If the regression is statistically significant density-dependence is suspected (Guy and Brown 2007). For those instances where we suspected density-dependence we fit our data to Beverton-Holt and Ricker spawner: recruit curves (Guy and Brown 2007, Hilborn and Walters 1992) and evaluated potential carrying capacity and related survival parameters.

Trends in Coho Salmon Abundance

Trends in coho and steelhead abundance, productivity, and survival over 11 years and nine 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 abundance versus year were examined with t-tests.

Regional Spawning Survey Abundance Estimation

We conducted biweekly spawning ground surveys in 41 regional GRTS reaches from December 2009 to April 2010. To improve the utility of the data set to track population trends we used a three year rotating panel design with 40% of the selected reaches sampled every year (Trent McDonald Personal Communication). Table 1 shows the reaches sampled during 2009-10. 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 (Gallagher et al. 2010a). 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) and Adams et al. (2010) to estimate regional abundance where the average number of redds in our 41 reaches was multiplied by the total number of reaches 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 and coefficients of variation (CV). Narrower 95% confidence intervals (and thus smaller SD) and smaller CV's 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 paired 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 GRTS Draw

Nine of the 41 GRTS reaches (21%) were unavailable for sampling because landowners denied us permission to enter. These reaches were replaced by the next nine in the list (reaches 17-19, 75-76, and 78-80) to fill out our required sample size of n = 41 or a 12% sample. Sampling the 41 reaches selected for this study resulted in a 14% sample of all identified Chinook reaches (n = 16 of 113 identified Chinook reaches) for evaluating Chinook escapement sample size and reach variances. The GRTS sample resulted in sampling reaches in all independent populations in the two coho salmon diversity strata in the CCC ESU.

Life Cycle Monitoring

Adult Escapement

We estimated 5 adult coho salmon returned to Caspar Creek, 63 to the SF Noyo River above the ECS, and 9 to Pudding Creek. Steelhead escapement was estimated at 37 to Caspar Creek, 61 to Noyo River ECS, and 27 Pudding Creek. Details are provided below.

We did not tag any coho salmon in Caspar Creek and observed four untagged fish above the weir. Therefore we were not able to generate a capture-recapture estimate for coho salmon in this stream. However, we used the live fish observations and the multi-year average residence time from Gallagher et al (2010b) to generate an Area-Under-the Curve estimate of 5 coho salmon (95% CI 3-9). This estimate had a 95% confidence width of 59% (Table 2). We tagged and released 42 coho salmon above the Noyo River ECS and observed 15 tagged and eight untagged fish during spawning ground surveys. We estimated a total of 63 (95% CI 42-112, CV = 0.25, confidence limit width = 55%) coho salmon were above the ECS. In Pudding Creek we estimated there were 9 coho salmon (95% CI 4-27, CV = 0.52, confidence limit width 126%).

We captured and tagged 13 steelhead in Caspar Creek and observed three tagged and one untagged fish above the weir. Thus we estimated there were 37 (95% CI 18-178, CV = 0.58, 95%, confidence limit width = 220%) steelhead in this stream (Table 3). We tagged and released 13 steelhead above the Noyo River ECS and observed two tagged and nine unmarked steelhead during spawning ground surveys. We estimated there were 61 (95% CI 35-3,608, CV = 0.71, confidence limit width = 2,912%) steelhead above the ECS. In Pudding Creek we estimated there were 27 steelhead (95% CI 12-225, CV = 0.71, confidence limit width = 400%).

All live recaptured coho salmon and steelhead had both their floy tags and operculum punches, thus this type of tag loss was 0%. All carcasses had their floy tags but two lost their operculum punch. Therefore floy tag loss on carcasses was 0% and operculum punch loss was 22.2%. Of the 44 coho salmon adults captured with PIT tags (0 in Caspar, 42 in SF Noyo, and 2 in Pudding Creek); only one did not have a maxillary clip. We captured two adult salmon with maxillary clips that did not have PIT tags. Thus PIT tag loss was 11.1% and maxillary clip loss was 5.9%. From these data we estimated that one coho salmon lost both types of marks.

All PIT tag recaptured coho salmon adults were originally marked as smolts in spring 2008. These fish were between 84 and 115 mm (average = 97, SE = 9.3) when captured and tagged as smolts between March and May 2008. Average smolt size in the Noyo River during 2008 was 97 mm (SE = 9.3mm). These fish spent about 18 months in the ocean and returned at between 59cm and 67cm fork length (average = 64.4cm, SE = 0.90cm). The female: male ratio of the returned PIT tagged fish in the South Fork Noyo River was 0.89:1.00. The female: male ratio of the returned PIT tagged fish in Pudding Creek was 0.89:1.00.

The steelhead female to male ratio was 1.17:1.00 in Caspar Creek and in the South Fork Noyo River. In Pudding Creek the steelhead female to male ratio was 1.00:1.00.

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 0.79 coho salmon per redd. Because we could not make a mark-recapture estimate for coho salmon in Caspar Creek, we did not use this data for calculating spawner: redd ratios for this species. We estimated 1.17 steelhead per redd from our mark-recapture experiments and redd surveys in our LCS streams in 2010.

Smolt Abundance

Coho smolt abundance estimates were highest in Pudding Creek and lowest in Little River in spring 2010 (Table 4). We did not mark any coho salmon or steelhead with PIT tags in Caspar Creek or the South Fork Noyo River during spring 2010 because adult returns were very low in 2008-09 and we did not anticipate a large number of smolts to be available for tagging. Using fin clips we estimated Caspar Creek smolt production of 659 (SE = 57) coho salmon and 1281 (SE = 111) steelhead during spring 2010 (Tables 4 and 5). In Pudding Creek we marked 2,222 coho salmon and 251 steelhead with PIT tags and estimated 13,920 (SE = 586) coho smolts and 2,727 (SE =162) steelhead smolts. Our smolt estimates for the South Fork Noyo River were 2,965 (SE = 122) steelhead and 951 (SE = 52) coho salmon. At a trap installed at the Pudding Creek Dam we PIT tagged 39 coho salmon and 2 steelhead smolts. We did not estimate smolt abundance for this trap during spring 2010 because we weren't able to operate this trap continuously due to high flows.

Based on captures in our downstream traps, the percentage of coho salmon displaying two-year stream residency life history was low averaging 0.81% over four years in three streams. In the three streams where we used PIT tags we recaptured a number of coho salmon in the smolt traps during spring that were first marked 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 0.85% (range 0.20% to 1.22%) 2006 to 2007, 0.69% (range 0.09% to 1.62%) in 2007 to 2008, 1.19% (range 0.54% to 2.13%) during 2008 to 2009, and 0.50% (range 0.22% to 0.76%). Treating the streams as replicates there was a significant difference in the proportion of fish with this life history among three streams (ANOVA f = 0.571, df = 11, p = 0.02, α = 0.63). When examined individually there was a significant difference between Caspar Creek and the South Fork Noyo River (Tukey's q = 4.77, p = 0.02) but no significant difference between Pudding Creek and Caspar Creek or the South Fork Noyo River (Tukeys q < 3.20, p > 0.11). However, the data from our PIT tag arrays in Caspar and Pudding Creeks suggests the percentage of coho salmon displaying two-year stream rearing was higher than estimated from trap data alone. The average percentage of coho salmon showing a two-year life history with recapture detections and trap captures combined was 2.5% for Pudding Creek and 19.2% (2009 data only). In Pudding Creek this proportion was higher in 2009 (3.9%) than in 2010 (1.1%). However, because there was only one array at the Dam on Pudding Creek we were not able to estimate the detection probabilities and we assume the number of fish with two year freshwater rearing was actually higher.

Late-Summer Juvenile Abundance

We PIT tagged 214 coho salmon in Pudding Creek during fall 2009 electrofishing operations. We did not PIT tag any fish in Caspar Creek this season during electro-fishing. The average coho salmon density in Caspar Creek was 0.09 (SD = 0.18) fish per meter and estimated there were 704 coho juveniles in this stream during fall 2009. We estimated there were 20,632 (95% ci 2697 to 39,273) coho in Pudding Creek in September 2009.

Survival

Coho salmon egg to smolt survival (freshwater) ranged from 1% to over 20% over the last nine years and was very similar among the three LCS (Figure 4a). From our summer population and smolt trap captures we estimated 2009-10 overwinter (Parr to smolt survival) in Caspar Creek at 0.94 (95% CI 0.00-1.00) and in Pudding Creek it was 0.66 (95% CI 0.36-2.02). Coho smolt to adult (marine) survival was similar among streams over nine years and ranged from 0.002 to 0.17 (Figure 4b, Table 6) as marine survival declined freshwater survival increased (Figure 4c). Treating years as replicates smolt to adult survival was not significantly different among streams (ANOVA H = 5.54, df = 3, p = 0.14). Treating streams as replicates smolt to adult survival was significantly different over eight years (ANOVA H = 22.37, df = 8, p = 0.004). Examined individually there was no difference among years (Dunn's q < 2.86, p > 0.05).

Based on our downstream trapping and adult mark-recapture population estimates the 2008 smolt to 2009-10 adult survival was >1% at two of three LCS (Table 6). In the South Fork Noyo River the smolt to adult survival thus estimated was 0.02 (2.00%). 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 0.028 (2.80%). Smolt to adult survival has been low over the past four years yet appears improved slightly in 2010 compared to the previous three years. Smolt to adult survival in Pudding Creek from smolts PIT tagged in 2008 to adult returns in 2008-09 was 0.20% (0.002). These estimates are very similar to our apparent survival estimates based on the comparison of abundance estimates of these two life stages (Table 6).

For the following coho cohort classes the recruits per spawner were less than 1: 2002-03 to 2005-06; 2003-04 to 2006-07; 2004-05 to 2007-08; 2005-06 to 2008-09; and 2006-07 to 2009-10 (Table 6). Treating years as replicates, recruits per spawner estimates were not significantly different among streams (ANOVA H = 0.55, df = 3, 8, p = 0.91). When streams were treated as replicates, recruits per spawner estimates were significantly different over seven years (ANOVA H = 23.84, df = 7, 8, p = 0.001). Examined by year recruits per spawner were only significantly different between 2001-04 and 2005-08 (Dunn's q = 3.38, p < 0.05). There were no other significant differences in recruits per spawner for the other years data (Dunn's q <3.09, p > 0.05).

Trends in Coho Salmon Abundance, Productivity, and Survival

There was no significant regional trend in coho salmon escapement over the last 11 years (Figure 5a). When examined by year class no cohort showed a significant negative trend in escapement over three generations (Figure 5b-d). If we lower the acceptance probability to $p < 0.10$ one of the three cohorts exhibited significant negative escapement trends. When evaluated by spawners per intrinsic potential-km^{-1} (Bjorkstedt et al. 2005) and using the geometric mean approach of Spence et al. (2008) there were significant negative trends in coho salmon escapement in all of the study streams over the past nine years (Tables 7-8). Based on risk categories in Spence et al. (2008) extinction risks of these populations were moderate to high (Tables 7-8).

There were no significant regional trends in coho salmon smolt abundance over the past ten years (Figure 6). Similarly, there were no significant trends in coho salmon smolt abundance for three cohorts over three to four generations (Figure 6).

