

**Status Review Update for Coho Salmon (*Oncorhynchus kisutch*)
from the Central California Coast and the California portion of
the Southern Oregon/Northern California Coasts Evolutionarily
Significant Units**

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SUMMARY

Coho salmon (*Oncorhynchus kisutch*) data in California were reviewed to provide an update of its status. This review was based only on biological information and uses the “best available data” to analyze the current condition of this species. The geographical area covered includes the Central California Coast ESU and the California portion of the Southern Oregon/Northern California Coasts ESU. In previous status reviews, findings were that the Central California Coast ESU was presently in danger of extinction and that the Southern Oregon/Northern California Coasts ESU was likely to become endangered in the foreseeable future.

Two general types of data were analyzed: presence-absence data and population trend data. Presence-absence data included in the analysis were collected using a number of different sampling techniques over different periods of time between 1989 and 2000. It is important to note that a record of “presence” does not necessarily indicate persistent populations. Nor does a record of “absence” preclude the possibility of coho salmon within the system, only that they were not detected during sampling. Population trend data came from a wide variety of sampling methods including juvenile surveys, downstream migrant trapping, upstream migrant trapping, and spawning and redd surveys. For the trend analysis, we used population data only from streams where a minimum of six years of sampling had been conducted at the same location and using consistent methods. This was done so that the analysis would include at least two complete cycles of the coho life history.

The percentage of sampled streams for which coho salmon were found to be present declined over the 1989-2000 time period, with greater declines occurring in the southern part of the range. In the Central California Coast ESU, coho historical presence was identified in 278 streams. The percentage of these streams for which presence has been detected at least once during the three-year period has remained relatively constant (between 44% and 48%) through time, the notable exception being the 1995-1997 period, when 61% of the surveyed streams were found to have coho salmon. In the California portion of the Southern Oregon/Northern California Coasts ESU, the percentage of streams with coho present was higher than the Central California Coast ESU, but declined from 1989 to 2000. Because of the substantial difference in the number of streams included in the analysis, these results are not directly comparable to those presented in Brown and Moyle (1991).

Population trend data indicate a general downward trend throughout the state, though there is some variation among streams. In the Central California Coast ESU, abundances in the 1990's were clearly lower than in the mid-to-late 1980's. The values of coho replacement rates (CRR) were less than one for 126 of 229 observations, indicating a significantly ($p = 0.0045$) higher likelihood that abundance decreased rather than increased. The 1996 and to a lesser degree 1997 year classes were clearly strong ones. This is relevant because the BRT conclusions were based largely on data collected in those years. In the California portion of the Southern Oregon/Northern California Coasts ESU, there appears to be a general decline in abundance, but trend data are more limited in this area and there is variability among streams and years. Here, the value of CCR was less than one for 40 of 67 observations, which was significantly ($p = 0.0278$) higher than expected based on a probability of 0.5.

Levels of hatchery production of coho salmon in California are much lower than in Oregon and Washington. In the Central California Coast ESU, coho hatchery production has decreased with Warm Springs Hatchery being converted into a captive broodstock facility and Monterey Bay Salmon and Trout unable to get sufficient numbers of fish for broodstock in recent years. Only the Noyo Station program is still consistently in operation but has missed production years. In the California portion of the Southern Oregon/Northern California Coasts ESU, Trinity River Hatchery maintains large production and is thought to create significant straying to natural populations. Irongate and Rowdy Creek Hatcheries has experienced low numbers of returns and therefore limited production.

This status review update agrees with previous BRT conclusions. The Central California Coast ESU is presently in danger of extinction. The condition of coho salmon populations in this ESU is worse than indicated by previous reviews. The California portion of the Southern Oregon/Northern California Coasts ESU is likely to become endangered in the foreseeable future.

INTRODUCTION

Previous status reviews for coho salmon (*Onchorhynchus kisutch*) in California have noted the lack of long-term data for assessing population trends for coho salmon in the state (Moyle et al. 1994; Weitkamp et al. 1995; Schiewe 1996). The decline in salmon abundance and the subsequent listing of coho salmon as “threatened” under the Endangered Species Act (ESA) in two Evolutionarily Significant Units (ESUs) in California has prompted an increase in the amount of monitoring of coho populations over the last six to eight years. Although there remains a limit on the ability to directly compare current population abundance with historical abundance, the availability of consistently gathered survey data and hence the ability to track coho salmon status has increased in the last several years.

The purpose of this document is to provide an updated review of coho salmon status in California, focusing on data collected over the last twelve years. This review is based on “best available data,” but there are still sources of data that were unavailable to the Southwest Fisheries Science Center (SWFSC). The review considers only biological data and not habitat quality. The conclusions herein represent the consensus of opinion by SWFSC biologists that have been active in the Biological Review Team (BRT) process.

This analysis covers those areas of the coho salmon’s historical range that lie within the Central California Coast ESU and the California portion of the Southern Oregon/Northern California Coasts ESU. The Central California Coast ESU extends from the San Lorenzo River in Central California to Punta Gorda in Northern California, including tributaries to San Francisco Bay, but excluding populations from the Sacramento-San Joaquin River system. Coho salmon have occasionally been observed in streams south of the San Lorenzo River, including two confirmed reports in Aptos Creek (Patrick Colson, CDFG, pers. comm.). Whether these reports are isolated cases of straying or successful re-establishment of populations in this creek is not known. There are also anecdotal historical reports of coho salmon in the Big Sur and Carmel Rivers (Hassler et al. 1991). These populations are considered part of the Central California Coast ESU if they are not the result of stock transfers (Weitkamp et al. 1995). The Southern Oregon/Northern California Coasts ESU extends from Punta Gorda to Cape Blanco in southern Oregon, inclusive of the Klamath-Trinity River system (Weitkamp et al. 1995). For this ESU, we considered only streams within California, including tributaries to rivers that enter the ocean north of the Oregon border (i.e., the Illinois and Winchuk Rivers).

LISTING HISTORY

In 1993, the National Marine Fisheries Service (NMFS) received a petition to list coho salmon in Scott and Waddell creeks as a threatened or endangered species from the Santa Cruz County Planning Department (Bryant 1994). In 1994, NMFS announced its determination that coho salmon from Scott and Waddell creeks do not constitute an ESA species (i.e., distinct population segment) and that a listing was not warranted (NMFS 1994). However, as a result of this and other petitions to list local stocks of coho salmon, NMFS initiated a coastwide review of coho salmon status (NMFS 1993).

Coho salmon data were reviewed by the BRT in the original status review (Weitkamp et al. 1995) and again after the one-year comment period, considering new data submitted during that time (Schiewe 1996, 1997). The BRT concluded that coho salmon in the Central California Coast ESU were presently in danger of extinction and that coho salmon in the Southern Oregon/Northern California Coasts ESU were likely become endangered in the foreseeable future. These decisions were largely based on presence/absence data for coho salmon in streams where they had historically occurred as described in Brown and Moyle (1991) and Adams et al. (1999). Subsequently, the Central California Coast coho ESU was listed as threatened on Oct. 13, 1996 and the Southern Oregon/Northern California Coasts coho ESU was listed as threatened on May 6, 1997.

METHODS

Presence-Absence Analysis

Historical Presence

We compiled a list of streams for which there was historical evidence of coho salmon presence using a variety of published and unpublished sources. Principle among published sources were the reviews of Brown and Moyle (1991), Hassler et al. (1991), Ellis (1997), Adams et al. (1999), and Kier Associates (1999). These reviews in turn drew heavily on several key sources including Cherr and Griffen (1979a,b,c,d,e,f), Boberg and Kenyon (1979a,b,c,d), and Mills (1983). Additional unpublished information was obtained from agency biologists, scientists, private landowners, water districts, nonprofit groups, and consultants.

The list of streams with historical evidence of coho salmon presence is provided in Appendix A. We chose to organize the list geographically as follows. River basins are listed from north to south according to where the eventual outlet stream or river enters the Pacific Ocean. Within a basin, tributary streams and rivers are listed in the order that they enter the mainstem as one moves upstream from the river mouth. A similar hierarchy was employed for tributaries, with streams listed in order from mouth to headwaters. Where a river splits into two or more major forks, we listed the north or west fork first followed by the south or east fork. This geographic arrangement was chosen to reduce confusion that has occurred in past reviews where multiple streams with the same name occur in the same watershed.

Current Present-Absence

For each stream on the historical list, we attempted to find any available information on coho salmon presence or absence based on surveys conducted from 1989 to 2000, which, given the coho three-year life cycle typical in California, covers the last four generations. Data were gathered from a variety of sources including published literature, unpublished reports, unpublished data and personal communications from agencies, tribes, private landowners, and nonprofit groups. Survey methods used by various sources included electrofishing, snorkeling, downstream or upstream migrant traps, spawning surveys, and carcass counts.

For each stream, we recorded whether coho salmon were observed (present) or not (absent) in each year that a survey was conducted. Interpretation of these data should be tempered by several facts. First, a record of “presence” indicates that at least one individual representing one or more life stages (e.g., young-of-the-year [YOY], yearlings, or adults) was observed during that particular year. For adult surveys that spanned portions of two calendar years were listed as occurring in the first year (i.e., spawners observed in the 1999-2000 spawning season were listed as present in 1999 but not necessarily 2000).

Second, although records of presence definitively establish that coho salmon occurred at a particular site, it does not necessarily mean that populations are persistent. In more than one instance, we were informed by researchers that coho salmon were absent from streams in the fall where they had been previously observed in spring or summer. Nevertheless, we tallied these as “presences” since there was no way to determine whether similar phenomena occurred in other data or in the historical record of presence-absence data. Additionally, it should be noted that our analysis weighs sites equally with respect to presence regardless of the number of fish observed. Thus, while at a coarse level, changes in the percentage of streams with coho present provide some indication of population trends, region-level declines can be masked by the presence of small numbers of fish. Conversely, although we specifically noted where the number of observed fish was small (five or fewer), certain sampling protocols (e.g., sampling of short reaches, or presence/absence surveys where sampling was terminated when coho were found, such as used by Adams et al. [1999] and Kier Associates [1999]) could lead to the appearance of small numbers of fish when in fact they are more abundant.

Finally, it is also important to note that a record of “absence” does not preclude the possibility that fish were present in the system. Many of the sample sites used in the analysis are index reaches of limited length (often 30 m to 100 m) and may not reflect conditions elsewhere in the watershed, though frequently index reaches are selected based on known historic occurrence of fish. Coho salmon are commonly patchily distributed within a watershed, and the occupied area may vary from year to year based on environmental conditions or where adults happen to spawn. As populations become smaller in size, the probability that short index reaches will contain fish is expected to decline. Despite these limitations, the consistent temporal patterns of presence-absence (and abundance) that occur across large areas (whole watersheds and even regionally) suggest that these index reaches do capture gross patterns of presence-absence through time, even if data from individual years at a site may be inaccurate. Presence-absence data for each stream and year are presented in Appendix B.

Analysis

For our analysis, we examine trends in the percentage of streams surveyed that showed coho presence from 1989 to 2000. Data are presented both on an annual basis and as summaries for three-year intervals: 1989-1991, 1992-1994, 1995-1997, and 1998-2000. These temporal blocks are used for two reasons: to encompass the three potential brood lineages in a particular system and to facilitate comparisons with previous analyses. Data are summarized by ESU, as well as by counties and major river basins within ESUs.

Weighted logistic regression was used to synthesize and describe the joint effects of geography and year on the probability that a survey would indicate “presence” of coho salmon. Survey data were roughly aggregated by geography, using county and major drainages to guide classification. The proportion of “presences”, p , in the available data was calculated for each year for each geographic region. We fit the model

$$\text{logit}(p) = (\alpha * t) + (\beta * s) + \delta \quad (1)$$

to the resulting dataset, where the $\text{logit}(p)$ is defined as $\ln(p/(1-p))$, t represents year, g represents space (the geographic “index” of the groups defined in Table 1), and greek letters are the fitted coefficients. We used the number of observations used to calculate a given proportion present to weight the importance of that proportion in the regression.

Population Trends

Current population trends were analyzed for 41 streams in 17 major watersheds in the Central California Coast ESU and 9 streams in 3 major watersheds in the California portion of the Southern Oregon-Northern California ESU. Ideally long-term records (e.g., more than 10 years) of abundance of either adult migrants (or spawners) or outmigrants provide the best information on population trends, though the former can be substantially influenced by ocean harvest. Such records, however, are exceedingly rare in California, and the majority of populations for which these records are available have been substantially influenced by hatchery operations and thus may or may not reflect abundance trends in naturally spawning populations. Where such records exist, we report population numbers and make note of potential biases in the data.

Whereas long-term records of abundance are lacking, a number of monitoring programs were initiated in the 1990s by agencies, tribes, private landowners, water districts, nonprofit groups, and others, and these efforts have resulted in a number of shorter-term records of abundance. The criterion we used for including a stream in this report was a minimum of six years of data for which sample sites and survey methods were consistent over all years. The six-year criterion was chosen to encompass two full generations of coho salmon. The consistency criteria excluded several sites where longer-term records are available, but where comparing numbers among years might lead to erroneous conclusions.

Among the data sets we used, researchers and authors employed a variety of survey and analytical methods, and the robustness of these methods for assessing population trends is highly variable. A brief

discussion of different types of surveys and analyses, as well as their potential limitations and biases, is warranted.

Juvenile surveys

By far the most widely available data on salmonid abundance in California has been generated by juvenile surveys (electrofishing or snorkeling) conducted in rearing habitats. In most cases, data are collected each year at one or more index sites within a stream at approximately the same time of year, usually summer or fall when flows are lowest. Generally, selection of index sites is nonrandom and dictated by ease of access or local knowledge (or presumed knowledge) of fish presence or relative abundance. Additionally, because the same sites are sampled each year, interannual shifts in spatial distribution of coho salmon among years due to random events or changes in habitat resulting from natural or anthropogenic disturbances both can influence the number of fish observed at a particular site. Finally, if time of sampling differs from year to year, then data are confounded by the natural rate of mortality. For all of these reasons, conclusions about population trends based on limited sampling at index reaches should be viewed cautiously.

Abundance information for juveniles was reported in a variety of different units including 1) number of fish per linear distance of stream sampled; 2) number of fish per square meter of habitat (averaged over all habitat types sampled); and 3) expanded population estimates where habitat-specific density is multiplied by available habitat in a stream to obtain an overall population estimate (i.e., number of fish) for the stream. In this report, in all cases, where fish are reported as fish per linear distance of stream (Waddell and Scott creeks in Santa Cruz County, Gazos Creek in San Mateo County, and Redwood Creek in Marin County), these values represent total counts data rather than true density estimates, since no attempt was made to correct for variability in capture efficiency among years. Thus, differences in fish counts may reflect, in part, differences in sampling efficiency due to visibility, stream discharge, or operating efficiency of the electrofisher. Where there was a choice between using density estimates or expanded population estimates, we reported the expanded estimates, provided the expansions accounted for habitat unit types. The reliability of these expanded estimates, however, depends on the fraction of total habitat sampled for fish, and an appropriate distribution of fish sampling sites among the potential habitats.

