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A REGIONAL APPROACH TO MONITORING SALMONID ABUNANCE TRENDS: A PILOT PROJECT FOR THE APPLICATION OF THE CALIFORNIA COASTAL SALMONID MONITORING PLAN IN COASTAL MENDOCINO COUNTY: YEAR III

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Coastal Mendocino County Salmonid Monitoring Project

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ABSTRACT

This report documents the results of a three-year pilot study, funded by the Fisheries Restoration Grants Program, to evaluate monitoring methodologies for California's Coastal Salmonid Monitoring Plan. We treated five coastal Mendocino County streams as a coastal region of California to evaluate the use of life cycle monitoring streams (LCS) and regional spawning surveys (SGS) for monitoring salmonid population escapement. The primary purpose of this study was to assess: 1) if the field sampling protocols provided statistically valid and accurate adult abundance estimates, 2) the logistical problems encountered, and 3) the level of resources needed for regional LCS and SGS monitoring. We examined escapement estimation methods, calibration of SGS data from LCS data, regional sampling rates and statistical power, produced annual abundance estimates, and evaluated regional trends. To estimate LCS escapement and calibrate potential bias in SGS estimates we used live fish capture-recapture methods and spawning ground surveys in three LCS. Fish were captured and tagged at the Pudding Creek fish ladder, the Noyo River Egg Collecting Station (ECS), and a floating board resistance weir in Caspar Creek. Recaptures were visual observations of fish during SGS in these streams. Redds were counted in all reaches in the three LCS. To estimate regional escapement, spawning density was estimated in a random sample of stream reaches and expanded to calculate total regional escapement. For regional SGS escapement estimates two sampling designs were used: 1) a 10% sampling rate of stream reaches in our regional area drawn by a Generalized Random Tessellation Sampling (GRTS) scheme, and 2) a 33% stream reach sampling rate in non-LCS combined with total count estimates from LCS for a Sum-of-Streams (SOS) regional estimate. Additional reaches were selected in GRTS order to evaluate results of sampling at 10%-35% GRTS during the last two years of study. To estimate adult escapement in spawning reaches we used carcass capture-recapture, live fish counts, redd counts, redd area measurements, and spawner: redd ratios developed in the LCS. We evaluated sample size and statistical power for application of this approach to regional escapement monitoring. Smolt abundance was estimated from downstream trapping in Caspar and Pudding creeks and in the Little and South Fork Noyo rivers. Available smolt abundance data from 2001 to 2008 and adult return data from 2000 through 2007-08 were used to estimate smolt to adult and adult-to-adult survival. The LCS capture-recapture methods produced reliable coho escapement estimates for Pudding Creek and the South Fork Noyo River and provided information for reducing bias in SGS estimates. The coho and steelhead capture-recapture estimates for the other LCS streams had large confidence bounds due to the low numbers of marked and recaptured fish. Carcass capture-recapture was not reliable because too few carcasses were observed. Regional SGS escapement was best-estimated using spawner: redd ratios developed at LCS streams. The 10% GRTS escapement estimates were not different from the SOS estimates and precision was within 30%. Increasing GRTS sampling effort did not improve the escapement estimates or their precision. Further examination of reach variance and its effect on sample size, in conjunction with establishing the coast-wide transferability of spawner: redd ratios, is an important next step in developing a GRTS based two-stage monitoring program for California's coastal salmonids. The results of this study suggest that a sample size of $\geq$ 40 reaches should have sufficient statistical power to detect regional trends in salmon populations. We recommend that this regional escapement monitoring approach be employed and tested at actual regional spatial scales consistent with ESA recovery planning efforts.

INTRODUCTION

Accurate estimates of escapement are essential for effective management and conservation of salmonids (Busby et al. 1996, McElhany et al. 2000). In coastal Northern California Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutc*h) and steelhead (*O. mykiss*) are listed species under the U. S. Endangered Species Act (Federal Register 1999, 2000, 2005). Coastal coho salmon are also listed under the California State ESA as threatened in coastal Northern California (CDFG 2003). Delisting criteria will presumably depend on whether important populations have reached abundance thresholds (Spence et al. 2008), one of the four key components of the Viable Salmonid Population (VSP) concept (Busby et al. 1996). The Steelhead Restoration and Management Plan for California (McEwan and Jackson 1996) recommends population monitoring of naturally produced stocks. The Recovery Strategy for California Coho Salmon (CDFG 2004) states that population monitoring will be necessary to determine if recovery goals and quantatative recovery targets have been met.

In 2005 NOAA Fisheries submitted an Action Plan for monitoring California's coastal salmonids (Boydstun and McDonald 2005) to CDFG. This was the final report of a CDFG grant funded project to develop a plan to monitor the status and trends of salmonid populations at the evolutionarily significant unit (ESU) or other large regional spatial scale. The Action Plan describes a sampling scheme to monitor the four VSP components: abundance, population growth rate, population spatial structure, and diversity (McElhany et al. 2000). This plan follows a sampling scheme similar to the Oregon Plan (Stevens 2002, Firman and Jacobs 2000) where metrics of adult and juvenile population status and data on habitat conditions are collected in a rotating panel design (Overton and McDonald 1998) to monitor regional salmonid populations. Boydstun and McDonald (2005) propose using a two-stage approach to estimate regional population status. First stage sampling is comprised of extensive regional Spawning Ground Surveys (SGS) to estimate spawning escapement from redd, live fish, and carcass counts collected in stream reaches selected under a Generalized Random Tessellation Sampling (GRTS) rotating panel design at a 10% sampling rate. Second stage sampling consists of producing escapement estimates in Life Cycle Streams (LCS) through either total fish counts of returning adults or mark/recapture studies. These second stage estimates are considered to represent the true escapement of adults into the LCS. Second stage sampling is then used to calibrate first stage estimates in order to produce an adult abundance estimate for the region as a whole.

Under the Action Plan, LCS are locations where complete freshwater life history and habitat conditions are monitored, and must be located in watersheds where it is possible to accurately estimate numbers of spawning adults and their corresponding smolt production with high confidence. Boydstun and McDonald (2005) suggest that first stage sampling could utilize: 1) redd counts, where redds are converted to adult numbers using spawner: redd ratios from second stage sampling, 2) repeated live fish counts utilizing Area Under the Curve (AUC) estimation techniques (Hilborn et al. 1999), or 3) salmon carcass capture-recapture techniques (Boydstun 1987). The Action Plan calls for the California Department of Fish and Game to determine which of the above methods is most appropriate following a few years of field experience and data analysis. This is the overarching function of the pilot project described herein.

This report documents the results of a three-year pilot project for evaluating salmonid abundance monitoring methodologies for California's Coastal Salmonid Monitoring Plan (CSMP). This study was a cooperative effort between the Department of Fish and Game and Campbell Timberlands Management with oversight from NOAA Fisheries, Southwest Fisheries Science Center. The primary purpose of this pilot study was to assess three aspects of the CSMP: 1) field sampling protocols used to provide statistically valid and acceptably accurate estimates, 2) logistical problems and challenges encountered 3) level of resources needed for regional and LCS monitoring. The secondary purpose of this study was to produce annual abundance estimates and evaluate trend detection methods. We provide results for adult escapement during winter 2007-2008 and smolt abundance during spring 2008. The result of the first two years' effort is documented in Gallagher and Wright (2007a, 2007b).

For this study, we treated five coastal Mendocino County streams (Figure 1) as a hypothetical region of coastal California. Two of these five streams and a sub basin of the Noyo River were treated as LCS (second stage sampling), where three different types of adult capture structures were tested: 1) a flashboard dam and fish ladder on Pudding Creek, 2) the Noyo River Egg Collecting Station (ECS) on the South Fork Noyo River, and 3) a floating board resistance weir in Caspar Creek (Figure 1). Fish were marked and released at each of these structures. Recaptures were live fish observations made during spawning ground surveys in all available spawning habitat in these streams. To estimate regional escapement we employed two approaches using spawning ground survey data. The first approach followed the first stage sampling 10% GRTS approach of Boydstun and MacDonald (2005). For comparison, we used a second approach to estimated regional escapement by summing the LCS SGS escapement estimates with estimates for the three extensively monitored basins at a 33% sampling rate following Gallagher and Gallagher (2005).

Screw traps were operated in Pudding Creek and the South Fork Noyo River and fyke traps were used in Caspar Creek to estimate smolt abundance. We discuss data collection, management, and analysis in relation to long term monitoring under the California Coastal Salmonid Monitoring Plan and provide recommendations for improved monitoring of California's coastal salmonids.

MATERIALS AND METHODS

Study Area

The three intensively monitored LCS (Figure 1) 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 seven consecutive years' adult escapement estimates in this stream (2000-2008). The stream and watershed are similar in size to Caspar Creek. South Fork Noyo has a long history of coho data relating to the Noyo ECS and known numbers of coho salmon can be marked and released above the ECS. There are over seven years data on coho escapement, redd counts, and smolt abundance above the ECS (2000-2007). The Noyo River has a stream gage, and there is a history of CDFG management activities in this watershed. Chinook and coho salmon and steelhead are found in this stream; and the entire watershed is owned by CDF. Caspar Creek was chosen because there are many years of adult escapement, juvenile rearing, and downstream trapping data available, it is also a California Department of Forestry (CDF) experimental watershed, and has a history of monitoring and restoration activities. The South Fork of Caspar Creek is gauged and many water quality parameters are collected and reported in real time (www.fsfed.us/psw/topics/water/caspar).

The three extensively monitored basins in our hypothetical region (Figures 1-4) were selected for a variety of reasons. Mainstem and upper Noyo River represents a large watershed that extends considerably further inland than many coastal Mendocino streams. There are four consecutive years of data on adult escapement and smolt abundance (2000-2003). Chinook and coho salmon and steelhead are all present and access to the stream is established. There is also a real time stream flow gauge present on this stream http://waterdata.usgs.gov/ca/nwis/uv?11468500). Hare Creek supports coho salmon and steelhead, and there are four consecutive years of data on adult escapement and smolt abundance (2000-03, Appendix 1). The entire watershed is within CDF Jackson State Demonstration Forest. Little River has over six years of adult escapement and smolt abundance data for coho and steelhead, and the entire watershed is located in Van Dame State Park.

LCS Capture-Recapture Experiments

In the three LCS (Caspar and Pudding creeks and the South Fork Noyo River above the ECS), live fish capture-recapture methods were used to estimate escapement and calibrate potential bias in spawning escapement estimates for coho and steelhead. We used live fish counts, redd counts and measurements, and carcass capture-recapture data from spawning surveys to estimate escapement following Gallagher and Gallagher (2005) and Gallagher (2005a-b). The results from the LCS streams were used to correct potential bias in spawning ground escapement estimates for the extensively monitored streams (Gallagher and Wright 2007a).

To estimate escapement we marked and released fish with weekly time-specific individually numbered bi-colored floy tags (Glen Szerlong, NOAA Fisheries, Santa Cruz, Personal Communication). 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 to estimate tag loss, residence time *(rt)*, and to calculate capture-recapture estimates from carcass data. We used the Schnabel capture-recapture method to estimate coho and steelhead escapement during 2007-08 and 95% confidence limits were obtained from the Poisson distribution (Krebs 1989). Adult fish were captured, marked and released at three types of structures: 1) a fish ladder and flashboard dam located 0.25 km from the Pacific Ocean Pudding Creek, 2) an egg collecting station (ECS) on the South Fork Noyo River, and 3) a floating board resistance weir constructed on Caspar Creek 4.9 km from the Pacific Ocean (Figure 1). Adult steelhead were also captured and marked in screw traps on Pudding Creek and the South Fork Noyo River, in fyke traps on Caspar Creek, and opportunistically using gill nets in the mainstem Noyo River.

Chinook and coho escapement was also estimated by carcass capture-recapture methodology (marked independently of the floy tag experiments described above). All carcasses observed during spawning surveys were marked with uniquely numbered metal tags (Gallagher and Knechtle 2003). Escapement was estimated using the Jolly-Seber method or the Schnabel method when recaptures were less than seven (Krebs 1989). We examined the carcass mark-recapture data by survey reach to determine if it was useful for producing reach specific escapement estimates.

Spawning Ground Surveys

For the regional escapement estimates, two sampling survey designs were used. The first approach used a 10% sampling rate drawn from the regional sampling frame (Figures 3 and 4) using a Generalized Random Tessellation Sampling (GRTS) scheme as described in the Action Plan (10% GRTS). Regional abundance was estimated by multiplying the average density (fish or redds) from the sample reach data by the total length of streams in the sampling frame. The second approach used a 33% sampling rate following Gallagher and Gallagher (2005) in the three extensively monitored watersheds (Figure 2) and combined the resulting whole stream estimates with total counts of all reaches in the LCS to produce a regional sum-of-streams (SOS) estimate for comparison to GRTS sampling. Confidence limits were estimated using bootstrap with replacement and 1000 iterations (Trent MacDonald, West Inc., Personal Communication).

To estimate escapement in the intensively and extensively monitored watersheds we used data collected during spawning surveys following Gallagher and Knechtle (2003). Over and under-counting errors in redd counts (bias corrected) were reduced following Gallagher and Gallagher (2005) and Gallagher et al. (2007). 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. Redd count observer efficiency was estimated as the seasonal average of the proportion of species corrected previously observed redds resighted on subsequent surveys for each reach. Thus estimated redd count observer efficiency was used to adjust species corrected redd counts to account for this source of undercounting error (see Gallagher et al. 2007).

The entire extent of spawning habitat was surveyed in the LCS streams to maximize the observation rate of tagged and untagged fish and to provide data for evaluating potential biases in escapement estimates derived from spawning surveys. For the SOS sampling design Hare Creek, Little River, and the Noyo River were divided into 0.5 to 4.5 km reaches and a third of these were randomly selected for spawning ground surveys (Figure 2). For the 10% regional GRTS sampling design all spawning habitat in the five streams was divided into uniquely identified reaches ranging in length from 0.26 to 3.79 km (Danna McCain, Institute for River Ecosystems, Personal Communication) resulting in a sample frame with 76 reaches. Trent MacDonald (West Inc.) used this sample frame to create a GRTS sample draw where each reach in the sample frame was assigned a numerical GRTS Order (Table 1). To achieve a 10% sampling rate, eight reaches were sampled each year. To improve the utility of the data set to track population trends, the first three reaches (GRTS Order 1-3) were sampled each year. For each successive year of the study the next five subsequent reaches were added to that year's surveys, e.g. in 2005-06 GRTS Order numbers 1-3 and 4-8 were sampled; in 2006-07 GRTS Order numbers 1-3 and 9-13 were sampled; etc. The reaches sampled over the three year study period are shown in Figure 3. Two reaches (9 and 12) were replaced with reaches 14 and 15 due to access issues.

Surveys were conducted approximately biweekly from early-December 2007 to late-April 2008 in all selected stream reaches. Due to the need to sample all habitat in the intensively monitored streams and our intent to continue complete sampling in Little River, a systematic sample of 29 additional GRTS reaches was available to examine sampling rate at the regional scale. In 2007 and 2008 additional reaches were selected in GRTS order to examine GRTS sample rates between 10 and 35%. Redd density was calculated from the bias corrected redd counts divided by the reach length (km) for each survey segment. For the extensively monitored streams the 95% confidence intervals about the redd count and redd based escapement estimates were calculated using bootstrap with replacement of 1000 iterations by treating stream reaches as samples for each stream. In the LCS, redd counts were totals of biased corrected counts in each reach.

Escapement Estimates

Spawner: Redd Ratios

Relationships between redd counts and escapement estimates were examined using correlation. We evaluated the use of the number of fish per redd (spawner: redd ratio) to convert bias corrected redd counts into fish numbers. We calculated spawner: redd ratios by dividing capture-recapture estimates for coho and steelhead by the bias corrected redds counts for all available data (Table 2). These estimates were then used to convert redds counts into fish numbers in each stream using multiyear and annual multi-stream average spawner: redd ratios. We used the 2006 and 2007 data to develop a model to predict coho escapement from redd counts (Equation 1) and tested it with the 2008 data. We also evaluated the predictive ability of the regression model for steelhead (log steelhead escapement = 1.351 + (0.458 * log redd count) presented in Gallagher (2005) with three years data. Transferability of the field estimated spawner: redd ratios among streams and over years was evaluated using ANOVA. Spawner: redd ratios were used to convert bias corrected redd counts into fish numbers for each reach and these numbers were transformed into density by dividing by reach length.

Equation 1

Log Coho Salmon Escapement = 1.025 + (0.728 * Log Redd Count)

AUC

Spawning population estimates were derived from live fish observations using the AUC (English et al. 1992, Hilborn et al. 1999). Coho *rt* was estimated from the time between the initial capture of live fish and the recapture of tagged fresh (clear eyes and no fungus assumed recently deceased) carcasses in Caspar Creek 2005-07, Pudding Creek 2003-04 through 2007-08, and in the South Fork Noyo River above the ECS 2001 through 2008 (Table 3). We estimated steelhead *rt* as the time between capture and recapture of tagged fish in Pudding and Caspar creeks and the Noyo River (Table 4). We evaluated the utility of using annual three-stream average and multi-year average *rt* estimates for estimating escapement with AUC. Transferability of *rt* among streams and over years was evaluated using ANOVA. Observer efficiency (*e*), the ratio of total fish seen to the total present (Korman et al. 2002), was estimated as the total number of marked fish observed during spawning surveys divided by the total number of marked fish present (Table 5). Live fish density for each reach was calculated by dividing the AUC estimates by reach length.

Bias in Spawning Ground Survey Escapement Estimates

We used the results of the mark-recapture experiments and SGS escapement estimates from the LCS to identify and quantify potential biases in spawning ground survey escapement estimates. This was similar to the approach used in Oregon where index weir counts are used to correct for biases in redd counts for steelhead population monitoring (Susac and Jacobs 2002). Relationships between redd counts and escapement were used to convert redd counts to fish numbers and 95% confidence bounds were calculated using bootstrap simulation with 1000 iterations.

Regional Escapement

During November 2006, we field verified and delineated all the selected GRTS stream reaches for access. The regression model of Gallagher and Wright (2007a) was used to correct GIS reach lengths (Table 1) and these lengths were used for calculating fish and redd density.

Regional GRTS escapement estimates followed the methods outlined by Boydstun and MacDonald (2005) where redd or fish density is averaged for GRTS sample reaches and the result multiplied by the total length of habitat in the sample frame. Due to the low sample size (10% – 35%, n = 8 to 23), the 95% confidence intervals for these estimates were calculated using bootstrap with replacement of 1000 iterations (Trent MacDonald, West Inc. Personal Communication). For comparison to the GRTS estimates, a systematic random sampling estimate was generated using an over sample of 29 GRTS reaches, and a SOS estimate was calculated by adding LCS total counts to individual stream estimates for the extensively monitored basins.

Sample Size and Statistical Power

Data collected for this study was combined with other reach density data for these streams from 2000 to 2005 (S. Gallagher, unpublished) to examine sample sizes for using redd counts (spawner: redd ratio expansions) and AUC for coast-wide regional monitoring. This data was examined following Krebs (1989) and was best described by the negative binomial distribution. We examined this data to determine if it could be used to estimate regional sample sizes by testing for trends. If this data showed no temporal trends, it can be combined and used in Equation 2 to estimate sample size for different levels of desired precision in the data (C. Gallagher, Clemson University, S.C., Personal Communication).