Coho salmon productivity (recruits per spawner) showed a significant negative trend over the past eight years (Figure 7). Examined by year class all three cohorts showed significant negative production trends (Figure 7). Similarly, coho salmon smolt to adult (marine) survival showed a significant negative trend over the past eight years (Figure 8). All three cohorts showed a significant negative trend in smolt to adult survival over three generations (Figure 8). Freshwater (egg to smolt survival) showed a significant positive trend over the past nine years (Figure 9). Only one of three cohorts showed a significant positive trend in freshwater survival.

For coho salmon it appears that marine survival was more influential in the observed variability in population abundance over our time series than was freshwater survival. Key-factor analysis showed that marine survival more closely tracked variation in total survival than did freshwater survival (Figure 10) for all three LCS. Marine survival was relatively more important than freshwater survival for the South Fork Noyo River population (0.81 versus 0.19), for the Caspar Creek population (0.70 versus 0.30), and for the Pudding Creek population (0.99 versus 0.01). Thus it is reasonable to conclude that marine survival drove coho salmon population abundance over this time period.

Our k-value versus life stage abundance regression analysis indicates density dependence in freshwater but not in the marine environment (Figure 11). This pattern was the same in all three LCS. Regressions of freshwater life stage k-values against the number of eggs estimated in each stream were statistically significant. However, marine k-values versus smolt abundance regressions were not significant (Figure 11).

We fit our smolt and egg data to Beverton-Holt and Ricker recruitment functions and examined the resulting graphs to help identify carrying capacity. Pudding Creek appears the most productive and had a smolt carrying capacity of around 20,000 animals (Figure 12). Caspar Creek appears to have a smolt carrying capacity of about 4,500 individuals and the South Fork Noyo River asymptotes at about 8,000 smolts.

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 = 13.37, df = 13, p = 0.42) during 2009-10 (Figure 13). Steelhead redd density was not significantly different among streams we surveyed in coastal Mendocino County (ANOVA H = 12.94, df = 13, p = 0.45) during 2009-10.

Chinook salmon redd density was not significantly different among streams in our study area (ANOVA H = 1.18, df = 4, p = 0.88).

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 1,327 (95% CI 651-2,161) coho salmon redds and 1,050 (95%CI 515-1,711) adult coho salmon in coastal Mendocino County during 2009-10 (Table 2). Coho salmon confidence limit widths were 57% with n = 41 and decreased to 42% when we included reaches from the LCS's (n =80). There were 1,769 (95% CI 976-2,270) steelhead redds and 2,073 (95% CI 1,144-3,188) adult steelhead escaped to spawn in coastal Mendocino streams (Table 3). Steelhead confidence limit widths were 49% at n = 41 and 33% at n = 80. The Chinook salmon escapement estimate was 50 (95% CI 0-125) and we estimated there were 20 Chinook salmon redds in coastal Mendocino streams during 2009-10 (Table 9).

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 (Tables 2, 3 and 9). Individual stream estimated confidence limit widths ranged from 70% to 128% for coho salmon, 52% to 106% for steelhead, and 129% to 155% for Chinook salmon. There were a number of streams where we did not observe any salmon or steelhead redds and thus did not estimate escapement for these streams Tables 2, 3, 9).

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 ($t = 1.079$, $df = 4$, $p = 0.35$, $\alpha = 0.06$). Similarly, steelhead census redd counts and estimates made by multiplying regional redd density by stream length were not significantly different ($W = 7$, n= 11:4, $p = 0.44$).

Although redd density was not significantly different among streams, coho salmon and steelhead redds were distributed in a clumped spatial pattern (Standardized Morasita Index = 0.52, and 0.51, respectively). We found Chinook salmon redds in 25% of the reaches surveyed for this species and did not observe alive or dead Chinook salmon in any reaches during 2009-10. We observed coho salmon redds in 44% and adult coho in 19% of the survey reaches. We observed steelhead redds in 70% and adult steelhead in 30% of the survey reaches.

The confidence limit widths for our regional sampling were greater than 30% (Tables 2, 3, and 9). Using data collected for this region during 2009-10, it appears to attain confidence limits with 30% precision and 90% certainty we need to sample 184 coho salmon reaches, 241 Chinook salmon reaches, and 74 steelhead reaches (Table 10). This level of sampling would require sampling more than half 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 leveled out at n = 41 and did not substantially decrease after n = 58 reaches (Figure 14). The coefficient of variation in mean coho salmon redd density was 2.11 at n = 41 and improved slightly with continued sampling (cv = 1.88 at n = 80). For steelhead the variation about mean redd density did not substantially decrease after about 43 reaches (Figure 14b) and coefficient of variation was 1.61 at n = 41 and did not improve with continued sampling (cv = 1.67 at n = 80). 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 14c). However, the sample size was small.

DISCUSSION

Mendocino Coast Regional Sample

The Action Plan (Boydstun and McDonald 2005) suggests a 3, 12, 30 year revisit design. These rotations are based on the life cycles of salmonids present in the area. The Action Plan states that 40% of the GRTS sample reaches should be assigned as annual samples. In 2008-09 our sample rotation was 40% (16) of the 41 reaches were sampled every year and the remaining 60% were selected following our 2008-09 study (Gallagher and Wright, 2008). Where, in 2007-08 we sampled reaches 1 to 41 and in 2009-10 we sampled reaches 1-16 and 42 to 66. We were unable to sample 21% of the selected GRTS reaches due to land owners refusing us access to sections of stream on their property. These reaches were replaced by the next reaches in the GRTS list to fill our sample size of 41 (Table 1). The unusable sample rate for 2009-10 was almost identical to that of 2008-09.

Life Cycle Monitoring

Adult Abundance

The coho salmon escapement estimate in Caspar Creek was based on AUC because we did not capture and tag any fish at our weir. Abundance was very low in all three streams this season resulting in low precision in our escapement estimates. In the South Fork Noyo River and Pudding Creek our precision was above the 30% recommended by Jacobs and Nickelson (1998) for monitoring coho salmon. Crawford and Rumssey (2009) suggest that salmon monitoring strive for CV’s of ± 15%. The CV’s for our coho mark-recapture experiments in Pudding Creek (55%) and the South Fork Noyo River (25%) were above this level. However, Krebs (1989) states that CV’s for fish populations generally range from 0.50-2.00(50% to 200%), indicating that Crawford and Rumsey’s suggestion that monitoring strives for CV’s of ± 15% is optimistic and perhaps unattainable. Our lack of precision in our capture recapture data is likely the result of too few observations of marked fish, a result of low overall spawner abundance. We only observed a total of 10 marked coho salmon in creeks during spawning ground surveys above the ECS this year. In Pudding Creek we only saw four coho salamon on the spawning grounds, three were marked. Coho escapement to our LCS's during 2009-10 was the second lowest we have observed over 11 years, with 2008-09 being the lowest. Compared to previous years where we tagged over 100 fish at Pudding Creek; we only tagged 9 coho salmon this year. This clearly influenced the precision of our estimates. In addition, an unknown number of fish may have gotten through the fish ladder early in the season because the trap was not set properly the first few days of the run. This was discovered and corrected within a few days.

Our Steelhead mark-recapture escapement estimates were very imprecise again this year. Jacobs et al. (2001) defined ± 30% as target precision levels for steelhead redd count estimates in Oregon. Gallagher et al. (2010 b) state that for steelhead, managers may have to except lower precision in steelhead estimates or use redd areas. We attributed this to low abundance and 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 achieved 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. Between 2004 and 2008 the precision in the live coho capture-recapture estimates for Pudding Creek was < 30% and in two of these years it was ≤ 25%. Since 2009 the precision in our data has been over 30%. The precision in our steelhead numbers has been > 30% over the past several years. 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, primarily due to low abundance. For this species, managers may have to accept larger uncertainties in escapement estimates. This may also hold true for coho salmon in some years (Gallagher et al. 2010b). However, management for recovery primarily means listing decisions, and a delisting decision will likely be based on data from sustained higher abundance levels when both precision and accuracy levels would be much improved.

Smolt Abundance

PIT tags allowed us to mark individual fish and collect fish specific data during multiple recaptures in Pudding Creek. We did not PIT tag salmon in Caspar Creek or in the South Fork Noyo River during 2010 because too few adults had spawned in these streams the previous winter. 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 the Pudding Creek array during 2010 are less than observed by Bell (2001). We were not able to produce detection probabilities at this array and for this reason it is very likely that the proportion of fish with two-year residency is much higher than we report here. 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 and our 2008 smolts marked at Caspar Creek caught again in 2009 (19% ± 2) suggested that about 20% of the year old coho tagged in spring 2006 remained in these streams for an additional year (Gallagher and Wright 2007). 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 our LCS are similar to those of the other coastal California streams where this life history has not been observed. Based on our recapture of adults with PIT tags first marked as smolts, the average size at smolting was about 98 mm, suggesting there is a threshold size necessary for coho migration to the ocean (Gallagher and Wright 2009). Fish that fail to meet this size by the end of spring may remain in the stream 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 (Gallagher and Wright 2009). 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 eight 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 higher in 2009-10 (except in Pudding Creek) 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 five years compared to the previous four (Table 6). Coho smolt to adult (and adult-to-adult) survival is influenced by ocean conditions at the time of ocean entry. Our key factor analysis showed that ocean survival was more influential in driving population production than was freshwater survival, furthering the notion that ocean conditions at the time coho salmon smolts immigrate to the sea is important to survival (Spence and Hall 2010).

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%) during 2009 (Gallagher and Wright 2010). This suggests that PIT tags did not influence survival differently than clipping the maxillary bone only. In Pudding Creek none of the PIT tagged returning adults were missing maxillary clips and we did not capture any fish with maxillary clips that lacked PIT tags. However in the South Fork Noyo, we had 11% PIT tag loss for adults retuning in 2010, the first year we actually saw many PIT tag returns. This is similar to Knudsen et al. (2009) where Yakima River hatchery Chinook salmon had 18% pit tag loss.

It appears rather clear that conditions in the marine environment have a greater influence on overall survival relative to freshwater. However, our Key-Factor analysis suggests there is density dependence (e.g. carrying capacity, competition, favorable habitat, etc.) in the freshwater phase of the coho salmon's life cycle but there is no evidence for density dependence in the marine environment Figure (11). Thus we believe by further investigating this observation, such as examining egg to parr and par to smolt survival relative to physical variables like stream flow and habitat conditions during different seasons, we can discover where in the freshwater environment these factors affect population dynamics and begin to understand the mechanisms that influence survival and abundance in these three streams. Fitting our egg and smolt abundance estimates to spawner-recruitment curves (Figure 12) gives us a rough idea of carrying capacity in these three streams. One obvious result of this exercise is the observation that Pudding Creek appears to be two to three times more productive in terms of smolt abundance than either the South Fork Noyo River or Caspar Creek. The question becomes, why? The South Fork Noyo is somewhat larger, and Caspar Creek somewhat smaller, than Pudding Creek. But these streams are all very close to each other. The task now is to further evaluate our data (adding parr abundance) and reexamining key-factors and recruitment as well as evaluating physical data such as summer low/ winter high flows, temperature, sediment, turbidity, etc. so we can begin to understand where between eggs and smolts is limiting. As we learn about these factors and the mechanisms driving them we can formulate hypotheses and develop experiments and restoration actions to improve freshwater conditions.