Downstream migrant trapping

A handful of data sets derived from downstream migrant trap operations were available. We included data only for yearling fish, since numbers of YOY fish caught in migrant traps can fluctuate dramatically for reasons unrelated to population density. Often in these trapping efforts, coho salmon were caught incidentally by researchers collecting data on chinook salmon and steelhead. We used trapping data for trend analysis only if the sampling period consistently encompassed the period in spring when coho are most likely to emigrate—from March to May or June.

Data from outmigrant trapping efforts are most commonly reported in terms of total number of individuals captured. Consequently, assessing trends in abundance is potentially risky, since capture efficiencies vary substantially within and among years as a function of streamflow. Nevertheless, we present these data because they appear to capture gross trends in abundance reasonably well. Where population estimates were calculated (based on mark-recapture estimates of trap efficiency), we used these data rather than fish counts.

Upstream migrant trapping

Traps or weirs for collecting upstream migrant adults provided data for a few streams; however, virtually all of the upstream migrant data included in this report was gathered at facilities associated with hatcheries. Consequently, population trends apparent in these data may or may not reflect trends among wild populations. Additionally, in some cases (e.g., Noyo Egg Collecting Station), adult fish are usually collected only up until the desired number of brood fish is attained. Thus, these counts may

underestimate abundance, particularly in years with high returns. At other locations (e.g., Shasta River), counting of coho salmon was incidental to counting of steelhead or chinook salmon; thus, the numbers presented may represent an incomplete census.

Spawning Surveys and Redd Counts

Spawning surveys for coho salmon were also relatively rare. Because coho typically spawn during periods of high flow, visual observation of coho can be difficult. In the few data sets we found, data were reported as the maximum live/dead count, which is the maximum number of live fish plus carcasses observed on any one survey. Although there are methods for obtaining population estimates from repeated surveys of this type, no such data were available to us.

We also report redd count data from a single watershed (Lagunitas Creek). In general, redd counts tend to underestimate total spawning population; however, like other data types they can provide an index of relative abundance among years. Potential biases in using redd data for trend detection include variable observing conditions among years, superimposed redds, or multiple redds resulting from a single individual.

Analysis

Analysis of population trends is summarized by geographic regions corresponding to those delineated in the presence-absence analysis. Plots of abundance estimates or indices over time are presented for major watersheds and, when possible, for subwatersheds within larger basins. Due to the generally consistent three-year life cycle of female coho salmon in California, comparison of interannual changes in abundance is largely meaningless, since any changes in environmental factors affecting coho populations at annual time scales are confounded by differences between largely independent brood-year lineages. Therefore, we estimated cohort replacement rates (CRR) for each generation of each brood-year lineage for which we had an estimate or index of abundance at year t and year $t+3$. The cohort replacement rate CRR is calculated as the ratio N_{t+3} / N_t , and describes the rate of population growth over a single generation. Values greater than one indicate an increase in abundance; values less than one indicate a decrease in abundance. Cohort replacement rates were calculated only for pairs of data that did not include an abundance estimate or index of zero.

Assuming 1) that populations of coho salmon have exhibited no net change in population size in recent years, and 2) that the method used to estimate abundance within each time series has an equal probability of overestimating or underestimating abundance (or at least that the method of estimating abundance exhibits consistent bias, such that if bias were removed, the assumption of equal probability of overestimation or underestimation would hold), it may be expected that any given estimate of λ has an equal probability of exceeding one or falling below one. To determine if the distribution of cohort replacement rates indicated systematic changes in abundance of coho salmon across cohorts and geography, we tested the null hypothesis that cohort replacement rates did not indicate systematic decline by calculating the probability of observing the number of CRR < 1 in a binomial sample with $\Pr[\text{CRR} < 1] = 0.5$.

RESULTS

Presence/Absence

We found some evidence of coho salmon occurrence in 877 streams in California. The increase in number over the 582 streams reported by Brown et al. (1994) reflects several factors. First, for a number of streams, new historical records have been uncovered since 1991. Additionally, surveying of streams for a number of salmonids has intensified during the 1990s and coho have been found in locations where no previous records were available. Kier Associates (1999) reported records of occurrence in 123

streams not reported in Brown and Moyle (1991) in the Southern Oregon/Northern California Coasts ESU. We also reported coho salmon in streams regardless of the size of the stream or the linear distance of stream accessible to salmon. In several cases, fish were reported near the mouths of streams that were tributary to known coho producing streams. It is quite possible that these fish migrated into these systems from adjacent waters. Finally, while the number of streams listed as potential coho streams here is larger than previously reported, there is no way to be certain how many of these observations of occurrence represent persistent populations of coho and how many are isolated occurrences of straying by coho into streams that typically do not support them.

Overall in California, the percentage of surveyed streams showing coho salmon presence has declined with time (Figure 1). In 1989 and 1990, coho salmon were found in approximately 80 percent of the historical streams surveyed. From 1998 to 2000, that percentage has dropped to between 51 and 66 percent (average 58). Comparison among time intervals should be done with some caution. The number of streams surveyed has varied over the last twelve years, with the greatest percentage of historic streams being surveyed in the 1994, 1995, 1996, and 2000 period. Thus, some of the changes in percentage may be an artifact of increased sampling intensity. It is difficult, however, to gauge the influence of sampling intensity. On one hand, the listing of coho salmon under ESA likely simulated sampling in some habitats not formerly believed to be good coho habitat. On the other hand, much recent monitoring work has focused on those streams that are believed to be the most likely sites to find coho salmon.

A logistic regression analysis indicated a significant relationship between the probability of finding fish present in a stream and both time and geographic index. This relationship is described by the equation:

$$\text{logit}(p) = 2.7027 - (0.1127 * \text{time}) - (0.1456 * \text{geographic_index})$$

The response surface generated suggests that the likelihood of detecting a coho “presence” in streams where they were historically present has decreased throughout California from 1989 to 2000, and that the trend has been more pronounced in the southern part of the range (Figure 2).

Direct comparison of the percentages presented in this report with those in previously published papers for the purpose of analyzing trends through time is not advised. Previous authors have used different criteria for establishing presence (e.g., different time frames, professional judgement rather than direct observation), and the number of streams surveyed has varied widely.

Central California Coast ESU

Overall, we found evidence of historical coho salmon occurrence in 278 streams in the Central Coast ESU. Current (within the last 12 years) presence-absence information for these streams is summarized in three-year time intervals: 1989-1991, 1992-1994, 1995-1997, and 1998-2000 (Table 2). The percentage of these streams for which presence has been detected at least once during the three-year period has remained relatively constant (between 44% and 48%) through time, the notable exception being the 1995-1997 period, when 61% of surveyed streams were found to have coho salmon. This was the most intensively sampled period, with 58 percent of historical coho streams being sampled at least once during the three-year interval, and coincided with the relatively strong year classes of 1996 and 1997. Eighteen fewer streams were sampled in the 1998-2000 period. However, this difference in sampling intensity alone cannot account for the change in percent presence of coho from 1995-1997 to 1998-2000.

Southern Oregon/Northern California Coasts ESU

In the California portion of the Southern Oregon/Northern California Coasts ESU, the percent of streams with coho present in at least one brood year has shown a decline from 1989-1991 to the present. In 1989-1991 and 1992-1995, coho were found in over 80 percent of the streams surveyed. Since then, the percentage has declined to 69 percent in the most recent three-year interval. As with the Central

California Coast ESU, fewer streams were sampled in the most recent interval; however, this again cannot account for the declining trend observed.

Population Trends – Central California Coast ESU

Santa Cruz County, San Mateo County, and San Francisco Bay

Long-term data on the abundance of coho salmon in streams within Santa Cruz and San Mateo counties are limited. Records of adult spawners and outmigrating smolts from Waddell Creek between 1933 and 1942 (Shapovalov and Taft 1954) constitute the only historical record of abundance in the county; there are no current adult data for comparison. Juvenile surveys in Scott and Waddell creeks in Santa Cruz County, and Gazos Creek in San Mateo County have been conducted by Jerry Smith (San Jose State University) since 1992. Surveys have also been conducted regularly in the San Lorenzo River and its tributaries; however, no juvenile coho salmon have been documented since the 1980s (Don Alley, D.W. Alley & Associates, personal communication). We found no systematic surveys of streams in the San Francisco Bay area, where coho appear to be extinct.

Adults

Historical Population Information - Adult coho salmon were enumerated at Waddell Creek weir during the nine-year period between 1933 and 1942 (Shapovalov and Taft 1954). On average, 247 adults passed through the fishway each season (range 84-583). Additionally, an average of 66 adults either passed directly over the dam or spawned in Waddell Creek below the dam; thus, the total spawning population averaged 312 fish during the nine-year period (Figure 3).

Historical information on population sizes of coho salmon in Scott Creek is limited to three years of adult counts from the 1936/1937 to the 1938/1939 spawning seasons (Shapovalov and Taft 1954). During this period, an average of 523 coho (range 374-681) passed through the trapping facility each season (Shapovalov and Taft 1954). These numbers may represent an incomplete census of spawners as the purpose of the study was to examine the proportion of 2- and 3-year old spawners in the population. These historical numbers are complicated by the fact that between 1933 and 1936, an average of 12,215 hatchery juveniles (size unknown) were planted in Scott Creek annually (CDFG 1998).

Current Population Information – No current datasets with six or more years of record are available.

Smolts

Historical Population Information - From 1933 to 1942, the average number of smolts¹ passing downstream through the trap was 2,040 (range 152-4,911)(Figure 4). These counts from Shapovalov and Taft (1954) substantially underestimate total smolt production in the Waddell Creek system. During April and May, the period during which the majority of coho smolts emigrated, only about 25% of the total flow typically was routed through the trap, with the remaining 75% of the flow passing over the dam (Shapovalov and Taft 1954); thus, large numbers of fish passed over the dam without being counted. All smolts moving through the trap were marked; thus, by examining the ratio of marked to unmarked fish in subsequent adult populations, a crude estimate of total population size was gained. Based on these estimates, Shapovalov and Taft (1954) concluded that only about one-third of the smolt population was captured each year. Thus, it is reasonable to assume that average annual smolt production was at least 6,000 fish during the nine years of sampling.

Another piece of circumstantial evidence supports the contention that smolt populations in Waddell Creek were larger by a factor of three or more than the numbers of fish collected in the

¹ Although fish are reported as smolts, about 8% of downstream migrants exited the stream in the period from November to February and were unlikely to have had the physiological morphological characteristics typically associated with smolts.

outmigrant trap. For 2,040 smolts (the nine-year average catch) to produce 313 adults (the average estimated number of spawners during this period), ocean survival would have had to exceed 15%. Such a high ocean survival rate for coho salmon is extremely unlikely, given that even during periods of favorable ocean conditions, marine smolt-to-adult survival of coho salmon typically is 5% or less. If one assumes 5% marine survival for a mean spawning population of 312 fish, the corresponding number of smolts is 6,240—very close to Shapovalov and Taft's (1954) estimates.

Current Population Information – No current datasets with six or more years of record are available.

Juveniles

Historical Population Information - No historical datasets with six or more years of record are available.

Current Population Information - Systematic sampling of juvenile coho salmon in Waddell and Scott Creeks has been conducted in 1988 and then annually from 1992 to the present (Smith 2001a). Gazos Creek has been surveyed annually since 1994. The number of stations surveyed in each of these streams has varied among years and streams. To facilitate interannual comparisons, we considered data only from sites that have been sampled in all years of the time series. Abundance is reported as fish per 100 lineal feet of stream; however, these are simply fish counts rather than population estimates for the habitats sampled; no correction was made to account for capture efficiency.

The data from Waddell, Scott, and Gazos creeks indicate that over the past decade coho were most abundant in 1993, 1996, and 1999 (Figure 5). The 1994/1997/2000 brood lineage appears to have been extirpated from Waddell and Gazos creeks, and is very weak in Scott Creek. Smith (2001b) reported that coho numbers were lower in 2000 than in any of the previous nine years. The 1992/1995/1998 brood lineage is weak in all three streams, but particularly so in Gazos and Waddell Creeks.

Marin County

Adults

Historical Population Information – Adult coho spawner surveys have been conducted sporadically in Lagunitas Creek and its tributaries since the 1950s. Early surveys from 1950-1970 were conducted by California Department of Fish and Game. Although these surveys document distribution and could provide a coarse index of abundance in certain reaches, they are not sufficiently robust to be used in a more detailed assessment of population trends (R. Smith, National Park Service, pers. comm.).

Current Population Information – A more consistent record of redd counts in Lagunitas Creek and three of its tributaries, Olema Creek, Devils Gulch, and San Geronimo Creek is available from 1995 to 2000. The number of redds in these streams has remained fairly constant over the past six years, with the highest accounts occurring in the 1996-97, 1997-98, and 1999-2000 spawning seasons (Figure 6).

Smolts

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – No current datasets with six or more years of record are available.

Juveniles

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – Data on summer juvenile abundance is available for Lagunitas Creek and two of its tributaries for the period from 1993 to 2000. Although population expansions based on density within different habitat types are available for some years, expansions have not been completed

for the 1998-2000 period (E. Ettinger, Marin Municipal Water District, pers. comm.). Thus, only total fish counts are presented here. Both the 1994 and 1997 brood years were relatively strong in Lagunitas Creek and its tributaries; however, the overall trend suggests a decline in abundance (Figure 7). The average abundances (all streams combined) are lower for 1998, 1999, and 2000 than in any of the five preceding years.

Juvenile abundance has also been reported for Redwood Creek in the Golden Gate National Recreation Area for years 1994 to 2000 (Smith 2001b). As with the time series from Waddell, Scott, and Gazos creek, we considered only sites that were sampled every year during that period to provide a consistent index of abundance. The data indicate that the 1995 and 1996 brood years were relatively strong, but that populations have declined since then (Figure 8).

Sonoma County

Long-term records of coho salmon abundance in Sonoma County are exceedingly rare, both historic and current. We found only one site with records meeting our criteria for inclusion in the trend analysis.

Adults

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – No current datasets with six or more years of record are available.

Smolts

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – No current datasets with six or more years of record are available.

Juveniles

Historical Population Information – No historical data with a minimum of six years of data are available.

Current Population Information – Two sites on the Little North Fork Gualala River have been sampled by the California Department of Fish and Game (CDFG) in all years since 1988, except for 1994, 1996, and 1997. Coho salmon were present in the first year of sampling, but have not been reported since (Scott Harris, CDFG, unpub. data).

Although there are scattered electrofishing records in tributaries of the Russian River, we found no datasets that met our criterion of six or more years of consistent record.

Mendocino County

Compared with other regions of California, records of coho salmon abundance in streams entering the ocean in Mendocino County are relatively abundant, though most of these records are fairly recent. We found consistent records for 31 sites in Mendocino County, representing 9 major watersheds (Caspar Creek, Little River, Big River, Usal Creek, Ten Mile River, Pudding Creek, Noyo River, Albion River, and Big Salmon Creek).

Adults

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – No current datasets with six or more years of record are available.

Smolts

Historical Population Information – Downstream migrant traps have been operated annually on Caspar Creek and Little River by the California Department of Fish and Game since 1986. These data are discussed under current population information below. No other long-term records of outmigrating smolts are available for this geographic region.

Current Population Information – The Caspar Creek and Little River downstream migrant traps are rotary screw traps and thus sample only a portion of the water column. Estimates of capture efficiency are only available for the last year of sampling, so values reported are counts of fish, rather than population estimates.