Equation 2

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

Where $\bar{x}$ is the mean value expected in data, *k* is the negative binomial exponent, r is the desired level of error as a percentage (10%, 25%, 30%, and 50%), and t_{α} is the probability of not achieving desired level of error (from Krebs 1989).

Redd density data collected on 40 reaches during all three years of the study was used in the program MONITOR (Gibbs 1995) to examine the statistical power of a monitoring program using this type of information. Temporal variance in the sample counts was calculated following Gibbs (1995). The model was run using one and two tailed tests with α = to 0.05 and 0.10. We examined the power of the density data to detect trends with increasing sample size (n = 8 to 40) and with increasing years of surveys (n = 3 to 18).

Smolt Abundance

We used downstream migrant traps to estimate smolt abundance using capture-recapture methodology in the LCS and Little River. Traps were placed in the streams in mid-March and checked daily until early-June 2008. Three fyke traps were operated in Caspar Creek. One trap was located about 5.0 km above the Pacific Ocean in the main stem of Caspar Creek. Two other traps were placed above the confluence of the North Fork and South Fork Caspar Creek; one in the South Fork and the other in the North Fork. We acquired and 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. CTM operated a screw trap in Pudding Creek.

In general, we followed the methods of Gallagher (2003) and 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 we used MS 222.

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.

We used a similar approach to calculate populations for each species and size/age class using a two-trap analysis for Caspar Creek. All fish captured and marked at the two traps above the confluence of the North Fork and South Fork were treated as the marked and released portion in the Darr input matrix; all marked fish recaptured at lower trap were treated as recaptured in the matrix.

Survival

We estimated coho smolt to adult survival for three streams over five years from smolt abundance data from 2001 to 2004 (Harris 2001, 2002, 2003, 2004) and adult return data from 2000 through 2007-08 (Gallagher and Wright 2007a-b). Coho spawner/recruit (spawner/spawner) ratios for six consecutive years were estimated using data from this study. Over winter survival was estimated for Caspar and Pudding Creeks using data collected during summer electrofishing: 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 over eight years and four complete coho life cycles were examined following MacDonald (et al. 2007) using a trend detection package in R (www.r-project.org) developed for this purpose (Trent MacDonald, Personal Communication). Coho salmon population trends were also examined following methods described by Spence et al. (2008). We also used our data to examine coho population viability using models and procedures in Spence et al. (2008). Trends in redd counts and redd densities versus year were examined with t-tests.

Effort

The spawning survey protocols of Gallagher et al. (2007) and Gallagher and Knechtle (2003) provide instructions for recording information on total drive time drive to and from each site and total time to survey each reach. We used this information and estimates of driving distance, mileage rate, and staff time costs to estimate costs per survey reach for regional monitoring. We used similar effort estimates to determine costs for monitoring adult escapement at the LCS.

Data Analysis

Analysis and calculation of the redd data and AUC escapement followed Gallagher and Gallagher (2005) and Gallagher (2005b). An ANOVA or the Kruskal-Wallis ANOVA on ranks when Standard Kurtosis p-values were < 0.05 were used to test if estimates *rt* and *e* were different among streams or over years. Relationships between capture-recapture escapement estimates and redd counts were examined with correlation. Repeated measures ANOVA, treating years or streams as samples, was used to test for differences in survival estimates among streams and over years. We compared population estimates, *rt*, and, spawner: redd ratios with ANOVA or the Kruskal-Wallis ANOVA on ranks when Standard Kurtosis p-values were < 0.05. Predicted and observed *e* was compared with t-tests. Examination of sample size for regional sampling used the negative binomial procedure of Krebs (1989). Statistical significance was accepted at p < 0.05, although, endangered species management often accepts statistical significance at the < 0.10 level (Peter Adams, NOAA Fisheries Santa Cruz, Personal Communication).

RESULTS

LCS Experiments

Carcass capture-recapture methods were not reliable for any species because too few fish were marked and recovered. During all three years of the study carcasses capture-recapture estimates vastly underestimated release counts above the Noyo ECS (Figure 5). Coho carcass capture-recapture estimates were orders of magnitude lower than live fish estimates (data not presented) and we were unable to produce these estimates for any stream in 2008. Nor were we able to produce reach level carcass capture-recapture escapement estimates necessary for regional monitoring. Based on carcass capture-recapture, Chinook salmon escapement in the Noyo River during 2007 was 2-4-157. We were unable to estimate Chinook salmon escapement with carcass capture-recapture during 2006 or 2008.

Live fish capture-recapture using brightly colored floy tags where permanent structures were used to capture coho and steelhead produced escapement estimates with tighter 95% confidence bounds. We did not capture and mark any live Chinook salmon at any of our weirs and were thus not able to evaluate the methodology for this species. Coho salmon capture-recapture escapement estimates had 95% confidence limits ≤ 70% of the point estimates for Pudding Creek and the South Fork Noyo River (Figure 6, Table 6). The Pudding Creek point estimates had 95% confidence limits of ≤ 30% in two of five years. In contrast, the 95% confidence limits about the point estimates for coho salmon at Caspar Creek, a floating board resistance weir, was > 100% over two years. Coho salmon returns were lowest during 2008 and we were unable to produce reliable confidence limits for the capture-recapture escapement estimates for Caspar Creek and the South Fork Noyo River because we did not observe any tagged fish during spawning surveys. Steelhead capture-recapture escapement estimates had larger 95% confidence limits than coho salmon for all three streams (Figure 2b). In only two instances were the steelhead 95% confidence limits < 50% of the point estimates and half the time they were > 100%. We were not able to produce capture-recapture escapement estimates for steelhead in the South Fork Noyo River during 2006. The temporary weir on Caspar Creek had lower confidence limits for steelhead than for coho salmon (Figure 6b, a).

Live adult coho salmon and steelhead did not loose their marks. Tag loss probability for fresh coho salmon carcasses averaged 0.28 for floy tags and 0.68 for operculum punches over three years (Table 8). Tag loss probability for the few tagged steelhead carcasses observed averaged 0.25 for floy tags and 0.75 for operculum punches over three years. Three steelhead kelts tagged in downstream traps in spring were recaptured fresh from ocean at our weirs the following winter. These fish retained their floy tags, but their operculum punches had, although still obvious, regenerated. Because carcasses lost both floy tags and operculum punches the capture-recapture estimates using carcass recapture data were less reliable than those based on live fish observations (Tables 6 and 7).

Coho salmon and steelhead redd counts were significantly positively correlated with the LCS capture-recapture escapement estimates (Figure 7, Tables 6 and 8). Thus redd counts alone may serve as a reliable measure of annual escapement. Results of the first two years of this study indicated that annual average spawner: redd ratios and the regression models for predicting adult abundance from redd numbers provided reasonable escapement estimates relative to the capture-recapture estimates (Figure 8). When we applied these results to the data from the last year of the study we found that escapement from annual three stream average spawner: redd ratio expanded redd counts overlapped the capture-recapture estimates in all cases, but the regression models results did not (Figure 8). Coho salmon and steelhead spawner: redd ratios were not significantly different among streams (ANOVA $F < 1.29$, 0.1, $df = 13$, $p > 0.35$). However, the power of these tests was low ($\beta < 0.08$). Taken together the above evidence supports the notion that annual average spawner: redd ratios from the LCS can be used to expand redd counts into escapement estimates.

Similar to the spawner: redd ratios the results of the first two years of the study suggested that AUC escapement was best estimated using the multi-year average *rt* and *e* calculated as the total number of marked fish observed divided by the total number marked and released (Figure 9). Coho residence time was not significantly different among streams or over years (ANOVA F = 1.71, df = 180, p = 0.12, ß = 0.27, Table 3). Coho salmon observer efficiency averaged 0.19 (S.E. = 0.01) and was not significantly different among streams (ANOVA F = 2.70, df = 0.11, p = 0.11, ß = 0.30). However, it was significantly different over years (ANOVA F = 4.31, df = 0.11, p = 0.044, ß = 0.53). Steelhead *rt* was significantly different among streams and years (ANOVA H = 22.61, df = 13, p = 0.046, Table 4). Without main stem Noyo River observations, steelhead *rt* was not significantly different among streams and years (ANOVA H = 13.99, df = 9, p = 0.12). Treating years as samples, steelhead *rt* was not significantly different among main stem reaches of the Noyo River (ANOVA F = 1.04, df = 4, p = 0.38, ß = 0.06). Nor was it different between Noyo River tributaries and the other small streams in this study (ANOVA H = 19.43, df = 11, p = 0.06). Therefore, we used tributary *rt* estimates for tributary and small stream observations and main stem estimates for main stem reaches. Steelhead observer efficiency averaged 0.18 (S.E. = 0.05) and was not significantly different among streams or over years (ANOVA F > 0.33, df = 6, p = 0.5).

The 2008 AUC escapement estimates developed using this data did not overlap the capture recapture escapement estimates for coho salmon for any stream (Figure 9a). However, they did overlap for steelhead in two of the three LCS (Figure 9b). Both 2007 and 2008 had, relative to previous years, low levels of coho salmon escapement in the LCS (Figure 6a).

Regional Spawning Escapement

The 10% GRTS redd counts, spawner: redd ratio expanded redd count escapements, and the AUC estimates overlapped the SOS and systematic sample estimates for coho and steelhead each year of the study (Figure 10, Tables 10 and 11). Treating years as samples coho salmon redd counts, spawner: redd ratio expanded redd count escapements, and AUC escapement estimates were not significantly different between the 10%, SOS, or systematic samples (ANOVA F > 0.21, df = 8, p > 0.58, β > 0.05). Similarly, steelhead redd counts, spawner: redd ratio expanded redd count escapements, and AUC escapement estimates were not significantly different between the 10%, SOS, or systematic samples (ANOVA F > 0.02, df = 8, p > 0.36, β > 0.05).

Sampling eight out of 76 reaches in a GRTS design provided reasonable regional estimates and increased effort did not significantly improve this result. Except for the coho AUC at 10%, increasing the GRTS sampling rate did not increase the precision of the resulting redd count or escapement estimates (Figure 11). The 10% to 35% GRTS redd counts and spawner: redd ratio escapement estimates overlapped SOS escapement estimates for both species and variation in the 95% confidence limits did not change after 10% (Figure 11). The coho AUC estimate at 10% GRTS in 2006-07 did not overlap the SOS estimate (Figure 11b), but it did after 15%. The coho and steelhead GRTS estimates were < 25% of the SOS estimates. All regional estimates had precision levels of ≤ 50%. This pattern was consistent over two years.

Smolt Abundance

Coho smolt abundance estimates were highest in Pudding Creek and lowest in Little River in spring 2008 (Table 14). We PIT tagged 1117 coho in Caspar Creek, 1662 in the South Fork Noyo River, and 4999 in Pudding Creek. In addition, 38 coho in Caspar Creek and 698 coho in Pudding Creek were PIT tagged during fall 2007 electro-fishing surveys. Coho capture probability for all traps ranged from 0.31 to 0.64 and was lowest for the two-trap method in Caspar Creek. In all three streams where PIT tags were used we captured a number of coho salmon in the traps during spring that were tagged and classified as year old fish during downstream trapping the previous spring. The average percentage of fish displaying this two-year stream residency pattern was 0.67% (range 0.30% to 1.50%) 2006 to 2007 and 1.00% (range 0.08% to 2.00%) in 2007 to 2008. Treating years as samples the proportion of coho salmon exhibiting a two-year stream residency patern was not significantly different among streams (ANOVA = 3.00 df = 2, p = 0.50). This data documents two-year freshwater residency life history for coho salmon in these streams.

Steelhead year old smolt abundance estimates were highest for the two-trap method in Caspar Creek and lowest in Little River in spring 2008 (Table 15). A total of 169 steelhead were PIT tagged in Caspar Creek, 691 in the South Fork Noyo River, and 479 in Pudding Creek. In addition, 44 steelhead in Caspar Creek and 381 steelhead in Pudding Creek were PIT tagged during fall 2007 electro-fishing surveys. We observed the largest number of two-year-old steelhead smolts in Pudding Creek and the lowest in Little River. Capture probability for year old smolts ranged from 0.004 to 0.39 and was lowest for the two-trap method in Caspar Creek. Capture probability for Y++ steelhead smolts ranged from 0.10 to 1.00.

The percentage of salmonid smolts recaptured multiple times or in more than one trap was generally low (Appendix 1). The time between capture and recapture ranged from a few days to over one month. The proportion of fish showing delayed migration was lower for steelhead than for coho, but overall it was rather low.

Survival

Coho smolt to adult survival was similar among streams over six years and ranged from 0.01 to 0.17 (Table 16). Treating years as samples smolt to adult survival was not significantly different among streams (ANOVA F = 0.003, df = 20, p = 0.99). However, the power of this test was low (ß = 0.05). Treating streams as samples smolt to adult survival was significantly different over five years (ANOVA F = 4.27, df = 20, p = 0.01, β = 0.77). The power of this test was below 0.80 and examined individually there was no difference among years (Tukey's q < 4.08, p > 0.08). Coho salmon smolt to adult survival estimated from adult PIT tag returns in 2008 (n = 9) from the 2006 releases (n = 3560) in Pudding Creek was 0.003 and was less than the value estimated in by dividing adult escapement by smolt abundance (Table 16). However, both estimates were ≤ 1%. We did not capture any PIT tagged adults at the Noyo ECS or at Caspar Creek in 2008.

Coho salmon recruits per spawner ratios were less than 1.00 for the 2002-03 to 2005-06, 2003-04 to 2006-07, and the 2004-05 to 2007-08 cohorts (Table 16). Treating years as samples, recruits per spawner estimates were not significantly different among streams (ANOVA $F = 0.33$, $df = 17$, $p = 0.80$). The power of this test was low ($ß = 0.05$). When streams were treated as samples, recruits per spawner estimates were significantly different over six years (ANOVA $F = 6.78$, $df = 21$, $p = 0.001$, $ß = 0.96$). Examined by year recruits per spawner were significantly different between 2000-01 to 2003-04 and 2003-04 to 2006-07, between 2001-02 to 2004-05 and 2004 to 2007, between 2000-01 to 2004-05 to 2007-08, and between 2001-02 to 2004-05 and 2004-05 and 2007-08 (Tukey's $q > 5.069$, $p < 0.02$). There were no other significant differences in recruits per spawner for the other years data (Tukey's $q < 4.01$, $p > 0.09$).

Coho over-winter survival using PIT tag releases in summer efishing and estimated numbers of these passing the smolt traps the following spring was 0.16-0.18-0.21 in Pudding Creek. These estimates overlapped the estimates of 0.21-0.42-1.00 for Caspar Creek. The estimates derived from summer population and smolt numbers the following spring were similar to the PIT tag estimates for both streams: in Pudding Creek 2006 to 2007 it was 0.37-0.53-1.00, for 2007 to 2008 over winter survival was 0.20-0.27-0.40, and for Caspar Creek 2007 to 2008 it was 0.01-0.53-1.00.

Trends in Coho Salmon Abundance

Coho salmon and steelhead redd and AUC densities did not exhibit significant trends between 2000 and 2008 ($r > -0.16$, $p > 0.05$, $n > 144$, Figure 12). There were no significant trends in coho escapement over the last seven years in these streams (Figure 13a). The 1999-2000 brood year showed no significant trends over two complete life cycles (Figure 13b). The 2000-01 brood year exhibited a significant negative trend over two complete life cycles (Figure 13c). The 2001-02 brood year showed no significant trends over two complete life cycles (Figure 13d). 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 17-18). Based on risk categories in Spence et al. (2008) extinction risks of these populations were moderate to low (Tables 17-18). However, there were differences in extinction probability predictions from different treatments of the data. There were no trends in coho salmon smolt abundance over nine years (Figure 14). Smolts from the 1999-2000, 2000-01, and the 2001-02 brood year showed no trends in abundance over two life cycles (Figure 14b-d).

Sample Size and Statistical Power

Coho salmon and steelhead redd and AUC densities did not exhibit significant trends between 2000 and 2007 ($r > -0.16$, $p > 0.05$, $n > 144$, Figure 12) and therefore were combined in Equation 2 to examine sampling rate for monitoring salmonids in coastal

California. Regional redd count surveys appear to provide higher precision with lower effort than AUC data (Tables 12 and 13). A sample size of 41 reaches will provide escapement estimates with 90% confidence limits of ± 30%. Increased precision will have added costs (Tables 12 and 13).

The statistical power of the monitoring using redd density increased with in increased sample size for both coho salmon and steelhead (Figure 15a-d). Sampling 40 reaches and using a one tailed test with $\alpha = 0.1$ appears sufficient to detect changes in abundance ≥ 5%. This monitoring would detect all but the smallest changes in populations in less than two generations (Figure 16). Monitoring 40 reaches and using two-tailed tests with $\alpha = 0.05$ would provide sufficient statistical power to detect changes of ≥ 10% in coho salmon and steelhead redd density. Using these parameters would require a longer period to detect changes (Figure 16). Sampling ≥ 25 reaches and using a one tailed test with $\alpha = 0.1$ appears sufficient to detect changes in abundance > 5%. This monitoring would detect all but the smallest changes in populations in less than three generations (Figure 17).

Effort

We surveyed each LCS and regional spawning reach approximately 12 times between 1 December 2007 and mid-April 2008 (range 3-17). Many small gulches were only surveyed a few times as low flows limited fish entries to these reaches. It took an average of 12.25 person hours (range 5.7 to 18.8) to prepare for, drive to and from, and survey one reach (for safety each survey requires two people). The average driving distance per reach was 45.3 km (range 16 to 150 km). Survey time and thus costs increased with increasing numbers of reaches (Table 19). It took between 400 and 495 person hours to operate the adult capture facilities used in this study (Table 20). We spent over 100 person hours entering and checking data. It took approximately 3020 person hours to operate the downstream traps but less than 60 person hours to enter and check the data, prepare data summaries, and run data matrices in Darr. We spent approximately 21,000$ on PIT tags and associated equipment. Data analysis and report preparation took about 980 person hours.

DISCUSSION

LCS Experiments

Crawford et al. (2007) describes methodology to use carcass capture-recapture to estimate salmonid escapement. However, this methodology clearly will not work for monitoring coastal salmonid escapement in Northern California. We were only able to produce coho carcass capture-recapture estimates for two of three LCS during 2007 and these estimates were orders of magnitude low. We observed too few coho salmon carcasses in any of the reaches surveyed during the study to develop reach level estimates. High flows and removal by predators can decrease the chance of finding carcasses and Cederholm et al. (1989) found that the occurrence of buried carcasses was greatly underestimated. While stream flows during the coho spawning period in 2007 and 2008 were generally low, carcass counts did not produce reliable escapement estimates and buried carcasses were likely not responsible for this result. Surveys were conducted about every 10 days, the frequency recommended by Crawford et al. (2007). Boydstun (1987) found no difference between Chinook carcass capture-recapture estimates and total live fish counts in Bogus Creek, California. We were only able to produce Chinook salmon carcass capture-recapture estimates in one of the three study years. Carcass capture-recapture efforts in this area were valuable because they provided observers with hands on experience in species identification and differentiation of the sexes. We recommend continued field efforts at carcass capture-recapture, but suggest that escapement estimates not be based on these data. Because carcasses lost both types of marks applied on live fish and because so few carcasses were observed we suggest mark-recapture studies at LCS use live fish resights rather than carcass recoveries.