Trends in Coho Salmon Abundance, Productivity, and Survival

We did not find significant trends in coho escapement over 10 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 7-8) and there was a negative trend in the geometric mean escapement for all four LCS coho populations. When we examined escapement trends by cohort none showed a significant negative trend at $p < 0.05$. If we increase the p-value for accepting statistical significance to $p \leq 0.10$, one of three cohorts showed significant negative escapement trend over 10 years. Both of these approaches to evaluate escapement trends 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 latter or because of cohort overlap that is not accounted for in our mixed model analysis but is using the geometric mean approach. Trend detection may be more appropriate over a longer time series (Spence and Williams 2011, 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 affects coho freshwater survival. When we examined adult coho salmon trends by cohort we found that only one cohort showed a significant negative trend whereas their smolt progeny did not, furthering the notion that poor ocean conditions was the cause. In addition, we saw no trends in smolt abundance and a positive trend freshwater survival, whereas productivity (recruits per spawner) and smolt to adult survival showed significant negative trends. Similar to Moore et al (In Press) low adult returns did not result in low smolt abundance. This coupled with our key factor analysis that showed that marine survival drives populations in our LCS suggests that ocean rather than freshwater conditions may be responsible for the negative trends we observed.

We did not examine steelhead trends due to the short time series in the data (only nine 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

For the second consecutive year 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, six independent populations, and eight 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 of 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. 2010 b, Gallagher and Wright 2008) if redd density variation in the 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 2009-10, a systematic rather than design based GRTS sample, precision in our estimates improved for coho salmon (42% versus 57%) and steelhead (33% versus 49%). However, the coefficient of variation did not improve with increased sample size for both species and variation about the mean (Figure 14) leveled out at n = 41 and did not substantially decrease after about 58 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 second lowest observed since 2000 and was outside the range of data we used earlier (Gallagher et al. 2010 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 regional CV's for coho salmon were 188% (n = 41) to 211% (n = 80) and increased sample size did not substantially 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. 2010b) 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. In addition, 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. The use of standardized data collection procedures and well trained staff (Gallagher et al. 2007) will contribute to increased precision in regional escapement monitoring. Finally, for regional and life cycle monitoring at low abundance, managers may have to accept larger uncertainties in escapement estimates. However, management for recovery primarily means listing decisions, and a delisting decision will likely be based on data from sustained higher abundance levels when both precision and accuracy levels would be much improved.

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).

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PERSONAL COMMUNICATIONS

Trent McDonald, West Inc., Laramie Wyoming, November 2006. October 2009
Dana McCain, Institute for River Ecosystems, Arcata, CA August 2005.
Glen Szerlong, NOAA Fisheries Santa Cruz, August 2004.

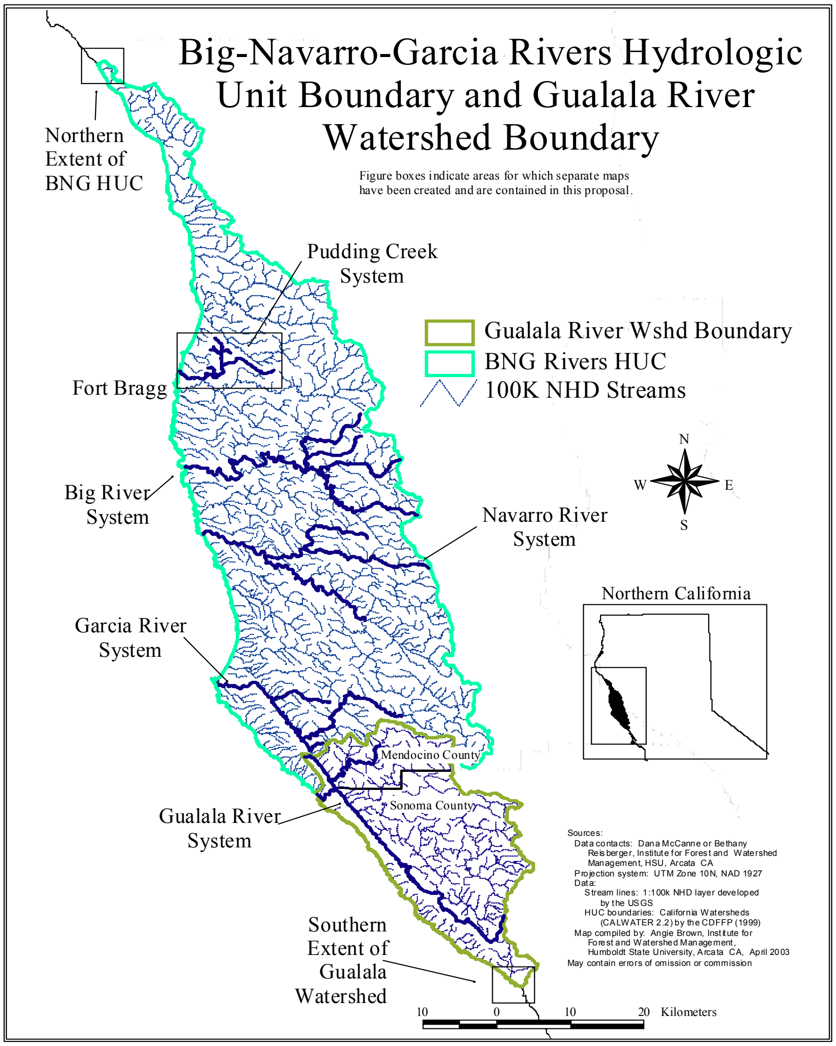
Big-Navarro-Garcia Rivers Hydrologic Unit Boundary and Gualala River Watershed Boundary

Figure boxes indicate areas for which separate maps have been created and are contained in this proposal.

Sources:
Data contacts: Dana McCanne or Bethany Reisberger, Institute for Forest and Watershed Management, HSU, Arcata CA
Projection system: UTM Zone 10N, NAD 1927
Data:
Stream lines: 1:100k NHD layer developed by the USGS
HUC boundaries: California Watersheds (CALWATER 2.2) by the CDFFP (1999)
Map compiled by: Angie Brown, Institute for Forest and Watershed Management, Humboldt State University, Arcata CA, April 2003
May contain errors of omission or commission

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

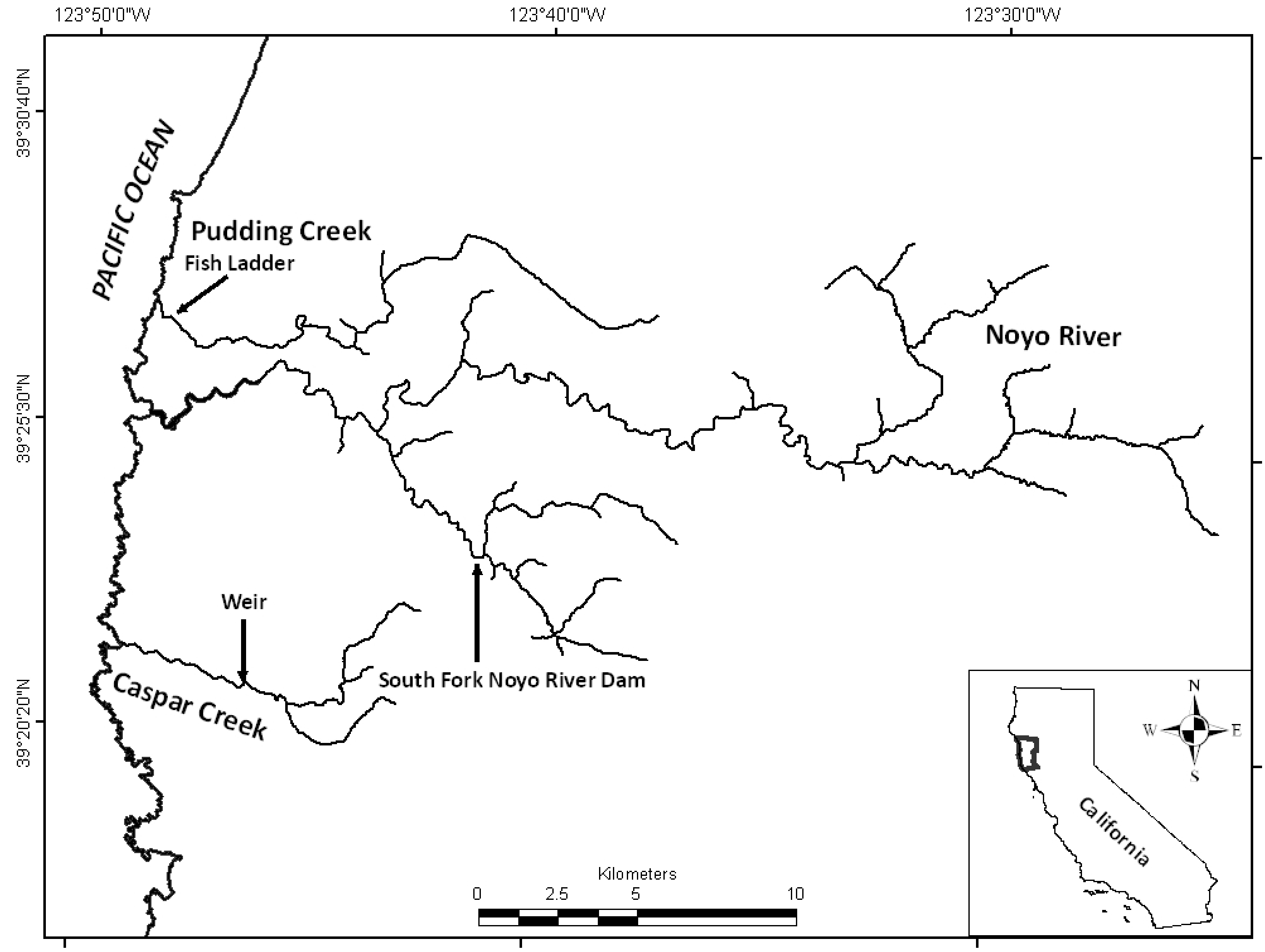

Figure 2. Location of the life cycle monitoring streams in Mendocino County, California. South Fork Noyo River Dam is the South Fork Noyo River Egg Collecting Station.

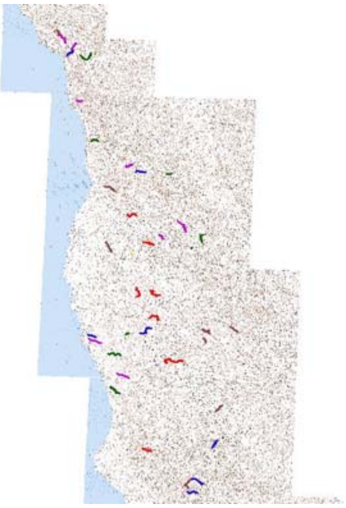

Figure 3. The spatial sample (GRTS) of the first 41 reaches for the Mendocino Coast regional CMP monitoring.