Trends in abundance are similar for both systems. Smolt counts were highest in the first four years of sampling and have declined since, though numbers are somewhat variable (Figures 9 and 10). The 1992/1995/1998 brood lineage appears to be the weakest in both streams, though Caspar Creek shows reasonably strong numbers in 1998.

Juveniles

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – Juvenile abundance surveys have been conducted by both private landowners and the California Department of Fish and Game on a number of streams and rivers in Mendocino County since the late 1980s and early 1990s. Streams surveyed include Usal Creek, Howard Creek, DeHaven Creek, Ten Mile River, Pudding Creek, Noyo River, Caspar Creek, Little River, Albion River, and Big Salmon Creek. In all cases, data are juvenile densities for index reaches; no population expansions are available.

Surveys in three smaller watersheds in the northern part of Mendocino County, Usal Creek, Howard Creek, and Dehaven Creek have yielded few fish in recent years. Usal Creek has been sampled annually since 1993; however, coho salmon were found only in 1993 and 1996 (Figure 11). Howard Creek was surveyed in 1986, 1988-1991, and 1998-1999. Fish were found only in 1988 and 1998. No fish have been found in DeHaven Creek in surveys covering 1993-1995 and 1998-2000. Thus, all three brood lineages in these coastal streams appear weak if not essentially extinct.

Sampling on index reaches on the South Fork of the Ten Mile River indicate that coho numbers have been generally low over the past eight years with 1996 being the notable exception (Figure 12). Of particular concern is the fact that very few fish have been captured in surveys from 1998-2000; a combined total of seven fish have been captured at eight index sites within this time period. Temporal patterns in fish abundance in the North Fork Ten Mile system are very similar, with very low densities of fish in all years except 1996, and a combined total of only nine fish reported over the past three years (Figure 13). The Middle Fork Ten Mile River and its tributaries have shown few coho juveniles since 1993, with modest increases in numbers at a single site in 1997 and 1999 being the only deviations from a general pattern of few or no fish (Figure 14). Only one fish has been reported since 1993 in a tributary to the mainstem Ten Mile River (Campbell Timberland Management, unpub. data).

Index sites on Pudding Creek were sampled annually between 1983 and 1995 (excluding 1990) by the California Department of Fish and Game, and from 1993 to 2000 by Campbell Timberland Management. The CDFG data indicates a decline in abundance after 1989 extending to the last year of sampling (Figure 15). Data from 1993 to 2000 from a second site shows increases in numbers for the 1996 and 1999 broad years; however, overall densities remain low (Figure 16). Because sampling occurred at different sites in these two time series, direct comparison of these densities is inappropriate.

Data from the Noyo River and its tributaries from 1993 to 2000 indicate that, like other Mendocino County rivers to the north, 1996 was a relatively strong year; however, unlike systems to the north, 1995 and 1997 were also comparatively strong years (Figure 17). Abundance decreased in 1998 and 1999, indicating that the strong years in 1995 and 1996 did not carry over into the subsequent generation. A modest increase in numbers was observed in 2000.

Juvenile density data at index sites has been collected by California Department of Fish and Game since 1986 in Caspar Creek and Little River. In both systems, the temporal patterns of abundance are similar. The highest densities of fish were observed from 1986 to 1989, and have generally declined since then (Figures 18 and 19). The relatively strong 1996 year class in the region was reflected in comparatively large numbers of fish in both these systems, though still not approaching numbers from the late 1980s. The years 1992 and 2000 were also moderately strong in Caspar Creek.

Data from two sites on the Big River indicate considerable variation among years, but not obvious trends in abundance. Again the strong 1996 year class observed elsewhere along the coast was evident in Big River surveys, but comparable densities were also observed in 1995, 1997, and 1999 (Figure 20).

Abundance data from index sites in the Albion River and its tributaries were collected annually from 1988 to 1996, and then again in 1999 and 2000. The data suggest a general downward trend from peak abundances in 1992 and 1993, though numbers have remained fairly constant since then (Figure 21). As with most other sites in this ESU, the 1996 year class was the strongest within the last five years.

Big Salmon Creek, the southern-most coho-bearing stream in Mendocino County has been surveyed annually since 1993. Strong years classes were apparent in both 1996 and 1997, much like in the Noyo and Big rivers (Figure 22). Numbers declined to pre-1996 levels in the past three years.

Summary of Central California Coast ESU Trend Data

The vast majority of time series data on coho salmon abundance available for the Central California Coast coho salmon ESU consists of summer density estimates derived from sampling at index sites of relatively short length. Most of these time series are short—six to eight years in duration—but a few extend back into the mid-to-late 1980s. Because of the nature of these data, conclusions must be drawn cautiously. Nevertheless, consistent patterns found in most basins within the ESU suggest that while these data may not be particularly robust in detecting trends within a specific stream reach, they do appear to track large-scale trends in abundance over watersheds and larger geographic areas reasonably well.

Several consistent patterns emerge from these data. Although time series data dating back to the 1980s were available for only three streams (Caspar Creek smolts and juveniles; Little River, smolts and juveniles; and Pudding Creek juveniles), in each case, the abundance in the 1990s was clearly lower than in the mid-to-late 1980s. Thus it is important to consider that variability in abundance observed in the 1990s is potentially variation around population means that are substantially lower than they were historically. It is also clear from the data that 1996 and, to a more limited degree, 1997 were relatively strong year classes compared with other years in the 1990s. This is relevant since the BRT conclusions made in 1996 were in part based on presence-absence information gathered in 1995 and 1996 (Schiewe 1996). Finally, although there is some variability among sites, the general overall trend during the 1990s is one of continued decline. Values of CRR (abundance at time $t+3$ /abundance at time t) for all paired observations of abundance (non-zero values only) are plotted in Figure 23. Overall, 126 of 229 CRR values were less than 1, indicating a significantly ($p = 0.0045$) higher likelihood that abundance decreased rather than increased at a particular site. Were a population increase as likely as a population decrease, and equal number of observations would be expected to fall above and below CRR = 1.

Population Trends – California Portion of Southern Oregon/Northern California ESU

Humboldt County

With the exception of records from the Eel River basin, long-term trend data—either historical or current—for coho salmon in Humboldt County (or Mendocino County streams that eventually enter the ocean in Humboldt County) are scarce. Two historical records of adult fish at Benbow Dam on the South

Fork Eel River and Sweasy Dam on the Mad River provide information on adult run sizes from late 1930s to the mid 1960s (Sweasy) and 1970s (Benbow); however, no current records exist for comparison. Juvenile surveys have been conducted on a number of streams in the 1990s in the Eel River basin. Additional surveys have been conducted in the Redwood Creek, Mad River, and Mattole River watersheds; however, none of these datasets met our criteria of having six or more years of data collected in a consistent fashion.

Adults

Historical Population Information – Numbers of adult coho salmon at Benbow Dam showed a long and general decline from an average of more than 13,000 fish in the 1930s and 1940s (range 7,327 to 25,289) to about 5,700 fish in the 1950s and 1960s (range 1,289 to 14,316), to fewer than 1700 fish in the 1970s (range 509 to 3,993) before the dam and counting facility were removed (Figure 24). At Sweasy Dam, coho adult counts averaged almost 400 fish in the years between 1938 and 1951 (range 73 to 725), before falling to an average of 37 fish in the seven years from 1952-1958 (range 2 to 91) (Figure 25). The population increased dramatically in 1962 and 1963, with the highest recorded counts occurring in those two years. A similar increase was observed in the South Fork Eel River during those years.

Current Population Information – No current datasets with six or more years of record are available.

Smolts

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – No current datasets with six or more years of record are available.

Juveniles

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – Summer surveys of coho salmon juveniles have been conducted in a number of index reaches in the South Fork Eel River drainage by both private landowners and California Department of Fish and Game. Data from these surveys indicate no obvious trends in abundance (Figure 26). The 1996 and 1997 year classes were relatively strong, as was the 1999 year class. The 1995, 1998, and 2000 year classes were comparatively weak

A longer-term data set from two sites in Hollow Tree Creek, a tributary to the South Fork Eel River, indicates a somewhat different pattern. As was seen in Mendocino County, a general decline in abundance has been observed since the late 1980s (Figure 27), and numbers in 1998 through 2000 are lower than for the rest of the 1990s. There is some suggestion in the data that the 1995/1998 brood lineage is the weakest in the South Fork Eel and its tributaries.

A final tributary to the main fork of the Eel River, Ryan Creek has been surveyed by the California Department of Fish and Game since 1986. Coho salmon were found in modest numbers in 1988 and 1989, and lower numbers in 1992. However, no fish have been captured at this site in the last eight years (Scott Harris, CDFG, unpub. data)

Del Norte County

Population trend data for Del Norte County, including the Klamath-Trinity system, are scarce aside from hatchery records. Monitoring of downstream migrants has occurred on two tributaries of the Trinity River (Willow and Horse Linto creeks); however, sampling has targeted other salmonids and the majority of coho salmon have typically migrated before traps are installed in the spring. Additional monitoring programs have been initiated in the Klamath-Trinity system by the Hoopa Valley and Yurok tribes; however, data are available for the past five or fewer years. A limited amount of information is

available on both adults and smolts in the Mill Creek, a tributary to the Smith River, and Wilson Creek, which enters the Pacific Ocean south of the Smith River.

Adults

Historical Population Information – No historical datasets with six or more years of record are available other than hatchery records described in the Artificial Propagation section below.

Current Population Information – Counts of adult spawners have been made annually on the West Branch of Mill Creek in the Smith River basin since 1980. Data reported are the maximum number of live fish and carcasses observed on any one survey. Maximum live/dead counts have ranged from a high of 28 to a low of 2 over the 20 years of record, with no obvious trend through time, though counts have been comparatively low over the past four years (Figure 28). Nor is there any evidence that the variability observed among years is related to the strength or weakness of any particular brood lineages.

A second set of spawning surveys has been conducted on both the west and east branches of Mill Creek and associated tributaries. These show maximum live/dead counts of between 30 and 40 in the period from 1993 to 1996 but counts of less than 11 in all subsequent years (Figure 29).

Smolts

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – Downstream migrant traps have been operated on the East and West Branches of Mill Creek from 1994 to 2000. Although expanded population estimates were provided, a discrepancy in numbers between data provided to us and other published documents led us to present total counts instead. These data suggest a relatively strong year in 1998 (1997 brood year) for both Branches of Mill Creek, and a similarly strong year on West Branch, but not East Branch in 1995 (Figure 30). Overall, it is difficult to discern a specific trend in these data.

Juveniles

Historical Population Information – No historical datasets with six or more years of record are available.

Current Population Information – Surveys of juvenile coho density in summer have been conducted in Wilson Creek since 1995. Population size has dropped precipitously during that time from an estimated population of almost 1400 in 1995 to fewer than 50 fish in 1999 and 2000.

Summary of Southern Oregon/Northern California ESU Trend Data

Current trend data for the California portion of the Southern Oregon/Northern California ESU are less available than for the Central Coast ESU, and we found only one dataset that contained information dating back into the 1980s. Consequently, drawing conclusions about changes in the status of coho salmon in this ESU is more difficult. Nevertheless, analysis of coho replacement rates (CRRs) indicates that a general decline in abundance for those populations analyzed. In 40 of 67 paired observations, the value of CRR was less than one, indicating a decrease in numbers from time t to time $t+3$ (Figure 31). This number was significantly higher than expected ($p = 0.0278$) based on a probability of 0.5.

ARTIFICIAL PROPAGATION

Artificial propagation of coho salmon by state, county, and private hatcheries has a long history in California dating back until at least until the 1890's. Transfer of eggs from other basins including out-of-state sources and out-of-basin releases of hatchery coho were common until 1980's. Even if records

were complete, the impacts of these activities are unknown. Therefore, the best approximation of the potential for hatchery impacts on the natural populations of coho salmon is a review of the relative magnitude and pattern of hatchery operations.

There are currently seven hatcheries producing coho salmon in California. Three of the hatcheries are in the Central California Coast ESU; Monterey Bay Salmon and Trout, Warm Springs, and Noyo Station Hatcheries. Monterey Bay Salmon and Trout Hatchery is a small privately supported operation started in 1976 on Big Creek, a tributary to Scott Creek, Santa Cruz County. There have been hatchery activities in this area since the 1890's. Warm Springs Hatchery is a CDFG-operated mitigation facility started in 1980 on Dry Creek, a tributary to the Russian River, Sonoma County. The Noyo Station Hatchery is a CDFG-operated enhancement facility started in 1962 on the South Fork of the Noyo River, Mendocino County. There are four coho hatcheries in California's portion of the Southern Oregon/Northern California Coasts ESU: Mad River, Trinity River, Irongate, and Rowdy Creek hatcheries. Mad River Hatchery is a CDFG operated enhancement facility started in 1970 on the Mad River, Humboldt County. Trinity River Hatchery is a CDFG operated mitigation facility started in 1958 on the Trinity River, Trinity County. Irongate Hatchery is a CDFG mitigation facility started in 1965 on the Klamath River, Siskiyou County. Rowdy Creek Hatchery is a small privately operated hatchery started in 1972 on Rowdy Creek, a tributary to the Smith River, Del Norte County.

Levels of hatchery production of coho salmon in California are smaller than those in Oregon and Washington and have been declining in recent years. Annual averaged (over a 5-year period, 1987-91) coho hatchery releases for the Central California Coast ESU are less than 0.3 percent of total coastwide hatchery releases of coho salmon. Hatcheries in the California portion of the Southern Oregon/Northern California Coasts ESU account for less than 1 percent of coastwide releases (Weitkamp et. al 1995, Table 5). In recent years, several hatcheries have not produced brood years due to a lack of spawning adults. Monterey Bay Salmon and Trout Hatchery has not produced coho since the 1997 release. Warm Springs Hatchery has terminated their coho program due to lack of returning adults and is planning to use the facility as a captive broodstock operation (Figure 32). Noyo Station and Rowdy Creek Hatcheries were unable to get adults for spawning in year 2000 (Figures 33 and 34). Mad River and Irongate Hatcheries both have reduced numbers of adult returns in recent years (Figures 35 and 36). Only Trinity River Hatchery has been able to maintain production (Figure 37).

In the Central California Coast ESU, hatchery operations are relatively small, but still may have a significant impact due to the small natural populations in the area. These hatchery operations have probably masked the true degree of coho decline in this ESU, but are also probably responsible for the coho's continued existence in the south. In the last ten years, hatchery practices have been limited to within basin stocks which would pose the least threat to genetic integrity. In the Southern Oregon/Northern California Coasts ESU, the principal concern is the large production of the Trinity River Hatchery. Potential outbreeding due to the large numbers of hatchery fish spawning in natural areas poses a significant threat to the genetic integrity of natural populations.

CONCLUSIONS

Central California Coast ESU

The BRT previously concluded that coho salmon stocks south of Punta Gorda are depressed relative to past abundance but that there are limited data to assess population numbers or trends (Weitkamp et al. 1995). Nevertheless, in 1995 the BRT unanimously concluded that natural populations of coho salmon in this ESU were in danger of extinction. In a subsequent status review that considered additional presence-absence information gathered in 1995-1996, it was reported that the percent of streams with coho salmon present was higher than previously estimated (Schiewe 1996). This did not fundamentally alter the BRT's conclusion; a majority of the BRT concluded that coho salmon were in danger of extinction, while a minority concluded that it was not presently in danger of extinction but that it was likely to become so in the foreseeable future.