The LCS live fish capture-recapture methodology developed for this study produced reliable coho salmon escapement estimates for Pudding Creek and the South Fork Noyo River and provided information for reducing bias in, and calibration of, the regional escapement estimates. Coho salmon escapement estimates using the floating board weir in Caspar Creek were improved in 2007 compared to 2006, but still lacked precision relative to the other LCS. Due to the structure of the Schnabel estimator we were able to estimate coho escapement during 2008, but because no marked fish were observed in two of three LCS we could not derive the upper bounds of the 95% confidence limits for these streams. 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 Gene Conservation Units in Oregon. Jacobs et al. (2001) 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%. Precision in the coho salmon capture-recapture estimates above the Noyo River ECS have been <50% over four years and < 25% for one season. Low coho salmon returns during the study period likely affected the precision of the capture-recapture estimates.

The steelhead capture-recapture estimates for the LCS had low precision due to the low numbers of marked and recaptured fish. We were unable to generate steelhead capture-recapture estimates above the ECS in 2006, but were able to make an estimate for the other years. Half of our steelhead capture-recapture estimates had precision of <50% and only one was within 30%. 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.

The main purpose for constructing and operating the floating board weir in Caspar Creek was to examine the utility of using this type of temporary structure for capturing and tagging salmonids, if successful it would give some flexibility as to where on the landscape LCS can be located. With continued improvement in design and operation, the floating board weir in Caspar Creek showed promise for capturing and tagging coho salmon and steelhead. However, after three years the 95% confidence limits were still > 50% of the point estimates. The variance about the steelhead estimates improved over time (Figure 6b). A similar floating board weir in Scott Creek, California has produced steelhead escapement estimates with 95% confidence limits ≤ 20% of the point estimates over the past few years (Sean Hayes, NOAA Fisheries Santa Cruz, CA, Personal Communication). In this study capture-recapture estimates were more precise where permanent structures were used to capture and tag adult fish.

Our results suggest that redd counts were reliable indices for monitoring salmonid escapement. Similar to previous work in this area (Gallagher and Gallagher 2005) and in Oregon (Jacobs et al. 2001) redd counts were significantly correlated with capture-recapture estimates. As the product only of reproductive adults, counts of salmon redds provide an index of effective population size (Meffe 1986). Dunham et al.(2001) suggest that redd counts are less intrusive and expensive than tagging, trapping, underwater observation, weirs, and genetics for inventorying bull trout populations, and that with limited resources more populations can be inventoried over a longer period. Redd counts are widely utilized to provide indirect estimates or indices of spawning escapement on rivers that lack counting facilities (Gallagher et al. 2007). Our findings corroborate the findings of previous studies and we suggest that redd counts can be used for regional monitoring of California's coastal salmonids.

Converting bias corrected coho and steelhead redd counts to fish numbers using spawner: redd ratios produced escapement estimates that were equally as reliable as capture-recapture estimates. Annual three stream average spawner: redd ratios had precision of < 50% over three years (Table 2). The precision in the multi-year spawner redd ratios was < 25% for coho and < 34% for steelhead (Table 2). Chinook redd counts can be converted to escapement using the observed sex ratio and an estimate of 1.01 redds per female (Murdoch et al. 2008). As a result of using point estimates in regression analysis, the precision associated with the predictive models for converting redd counts into escapement was < 10%. However, these models under predicted escapement and were shown to be unreliable.

Because coho and steelhead spawner: redd ratios developed for this study were not different among streams or over years they were reliable for converting regional redd counts into escapement for long term regional monitoring. The number of steelhead per redd in coastal Mendocino County was not different than reported by Susac and Jacobs (2002) for coastal Oregon rivers, but were slightly lower than 1.2 female steelhead per redd reported by Duffy (2005). Dunham et al. (2001) found considerable annual variation in bull trout spawner: redd ratios in Idaho, which they attributed to life history variation or bias in redd counts. Al-Chokhachy et al. (2005) attributed variation in bull trout spawner: redd ratios to differences in contributions from different life history forms. Steelhead spawner: redd ratios ranged from 1.04-3.15 in coastal Oregon over three years (Jacobs et al. 2001). Although we observed annual and between stream variation in coho salmon and steelhead spawner: redd ratios, they were not significantly different. This was likely due to reducing bias in redd counts, a result of following the methods of Gallagher and Gallagher (2005) and Gallagher et al. (2007). Annual spawner: redd ratios can be viewed as conversion factors for converting redd counts into escapement and as such they incorporate annual variation in survey conditions due to climatic conditions (e.g. high or low flows or turbidity levels). For example, during 2006 coho salmon spawner: redd ratios were much lager than other years (Table 2) because of difficult survey conditions, but expanded redd counts were not different than capture-recapture escapements (Figure 8). We recommend using annual LCS spawner: redd ratios to convert redd counts into escapement estimates.

The AUC method is sensitive to the time between surveys and estimates of *rt* and *e* (Hilborn et al. 1999) which should be estimated annually for each stream (English et al. 1992, Manske and Schwarz 2000). Capture-recapture experiments in the LCS streams provided reasonable estimates of *rt* and *e* and we used both annual three-stream average and multi-year average *rt* estimates. Because steelhead *rt* was different between main stem and tributary reaches we used separate *rt* estimates for observations in different areas. Korman et al. (2002) found steelhead *rt* (called survey life) for fish tagged lower in the system (e.g. main stem observations) was significantly longer than that of fish tagged in the upper parts of their study area. Neilson and Geen (1981) found that early arriving Chinook salmon had longer *rt* than those arriving later in the season. Because *rt* was not significantly different among streams or over years, and lumping the data increased sample size and thus decreased the variance, we used multi-year estimates.

During the first two years of the study the AUC using these variables generally produced escapement estimates that were not different than our capture-recapture estimates. However, at the conclusion of this study the AUC estimates using these variables were shown not reliable for producing escapement estimates. Lestelle and Weller (2002) found that AUC escapement estimates were more reliable than redd count estimates at high spawner abundance and that redd counts were better at low spawner abundance. Coho salmon escapement decreased over the study period and was lowest during 2008 (Figure 6a). Live coho may be more readily detected than redds during surveys conducted when conditions are marginal. Therefore, live fish observations may have utility for producing escapement estimates during wet or high abundance years. In contrast, average annual spawner: redd ratio conversions of redd counts into escapement were not different from capture-recapture estimates for any LCS. AUC escapement estimates should be evaluated annually for reliability relative to LCS capture-recapture experiments.

Regional Spawning Escapement

The use of LCS data (second stage sampling) to calibrate the first stage regional spawning ground GRTS sampling produced cost effective and reliable annual salmonid escapement estimates. It was surprising that sampling eight of 76 reaches produced comparable estimates to intensive sampling of the entire hypothetical region (e.g. the SOS estimates) and that increasing the sample rate did not change this outcome. Carcass capture-recapture did not work for producing individual reach densities needed for calculating regional escapement estimates in the GRTS sampling design. The GRTS estimates were within 25% of, and overlapped the, “true” SOS estimates. Krebs (1989) states that population estimates should be accurate to ± 25% for management purposes. Jacobs and Nickelson (2005) had confidence levels within 28% for similar coast wide monitoring of coho in Oregon.

Boydstun and MacDonald (2005) wrote that the most important feature of GRTS sampling is that it produces a randomized sample of units such that any contiguous subset of units constitutes a spatially balanced group. They further suggest that a sampling rate of 10% should be used for regional monitoring. Increasing sampling rates above 10% did not improve estimates or precision, except for the coho AUC estimates. This is likely a result of the spatially balanced sample (e.g. GRTS) and the use of bootstrap simulation to estimate 95% confidence bounds. Our results support the use of 10% GRTS sampling for monitoring California’s coastal salmonids.

Sample Size and Statistical Power

Our evaluation of sample size suggests that producing regional escapement estimates for California’s coastal salmonids may require a lower level of effort than anticipated by Boydstun and MacDonald (2005). If the assumption that the between reach variance observed in coastal Mendocino County is representative of all of coastal Northern California is valid, then estimating coast-wide escapement will require approximately 41 reaches. Boydstun and MacDonald (2005) estimated a 10% sample draw for coastal Mendocino County would result in an annual sample size of 203 reaches. At a cost of about $3,000 to survey one reach over the course of one season the difference between 41 and 203 is substantial. Further examination of reach variance and its effect on sample size, in conjunction with establishing the coast-wide transferability of spawner: redd ratios, is clearly the next step in developing a GRTS based two-stage regional monitoring program for California’s coastal salmonids.

Boydstun and MacDonald (2005) recommend using the normal approximation to estimate 95% confidence bounds for regional GRTS based escapement estimates if there are more than 30 reaches. A 10% GRTS sample at the scale of the coast of California (or the Central California coho -ESU) will likely result in a 10% GRTS draw consisting of more than 30 reaches. As a general rule, if a normal sample size estimator such as Equation 2 (Krebs 1989) indicates a sample size of 100 is needed for 25% precision, using the bootstrap will reduce the needed sample size by an order of magnitude (e.g. 10 reaches) (C. Gallagher, Clemson University, Clemson, South Carolina, Personal Communication). Thus the effect of using bootstrap simulation to estimate confidence bounds on sample size should also be evaluated.

The results of this study suggest that a sample size of ≥ 25 reaches should have sufficient statistical power to detect regional trends in less than three salmonid generations. Maxell (1999) found it necessary to use one tailed tests and $\alpha = 0.20$ to obtain statistical power ≥ 0.80 for detecting 50% and 20% declines which took up to 15 years of monitoring bull trout redds in Idaho. He suggested the statistical power of the monitoring would improve if errors in redd counts were identified and reduced and that one tailed tests should be employed. We reduced errors in redd counts as described above and found that with a sample size of 40 reaches using one tailed tests with $\alpha = 0.10$ we could detect changes $\geq$ 5% with sufficient statistical power. Decreasing α to 0.05 and using two tailed tests had statistical power to detect changes of $\geq$ 10% further suggesting that we have sufficiently reduced error in redd counts. Regional monitoring of California's coastal salmonids will likely occur at different population structural levels ranging from individual independent-dependent population segments to entire ESU's (Spence et al. 2008). Sampling $\geq$ 25 reaches in each of these smaller segments should result in ESU level samples of > 40 reaches, thus balancing the need for sufficient statistical power and precision in the estimates. Further evaluation of the power of monitoring salmonid population trends should be conducted while examining reach variance effects on sample size. Using annual spawner: redd ratios to convert redd counts into escapement from a regional GRTS approach that samples > 40 reaches would provide statistically valid and useful information on the status and trends of California's coastal salmonids.

Smolt Abundance

The use of screw traps in Pudding Creek and the South Fork Noyo River allowed sampling of smolt abundance in higher stream flows than could be sampled with fyke traps. However, low flows in late spring required the use of a motor on both the Pudding Creek and South Fork Noyo River traps. Pit tags allowed marking of individuals and data on multiple recaptures. 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 the estimates. In 2009-10, 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 in our downstream traps in spring 2006and 2007 and recapturing some of these in spring of 2007 and 2008. 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 2007b). However, more precise estimates using PIT tag numbers alone suggest that only about 1% to 2% of the coho salmon in the three study streams displayed this strategy. This pattern was consistent over two years. 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. Determining possible reasons for this coho life history in these creeks will require further research and monitoring.

Survival

Coho smolt to adult survival over six smolt to adult return cycles was similar to that reported by Bradford (1999), Logerwell et al. (2003), and Shapovolov and Taft (1954). Coho adult-to-adult survival was higher than the average value of 0.13 reported by Shapovalov and Taft (1954). However, both smolt to adult and recruits per spawner were significantly lower over the last three years compared to the previous three (Table 16). 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. Ocean productivity was poor during the time of salmonid ocean entry in 2005 and 2006 (Kudela et al. 2006) and adult-to-adult and smolt to adult survival during this period were likely negatively influenced by these conditions.

Trends in Coho Salmon Abundance

We did not find significant trends in coho escapement over nine years in four streams, similar to the findings of Gallagher and Knechtle (2004). This may be a result of the length of the time series or due to the three-year coho salmon life cycle. 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. It is unknown how the discovery of a two-year fresh water life history will affect these analyses. Trend detection may be more appropriate with more year's data (Spence et al. 2008) which include potential 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 (Smith and Ward 2000, Smith et al. 2000). If salmonid population abundance fluctuates on decadal or longer periods, the nine-year dataset examined 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. Nonetheless, the merit of this exercise was the exploration of potential methods using annual escapement estimates for trend detection. These data may also prove useful for population viability analyses (Legault 2005) such as done by Chilcote (2001) for steelhead in Oregon.

There were some differences in coho salmon extinction probability determinations depending on the method of evaluation (Tables 17-18). The number of spawners per IP-Km in Caspar Creek was < 40 where as both the harmonic and geometric mean determinations indicated a moderate extinction risk. However, Caspar Creek is likely a small stable population, which would probably never have populations > 2500 (see above). The number of coho per IP-Km in the Noyo River was low compared to the harmonic and geometric mean population estimates. This may be a result of the fact that population estimates do not exist for this river for 2003-04 and 2004-05. These data do not exist due to budget cuts.

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).

In Caspar Creek, the number of coho and steelhead currently returning to spawn appears to be the same as during the early 1960's. During the 1960-61 season Kabel and German (1967) counted coho and steelhead entering Caspar Creek at a mill pond fish ladder, which was removed in summer 1961. Although not clearly stated in their report, assuming that all fish entering the stream were counted at this ladder, there were a total of 322 coho and 92 steelhead in Caspar Creek in 1960-61. Following a strict three year life cycle the offspring of the 1961 coho reproduction would be encountered 13 generations later in 2001-02 and 14 generations later in 2004-05. In 2001-02 Gallagher (2003) produced an AUC estimate of 381 (range 305-565) coho for Caspar Creek and in 2004-05 the carcass based escapement estimate was 197 (95% CI = 129-411).

Comparison of Pudding Creek coho salmon data between the 1950's and 2000's (Table 21) suggests that marine survival and escapement were similar, although perhaps somewhat higher in the 1950's. Although we could not adequately account for hatchery influences and fish not counted when the dam was open during the 1950's, it appears that marine survival was similar then and now. Adult returns also appear similar, although we made numerous assumptions in extrapolating the information from the 1950's and these earlier data have 95% confidence intervals ranging from zero to infinity. We cannot be confident that there were or were not hatchery plants prior to the first year of egg collecting activities beginning in 1957, thus the first years data may be artificially high. Simply comparing total captures over the years and assuming capture facilities and efforts were similar between then and now, they appear somewhat higher in some of the early years relative to current data. Recruits per spawner was higher in the 1950's than it was between 2002 and 2008, under accounting for fish missed when the dam gates were open would increase these numbers. Overall it appears that coho adult returns were higher in the 1950's than they are now, but we can not say if this is statistically significant.

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, or sooner, 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. The transferability of residence time, observer efficiency, and spawner: redd data should continue to be evaluated. 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.

We recommend annual evaluation of spawner: redd ratio conversions of redd counts into escapement relative to capture-recapture escapement estimates as the best method for estimating abundance for regional spawning ground surveys. Capture-recapture at LCS streams should use weekly specific colored floy tags and operculum punches with recaptures made during spawning ground surveys. AUC escapement estimates should be evaluated annually for reliability relative to LCS capture-recapture experiments. Smolt abundance should be estimated annually at LCS streams using downstream migrant traps and PIT tag capture-recapture. Further examination of reach variance and its effect on sample size, in conjunction with establishing the coast-wide transferability of spawner: redd ratios, is clearly the next step in developing a GRTS based two-stage regional monitoring program for California's coastal salmonids. The effect of using bootstrap simulation to estimate confidence bounds on sample size should be evaluated.

ACKNOWLEDGEMENTS

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PERSONAL COMMUNICATIONS

Peter Adams, NOAA Fisheries Santa Cruz, January, 2007.

Colin Gallagher, Dept. of Math. Sci., Clemson University, Clemson SC, August 2007.

Trent MacDonald, West Inc., Laramie Wyoming, November 2006.

Dana McCain, Institute for River Ecosystems, Arcata, CA August 2005.

Glen Szerlong, NOAA Fisheries Santa Cruz, August 2004.

Mark Zuspan, CDFG, Arcata, CA December 2006.

Figure 1. Study area in northern California. Arrows indicate locations of adult capture structures in Caspar and Pudding creeks and the South Fork Noyo River.

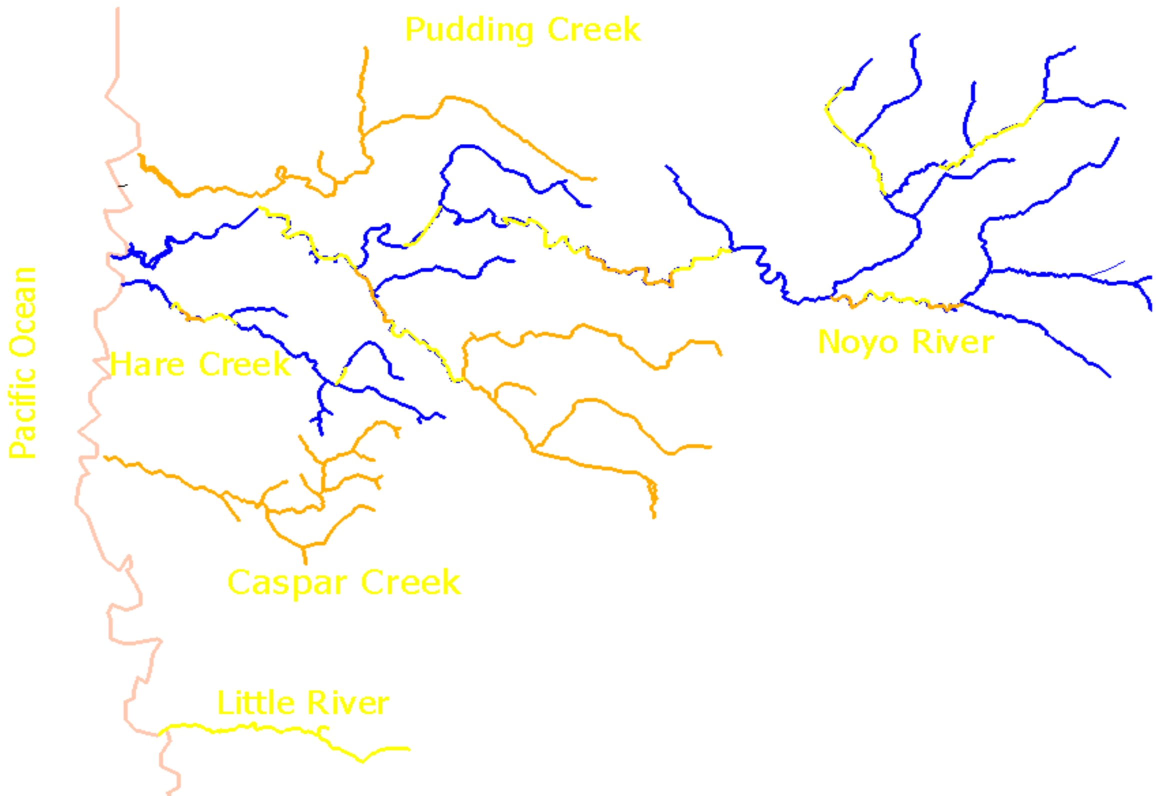


Figure 2. Sum of streams (SOS) spawning ground surveys for the 33% sampling rate in extensively monitored streams and complete surveys in the Life Cycle Monitoring streams. Yellow and orange indicate sampled reaches. All reaches were sampled in three LCS streams (Caspar and Pudding creeks and South Fork Noyo River) and in Little River.