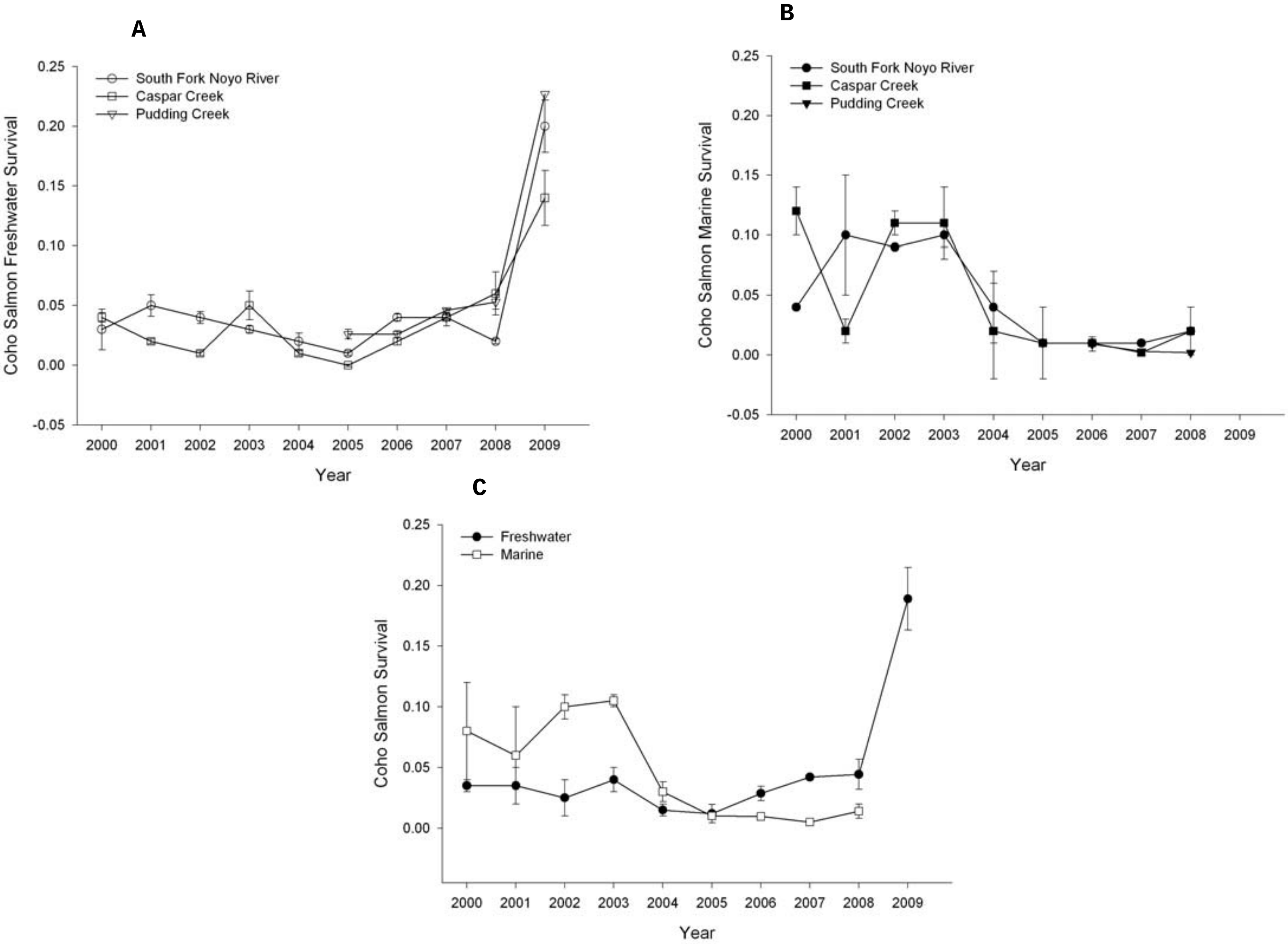

Figure 4. Coho salmon marine and freshwater survival from 2000 to 2009 in Coastal Mendocino County, California. A. Freshwater survival for three LCS streams. B. Marine survival for three streams. C. Three stream average freshwater and marine survival. Thin lines are 95 % confidence bounds. Note data are plotted by cohort so that year 2000 freshwater is eggs in 2000-01 to smolts in 2002 and marine is smolts in 2000 to adults in 2002.

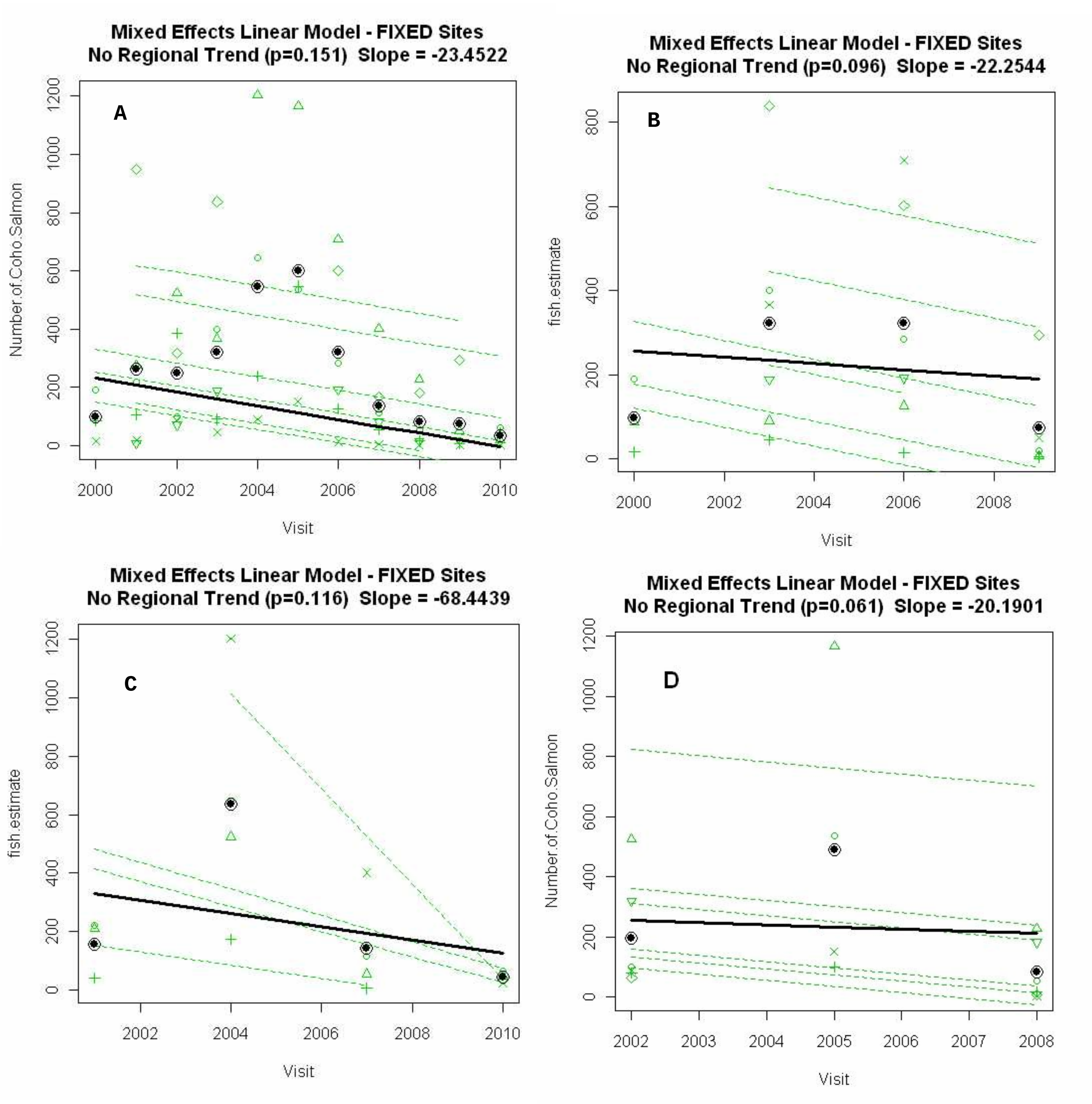

Figure 5. Coho salmon escapement trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2000 to 2010. A. All years combined. B. Cohort 1: 2000, 2003, 2006, 2009. C. Cohort 2: 2001, 2004 2007, and 2010. D. Cohort 3: 2002, 2005, 2008.

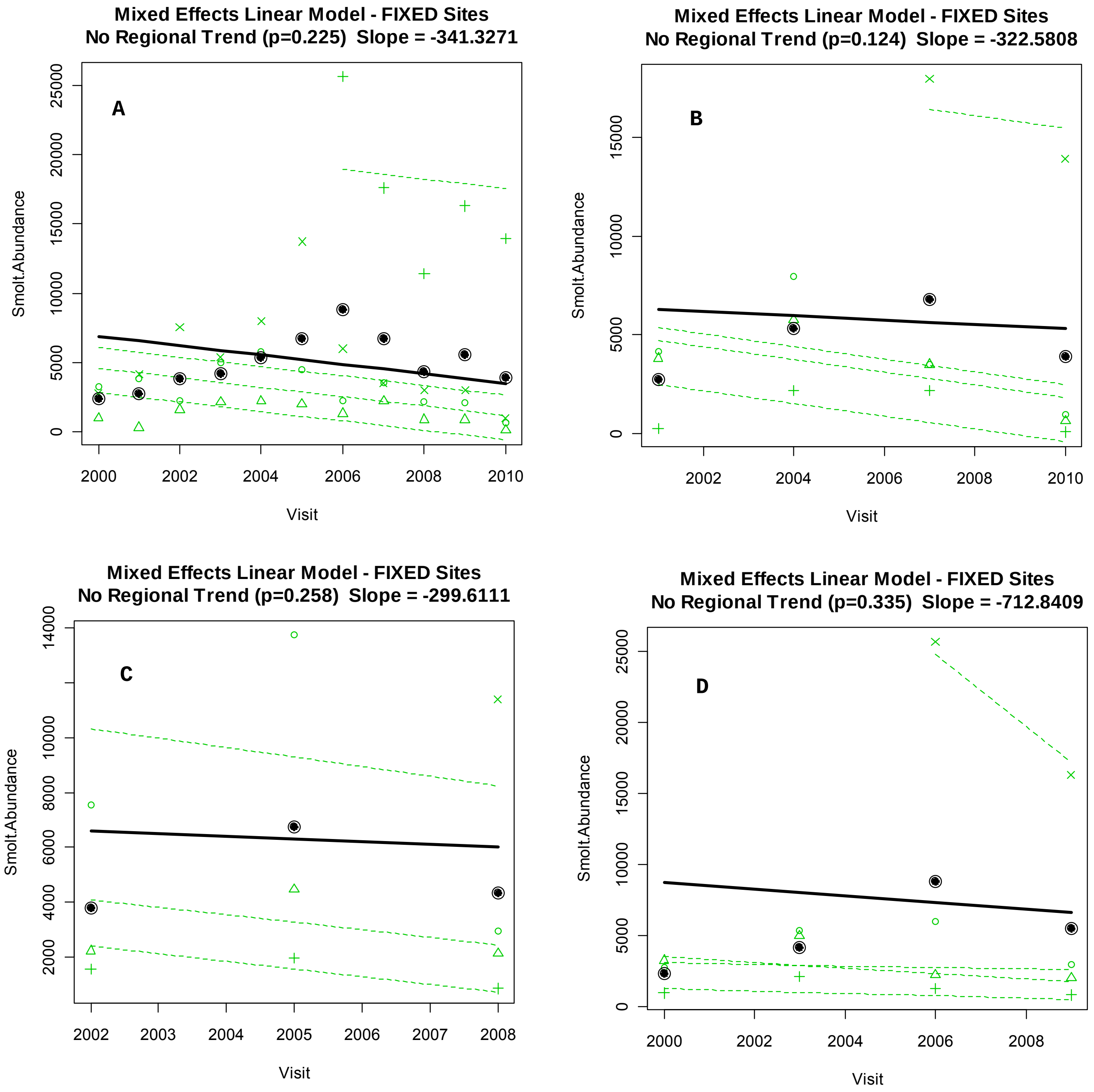

Figure 6. Coho salmon smolt abundance trends in Caspar and Pudding Creeks and the South Fork Noyo and Little Rivers 2000 to 2010. A. All years combined. B. Cohort 1: 2001, 2004, 2007, 2010. C. Cohort 2: 2002, 2005 and 2008. D. Cohort 3: 2000, 2003, 2006 and 2009.