Collectively, the recent presence-absence and population trend data presented in this report strongly suggest that throughout much of this ESU coho salmon continue to decline. Although the periods of high and low abundance vary somewhat among river basins, the majority show that the 1996 and 1997 brood years were relatively strong compared with years both before and after this period. Consequently, the picture resulting from presence-absence analysis conducted during the 1995-1996 period, which was considered in the decision to list coho as “threatened” in this ESU, may have been overly optimistic. Declines have been observed in several streams (e.g., Scott Creek, Santa Cruz County, and Lagunitas Creek, Marin County) where populations had before been considered relatively stable.

After considering this information, we conclude that the Central California Coast ESU is presently in danger of extinction.

California Portion of the Southern Oregon/Northern California Coasts ESU

The BRT previously concluded that coho salmon stocks between Punta Gorda, California, and Cape Blanco, Oregon are depressed relative to historical abundance, but again there was limited information from which to assess population abundance or trends (Weitkamp et al. 1995). They concluded that coho salmon in this ESU were not in danger of extinction, but were likely to become endangered in the foreseeable future. Subsequent status reviews (Schiewe 1996, 1997) concluded that more recent presence-absence information for the California portion of this ESU showed a lower percentage of streams with coho present than earlier reviews. However, their conclusion regarding the overall status of the ESU remained essentially unchanged.

Both the presence-absence and trend data presented in this report suggest that many coho salmon populations in this ESU continue to decline. Presence-absence information from the past twelve years indicates fish have been extirpated or at least reduced in numbers sufficiently to reduce the probability of detection in conventional surveys. Unlike the Central California Coast ESU, the percentage of streams in which coho were documented did not experience a strong increase in the 1995-1997 period. Population trend data were less available in this ESU, nevertheless, for those sites that did have trend information, evidence suggests declines in abundance.

After considering this information, we conclude that the Southern Oregon/Northern California Coasts ESU is presently not at risk of extinction, but is likely to become endangered in the foreseeable future. The conclusion is tempered by the fact that population trend data was limited, and further analysis may reveal declines sufficient to conclude that the California portion of this ESU is in danger of extinction.

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FIGURES

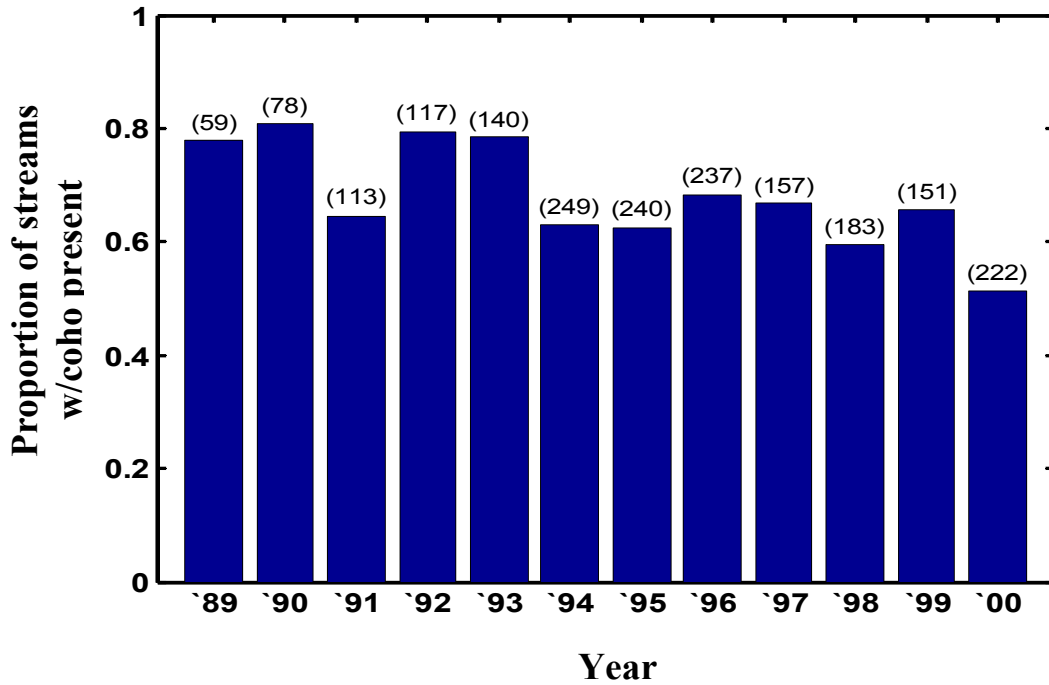


Figure 1. Percentage of historical coho salmon streams surveyed showing presence in years 1989 through 2000. Values indicate the number of sites that were surveyed for the particular year.

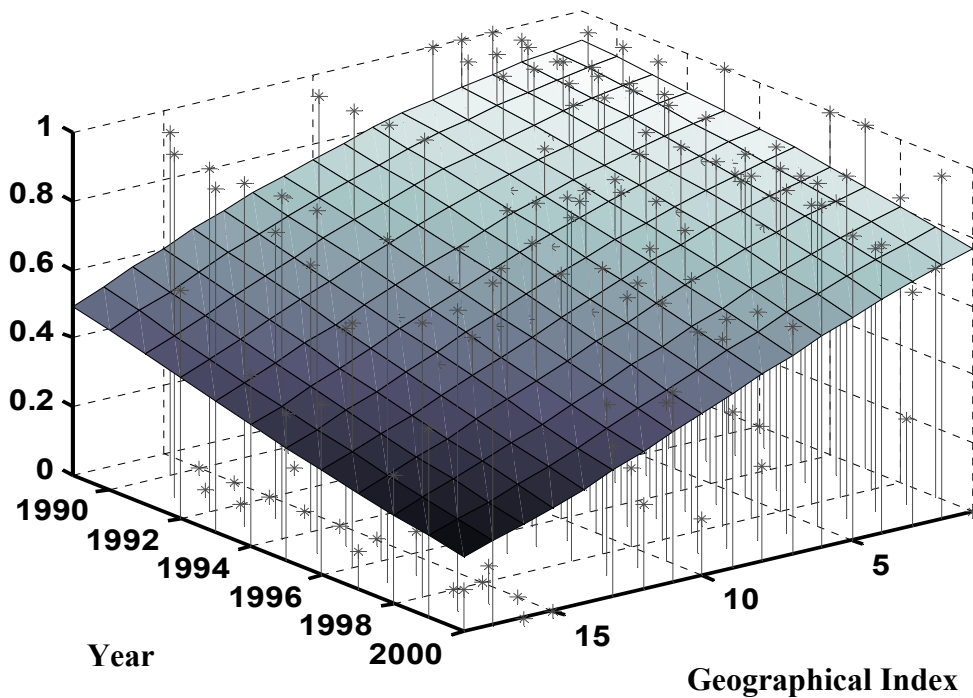


Figure 2. Response surface showing relationship between probability of presence in relation to year (1989-2000) and the geographical index (1 = northern-most, 21 = southern-most). See text for further discussion.

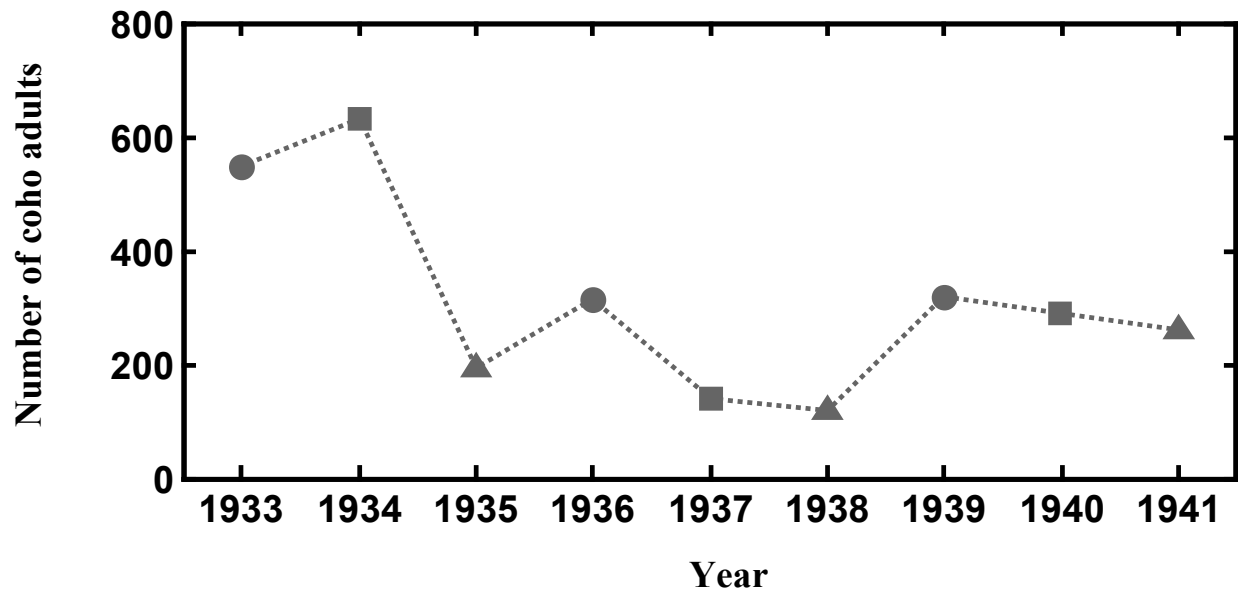


Figure 3. Estimated number of spawners in Waddell Creek, Santa Cruz County from 1933-1941. (Data source: Shapovalov and Taft 1954).

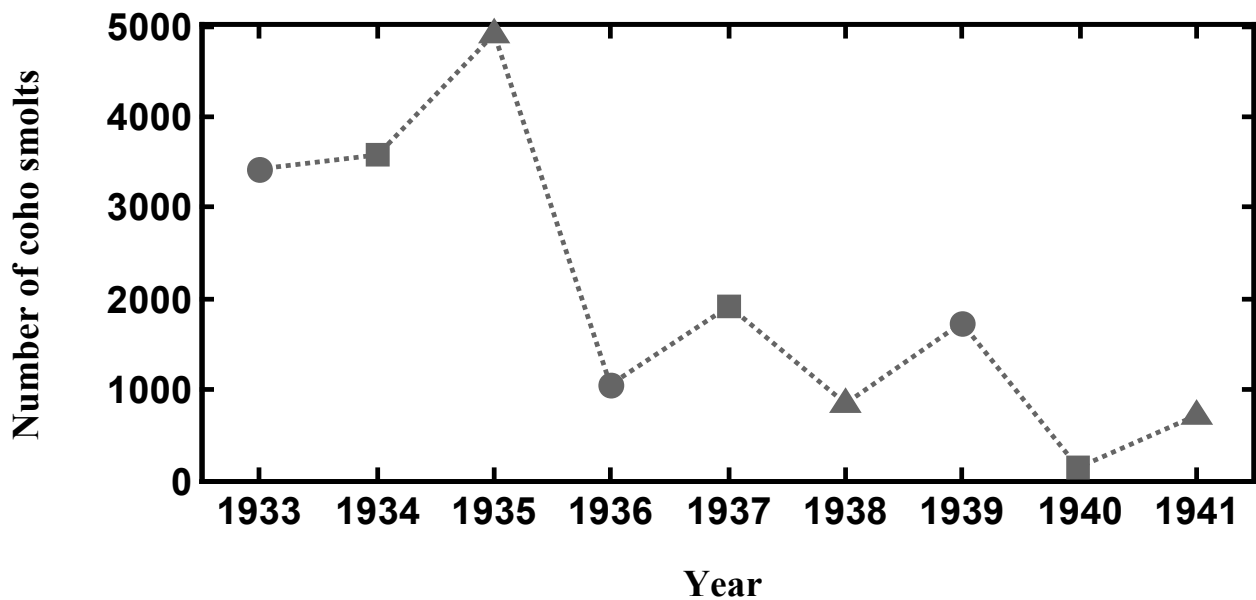


Figure 4. Counts of outmigrating smolts in Waddell Creek, Santa Cruz County from 1933-1941. (Data source: Shapovalov and Taft 1954).

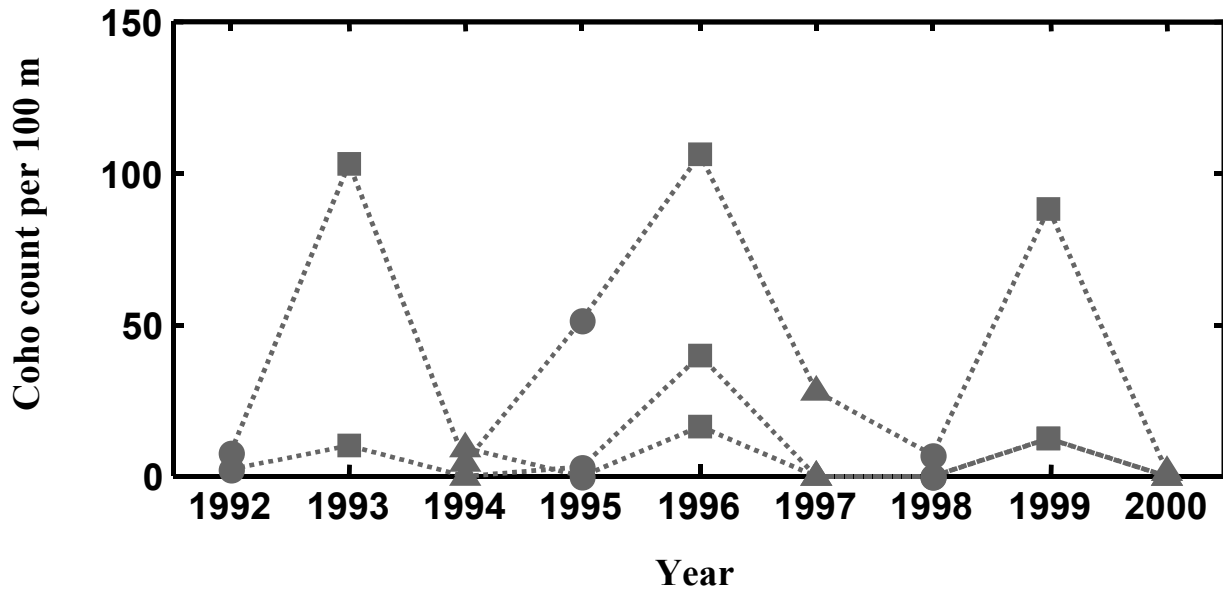


Figure 5. Summer juvenile coho salmon densities for index sites in Waddell and Scott creeks, Santa Cruz County, and Gazos Creek, San Mateo County, from 1992 to 2000. Symbols represent brood lineages. (Data source: Smith 2000a and previous reports.)