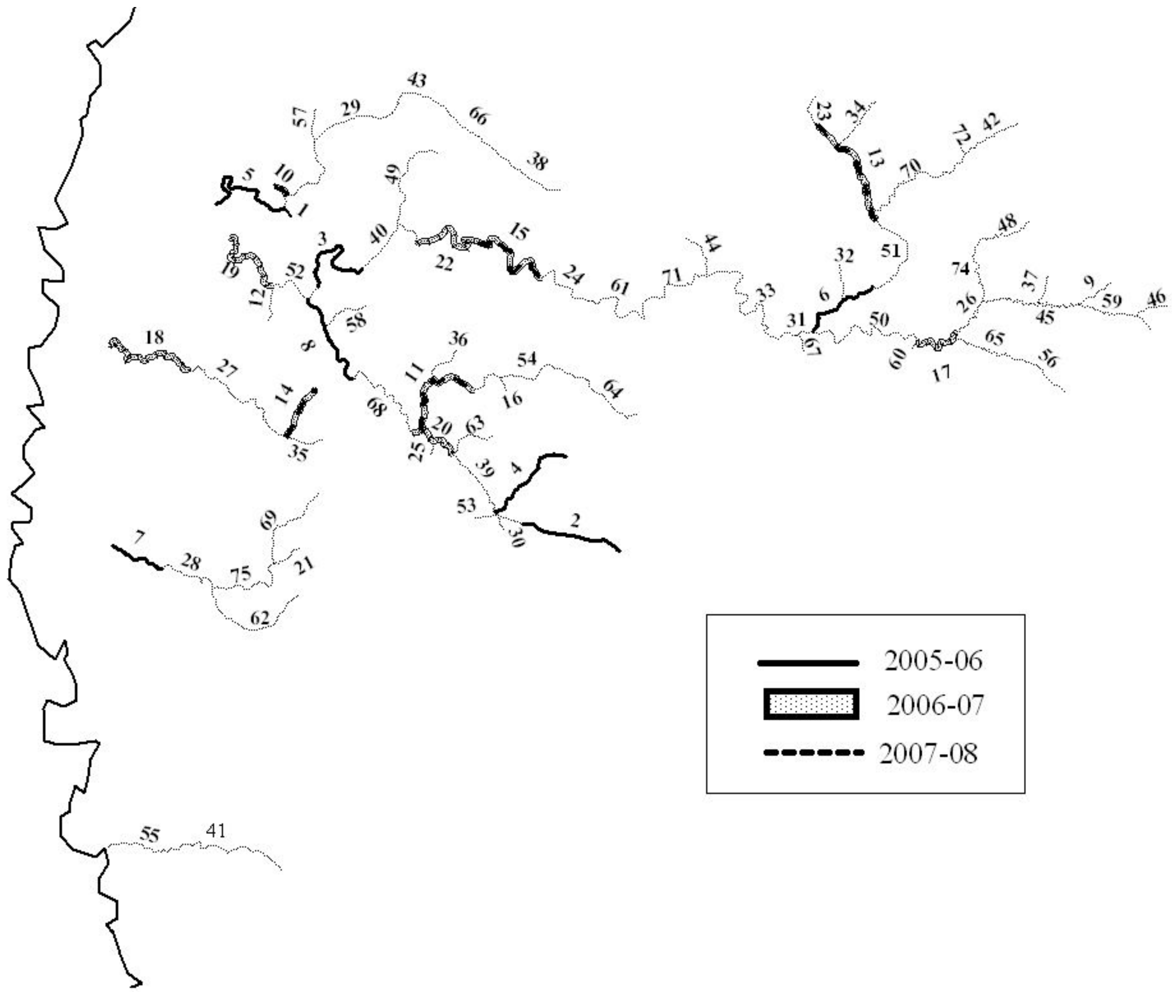


Figure 3. The 10% GRTS reaches sampled over three years. Numbers are numerical GRTS order.

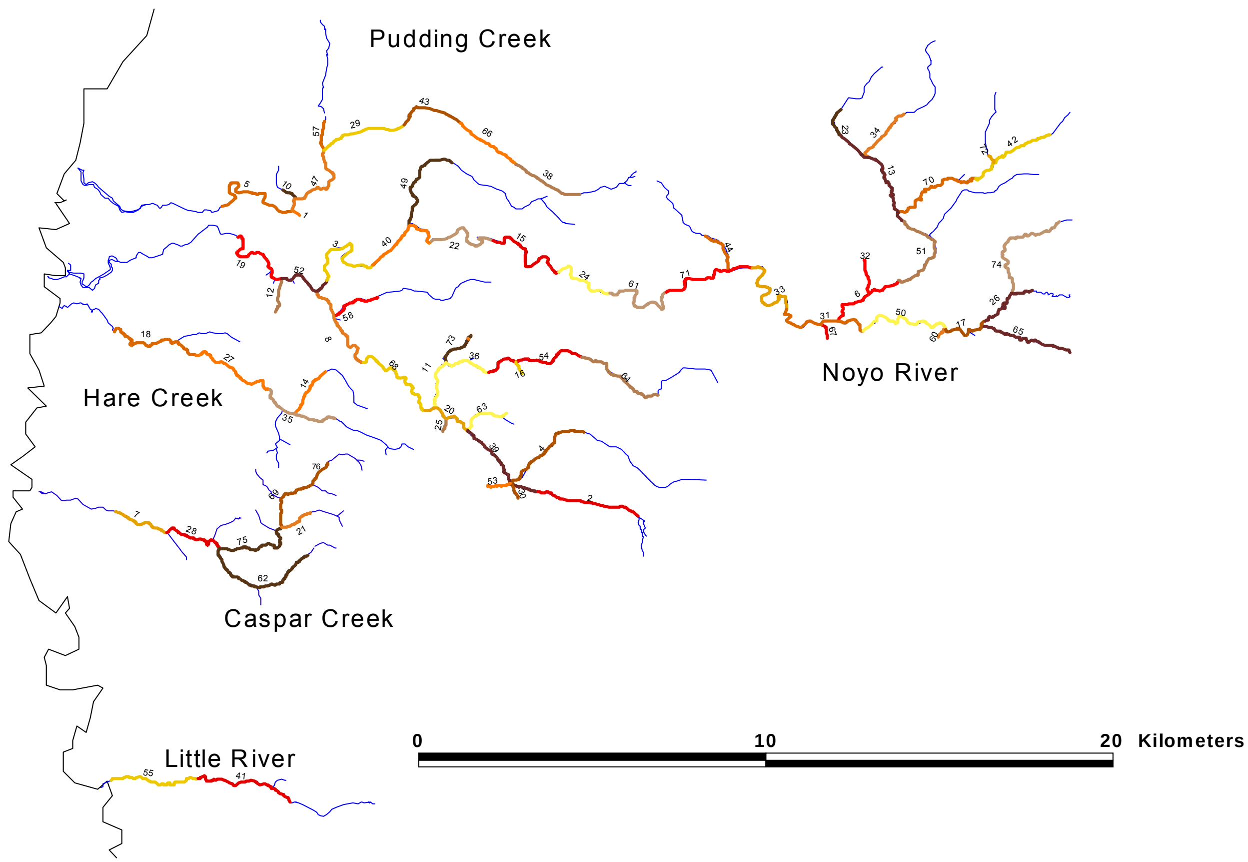


Figure 4. Mendocino coast pilot study regional sampling frame and GRTS ordered sample reaches. Numbers are GRTS sample reaches.

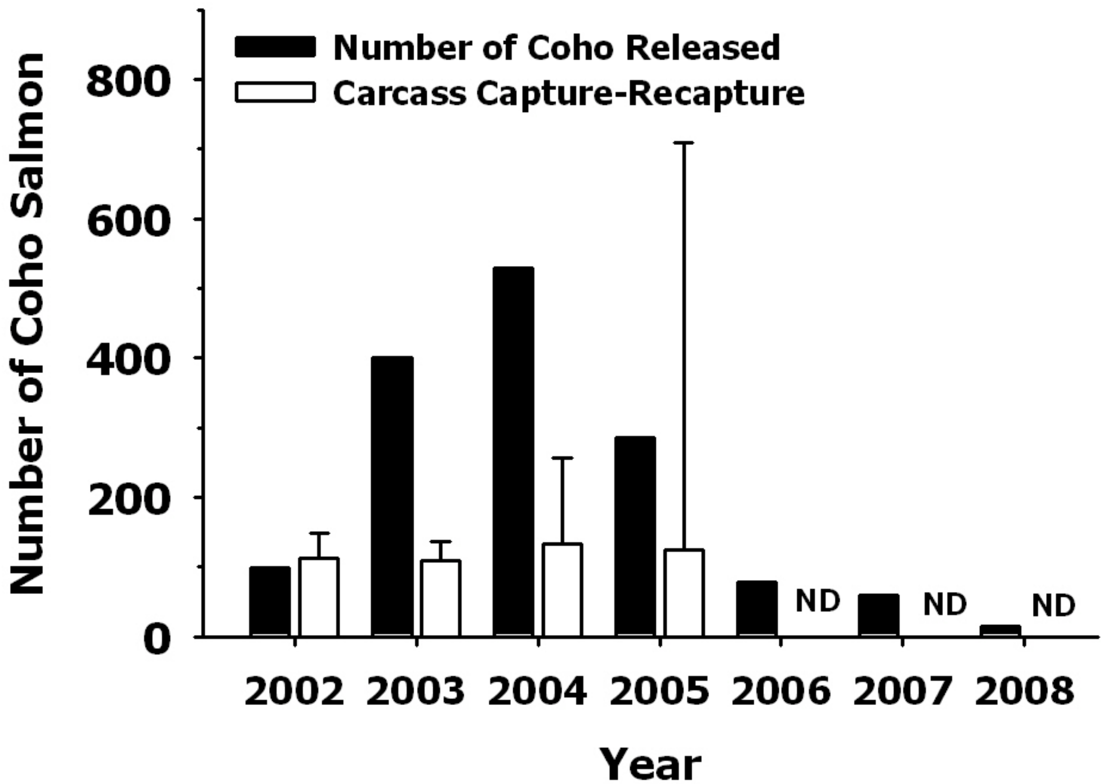


Figure 5. Coho salmon releases and carcass capture-recapture escapement estimates above the South Fork Noyo River Egg Collecting Station 2002-2008.

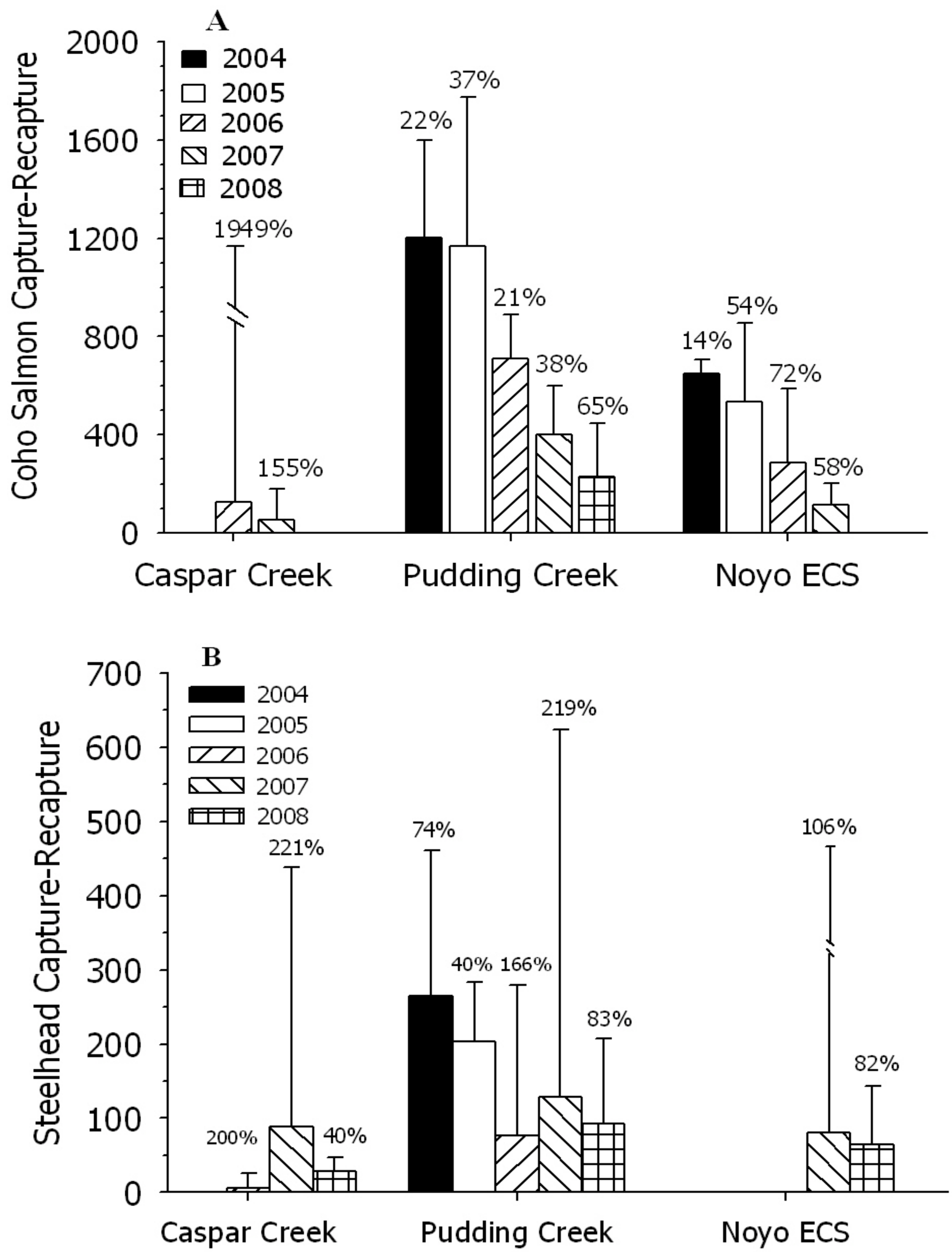


Figure 6. Coho (a) and steelhead (b) capture-recapture escapement estimates for several streams in coastal Mendocino County, California. Thin lines are 95% confidence bounds. Percentage numbers are precision of confidence bounds about the point estimates.

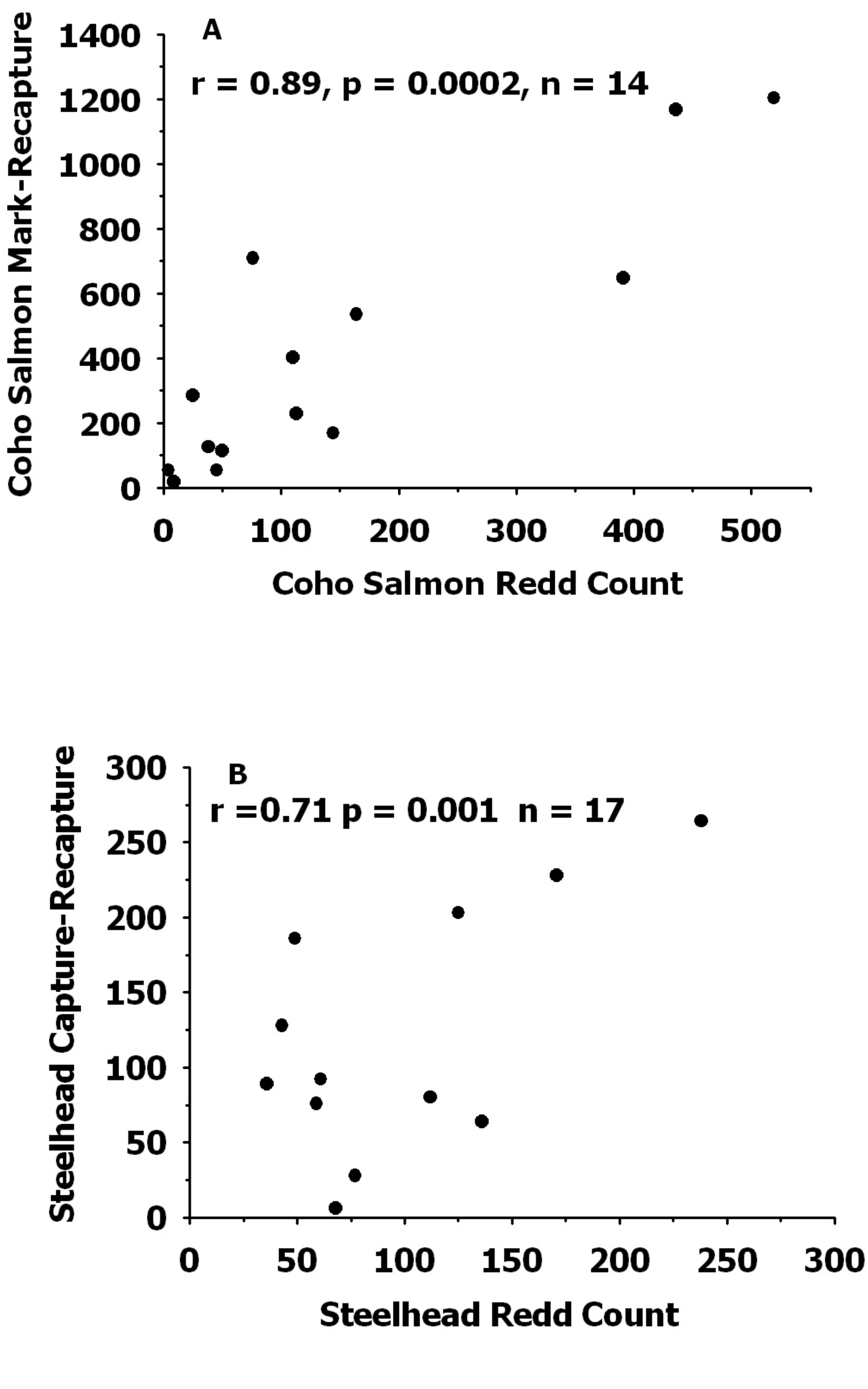
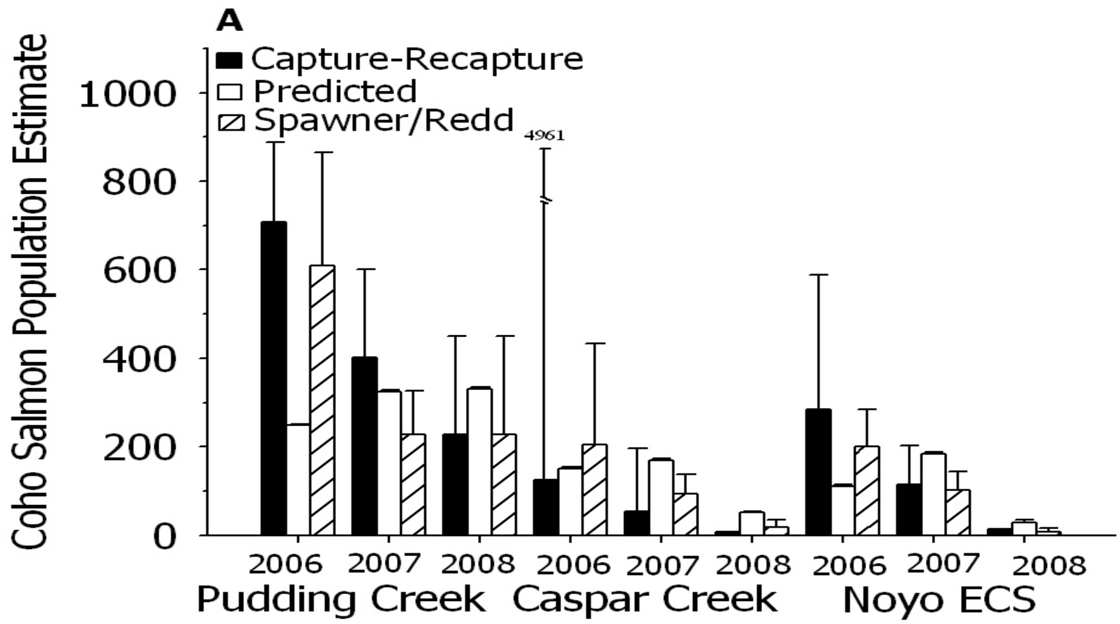


Figure 7. Coho salmon (a) and steelhead (b) capture-recapture escapement estimates versus redd counts in several coastal Mendocino County, California streams.