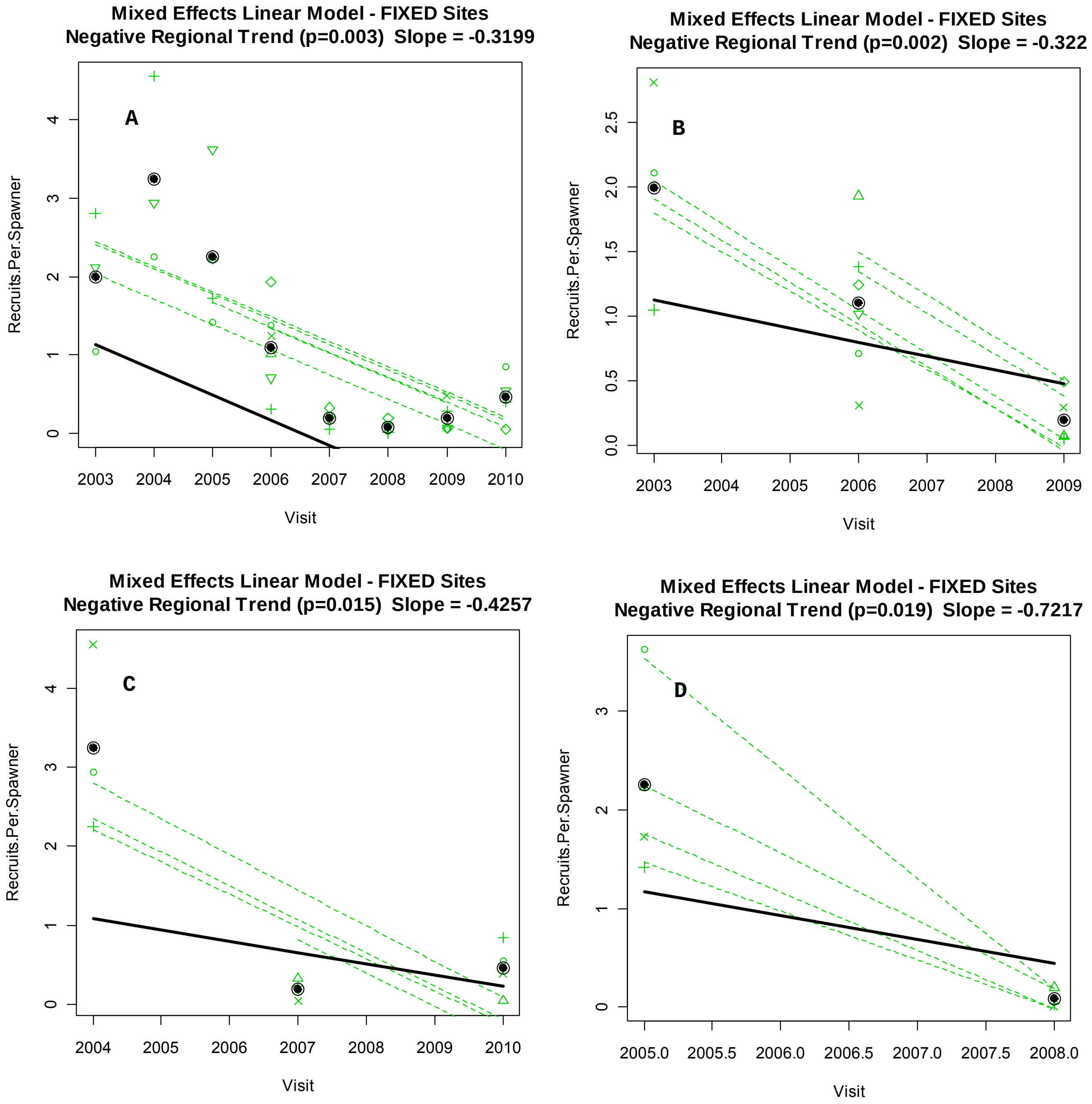

Figure 7. Coho salmon recruits per spawner trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2003 to 2010. A. All years combined. B. Cohort 1: 2003, 2006, 2009. C. Cohort 2: 2004, 2007, 2010. D. Cohort 3: 2004 and 2008.

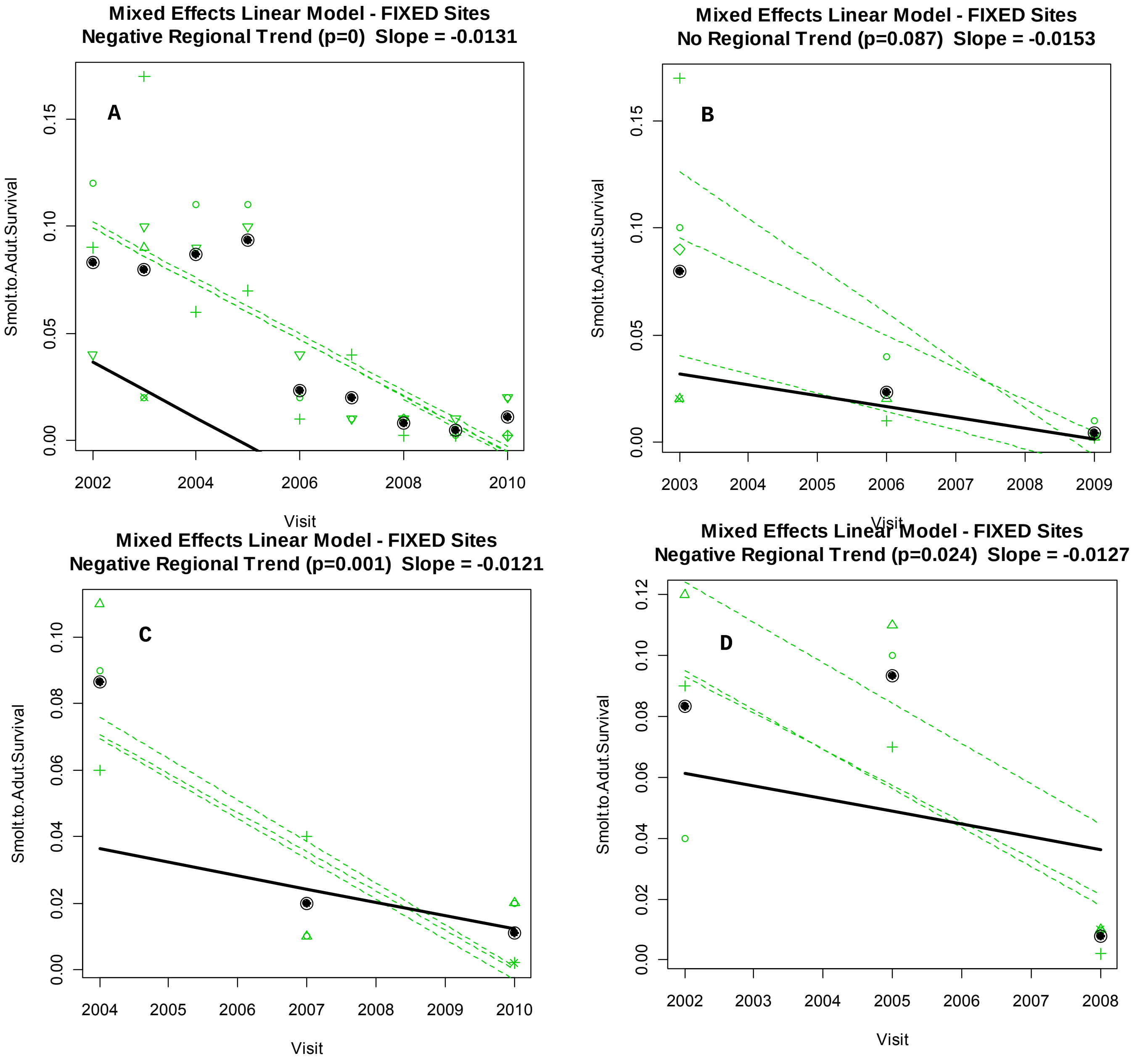

Figure 8. Coho salmon smolt to adult (marine) survival trends in Caspar and Pudding creeks and South Fork Noyo and Little rivers 2002 to 2010. A. All years combined. B. Cohort 1: 2003, 2006, 2009. C. Cohort 2: 2004, 2007, 2010. D. Cohort 3: 2004 and 2008.

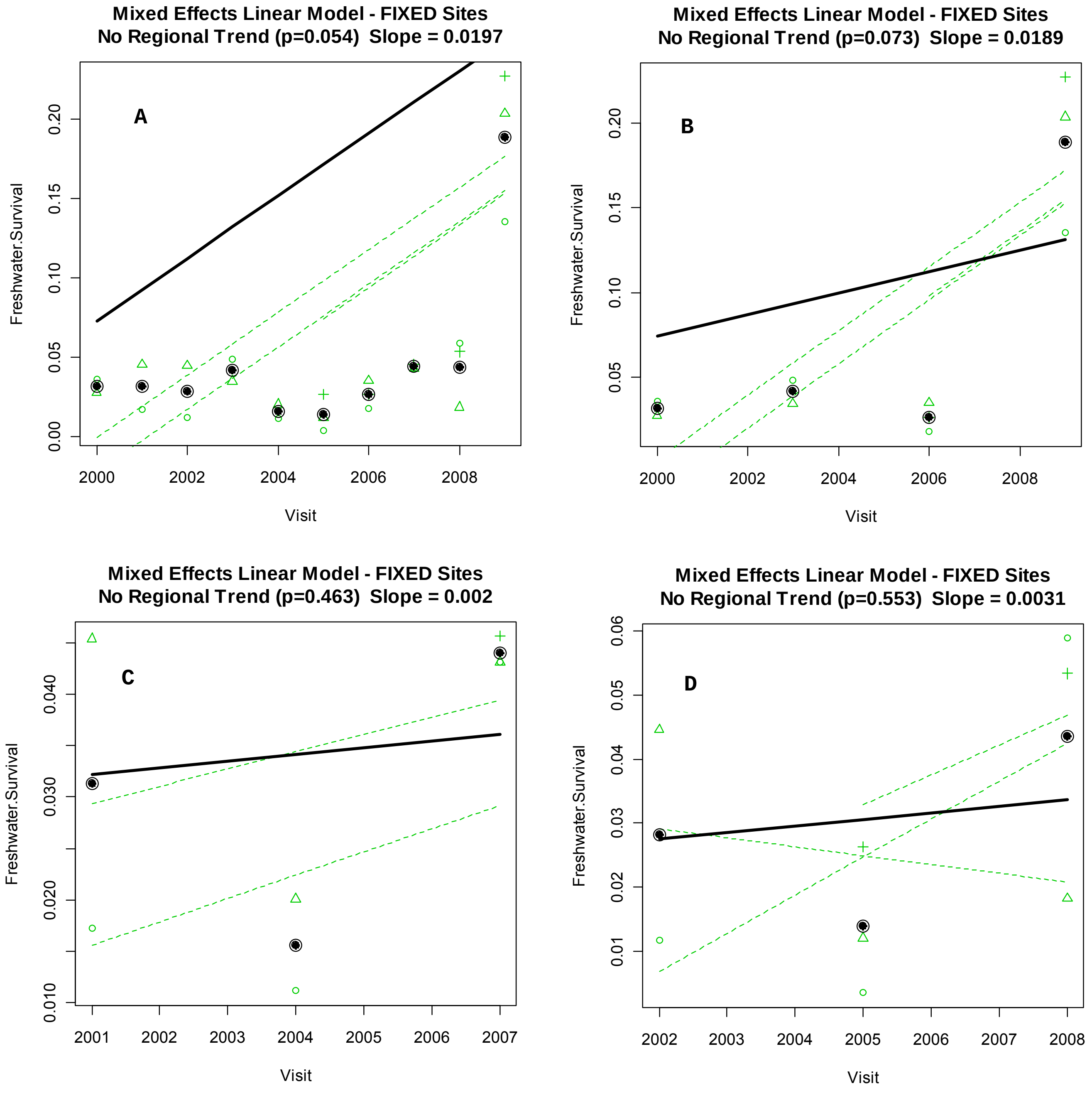

Figure 9. Coho salmon egg to smolt (freshwater) survival trends in Caspar and Pudding Creeks and South Fork Noyo and Little Rivers 2002 to 2010. A. All years combined. B. Cohort 1: 2003, 2006, 2009. C. Cohort 2: 2004, 2007, 2010. D. Cohort 3: 2004 and 2008.