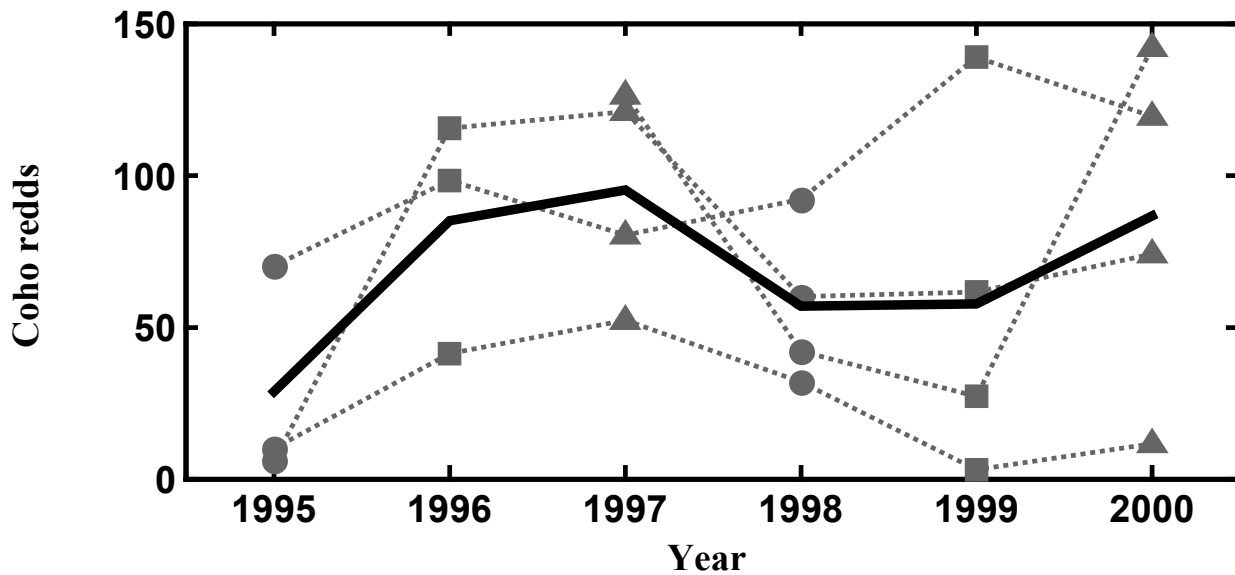


Figure 6. Redd counts Lagunitas Creek, and three tributaries, Marin County, from 1995 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: G. Andrew, Marin Municipal Water District, unpub. data)

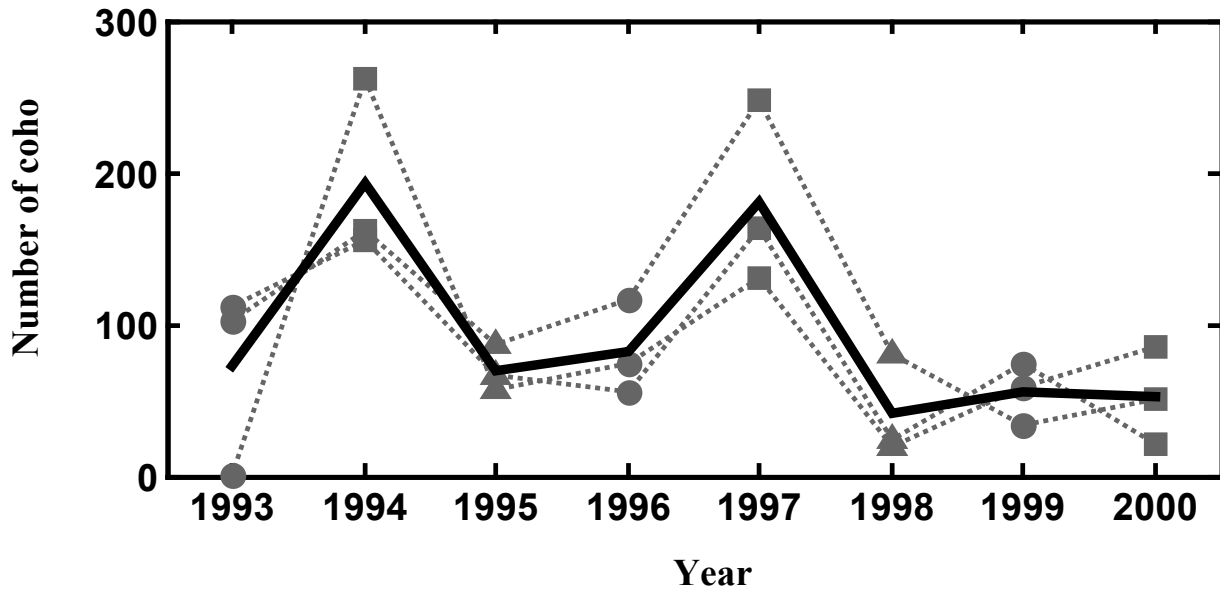


Figure 7. Summer juvenile coho salmon counts (total fish captured) for Lagunitas Creek and two tributaries, Devils Gulch, and San Geronimo Creek, Marin County, from 1993 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Greg Andrew, Marin Municipal Water District, unpub. data)

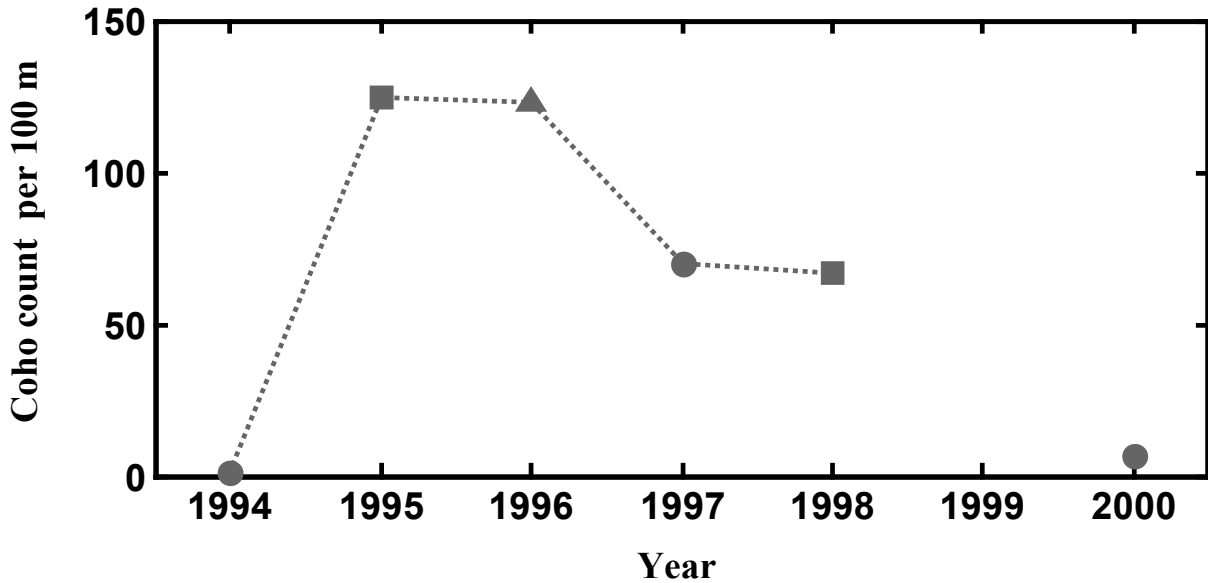


Figure 8. Summer juvenile coho salmon densities for index sites in Redwood Creek, Marin County, from 1992 to 2000. Symbols represent brood lineages. (Data source: Smith 2000a and previous reports.)

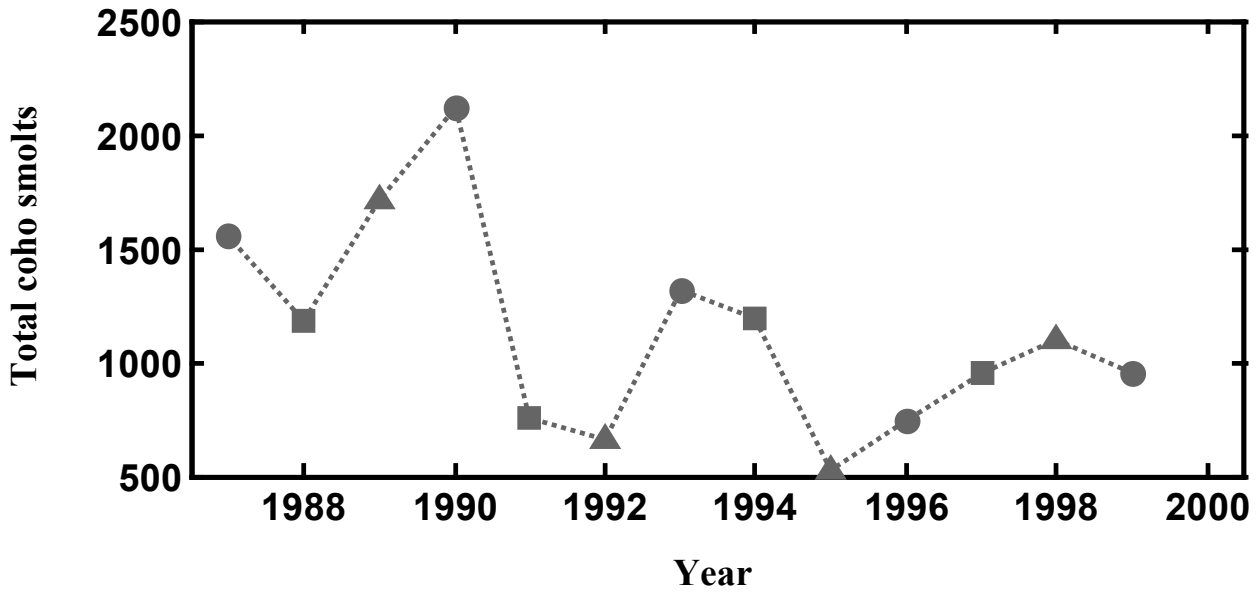


Figure 9. Coho salmon smolt counts in Caspar Creek, Mendocino County, from 1987 to 1999. Symbols represent brood lineages. (Data source: Scott Harris, CDFG, unpub. data)

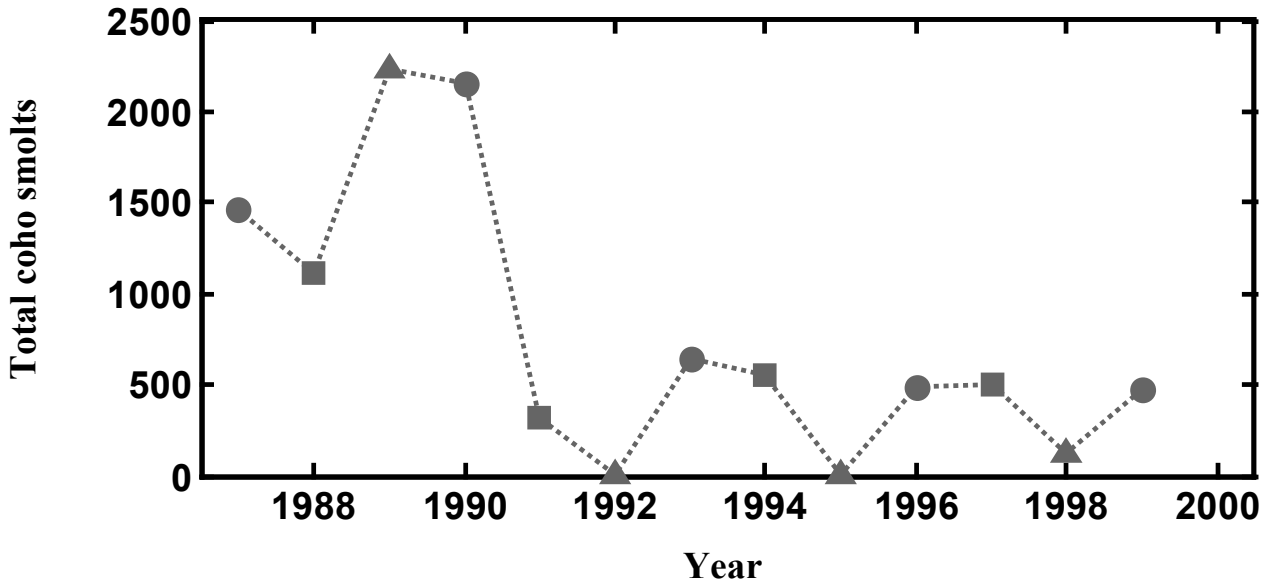


Figure 10. Coho salmon smolt counts in Little River, Mendocino County, from 1987 to 1999. Symbols represent brood lineages. (Data source: Scott Harris, CDFG, unpub. data)

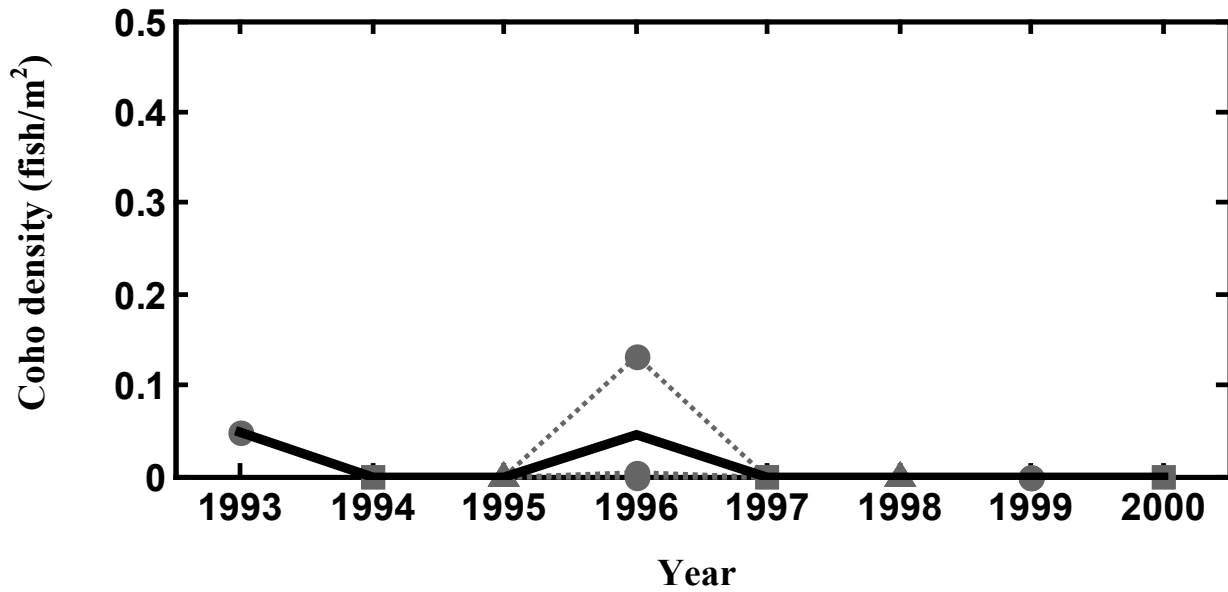


Figure 11. Summer juvenile coho salmon densities for three index sites in the Usal Creek basin, Mendocino County, from 1993 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