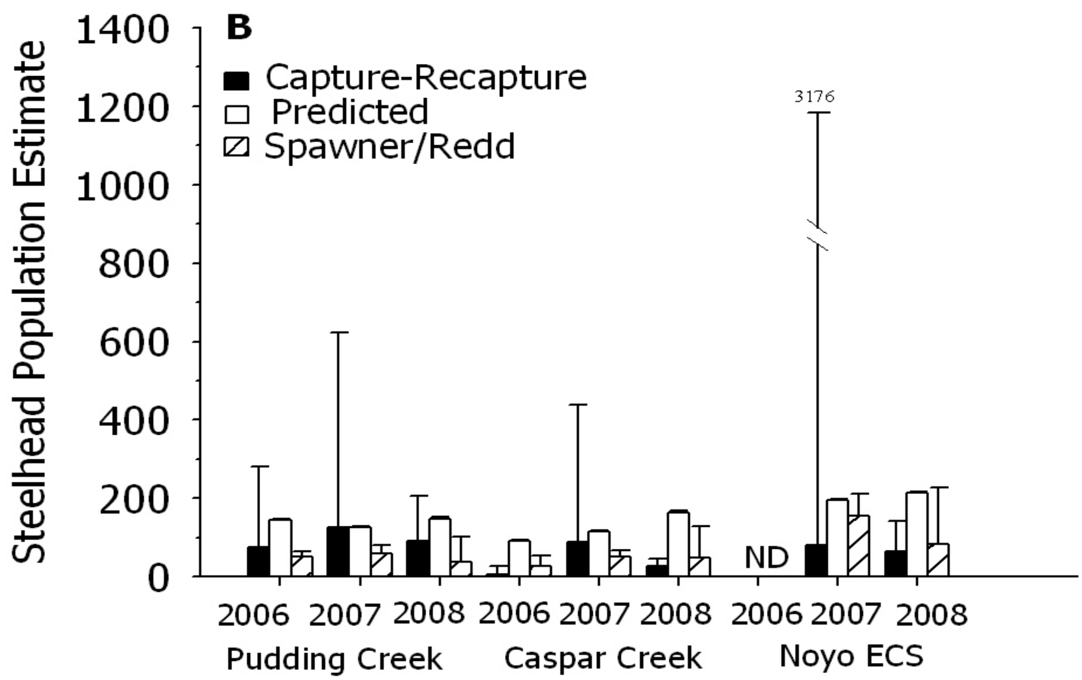
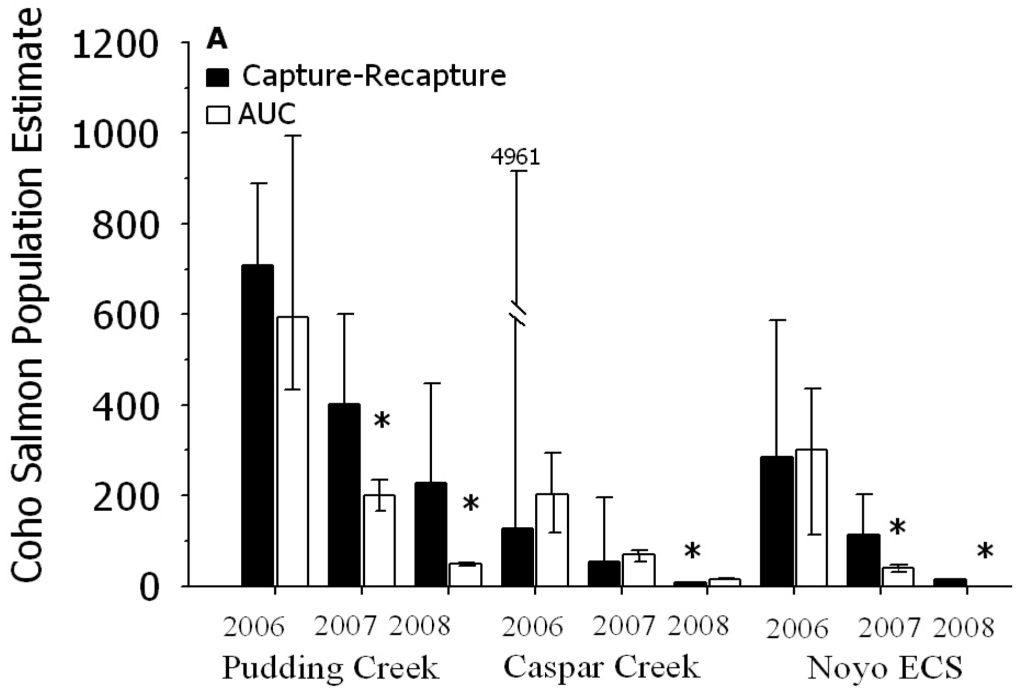


Figure 8. Coho salmon (a) and steelhead (b) escapement from capture-recapture experiments, annual spawner: redd expanded redd counts, and predicted from relationships between redd counts and capture-recapture numbers.



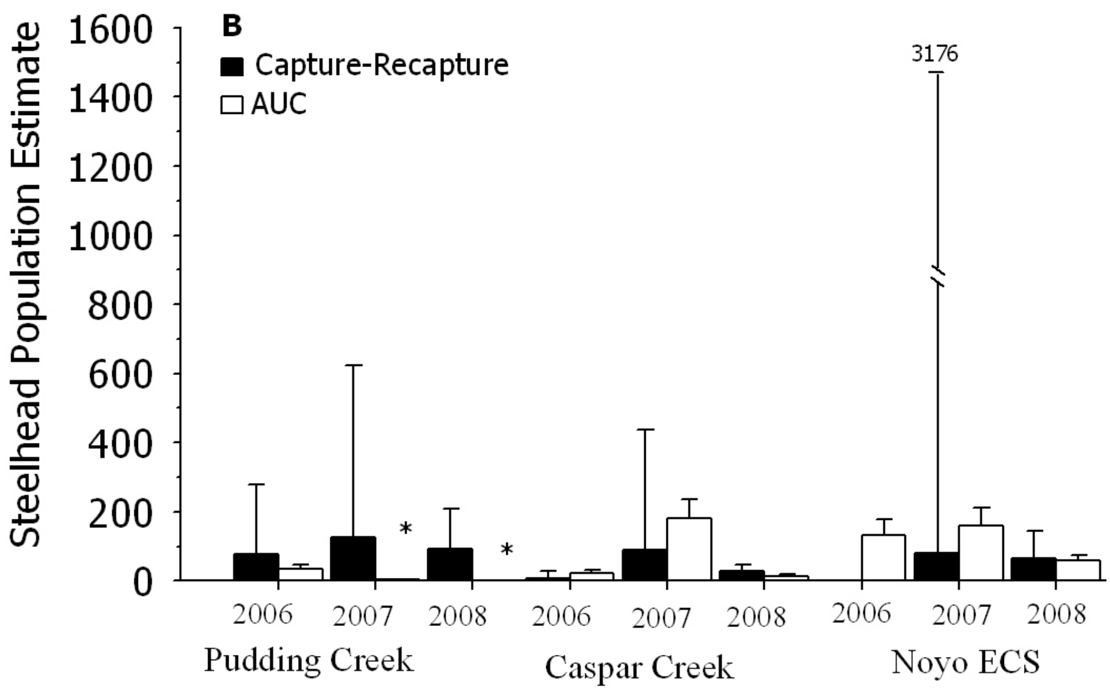


Figure 9. Comparison of coho salmon (a) and steelhead (b) capture-recapture and AUC escapement estimates for several coastal Mendocino County, California streams. Thin lines are 95% confidence bounds. Asterisks indicate lack of overlap among methods.

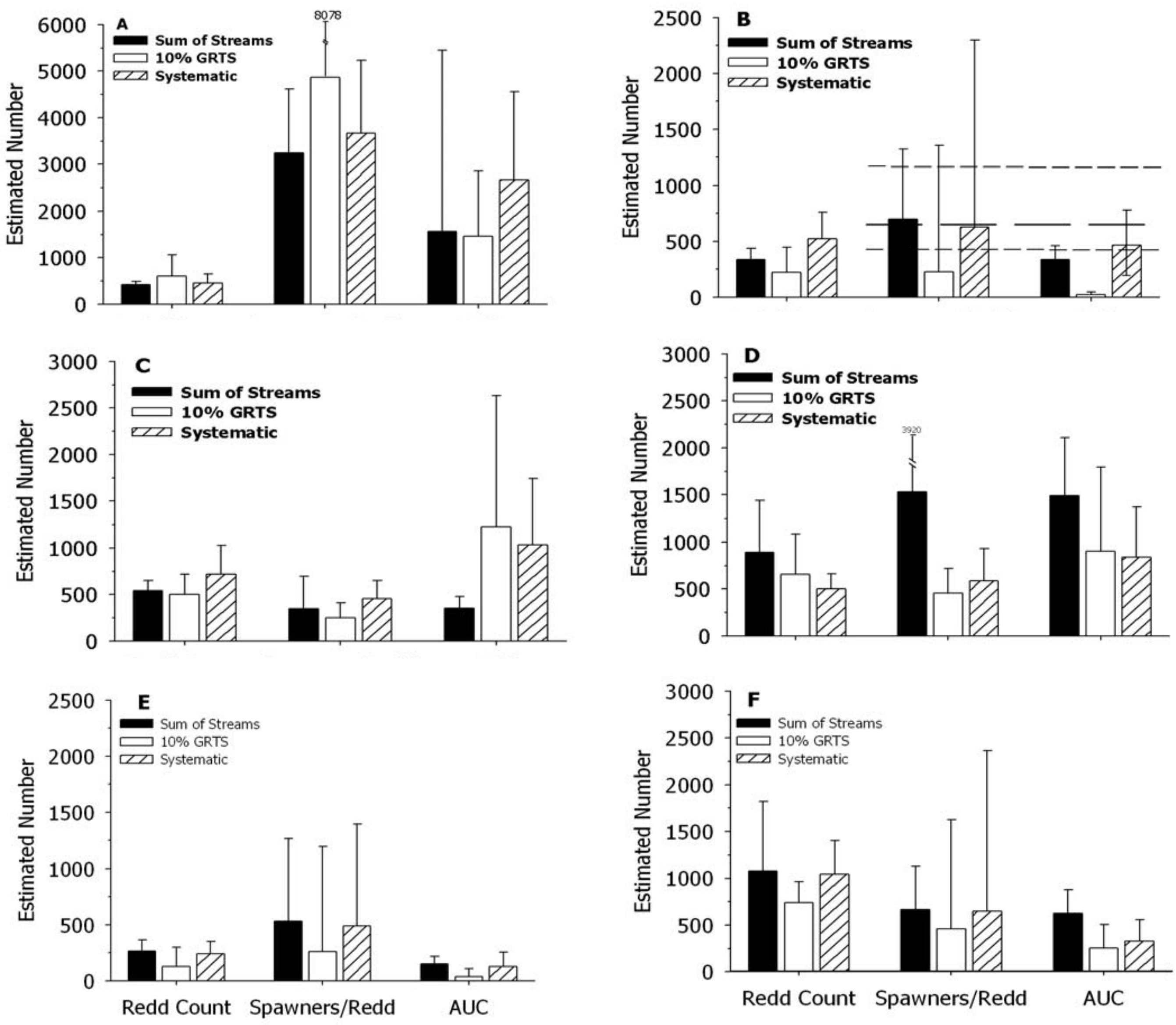


Figure 10**.** Regional Sum-of-Streams, 10% GRTS, and systematic sampling based redd counts and spawner: redd ratio expanded redd count and AUC escapement estimates for 2006 (a-b), 2007 (c-c), and 2008 (c-f). Coho salmon (a, c, and e). Steelhead (b, d, and f). Thin lines are 95% confidence limits. Dashed lines (dark is mean and light are 95% confidence limits) in panel b are summed capture-recapture estimates for comparison.

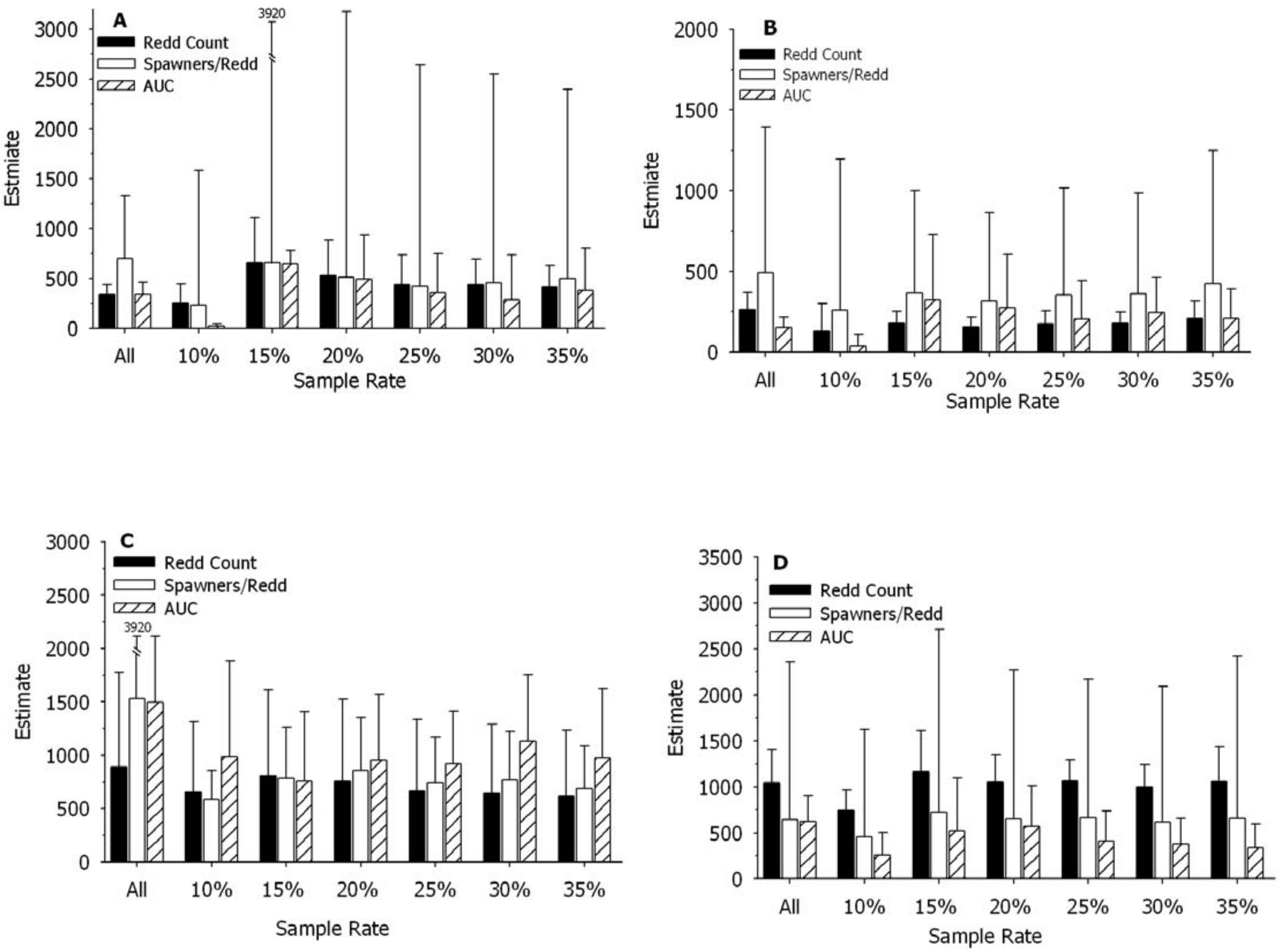


Figure 11. Regional coho salmon (a-b) and steelhead (c-d) escapement estimates in coastal Mendocino County, California for different GRTS sampling rates. A and C are 2007 and B and D are 2008. All is the sum-of-streams estimate. Thin lines are 95% confidence bounds.

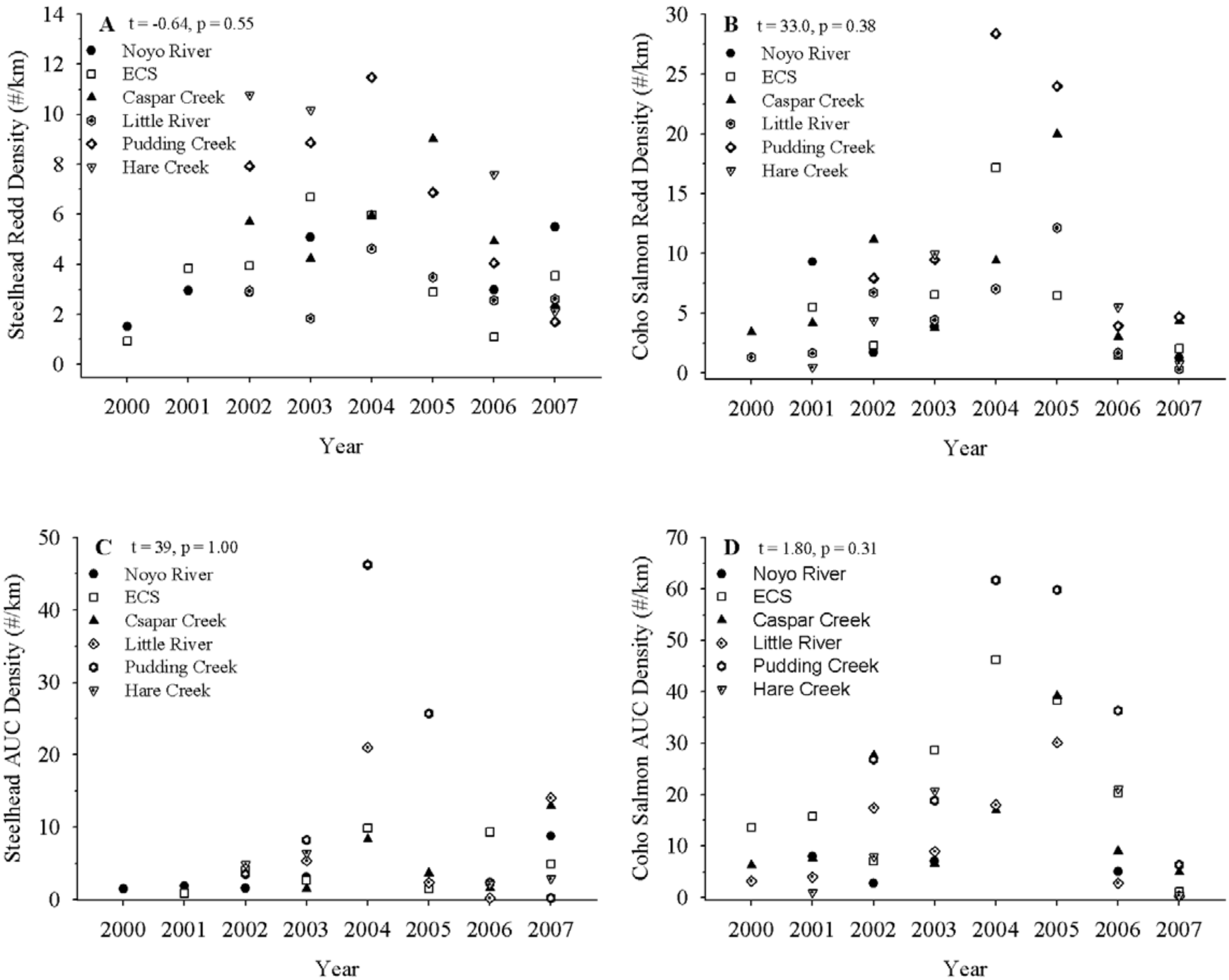


Figure 12. Coho salmon and steelhead redd (a-b) and AUC (c-d) densities for several coastal Mendocino County, California streams 2000 through 2007.