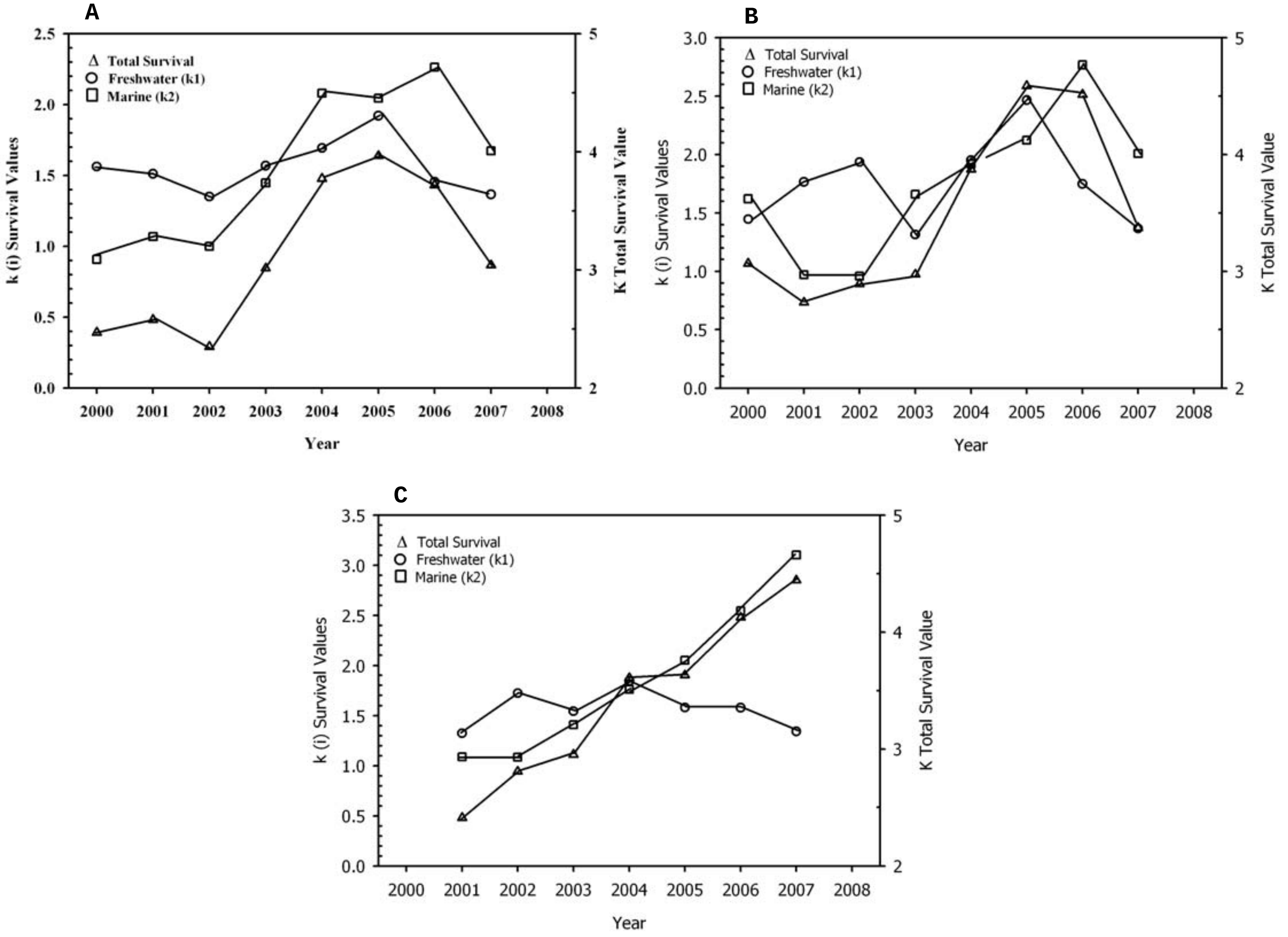

Figure 10. Key-factor survival analysis for three LCS streams in Coastal Mendocino County, California. A. South Fork Noyo River. B. Caspar Creek. C. Pudding Creek.

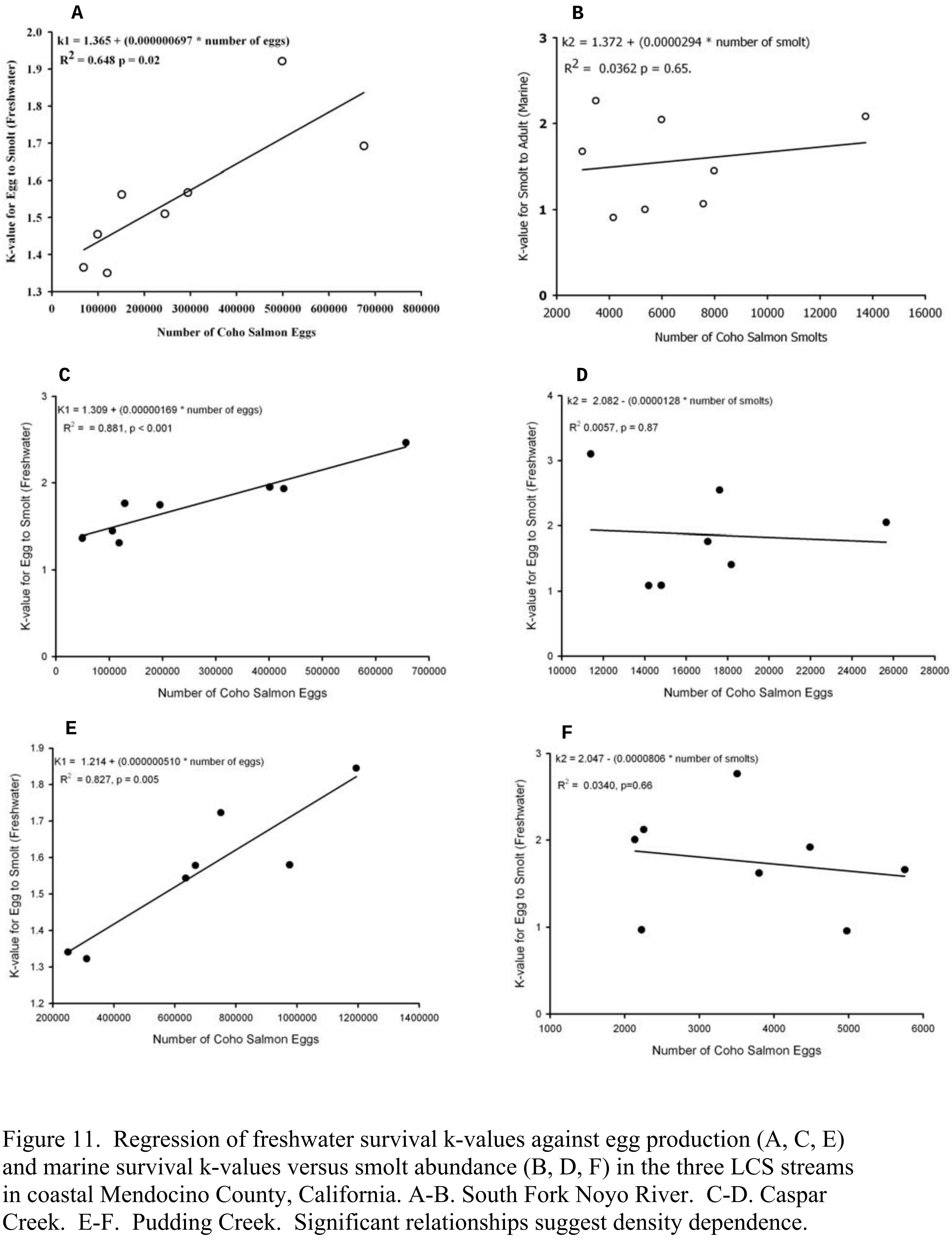

Figure 11. Regression of freshwater survival k-values against egg production (A, C, E) and marine survival k-values versus smolt abundance (B, D, F) in the three LCS streams in coastal Mendocino County, California. A-B. South Fork Noyo River. C-D. Caspar Creek. E-F. Pudding Creek. Significant relationships suggest density dependence.