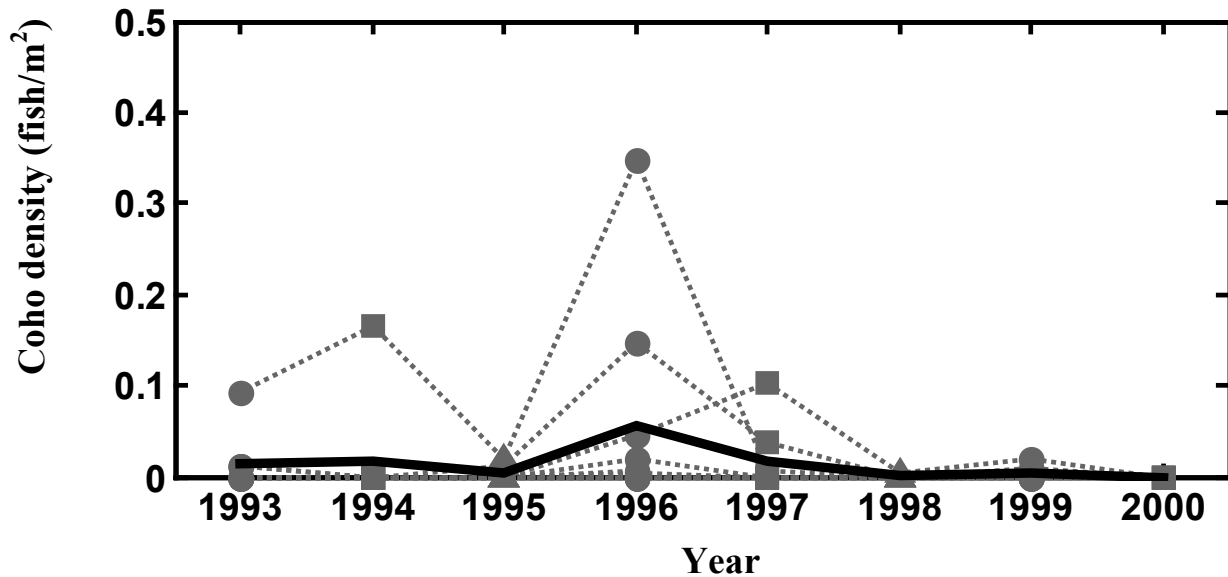


Figure 12. Summer juvenile coho salmon densities for eight index sites in the South Fork Ten Mile River basin, Mendocino County, from 1993 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

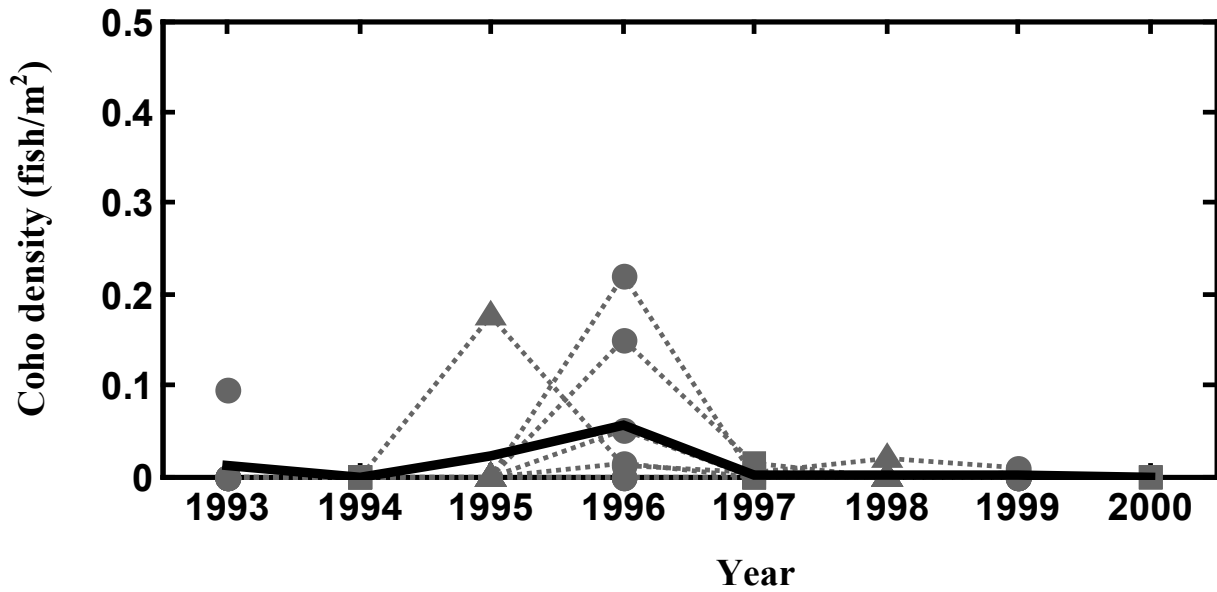


Figure 13. Summer juvenile coho salmon densities for six index sites in the North Fork Ten Mile River basin, Mendocino County, from 1993 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

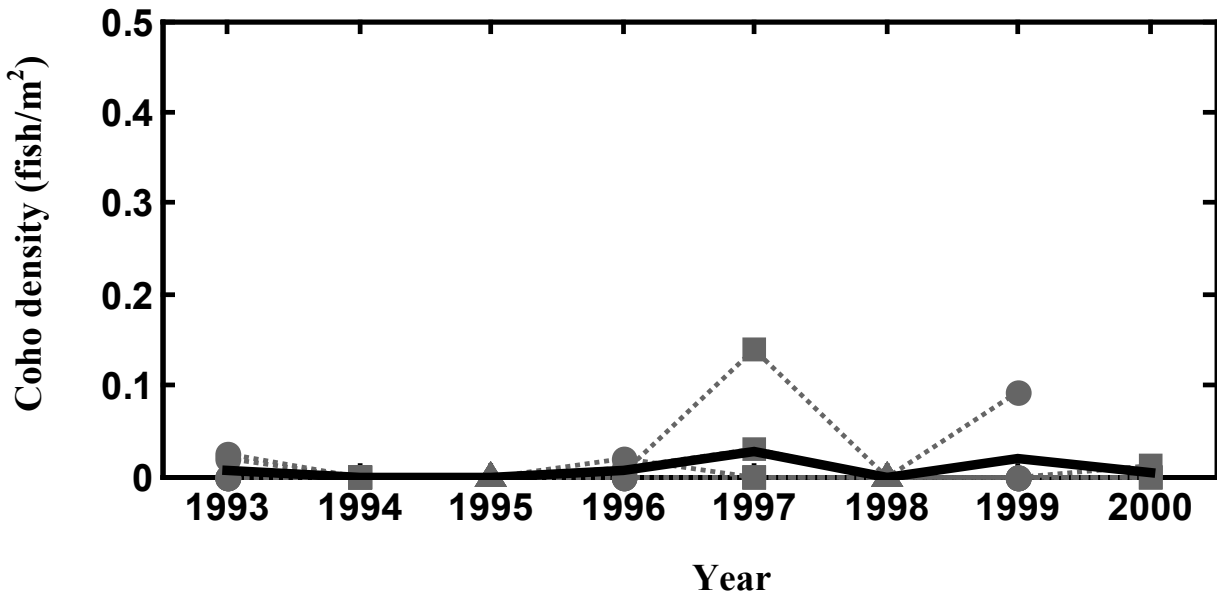


Figure 14. Summer juvenile coho salmon densities for three index sites in the Middle Fork Ten Mile River basin, Mendocino County, from 1993 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

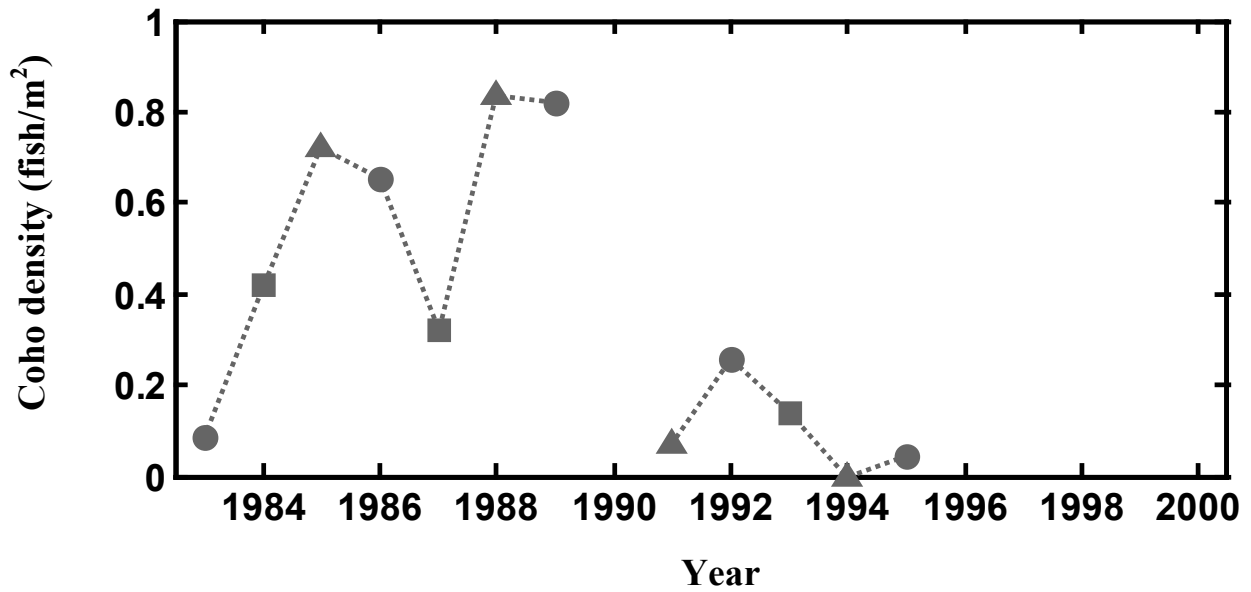


Figure 15. Summer juvenile coho salmon densities for an index site in Pudding Creek, Mendocino County, from 1983 to 1995. Symbols represent brood lineages. (Data source: Scott Harris, CDFG, unpub. data)

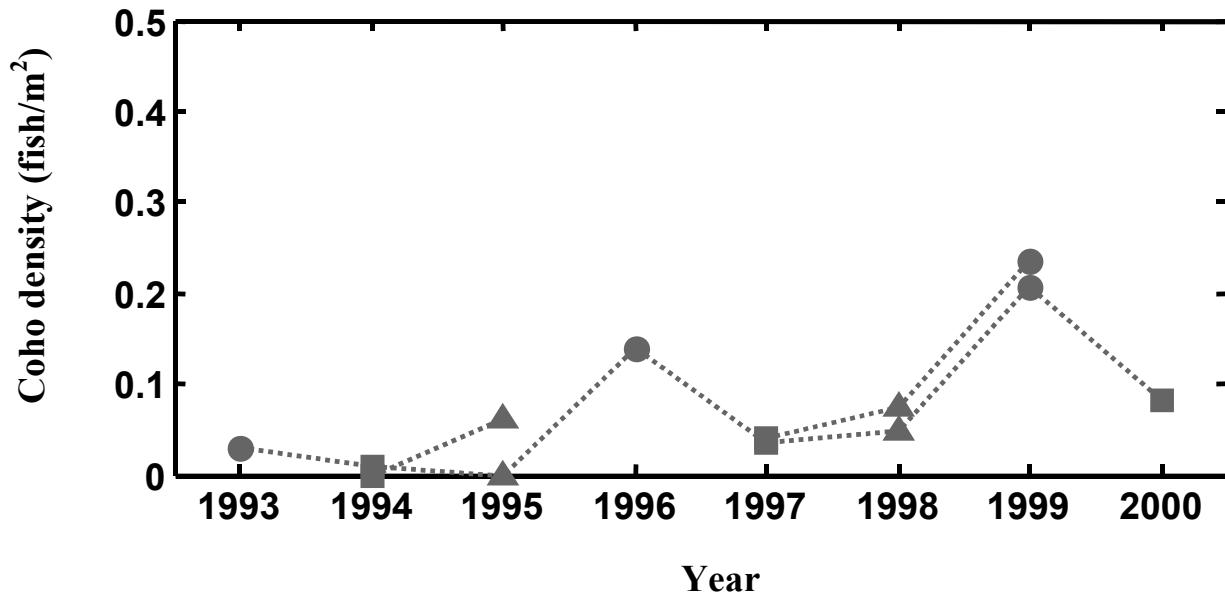


Figure 16. Summer juvenile coho salmon densities for two index sites in upper Pudding Creek, Mendocino County, from 1993 to 2000. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

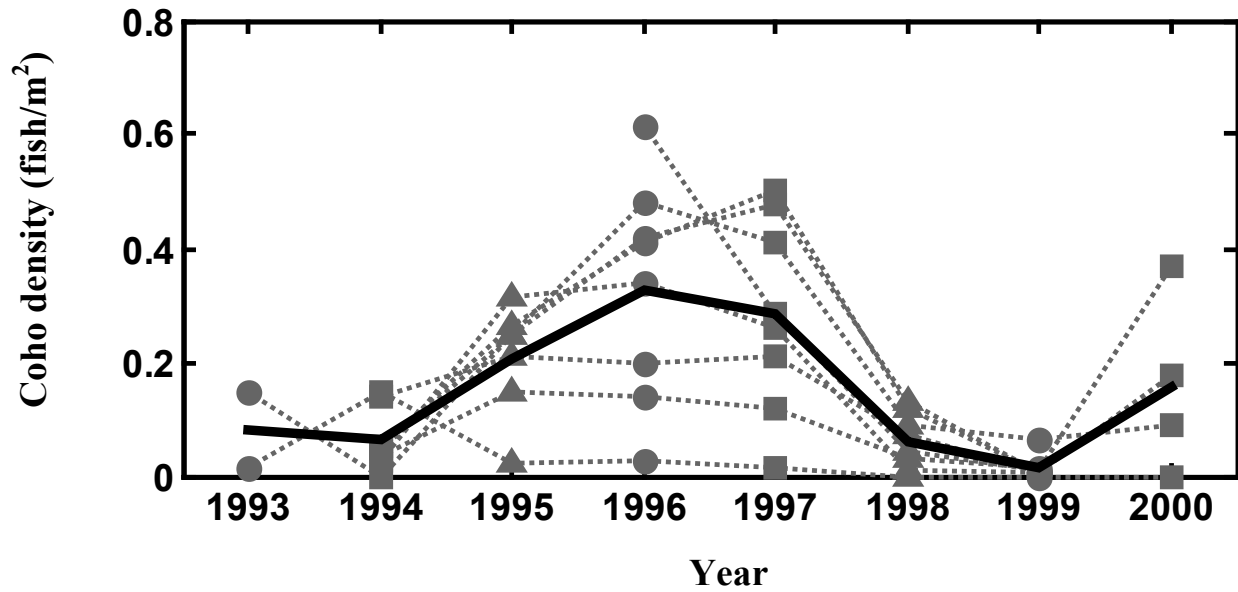


Figure 17. Summer juvenile coho salmon densities for eight index sites in the Noyo River basin, Mendocino County, from 1993 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