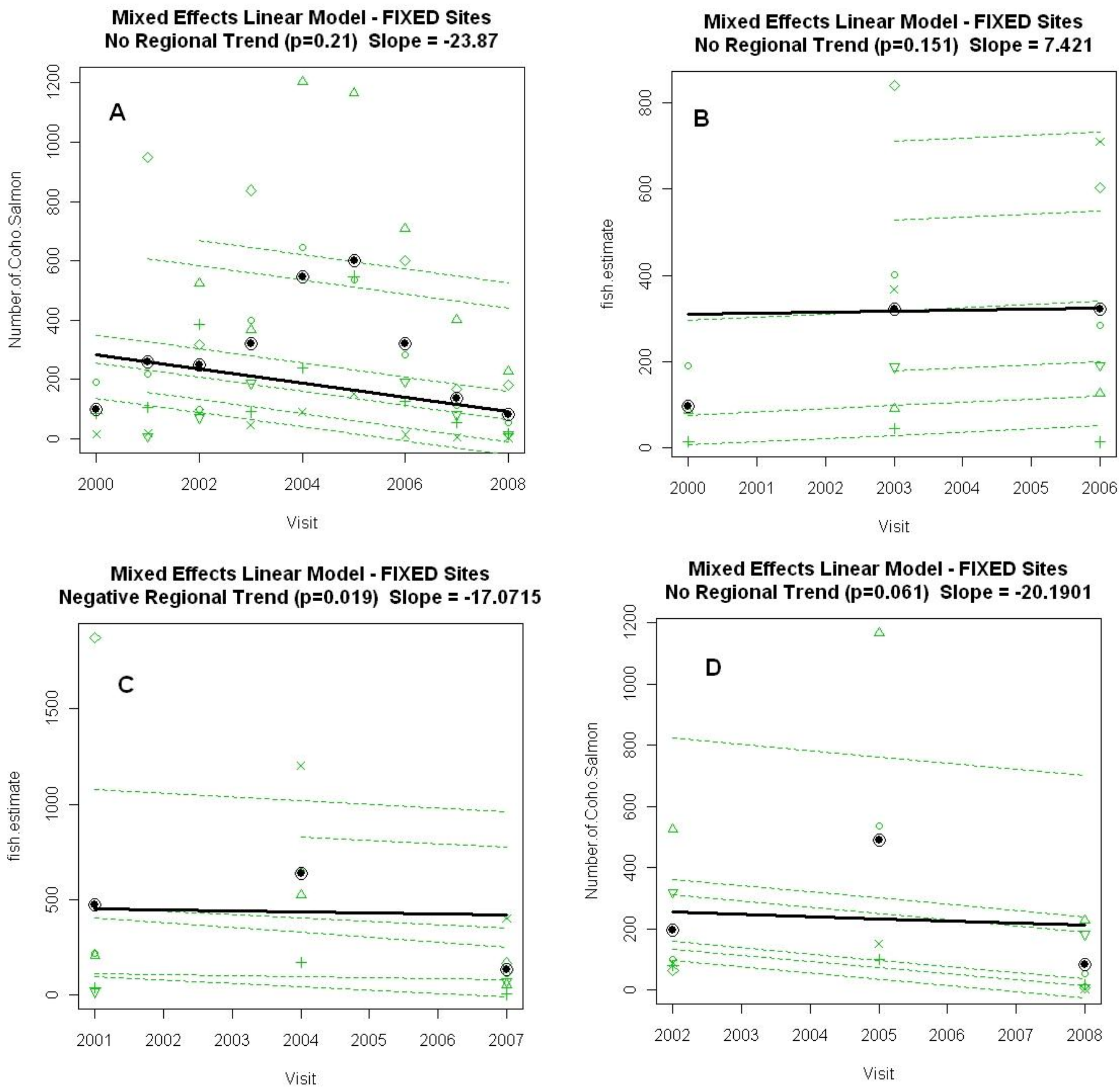


Figure 13. Coho salmon abundance trends. A). Adult returns to five streams 2000 through 2008. B). The 1999-2000 brood year over two complete life cycles. C). The 2000-01 brood year over two complete life cycles. D). The 2001-02 brood year over two complete life cycles.

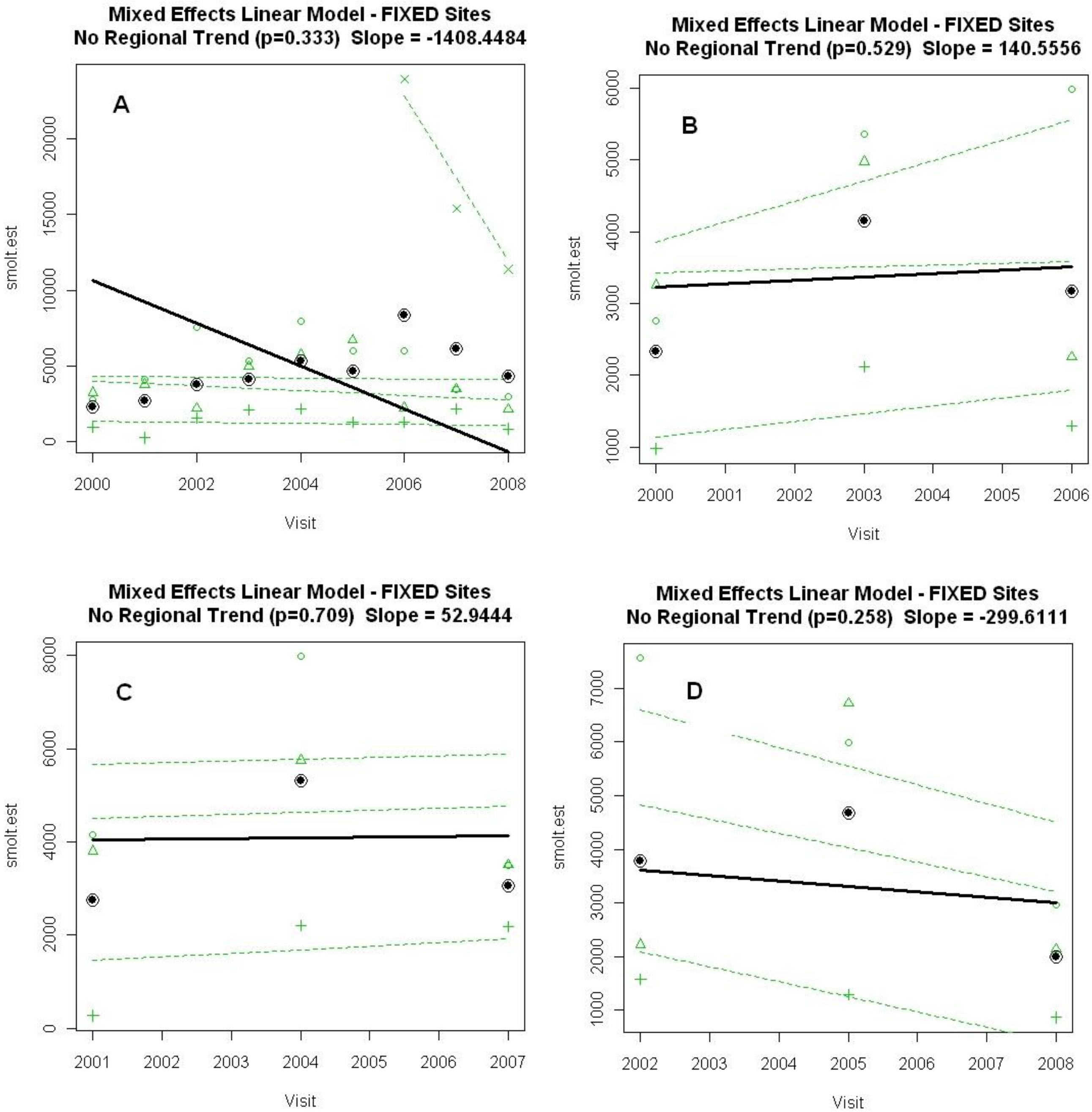


Figure 14. Coho salmon smolt trends. A). Smolt abundance in four streams 2000 through 2008. B). The 1999-2000 brood year over two complete life cycles. C). The 2000-01 brood year over two complete life cycles. D). The 2001-02 brood year over two complete life cycles.

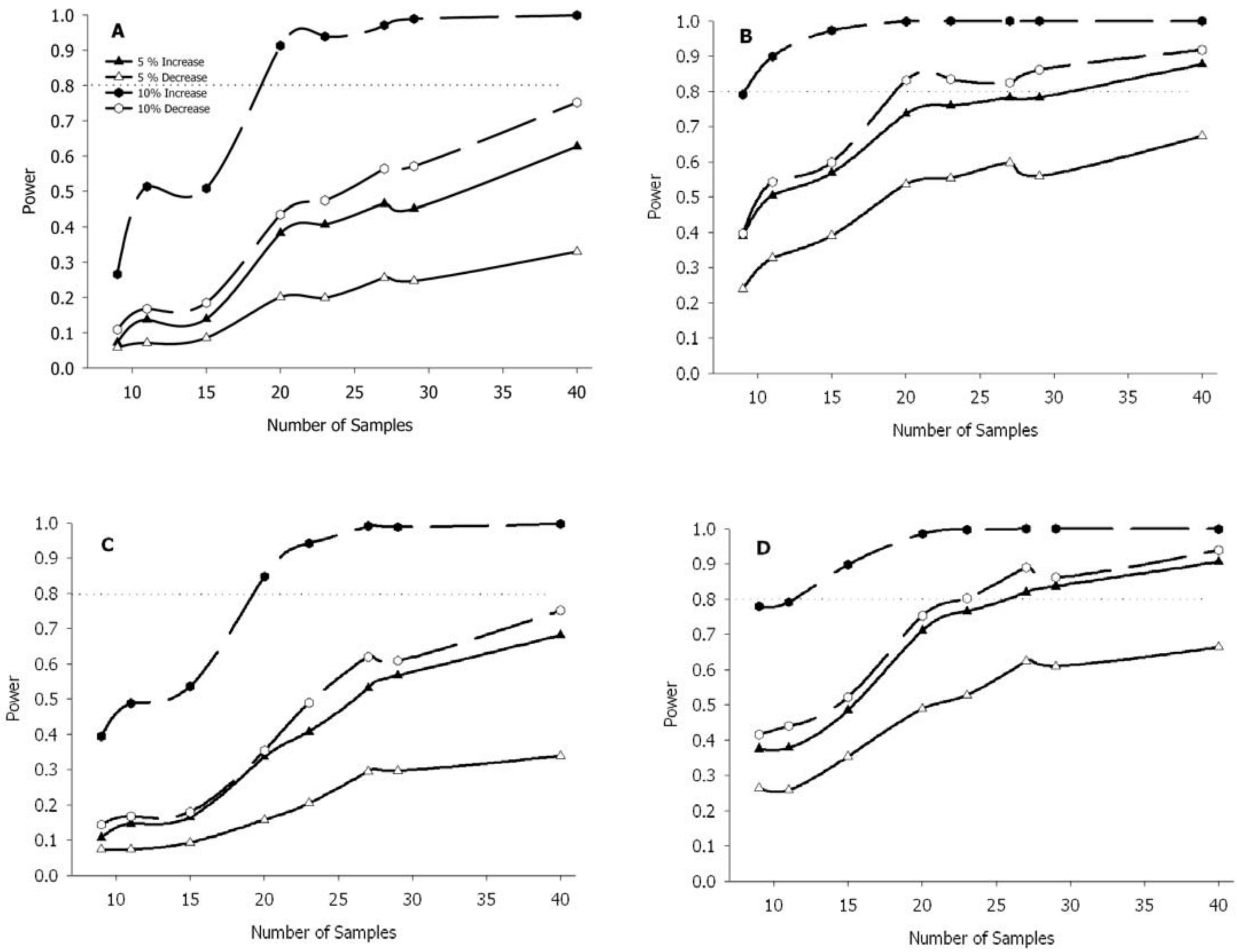


Figure 15. Number of sample reaches and estimated power to detect trends in coho salmon (a-b) and steelhead (c-d) populations based on redd densities. A and C are the results of two-tailed tests with α = 0.05. B and D are results of one-tailed tests with α = 0.10. Dashed line indicates p = 0.80.

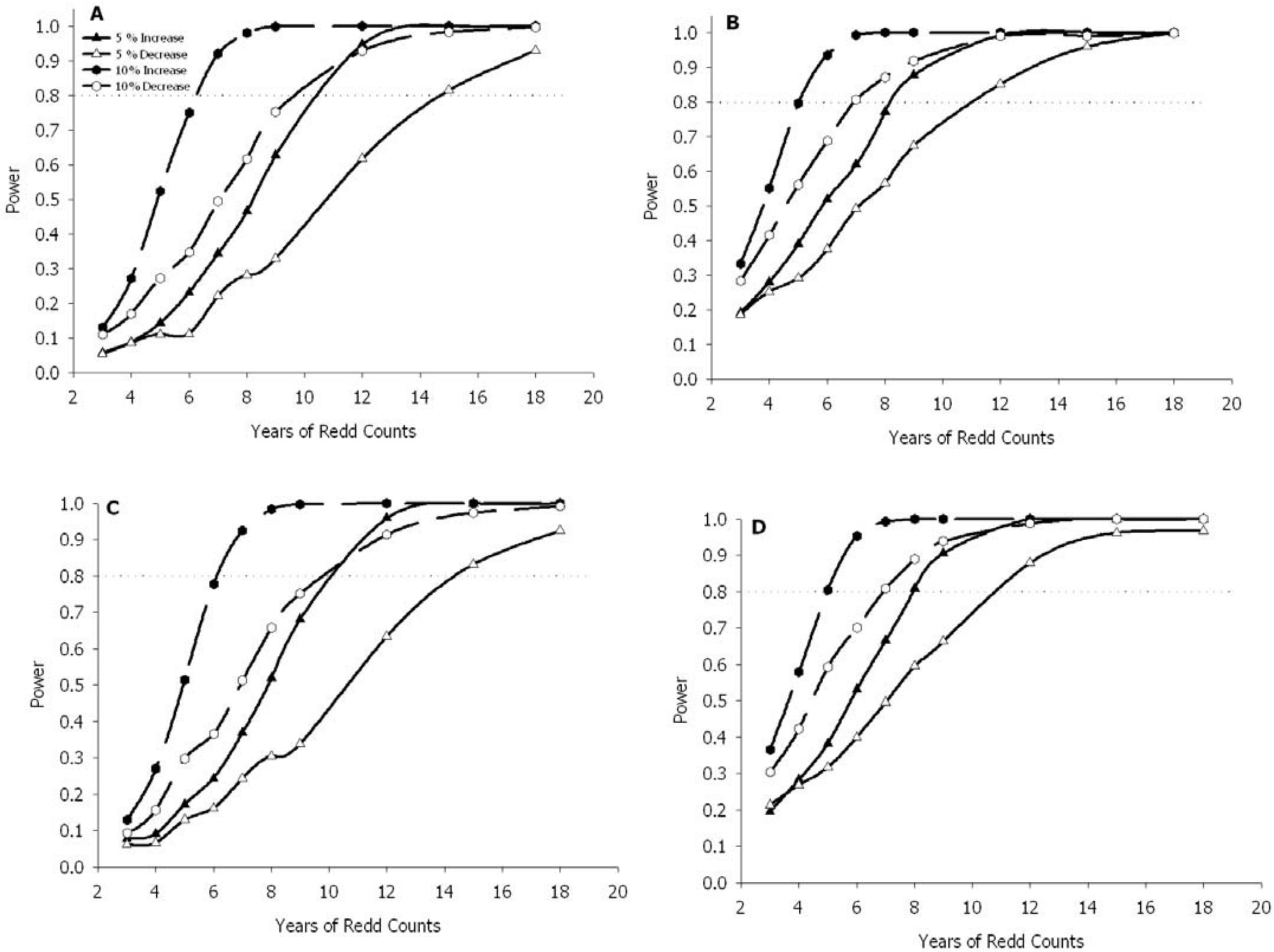


Figure 16. Power of trend detection with 40 reaches of coho salmon (a-b) and steelhead (c-d) redd densities sampled over 18 years. A and C are the results of two-tailed tests with $\alpha = 0.05$. B and D are results of one-tailed tests with $\alpha = 0.10$. Dashed line indicates $p = 0.80$.