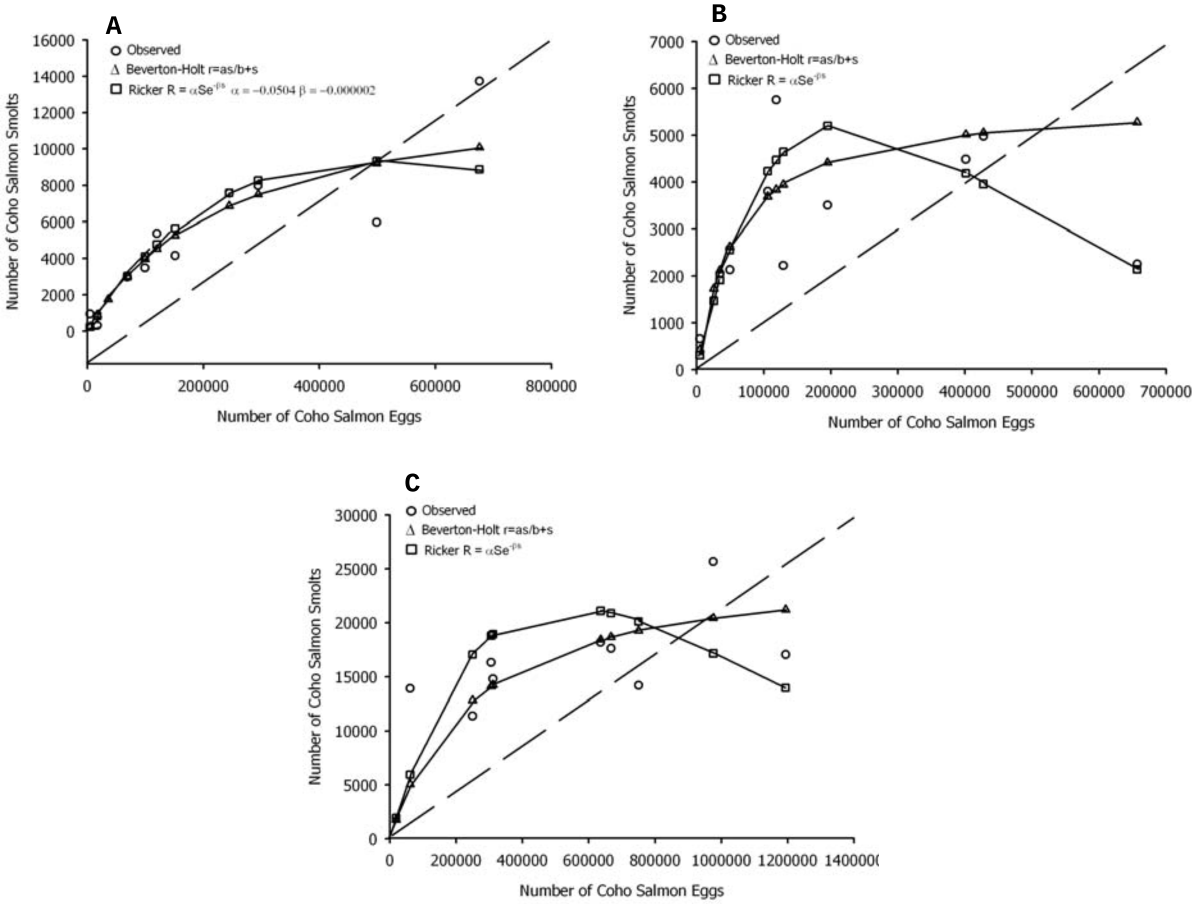

Figure 12. Coho salmon egg to smolt recruitment curves for three LCS streams in coastal Mendocino County, California. A. South Fork Noyo River. B. Caspar Creek. C. Pudding Creek. Dashed line indicates 1:1 replacement.

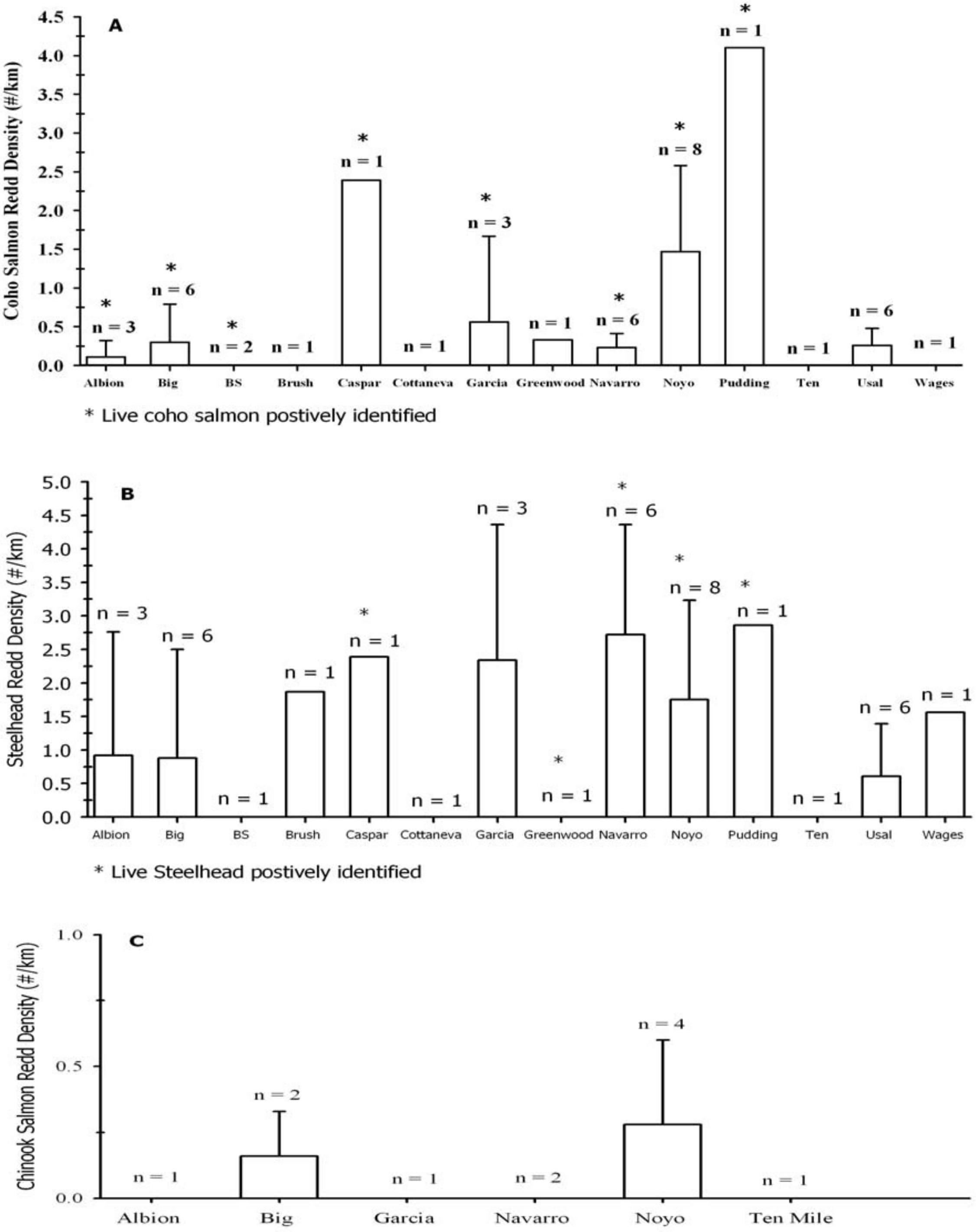

Figure 13. Redd density in coastal Mendocino streams surveyed during 2009-10. A. Coho salmon. B. Steelhead. C. Chinook salmon. Numbers indicate the number of GRTS reaches surveyed in each stream. Thin lines are 95% confidence limits. BS is Brush Creek.

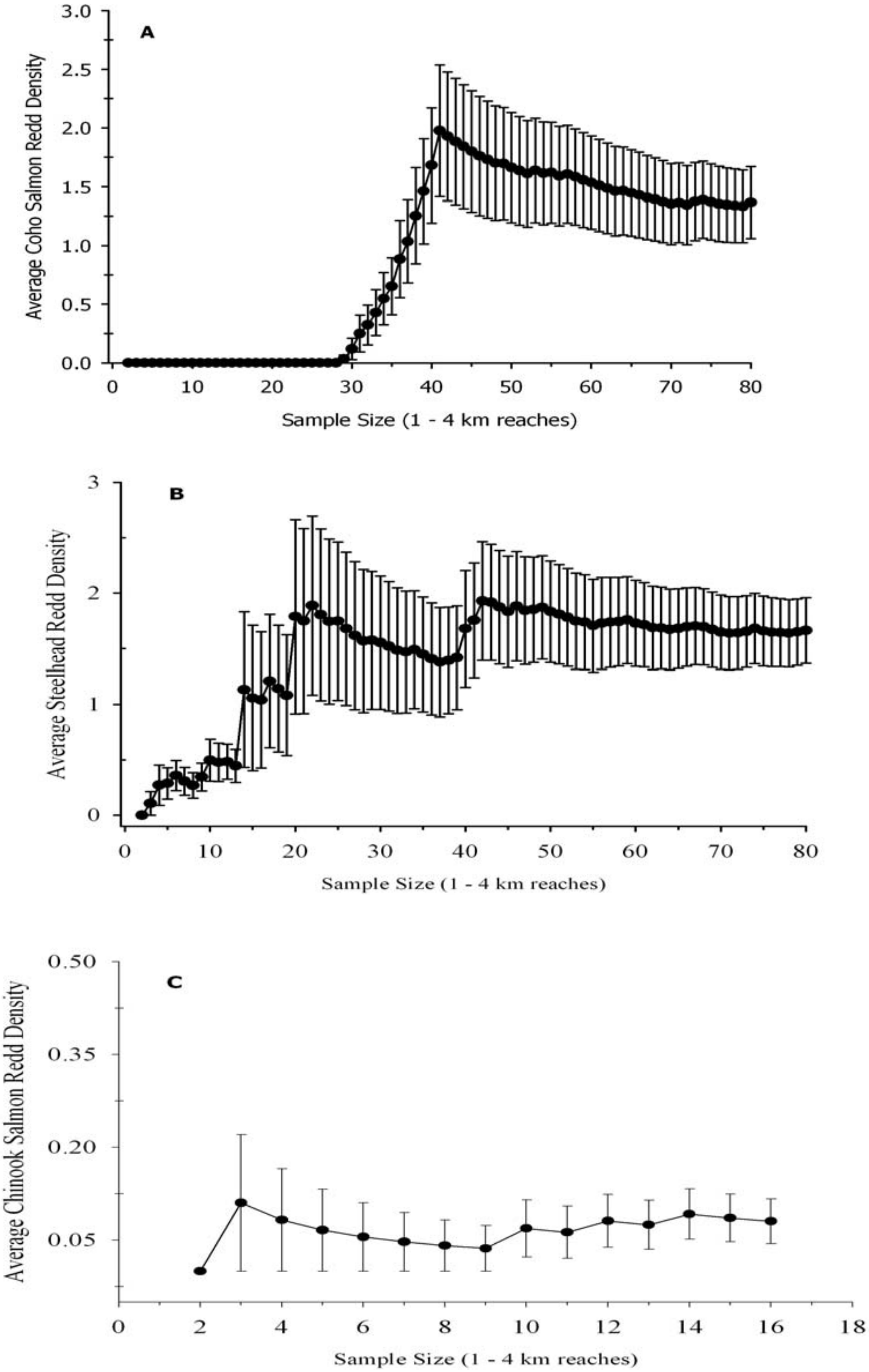

Figure 14. Cumulative mean density of coho salmon (A), steelhead (B), and Chinook salmon (C) redds (± SE) plotted against the number of sample reaches surveyed during 2009-10 in coastal Mendocino County, California.

Table 1. Grts order sample reaches and addition reaches (GRTS numbers >80 are from the LCS streams and represent a systematic sample), species designations and sample rotation for spawning survey reaches in coastal Mendocino County during 2009-10.