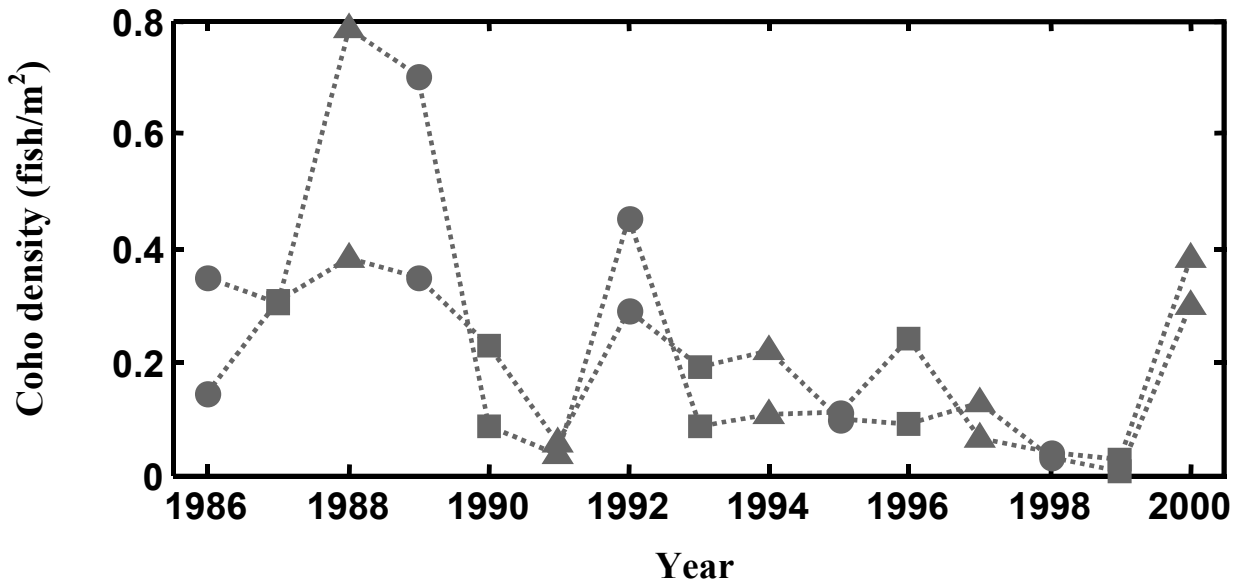


Figure 18. Summer juvenile coho salmon densities for two index sites in the Caspar Creek, Mendocino County, from 1986 to 2000. Symbols represent brood lineages. (Data source: Scott Harris, CDFG, unpub. data)

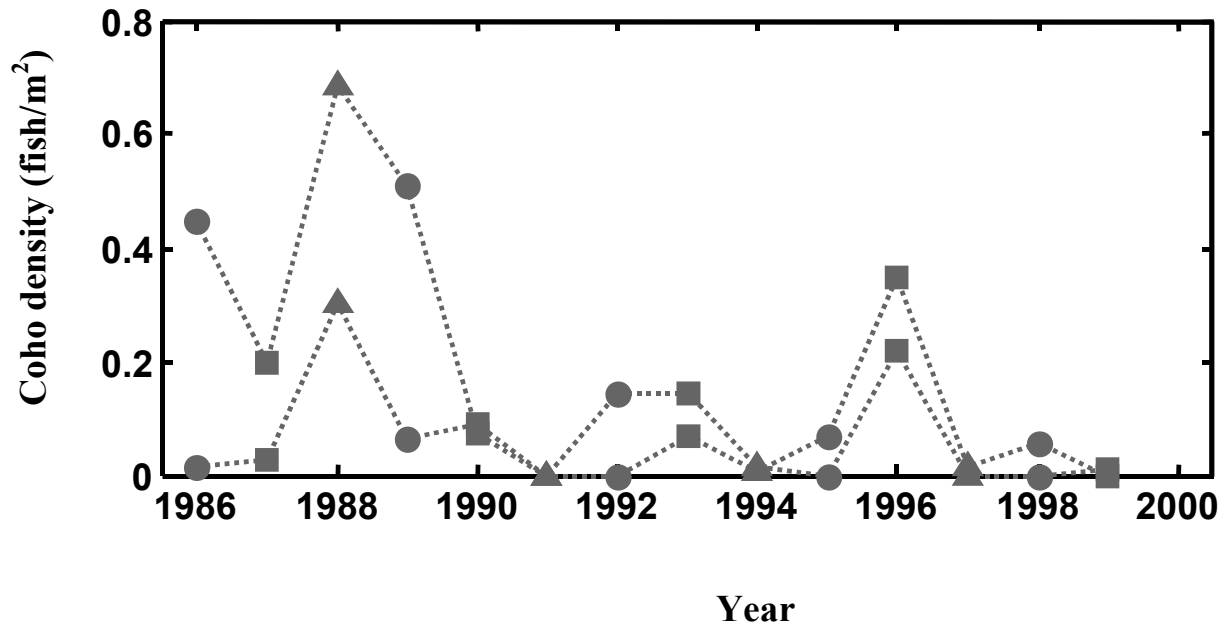


Figure 19. Summer juvenile coho salmon densities for two index sites in Little River, Mendocino County, from 1986 to 2000. Symbols represent brood lineages. (Data source: Scott Harris, CDFG, unpub. data)

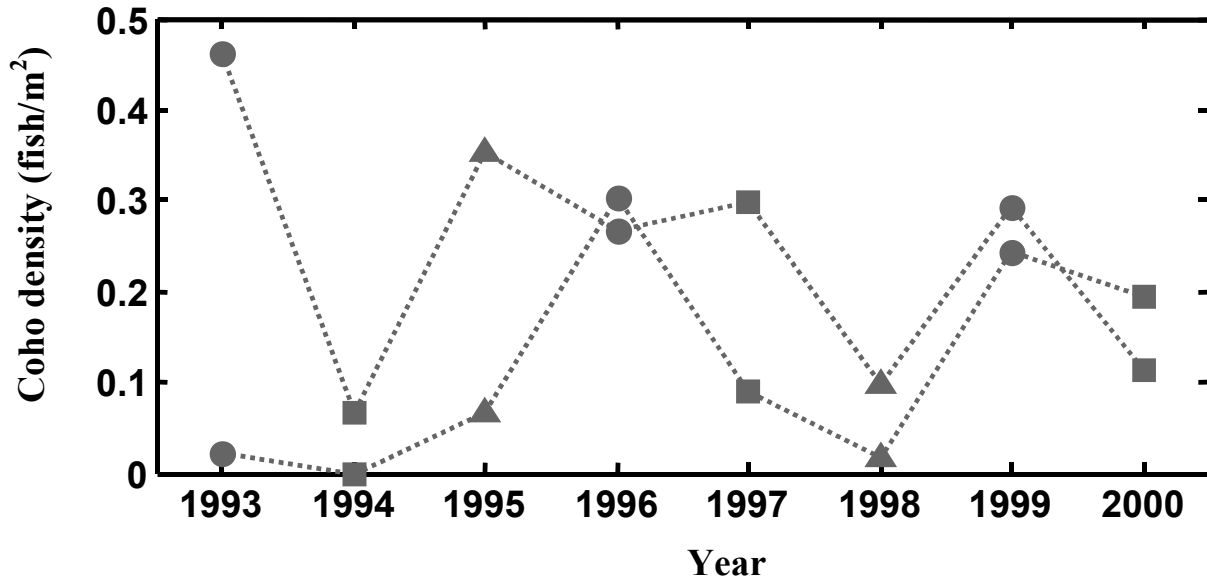


Figure 20. Summer juvenile coho salmon densities for two index sites in Big River, Mendocino County, from 1986 to 2000. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

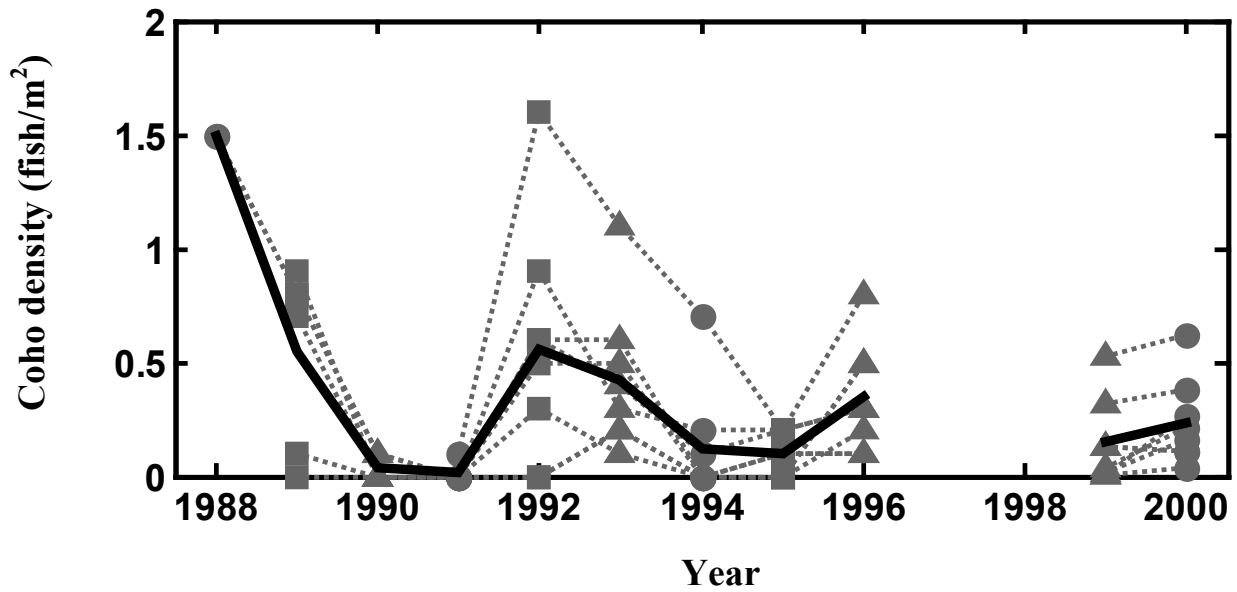


Figure 21. Summer juvenile coho salmon densities for seven index sites in Albion River and its tributaries, Mendocino County, from 1986 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Mendocino Redwood Company, unpub. data)

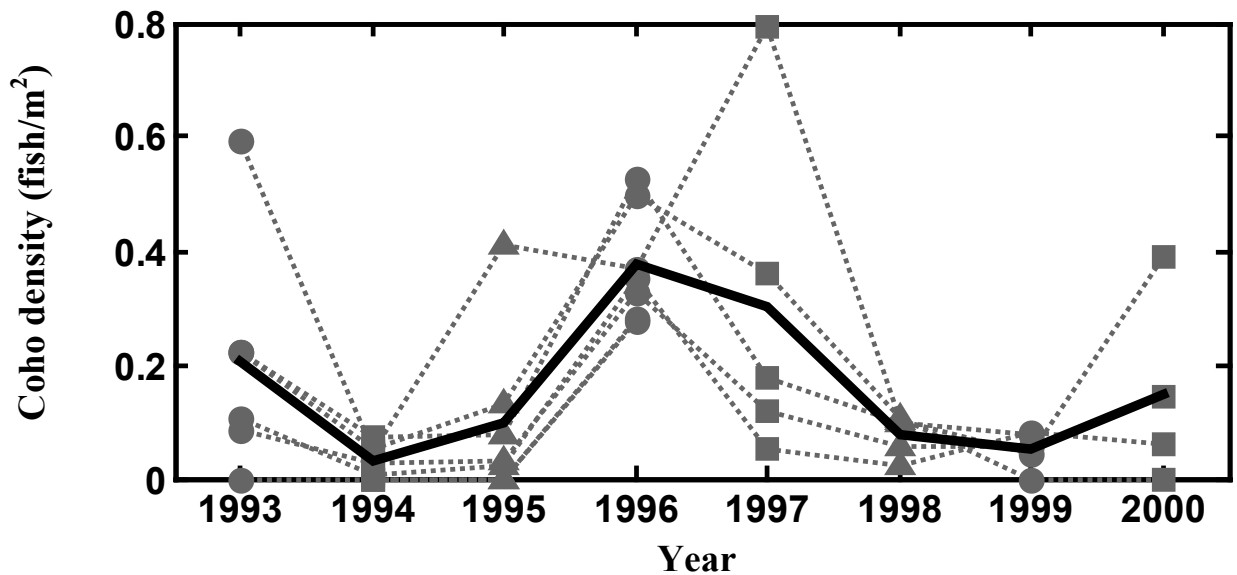


Figure 22. Summer juvenile coho salmon densities for six index sites in Big Salmon Creek and its tributaries, Mendocino County, from 1986 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

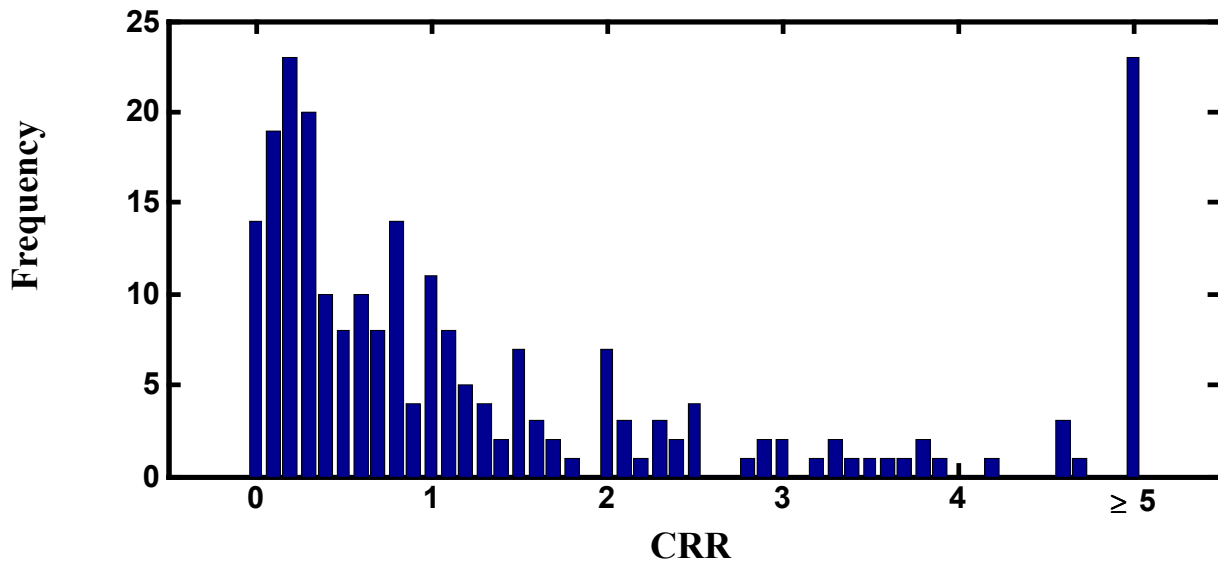


Figure 23. Frequency distribution of cohort replacement rates CRR for streams and rivers in the Central California Coast ESU indicating a significantly ($p = 0.0045$) higher likelihood of numbers decreasing with time. Values less than 1 indicate a decline in the abundance index from time t to time $t+3$.