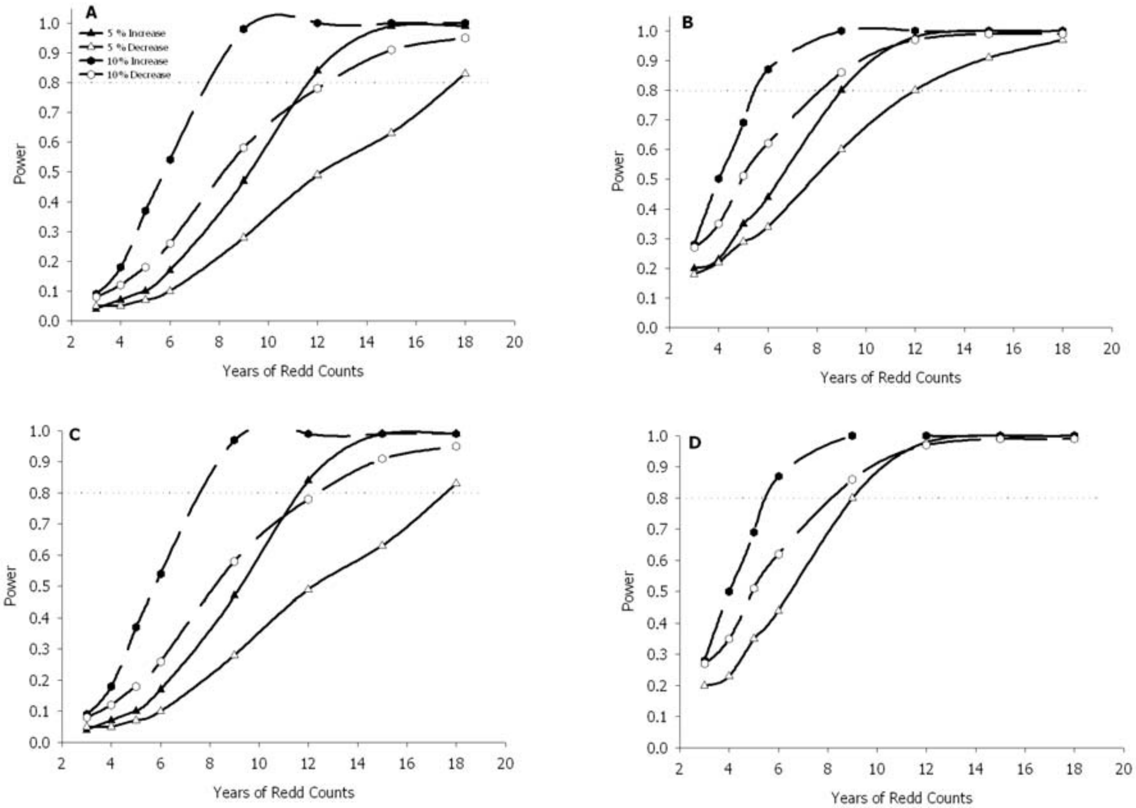


Figure 17. Power of trend detection with 25 reaches of coho salmon (a-b) and steelhead (c-d) redd densities sampled over 18 years. A and c are the results of two-tailed tests with $\alpha = 0.05$. B and d are results of one-tailed tests with $\alpha = 0.10$. Dashed line indicates $p = 0.80$.

Table 1. GRTS order, GIS and predicted reach length, Latitude-Longitude ID, stream name, and rotating panel sampling schedule.

Grts Order	Map Length (km)	Predicted Length (km)	Latitude Logitude ID	Stream Name	Sample Year
1	0.25	0.47	1237350394485	Pudding Creek	Every Year
2	3.11	3.08	1237256394246	South Fork Noyo River	Every Year
3	3.44	3.38	1238090394278	Noyo River	Every Year
4	3.09	3.06	1236581393696	South Fork Noyo River	2005-06
5	3.75	3.67	1238079394591	Pudding Creek	2005-06
6	2.59	2.60	1235507394210	Noyo River	2005-06
7	1.75	0.69	1238153393619	Caspar Creek	2005-06
8	3.14	3.11	1237256394246	South Fork Noyo River	2005-06
9	1.32	1.44	1234595394310	Noyo River	2006-07
10	0.50	0.69	1237342394522	Pudding Creek	2006-07
11	3.15	3.11	1236844393908	South Fork Noyo River	2006-07
12	1.16	1.29	1237376394280	Noyo River	2006-07
13	3.89	3.79	1235507394210	Noyo River	2006-07
14	1.72	1.80	1237311393877	Hare Creek	2007-08
15	3.32	3.27	1238090394278	Noyo River	2007-08
16	0.46	0.65	1236580394057	South Fork Noyo River	2007-08
17	1.73	1.82	1238090394278	Noyo River	2007-08
18	3.32	3.27	1238116394173	Hare Creek	2007-08
19	2.81	2.80	1238090394278	Noyo River	2008-09
20	1.75	1.84	1237256394246	South Fork Noyo River	2008-09
21	1.07	1.21	1237338393537	Noyo River	2008-09
22	2.76	2.75	1238090394278	Noyo River	2008-09
23	1.04	1.19	1235524394765	Noyo River	2008-09
24	2.22	2.26	1238090394278	Noyo River	2009-10
25	0.46	0.65	1236805393879	South Fork Noyo River	2009-10
26	2.28	2.32	1238090394278	Noyo River	2009-10
27	2.97	2.95	1238116394173	Noyo River	2009-10
28	2.07	2.13	1238153393619	Caspar Creek	2009-10
29	2.61	2.62	1238079394591	Pudding Creek	2010-11
30	0.50	0.69	1236571393687	South Fork Noyo River	2010-11
31	3.31	3.26	1238090394278	Noyo River	2010-11
32	1.18	1.32	1235402394298	Noyo River	2010-11
33	3.29	3.24	1238090394278	Noyo River	2010-11
34	2.00	2.06	1235430394703	Noyo River	2011-12
35	2.46	2.48	1238116394173	Hare Creek	2011-12
36	1.30	1.42	1236813394045	South Fork Noyo River	2011-12
37	0.88	1.04	1234732394311	Noyo River	2011-12
38	2.17	2.22	1238079394591	Pudding Creek	2011-12
39	3.21	3.17	1237256394246	South Fork Noyo River	2112-13
40	2.82	2.81	1238090394278	Noyo River	2112-13
41	3.28	3.23	1237900392738	Little River	2112-13
42	2.99	2.97	1235321394542	Noyo River	2112-13
43	2.18	2.22	1238079394591	Pudding Creek	2112-13
44	1.55	1.65	1235883394348	Noyo River	2113-14
45	3.24	3.19	1238090394278	Noyo River	2113-14
46	1.07	1.21	1234399394284	Noyo River	2113-14
47	3.02	2.99	1238079394591	Pudding Creek	2113-14
48	1.50	1.60	1234927394310	Noyo River	2113-14
49	3.22	3.18	1236955394453	Noyo River	2114-15
50	3.32	3.27	1238090394278	Noyo River	2114-15
51	3.24	3.19	1235507394210	Noyo River	2114-15
52	1.89	1.97	1238090394278	Noyo River	2114-15
53	0.70	0.87	1236578393689	South Fork Noyo River	2114-15
54	3.30	3.25	1236844393908	South Fork Noyo River	2115-16
55	2.88	2.86	1237900392738	Little River	2115-16
56	1.20	1.33	1235025394204	Noyo River	2115-16
57	1.00	1.15	1237253394670	Pudding Creek	2115-16
58	1.56	1.66	1237193394176	South Fork Noyo River	2115-16
59	2.71	2.72	1238090394278	Noyo River	2116-17
60	0.48	0.67	1235144394194	Noyo River	2116-17
61	3.02	3.00	1238090394278	Noyo River	2116-17
62	3.88	3.78	1237544393465	Caspar Creek	2116-17
63	1.60	1.70	1236730393844	South Fork Noyo River	2116-17
64	2.92	2.91	1236844393908	South Fork Noyo River	2117-18
65	3.09	3.06	1235025394204	Noyo River	2117-18
66	2.16	2.21	1238079394591	Pudding Creek	2117-18
67	0.54	0.73	1235562394199	Noyo River	2117-18
68	3.28	3.24	1237256394246	South Fork Noyo River	2117-18
69	2.96	2.94	1238153393619	Noyo River	2118-19
70	3.30	3.26	1235321394542	Noyo River	2118-19
71	3.10	3.07	1238090394278	Noyo River	2118-19
72	0.29	0.50	1235008394700	Noyo River	2118-19
73	0.03	0.26	1236741394119	Noyo River	2118-19
74	2.53	2.55	1234927394310	Noyo River	2119-20
75	2.82	2.81	1238153393619	Caspar Creek	2119-20
76	nd	3.66	nd	Caspar Creek	2119-20*

* Start over at lowest ever two years GRTS order number.

Table 2. Coho salmon and steelhead fish per redd estimates for some coastal Mendocino County streams 2000 to 2008. Coho salmon fish per redd estimates for the South Fork Noyo River above the ECS 2000 to 2003 are based on release counts. All other estimates are based on live fish capture-recapture experiments.

Year	Site	Number of Steelhead Per Redd			Year	Site	Number of Coho Salmon Per Redd		
		Point Estimate	Low 95% CI	High 95% CI			Point Estimate	Low 95% CI	High 95% CI
2000	Noyo River	1.37	0.00	2.35	2001	Noyo River ECS	1.54	nd	nd
2001	Noyo River	0.74	0.20	1.77	2002	Noyo River ECS	4.31	nd	nd
2002	Noyo River	1.55	0.33	2.67	2003	Noyo River ECS	0.86	nd	nd
2003	Noyo River	0.60	0.07	1.03	2004	Noyo River ECS	1.65	1.45	1.69
2004	Noyo River	nd	nd	nd	2005	Noyo River ECS	3.27	1.70	5.08
2005	Noyo River	nd	nd	nd	2006	Noyo River ECS	11.40	7.74	21.78
2006	Noyo River	0.57	0.25	19.33	2007	Noyo River ECS	2.28	1.52	4.04
2007	Noyo River	0.72	0.64	1.14	2008	Noyo River ECS	nd	nd	nd
2007	Noyo River ECS	0.71	0.27	28.36	2007	Noyo River	1.30	1.17	1.70
2008	Noyo River ECS	0.46	0.28	1.05	2004	Pudding Creek	2.02	1.35	3.98
2004	Pudding Creek	1.11	0.31	1.82	2005	Pudding Creek	2.68	2.18	3.85
2005	Pudding Creek	1.62	1.03	2.15	2006	Pudding Creek	9.33	8.40	10.83
2006	Pudding Creek	1.29	0.49	4.59	2007	Pudding Creek	3.65	2.68	5.46
2007	Pudding Creek	2.98	1.47	14.51	2008	Pudding Creek	2.02	1.35	3.98
2008	Pudding Creek	1.05	0.90	3.39	2006	Caspar Creek	3.32	1.37	121.00
2006	Caspar Creek	0.14	0.11	0.55	2007	Caspar Creek	1.20	0.62	4.36
2007	Caspar Creek	2.47	1.22	12.17	2008	Caspar Creek	nd	nd	nd
2008	Caspar Creek	0.36	0.17	0.61					
2006	Average	0.67	0.28	8.16	2006	Average	8.01	5.84	51.20
2007	Average	1.72	0.90	14.05	2007	Average	2.38	1.61	4.62
2008	Average	0.62	0.45	1.68	2008	Average	2.02	1.35	3.98
2000-08	Average	1.11	0.51	1.93	2000-08 [1]	Average	2.23	1.56	3.79

[1] Does not include 2006 data due to difficulties counting redds such that these data were outliers.

Table 3. Coho salmon residence time (time between capture and recapture as freshly dead carcasses) estimates for some coastal Mendocino County streams 2003 to 2008.

Year	Site		Coho Salmon Residence Time		
		n	Low 95% CI	Point Estimate	High 95% CI
2003-04	South Fork Noyo River	119	25.97	28.09	30.22
2004-05	South Fork Noyo River	21	21.14	26.81	32.48
2005-06	South Fork Noyo River	4	18.25	19.14	37.39
2006-07	South Fork Noyo River	1	na	21.00	na
2007-08	South Fork Noyo River	0	nd	na	nd
2003-04	Pudding Creek	19	28.99	32.63	36.27
2004-05	Pudding Creek	10	11.33	21.10	30.87
2005-06	Pudding Creek	6	14.38	25.00	35.62
2006-07	Pudding Creek	2	12.72	25.00	32.72
2007-08	Pudding Creek	14	11.70	17.00	22.33
2005-06	Caspar Creek	1	na	16.00	na
2006-07	Caspar Creek	1	na	21.00	na
2007-08	Caspar Creek	1	na	24.00	na
2005-06	Annual Average	11	15.03	21.73	28.42
2006-07	Annual Average	3	20.00	23.30	29.00
2007-08	Annual Average	1	na	24.00	na
All Years	Grand Mean	178	24.43	26.21	27.98

Table 4. Steelhead residence time (time between capture and recapture) estimates for some coastal Mendocino County streams 2000 to 2008.

Year	Site	n	Steelhead Residence Time		
			Low 95% CI	Point Estimate	High 95% CI
1999-2000	Noyo River Mainstem	3	24.76	38.00	51.24
2002-03	Noyo River Mainstem	2	na	28.00	na
2005-06	Noyo River Mainstem	1	na	48.00	na
All Years	Grand Mean Mainstem*	6	17.84	30.87	43.83
1999-2000	Noyo River Tributaries	8	6.99	12.13	17.26
2000-01	Noyo River Tributaries	3	6.55	16.67	26.78
2001-02	Noyo River Tributaries	1	na	15.00	na
2002-03	Noyo River Tributaries	4	2.40	13.25	24.10
2004-05	Noyo River Tributaries	2	0.00	10.00	27.24
2005-06	Noyo River Tributaries	na	nd	nd	nd
2006-07	Noyo River Tributaries	1	na	19.00	na
2007-08	Noyo River Tributaries	8	13.35	25.67	37.98
2003-04	Pudding Creek	8	3.00	9.37	15.75
2004-05	Pudding Creek	3	22.43	28.33	34.24
2005-06	Pudding Creek	na	nd	nd	nd
2006-07	Pudding Creek	2	6.40	47.00	87.60
2007-08	Pudding Creek	1	na	34.00	na
2005-06	Caspar Creek	na	nd	nd	nd
2006-07	Caspar Creek	1	na	21.00	na
2007-08	Caspar Creek	5	3.60	30.40	57.20
2005-06	Annual Average	29	11.33	15.43	19.54
2006-07	Annual Average	3	11.01	20.00	28.99
2007-08	Annual Average	15	20.27	27.80	36.20
All Years	Grand Mean	52	16.60	21.00	25.40

Table 5. Observer efficiency for live fish observations (number observed marked/ total marked) for three coastal streams in Mendocino County, California 2000 to 2008.

Year	Site	Observer Efficiency	
		Coho Salmon	Steelhead
2000-01	Noyo River	nd	0.08
2002-03	Noyo River ECS*	0.24	0.06
2003-04	Noyo River ECS*	0.22	nd
2003-04	Pudding Creek	0.20	0.18
2004-05	Noyo River ECS*	0.28	nd
2004-05	Pudding Creek	0.26	0.04
2005-06	Noyo River ECS*	0.18	0.11
2005-06	Pudding Creek	0.21	0.06
2005-06	Caspar Creek	0.14	nd
2006-07	Noyo River	0.19	0.29
2006-07	Noyo River ECS	0.17	0.08
2006-07	Pudding Creek	0.15	nd
2006-07	Caspar Creek	0.11	nd
2007-08	Caspar Creek	nd	0.57
2007-08	Pudding Creek	0.12	nd
2007-08	Noyo River ECS	nd	0.28
	Average	0.19 ± 0.03 (95%ci)	0.18 ± 0.0.12 (95%ci)

* Coho data from ECS releases in South Fork. Steelhead data from complete river surveys.

Table 6. Live coho salmon and steelhead capture-recapture escapement data for several coastal Mendocino County streams during 2007-08. Numbers in parentheses are recaptures. Numbers under total captured correspond with fish recaptured at the structures and under total observed they are tagged fish observed on the spawning grounds.

Site	Species	Total Captured	Number Marked	Total Observed	Population Estimate	Female: Male	Number of Females
Caspar Creek	Coho Salmon	5 (0)	5	3 (0)	6 - 17 - ∞	1.50:1.00	13
	Steelhead	14 (1)	14	15 (8)	13 - 28 - 47 17 - 93 - 1356 [1]	1.17:1.00	16
Noyo ECS	Coho Salmon	15 (0)	15	0 (0)	16 - 54 - ∞	0.36:1.00	10
	Steelhead	25 (4)	19	40 (5)	38 - 64 - 143 22 - 73 - 588 [1]	1.10:1.00	36
All Noyo	Coho Salmon	15 (0)	15	13 (0)	55 - 182 - ∞	1.25:1.00	114
	Steelhead	25 (4)	19	154 (5)	124 - 208 - 466	0.72:1.00	75
Pudding Creek	Coho Salmon	122 (2)	111	15 (13)	153 - 228 - 450 9 - 25 - 221 [1]	1.26:1.00	203
	Steelhead	49 (8)[2]	35	2 (0)	55 - 92 - 207 7 - 22 - 177 [1]	1.46:1.00	117

[1] Jolly-Seber Estimates.

[2] 7 Marked steelhead captured in PC screw trap.

Table 7. Coho salmon and steelhead live capture and carcass recapture escapement estimates for several coastal Mendocino County streams during 2007-08. Numbers in parentheses are recaptures. Numbers under total captured correspond with fish recaptured at the structures and under total observed they are tagged fish observed on the spawning grounds.

Site	Species	Total Captured	Number Marked	Total Observed	Population Estimate
Caspar Creek	Coho Salmon	5 (0)	5	0 (0)	ND
	Steelhead	14 (1)	14	2 (1)	21 - 56 - 2196
Noyo ECS	Coho Salmon	15 (0)	15	0	ND
	Steelhead	25 (4)	13	0 (0)	ND
All Noyo	Coho Salmon	15 (0)	15	0 (0)	55 - 182 - ∞
	Steelhead	15 (0)	15	2 (0)	ND
	Chinook Salmon	0	0	0	ND
Pudding Creek	Coho Salmon	111 (2)	111	8 (3)	385 - 780 - 3818
	Steelhead	0	0	0 (0)	ND

Table 8. Proportional tag loss over three seasons (2005-06, 2006-07, 2007-08) for adult capture-recapture experiments at LCS. Numbers in parentheses are 2007-08 data.

Location	Species	Live Fish		Carcasses	
		Operculum Punch	Floy Tag	Operculum Punch	Floy Tag
Caspar Creek	Coho Salmon	0 (nd) nd	0 (nd) nd	1.00 (nd) nd	0 (nd) nd
	Steelhead	0 (nd) nd	0 (nd) nd	0.75 (nd) nd	0 (nd) nd
Pudding Creek	Coho Salmon	0 (0) 0	0 (0) 0	0.71 (0.28) 0.75	0.67 (0.56) 0
	Steelhead	nd (nd) 0	nd (nd) 0	nd (nd) nd	nd (nd) nd
South Fork Noyo River	Coho Salmon	0 (nd) nd	0 (nd) nd	0.59 (nd) nd	0.5 (nd) nd
	Steelhead	nd (nd) o	nd (nd) 0	nd (nd) nd	nd (nd) nd

Table 9. Redd counts for some coastal Mendocino County streams during 2007-08.

Stream	Estmaition Method	Coho Salmon Redd Counts			Steelhead Redd Counts			Chinook Salmon Redd Counts		
		Field Count	OE Expanded	OE [3]	Field Count	OE Expanded	OE [3]	Field Count	OE Expanded	OE [3]
Pudding Creek	Sum of All Reaches [1]	90	113	0.85	49	61	0.78	0	0	na
South Fork Noyo above ECS	Sum of All Reaches [1]	3	4	0.75	120	136	0.88	0	0	0.00
Caspar Creek	Sum of All Reaches [1]	7	9	0.77	67	77	0.88	nd	nd	nd
Little River	Sum of All Reaches [1]	1	1	1.00	10	10	1	na	na	na
Hare Creek	33% Stream Sampling [2]	3	0 - 8 - 16	1.00	15	5 - 39 - 74	0.81	na	na	na
All Noyo	33% Stream Sampling [2]	51	81 - 128 - 175	0.85	326	589 - 755 - 947	0.87	3	0 - 5 - 12	0.75

[1] Pudding and Caspar creeks and South Fork Noyo above the ECS (LCS) and Little River are sums of counts of all reaches.

[2] Counts are totals of subreaches. OE expanded estimates are reach density * stream length (n = 33% sample rate) and 95% confidence limits were calcualted with bootstrap with replacement of 1000 iterations.