Stream Name	Tributary name	GRTS Order	Stream Length km	Species 1			Sample Rotation
Garcia River	Inman Creek	2	3.11	coho	steelhead		every year
Usal Creek	mainstem	3	2.41	coho	steelhead		every year
Noyo River	culi gulch	5	0.10	coho	steelhead		every year
Ten Mile River	Bear Haven Creek	6	2	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	3.40	coho	steelhead	Chinook	every year
Ten Mile River	South Fork Ten Mile River	11		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	4.20	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	South Fork Noyo River	30	3.13	coho	steelhead		year 1
Caspar Creek	mainstem	49	2.09	coho	steelhead		year 2
Navarro River	North Branch North Fork Navarro River	50	2.15	coho	steelhead	Chinook	year 2
Ten Mile River	mainstem	52	3.18	coho	steelhead	Chinook	year 2
Navarro River	Murray Gulch	53	0.57	coho	steelhead		year 2
Hare Creek	Bunker Gulch	54	1.96	coho	steelhead		year 2
Usal Creek	South Fork Usal Creek	55	2.33	coho	steelhead		year 2
Pudding Creek	mainstem	56	3.84	coho	steelhead		year 2
Little River	mainstem	57	2.83	coho	steelhead		year 2
Navarro River	mainstem	58	2.54	coho	steelhead	Chinook	year 2
Ten Mile River	Middle Fork Ten Mile River	60	2.68	coho	steelhead	Chinook	year 2
Big River	Dougherty Creek	62	2.69	coho	steelhead		year 2
Noyo River	Kass Creek	63	1.53	coho	steelhead		year 6
Usal Creek	Bear Creek	64	1.43	coho	steelhead		year 2
Noyo River	Little North Fork Noyo River	65	3.20	coho	steelhead		year 4
Noyo River	Bear Gulch	68	1.32	coho	steelhead		year 4
Cottaneva Creek	mainstem	69	3.22	coho	steelhead		year 3
Ten Mile River	Booth Gulch	70	1.14	coho	steelhead		year 3
Albion River	North Fork Albion River	71	2.61	coho	steelhead		year 3
Albion River	Little North Fork Albion River	72	0.44	coho	steelhead		year 3
Usal Creek	mainstem	73	2.46	coho	steelhead		year 3
Big River	mainstem	74	3.14	coho	steelhead	Chinook	year 3
Ten Mile River	South Fork Ten Mile River	75	3.31	coho	steelhead		year 3
Noyo River	mainstem	78	2.77	coho	steelhead	Chinook	year 3
Navarro River	South Branch North Fork Navarro River	79	1.72	coho	steelhead		year 3
Navarro River	South Branch North Fork Navarro River	80	2.98	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	0.20	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	2.80	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

Table 2. Coho salmon redd count and escapement estimates for regional monitoring of coastal Mendocino County's streams during 2009-10.

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	701	1135	1352	555	898	1308	42%
Lost Coast Diversity Strata	32	651	1327	2162	515	1059	1711	57%
Navarro Point Diversity Strata	9	137	649	1250	108	513	989	86%
Albion River	4	-	0	-	-	0	-	-
Big River	4	25	169	314	20	134	214	85%
Brush Creek[1]	1	-	0	-	-	0	-	-
Caspar Creek[2,3]	1*	-	26	-	3	5	9	56
Cottenteva Creek[1]	1	-	0	-	-	0	-	-
Garcia River	2	0	12	23	0	9	18	100%
Hare Creek[1]	1	-	0	-	-	0	-	-
Little River[2]	1*	-	1	-	-	2	-	-
Navarro River	6	200	571	998	159	452	790	70%
Noyo River	7	74	361	821	58	286	650	103%
South Fork Noyo River 2	1*	-	67	-	42	63	112	56%
Pudding Creek[2]	1*	-	14	-	4	9	27	128%
Ten Mile River	6	5	240	574	4	190	454	118
Usal Creek	6	0	3	7	0	2	5	107%
Wages Creek[1]	4	-	0	-	-	0	-	-

1 Only one reach was surveyed in this stream so confidence bounds can not be calculated.

2 Life cycle monitoring station complete census

3 Escapement etimated using AUC. No fish marked at weir.

* Number of regional GRTS reahces surveye in this LCS census stream.

Table 3. Steelhead redd count and escapement estimates for regional monitoring of coastal Mendocino County's streams during 2009-10.

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	41	976	1769	2720	1144	2073	2720	49%
Lost Coast Diversity Strata	32	725	1342	2120	849	1573	2485	52%
Navarro Point Diversity Strata	9	62	286	607	73	335	711	95%
Albion River	4	0	11	23	0	13	27	106%
Big River	4	9	96	203	11	113	238	101%
Brush Creek [1]	1	-	0	-	-	0	-	-
Caspar Creek [2]	1*	-	35	-	18	37	138	169
Cottenteva Creek [1]	1	-	16	-	-	187	-	-
Garcia River	2	69	207	345	81	243	404	66%
Hare Creek [1]	1	-	0	-	-	0	-	-
Little River [2]	1*	-	2	-	-	3	-	-
Navarro River	6	7	87	190	8	102	222	105%
Noyo River	7	175	506	921	206	593	1080	74%
South Fork Noyo River 2	1*	-	36	-	35	61	3608	169%
Pudding Creek [2]	1*	-	34	-	12	26	225	106%
Ten Mile River	6	50	162	274	59	190	321	69
Usal Creek	6	9	26	43	11	31	51	64%
Wages Creek [1]	4	-	30	-	-	35	-	-

[1] Only one reach was surveyed in this stream so confidence bounds can not be calculated.

[2] Life cycle monitoring station complete census

* Number of regional GRTS reahces surveye in this LCS census stream.

Table 4. Coho salmon smolt trap estimates for life cycle monitoring streams in coastal Mendocino County 2010. Numbers under estimates are standard errors, double these for 95% confidence limits.

Trap Location	YOY			Y+		
COHO	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability
Caspar Mainstem	34	68 48	0.5	259	659 57	0.44
Little River	0	ND	ND	33	85 22	0.5
SF Noyo	777	38073 37682	0.02	561	951 52	0.71
Pudding Creek (Screw)	47			4215	13920	0.38
Pudding Creek (Dam Trap)						

Table 5. Steelhead smolt traps estimates for life cycle monitoring streams in coastal Mendocino County 2010. Numbers under estimates are standard errors, double these for 95% confidence limits.

Trap Location	YOY			Y+ < 120			Y++			Y+ and Y++		
STHD	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability
Caspar Mainstem	1140	2736 964	0.42	297	962 119	0.39	146	334 31	0.44	443	1281 111	0.43
Little River	96	ND	ND	313	854 86	0.49	34	206 91	0.17	347	1005 104	0.44
SF Noyo	4627	22700 13298	0.23	943	2282 96	0.48	227	772 89	0.32	1170	2965 122	0.48
Pudding Creek Screw T	284			186	1124 65.00	0.31	227	1629 97.00	0.17	413	2727 162.00	0.24
Pudding Creek Dam												

Table 6. Coho salmon survival and productivity for several Mendocino County streams 2000 to 2010.

	Variable	Noyo Ecs			Pudding Creek			Caspar Creek			Little River		
		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
	2001 Smolts	1596	4152	6708	nd	nd	nd	3355	3799	4243	259	264	280
	2001 Smolts/ 2000 Adults	-	22	-	-	-	-	-	44	23	-	17	4
	2002-2003 Adults	-	401	-	333	367	401	70	91	112	42	45	48
	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
	Recruits/Spawner (03/00)	-	2.11	-	nd	nd	nd	na	1.05	0.60	nd	2.81	0.72
	2004 Smolts	7289	7975	8661	nd	nd	nd	4371	5753	7135	2038	2202	2366
	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
	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
	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
	2007 Smolts	3212	3488	3764	15313	17609	19905	2843	3505	4167	1855	2175	2495
	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	-
	Survival 07 Smolt to 09 Adult	-	0.01	-	0.002	0.003	0.005		0.002	-	- -	0.002	-
	Recruits/Spawner (09/06)	-	0.07	-	0.05	0.07	0.11		0.05	-	- -	0.29	-
chrt 2	2000-2001 Adults [9]	-	220	-	nd	279	nd	97	106	115	6	20	33
	2002 Smolts	5994	7562	9130	nd	nd	nd	1922	2224	2526	1441	1575	1709
	2002 Smolts/2001 Adults		34						21			79	
	2003-2004 Adults	530	647	706	1067	1204	1600	178	238	298	28	91	154
	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
	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
	2005 Smolts	9261	13727	18193	-	-	-	3792	4482	5172	1834	1974	2114
	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
	Survival 05 Smolt to 07 Adult	0.01	0.01	0.01	-	-	-	0.01	0.01	0.04	0.002	0.003	0.003
	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
	2008 Smolts	2829	2971	3113	10842	11390	11938	1786	2134	2491	800	863	923
	2008 Smolts / 2007 Adults	37	26	15	4	9	27	64	40	13	267	173	154
	2010 Adults	42	63	112	4	9.00	27.00		46.00			2.00	
	Survival 08 Smolt to 10 Adult	0.01	0.02	0.04	0.000	0.001	0.002		0.02			0.002	
	Recruits/Spawner (10/07)	0.55	0.55	0.55	0.01	0.02	0.04		0.85			0.40	
chrt 3	2000 Smolts	2102	2763	3424	nd	nd	nd	2889	3259	3629	917	975	1033
	2001-2002 Adults	76	112	148	438	524	610	352	386	420	50	88	126
	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
	2003 Smolts	4789	5357	5925	nd	nd	nd	4258	4976	5694	1885	2115	2345
	2003 Smolts / 2002 Adults	63.013158	48	40				12	13	14	38	24	19
	2004-2005 Adults	-	536	-	899	1167	1773	298	548	798	0	152	535
	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
	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
	2006 Smolts	4760	5980	7200	21862	25656	29450	1893	2253	2613	1176	1294	1412
	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
	Survival 06 Smolt to 08 Adult	0.003	0.01	na	0.0070	0.0089	0.0153	0.00	0.01	na	0.001	0.002	0.003
	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
	2009 Smolts	287	313	339	14367	16309	18251	1424	2044	2664	698	836	974
	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 are removed from estimates. No hatchery influence after 2004.

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 o

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 7. Coho salmon viability based on Spence et al. (2008) for several coastal Mendocino County streams 2000 through 2010.

Coho salmon viability based on Spence et al. (2008) for several coastal Mendocino County streams 2000 through 2007.

Stream	Harmonic Mean (per generation)		Number of Years	Extinction Risk [2]	Spawners/ IP-KM [4]
	Population Size	Effective Population Size [1]			
South Fork Noyo River	418	84	9	Moderate	9
Pudding Creek	957	191	7	Moderate	18
Caspar Creek	145	29	9	High	12
Little River	30	6	9	High [3]	7

1 Harmonic mean times 0.20.

[2] These data are for three generations.

[3] Spence et al. (2008) state that small stable populations are exempt.
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 8. Coho salmon trends based on Spence et al. (2008) for several coastal Mendocino County streams 2000 through 2010.

Stream	Geometric Mean	Number of Years	Slope	Negative Trend	Population Size ≤ 500
	Population Size				
South Fork Noyo River	154	9	-0.19	No [1]	Yes
Pudding Creek	271	7	-0.34	Yes	Yes
Caspar Creek	68	9	-0.35	Yes	Yes
Little River	16	9	-0.40	Yes	Yes

[1] $P = 0.08$. Significant negetive trend at $p < 0.10$.

Table 9. Chinook salmon redd count and escapement estimates for regional monitoring of coastal Mendocino County's streams during 2009-10.

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	11	0	20	50	0	50	125	125%
Lost Coast Diversity Strata	9	0	23	60	0	58	149	129%
Navarro Point Diversity Strata [2]	2	0	6	16	0	16	39	na
Albion River [2]	1	0	1	3	0	2	6	na
Big River	3	0	10	31	0	26	77	150%
Garcia River [2]	2	0	2	5	0	5	13	na
Navarro River [2]	2	0	4	10	0	10	25	na
Noyo River	3	0	9	18	0	22	44	na
Ten Mile River	3	0	7	20	0	20	51	155

[1] Escapement estimate assumes 2.5 fish per redd.

[2] Chinnok salmon redds and adults were not observed in these reaches. Estimates are based on regional average Chinook salmon redd density.

Table 10. 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 2009-10.

Precision	Confidence Limits			
	90%		95%	
	Steelhead	Coho	Steelhead	Coho
10%	665	1653	953	2370
20%	166	413	238	593
30%	74	184	106	263
40%	42	103	60	148
50%	27	66	38	95