[3] Observer Efficiency is total of LCS and Little River reaches and average of reaches for all Noyo and Hare Creek.

Table 10. Regional coho salmon population estimates for the sum of streams, systematic, and GRTS sampling designs 2007-08.

	Redd Density	Redd Count	Fish Per Redd	AUC
Sum of Stream [1]	-	216 - 263 - 318	292 - 531 - 1266	91 - 152 - 217
10% GRTS (n = 8)	0.36 - 0.97 - 1.74	62 - 128 - 300	84 - 259 - 1194	0 - 37 - 109
Systematic (n = 29) [2]	0.45 - 1.40 - 2.03	129 - 243 - 350	174 - 491 - 1393	33 - 129 - 255
15% GRTS (n = 11) [3]	0.60 - 1.05 - 1.46	103 - 180 - 252	139 - 364 - 1003	53 - 324 - 728
20 % GRTS	0.53 - 0.91 - 1.26	91 - 156 - 217	123 - 315 - 864	64 - 273 - 604
25% GRTS	0.69 - 1.02 - 1.48	119 - 175 - 255	161 - 354 - 1015	41 - 204 - 440
30% GRTS	0.63 - 1.04 - 1.44	109 - 179 - 248	147 - 422 - 1250	85 - 244 - 466
35% GRTS	0.75 - 1.21 - 1.82	129 - 209 - 314	174- -422 - 1250	64 - 208 - 393

[1] 33% sampling and total from LCS streams.

[2] 29 systematically sampled reaches, not including reaches used to calculate sos or 10% GRTS estimates.

[3] 15% is first 11 reaches in GRTS draw. 20% n = 15, 25% n = 20, 30% n = 23, and 35% n = 27 reaches.

Table 11. Regional steelhead salmon population estimates for the sum of streams, systematic, and GRTS sampling designs 2007-08.

	Redd Density	Redd Count	Fish Per Redd	AUC
Sum of Stream Estimates [1]	-	878 - 1078 - 1305	395 - 668 - 2192	183 - 626 - 902
10% GRTS (n = 8)	2.64 - 4.30 - 5.60	455 - 741 - 966	205 - 459 - 1626	67 - 254 - 507
Systematic (n = 29) [2]	3.85 - 6.05 - 8.15	664 - 1043 - 1406	299 - 647 - 2362	131 - 326 - 555
15% GRTS (n = 11) [3]	4.53 - 6.76 - 9.35	781 - 1167 - 1613	351 - 724 - 2710	135 - 527 - 1097
20 % GRTS	4.42 - 6.11 - 7.83	762 - 1054 - 1351	343 - 653 - 2270	212 - 573 - 1014
25% GRTS	4.80 - 6.19 - 7.50	828 - 1067 - 1294	373 - 662 - 2174	171 - 409 - 738
30% GRTS	4.43 - 5.79 - 7.21	764 - 999 - 1244	344 - 619 - 2090	155 - 374 - 657
35% GRTS	4.38 - 6.13 - 8.35	755 - 1057 - 1440	340 - 655 - 2419	143 - 339 - 595

[1] 33% sampling and total from LCS streams.

[2] 29 systematically sampled reaches, not including reaches used to calculate sos or 10% GRTS estimates.

[3] 15% is first 11 reaches in GRTS draw. 20% n = 15, 25% n = 20, 30% n = 23, and 35% n = 27 reaches.

Table 12. Estimated sample sizes for various desired levels of precision in redd densities for regional surveys.

Precision	Confidence Limits			
	90%		95%	
	Steelhead	Coho	Steelhead	Coho
10%	331	372	475	533
25%	53	59	76	85
30%	37	41	53	59
50%	13	15	19	21

Table 13. Estimated sample sizes for various desired levels of precision in AUC densities for regional surveys.

Precision	Confidence Limits			
	90%		95%	
	Steelhead	Coho	Steelhead	Coho
10%	1017	1123	1459	1610
25%	163	180	233	258
30%	113	125	162	179
50%	41	45	58	64

Table 14. Coho salmon downstream trapping results for traps in several coastal Mendocino County Streams during spring 2008. YOY is young-of-the year. Y+ are one year old fish. Y++ are two year and older fish. ND is no data. Numbers in parentheses are standard errors, double these for 95% CI's.

Trap Location	YOY			Y+		
COHO	Total Captured	N	Capture Probability	Total Captured	N	Capture Probability
Caspar Mainstem	2	ND	ND	689	2134 174	0.58
Caspar North Fork	30	ND	ND	652	ND	ND
Caspar South Fork	2	ND	ND	147	ND	ND
Caspar Two Traps	2	ND	ND	814	3708 375	0.31
Little River	4	ND	ND	553	863 30	0.63
SF Noyo	125	4250 4186	0.03	1847	2971 71	0.64
Pudding Creek	811	ND	ND	5813	11390 274	0.58

Table 15. Steelhead downstream trapping results for traps in several coastal Mendocino County Streams during spring 2008. Y+ are one year old fish. Y++ are two year and older fish. ND is no data. Numbers in parentheses are standard errors, double these for 95% CI's.

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	Total Captured
Caspar Mainstem	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Caspar North Fork	30	ND	ND	652	ND	ND	0	ND	ND	0	ND	ND	ND
Caspar South Fork	0	ND	ND	42	ND	ND	10	ND	ND	ND	ND	ND	ND
Caspar Two Traps	2	ND	ND	159	6534 3655	0.02	ND	ND ND	ND	186	ND	ND	ND
Little River	ND	ND	ND	295	1040 124	0.33	41	840 578	0.05	336	1225 125	0.28	ND
SF Noyo	11644	ND	ND	878	2729 172	0.34	902	2812 177	0.34	187	381 29	0.44	158
Pudding Creek	116	ND	ND	269	1303 187	0.44	225	812 142	0.37				171

Table 16. Coho salmon survival and spawner: recruit ratios for several Mendocino County streams 2000 to 2008.

Variable	Noyo Ecs [2]			Pudding Creek [3]			Caspar Creek [4]			Little River [5]			Noyo River [6]			
	Low [1]	Estimate	High	Low [1]	Estimate	High	Low [1]	Estimate	High	Low [1]	Estimate	High	Low [1]	Estimate	High	Low [1]
2000 Smolts	2102	2763	3424	nd	nd	nd	2889	3259	3629	917	975	1033	nd	nd	nd	820
2001-2002 Adults	76	112	148	nd	nd	nd	352	386	420	50	88	126	nd	nd	nd	nd
Survival Smolt to 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
1999-2000 Adults	-	190	-	nd	nd	nd	0	87	186	0	16	67	nd	nd	nd	nd
2001 Smolts	1596	4152	6708	nd	nd	nd	3355	3799	4243	259	264	280	16307	26765	37223	1763
2002-2003 Adults	-	401	-	nd	nd	nd	70	91	112	42	45	48	84	487	890	179
Survival Smolt to 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
Recruits/Spawner (03/00)	-	2.11	-	nd	nd	nd	na	1.05	0.60	nd	2.81	0.72	nd	nd	nd	nd
2000-2001 Adults	-	220	-	nd	nd	nd	97	106	115	6	20	33	nd	nd	nd	nd
2002 Smolts	5994	7562	9130	nd	nd	nd	1922	2224	2526	1441	1575	1709	nd	nd	nd	nd
2003-2004 Adults	530	647	706	nd	nd	nd	178	238	298	28	91	154	nd	nd	nd	nd
Survival Smolt to 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
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
2001-2002 Adults	76	112	148	438	524	610	352	386	420	50	88	126	nd	nd	nd	nd
2003 Smolts	4789	5357	5925	nd	nd	nd	4258	4976	5694	1885	2115	2345	nd	nd	nd	nd
2004-2005 Adults	-	536	-	899	1167	1773	298	548	798	0	152	535	nd	nd	nd	nd
Survival Smolt to 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
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
2006 Smolts	4760	5980	7200	21862	25656	29450	1893	2253	2613	1176	1294	1412	nd	nd	nd	nd
2007-2008 Adults [8]	16	54	8	153	228	450	6	16	8	1	2	4	109	259	697	0
Survival Smolt to 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
Recruits/Spawner (08/05)	0.21	0.48	na	0.35	0.44	0.74	0.02	0.04	na	0.03	0.02	0.03	nd	nd	nd	nd
2002-2003 Adults	-	401	-	333	367	401	61	91	121	7	45	83	84	487	890	163
2004 Smolts	7289	7975	8661	nd	nd	nd	4371	5753	7135	2038	2202	2366	nd	nd	nd	nd
2005-2006 Adults	178	285	588	588	709	888	48	126	4961	1	14	27	512	602	692	183
Survival Smolt to 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
Recruits/Spawner (06/03)	0.44	0.71	1.47	1.77	1.93	2.21	0.79	1.38	41.00	0.14	0.31	0.33	6.10	1.24	0.78	1.12
2003-2004 Adults	530	647	706	1067	1204	1600	178	238	298	28	91	154	nd	nd	nd	nd
2005 Smolts	9261	13727	18193	-	-	-	3792	4482	5172	1834	1974	2114	nd	nd	nd	nd
2006-2007 Adults	76	114	202	295	401	601	28	54	196	3	5	6	nd	nd	nd	nd
Survival Smolt to Adult	0.01	0.01	0.01	-	-	-	0.01	0.01	0.04	0.002	0.003	0.003	nd	nd	nd	nd
Recruits/Spawner (07/04)	0.14	0.18	0.29	0.28	0.33	0.38	0.16	0.23	0.67	0.04	0.05	0.11	nd	nd	nd	nd

[1] Adult and smolt data ranges are 95% ci's.

[2] 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 2005.

[3] Pudding Creek adult escapement from live fish mark-recapture for 2004-2006 and 1 redd per female for other years (95% ci based on redd count SE and n = 3 reaches).

[4] 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).

[5] Little River adult escapement from 1 redd per female (95% ci based on redd count SE and n = 2 reaches).

[6] 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).

[7] 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).

[8] Ecs and caspar mark-recapture from Schnabel method without recaptures so upper 96% confidence bounds are infinite.

Table 17. Coho salmon viability based on Spence et al. (2008) for several coastal Mendocino County streams 2000 through 2008.

Stream	Harmonic Mean (per generation)		Number of Years	Extinction Risk [1]	Spawners/ IP-KM
	Population Size	Effective Population Size [2]			
South Fork Noyo River	794	159	7	Moderate	11
Pudding Creek	2124	425	5	Moderate/Low	23
Caspar Creek	517	103	7	Moderate	14
Little River	88	17	7	High [3]	7
Noyo River	1311	262	2	Moderate/Low	4
Hare Creek	279	56	2	Moderate	7

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

Stream	Geometric Mean [1] Population Size	Number of Years	Slope	Negative Trend	Population Size ≤ 500
South Fork Noyo River	215	9	0.29	No	Yes
Pudding Creek	562	7	-2.63	No [2]	No
Caspar Creek	119	9	-1.56	No [2]	Yes
Little River	24	9	-1.04	No [2]	Yes
Noyo River	409	6	nd	No	Yes
Hare Creek	56	6	nd	No	Yes

[1] Spence et al. (2008) suggests a minimum of four generations of data. These data are from one to three generations.
[2] $r^2 < 0.28$, $p > 0.34$, $t < -0.90$. Slope not siginificant.

Table 19. Regional spawning ground survey (extensive) average cost per reach for eight surveys. Costs rounded to nearest dollar.

Number of Reaches	Person Hours [1]	Field Survey Cost [2]	Transportation [3]	Cost/Reach [4]	Cost/Fish [5]	Cost/Coho	Total Cost all Reaches
8 (10%)	98	$1,828	$214	$2,792	$320	$729	$22,336
29 (Systematic)	90	$1,684	$119	$2,554	$427	$734	$74,066
11 (15%)	94	$1,742	$132	$2,624	$267	$620	$28,864
15 (20%)	104	$1,933	$202	$2,885	$332	$814	$43,275
19 (25%)	100	$1,862	$209	$2,821	$321	$727	$53,599
23 (30%)	92	$1,721	$206	$2,677	$384	$814	$61,571
27 (35%)	93	$1,740	$211	$2,701	$374	$652	$72,927

[1] Two persons per survey and two hours per person per survey for office prep time.

[2] 13.20$/hr plus 0.28% benefits and 13% overhead =18.62/hr.

[3] Federal Milage Rate 0.485$/mi or 0.30/km.

[4] Includes field gear costs estimated at 750$.

[5] Chinook and coho salmon and steelhead. Does not inlcuded data storage, analysis, and reporting costs about 50 person hours/reach.

Table 20. Life cycle monitoring streams (Intensive Monitoring) adult escapement operational costs.

Site	Adult Tagging						
	Person Hours [1]	Field Costs [2]	Transportation [3]	Tagging Equipment	Palm Pilots	Saftey Gear	Total Cost
Pudding Creek	495	$9,217	$540	$3,747	$750	$500	$14,750
Noyo ECS	455	$7,909	$810	$3,747	$ 0 [7]	$500	$12,962
Caspar Creek [6]	400	$7,448	$675	$3,747	$ 0 [7]	$500	$11,691

[1] Two persons per trap check and two hours per person per survey for office prep time.

[2] 13.20$/hr plus 0.28% benefits and 13% overhead =18.62/hr.

[3] Federal Milage Rate 0.485$/mi or 0.30/km.

[4] Based on costs estimates for each stream.

[5] Chinook and coho salmon and steelhead. Does not inlcuded data storage, analysis, and reporting costs about 40 person hours/trap site.

[6] Does not include one time start up cost for building a weir of ~10,000$.

[7] Purchased in 2006.

Table 21. Pudding Creek coho salmon 1950's versus 2000's.

Years	Number of Generations	Historic Captures/Escapement [1]	Recent Population Estimates	Recent Capture Numbers	Smolt to Adult Survival	Recriuts/Spawner	
						1950's	2000's
1957-58 vs 2005-06	16	1257	588 - 709 - 888	360	0.01 vs 0.02-0.04-0.07 [2]		
1960-61 vs 2007-08 [6]	15	208	153-228-450	122	0.01-0.02 [3]	0.17	0.35 - 0.44 - 0.74
1963-64 [7]	14	950				4.57	
1958-59 [8] vs 2006-07	16	628	299 - 401 - 601	171	0.01 vs 0.01 [4]		
1958-59 vs 2003-04	15	-	1067 - 1204 - 1600	247			1.77 - 1.93 - 2.21
1961-62 [6]	14	515					
2964-65	13	998			0.04 vs 0.08-0.09 [5]	1.94	
1959-60 vs 2004-05	15	285	599 - 1167 - 1773	587	nd		nd
1962-63 [7]	14	1437				5.04	
1965-66 [7]	13	na					

[1] Estimated number less hatchery influence see capture totals estimated natural returns. Generally does not account for fish that bipassed trap.

[2] 1957-58 Brood year released in 59 returned 1960-61 vs 2005-06 adult data from ecs trapping.

[3] 2006 smolts to 2007-08 adults. Note PIT tag return estimate was 0.01.

[4] 1957-58 brood year 1959 smolts vs 2006-07 ECS data.

[5] 1964-65 retuns of 1963 smolts compared to 2003-04 ecs data.

[6] Hatchery influence

[7] Many fish bypass trap and hatchery influence

[8] Captures about equal to escapement

APPENDIX 1

Multiple captures from downstream migrant traps during spring 2007

Multiple recapture histories for coho salmon in downstream traps in some coastal Mendocino County, California streams spring 2007.

Caspar Creek Pit Tagged Coho Total Recaptures = 245

North Fork Caspar Creek- (53)	**Time between Capture and reccapture (Days)**												
All fish were marked at NFC and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	**69--75**	**76-81**	**82-89**	**90-97**
DARR Recapture results	4.08	6.12	0.408	0.81	4.8	3.6	0.81	0	0	0	0	0	0
Recaptured NFC/ then at Mainstem	0	0	0	0.408	0.408	0	0	0	0	0	0	0	0

South Fork Caspar Creek- (101)	**Time between Capture and reccapture (Days)**												
All fish were marked at SFC and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	**69--75**	**76-81**	**82-89**	**90-97**
DARR Recapture results	1.6	1.21	1.2	2.04	2.8	4.8	4.8	4.48	4.8	4.08	5.7	0	0
Recaptured SFC/ then at Mainstem	0.4	1.2	1.6	0	0	0	0	0	0	0	0	0	0

Mainstem Caspar Creek- (91)	**Time between Capture and reccapture (Days)**												
All fish were marked at MSC and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	**69--75**	**76-81**	**82-89**	**90-97**
DARR Recapture results	4.08	12.6	8.58	0.81	0.4	2.04	0.4	0	0	0.81	1.2	1.6	4.08
Recaptured twice at MSC	0.4	0	0	0	0	0	0	0	0	0	0	0	0

SF Noyo Pit Tagged Coho Total Recaptures = 596

South Fork Noyo- (596)	**Time between Capture and reccapture (Days)**												
All fish were marked at SF Noyo and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	**69--75**	**76-81**	**82-89**	**90-97**
DARR Recapture results(Single Recapture)	1.1	5.5	2.5	1.1	6.7	13.75	4.02	5.9	15	9.7	23	10.4	0.16
Recaptured twice at SF Noyo	0.34	0.34	0	0.17	0	0	0	0	0	0	0	0	0
Recaptured three times at SF Noyo	0	0	0	0	0	0	0.17	0	0	0	0	0	0

Multiple recapture histories for steelhead in downstream traps in some coastal Mendocino County, California streams spring 2007.

Caspar Creek Pit Tagged Onmy Total Recaptures = 50

North Fork Caspar Creek- (53)	**Time between Capture and reccapture (Days)**												
All fish were marked at NFC and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	**69--75**	**76-81**	**82-89**	**90-97**
DARR Recapture results	31.25	6.25	6.25	0	12.5	0	6.25	25	0	6.25	0	0	0
Recaptured NFC/ then at Mainstem	0	0	0	6.25	0	0	0	0	0	0	0	0	0

South Fork Caspar Creek- (101)	**Time between Capture and reccapture (Days)**												
All fish were marked at SFC and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	**69--75**	**76-81**	**82-89**	**90-97**
DARR Recapture results	3.7	0	3.7	3.7	0	22.2	44.4	22.2	0	0	0	0	0

Mainstem Caspar Creek- (91)	Time between Capture and reccapture (Days)												
All fish were marked at MSC and Then. . . .	**<7**	**7-14**	**15-21**	**22-28**	**29-36**	**37-44**	**45-52**	**53-60**	**61-68**	69--75	76-81	82-89	90-97
DARR Recapture results	0	0	28.5	0	0	28.57	14.3	28.57	0	0	0	0	0

SF Noyo Pit Tagged Coho Total Recaptures = 596

South Fork Noyo- (596)	Time between Capture and reccapture (Days)												
All fish were marked at SF Noyo and Then. . . .	<7	7-14	15-21	22-28	29-36	37-44	45-52	53-60	61-68	69--75	76-81	82-89	90-97
DARR Recapture results(Single Recapture)	**0.18**	**5.68**	**3.65**	**1.09**	**9.9**	**26.58**	**17.96**	**10.08**	**12.98**	**2**	**4.6**	**0.73**	**0**
Recaptured twice at SF Noyo	2.5	0.18	0.36	0.18	0.18	0.18	0	0	0	0	0	0	0
Recaptured three times at SF Noyo	0.18	0.18	0.18	0	0	0	0	0.18	0	0	0	0	0