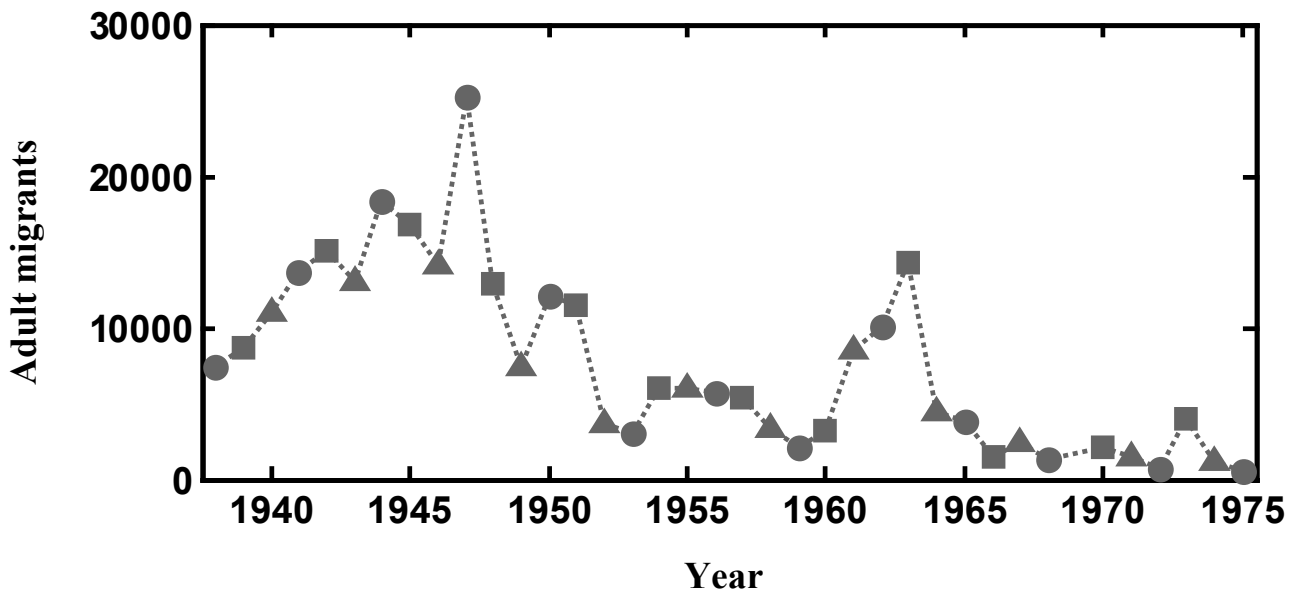


Figure 24. Adult coho counts at Benbow Dam, South Fork Eel River, from 1938 to 1975. (Data source: StreamNet 2001)

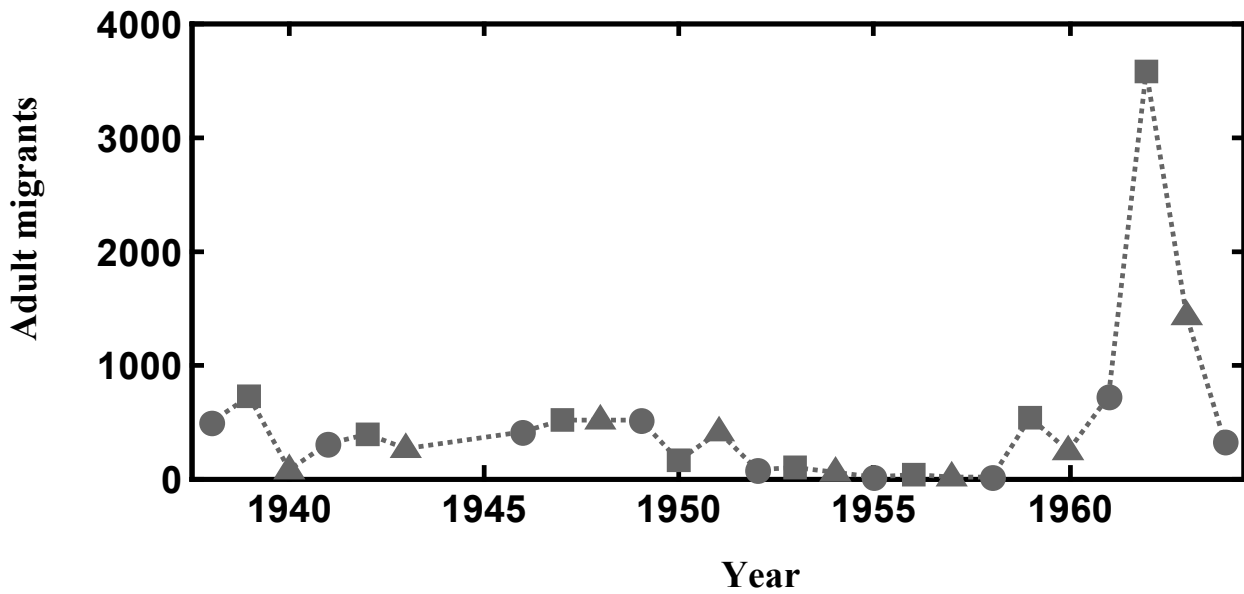


Figure 25. Adult coho counts at Sweasy Dam, Mad River, from 1938 to 1975. (Data source: StreamNet 2001)

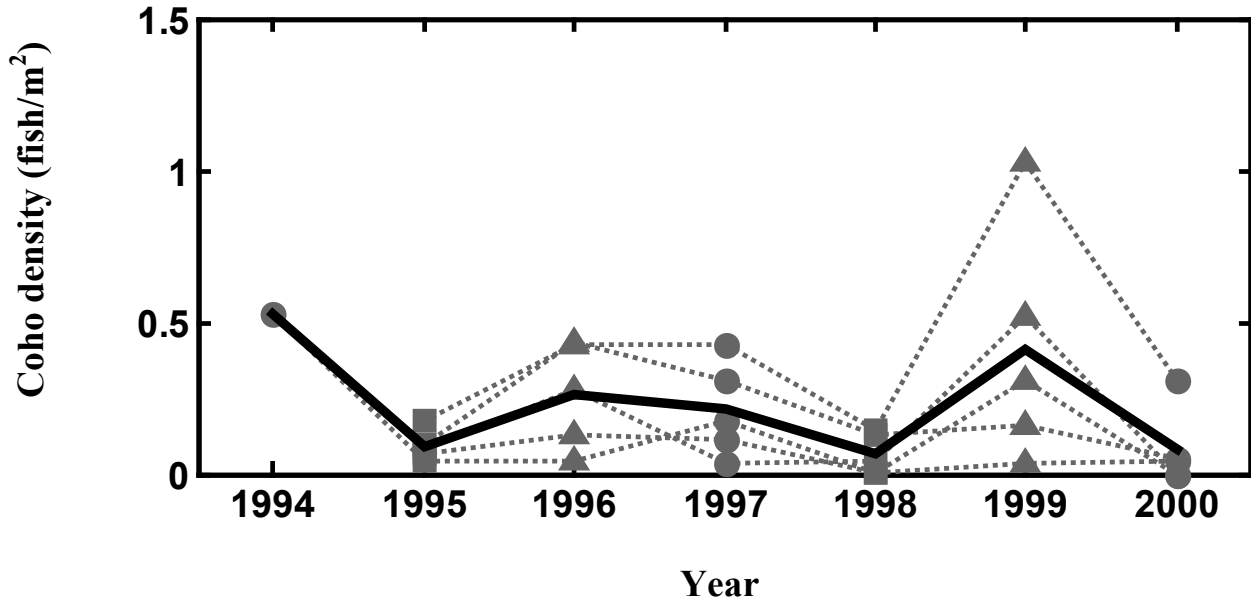


Figure 26. Summer juvenile coho salmon densities for five index sites in the South Fork Eel River and its tributaries, Mendocino and Humboldt counties, from 1986 to 2000. Heavy line without symbols indicates means for all sites. Symbols represent brood lineages. (Data source: Campbell Timberland Management, unpub. data)

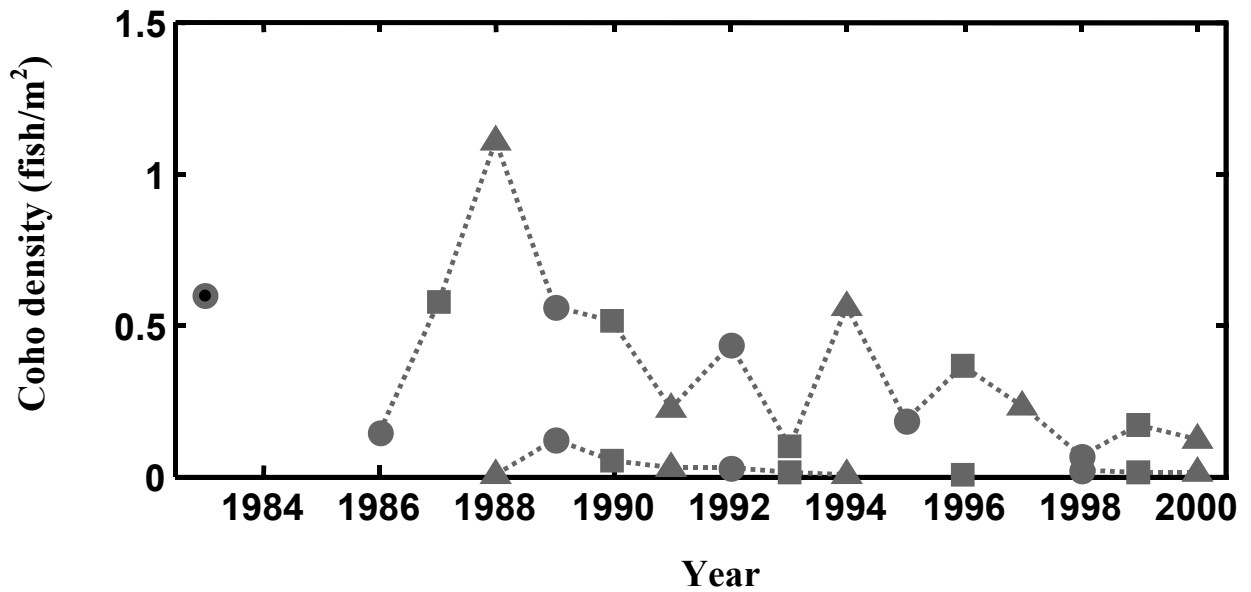


Figure 27. Summer juvenile coho salmon densities for two index sites Hollow Tree Creek, Mendocino County, from 1986 to 2000. Symbols represent brood lineages. (Data source: Scott Harris, CDFG, unpub. data)

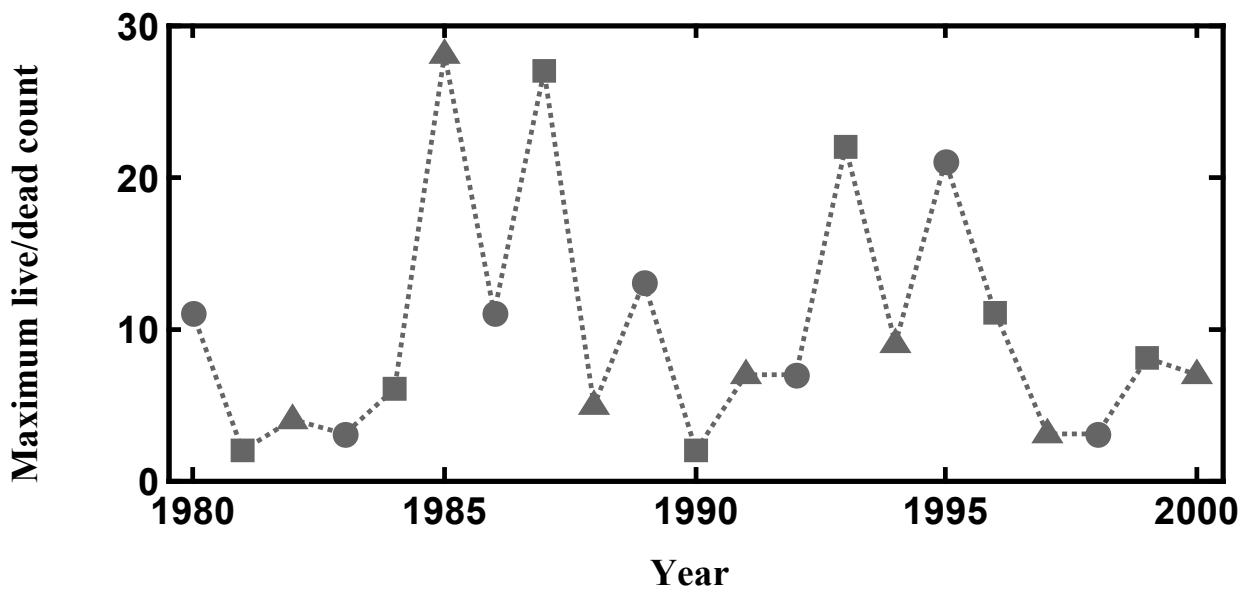


Figure 28. Maximum live/dead spawner counts for West Branch of Mill Creek, Del Norte County, from 1980 to 2000. Symbols represent brood lineages. (Data source: Waldvogel 1988; Jim Waldvogel, Cooperative Extension, unpub. data)

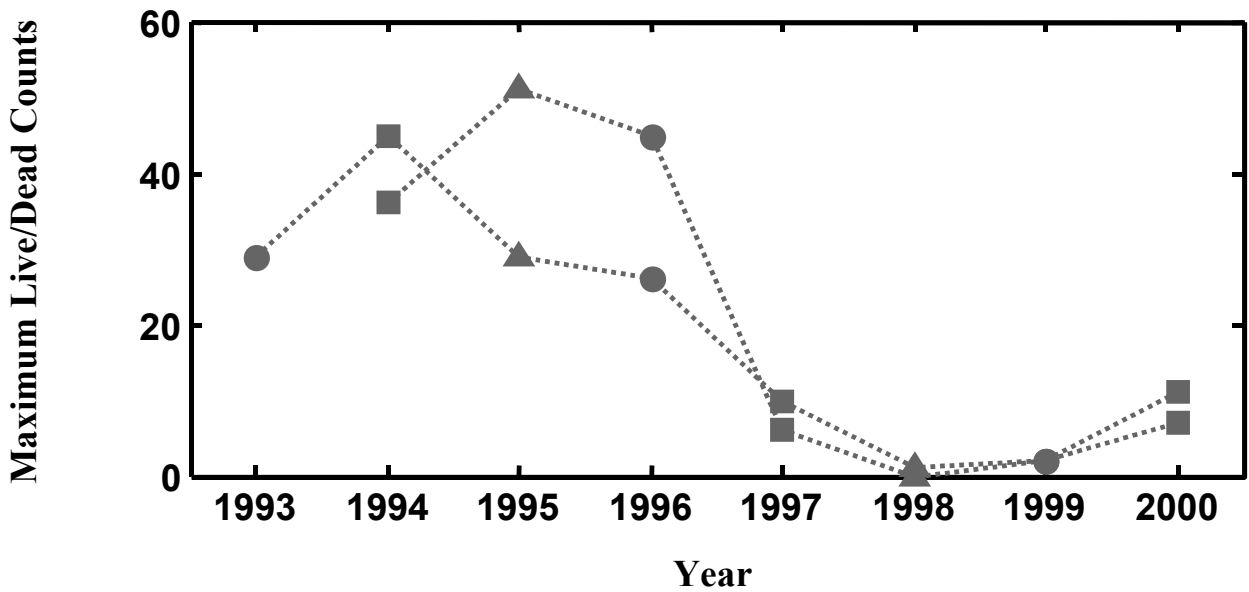


Figure 29. Maximum live/dead spawner counts for West Branch of Mill Creek, Del Norte County, from 1980 to 2000. Symbols represent brood lineages. (Data source: Paul Albro, Stimson Timber, unpub. data)

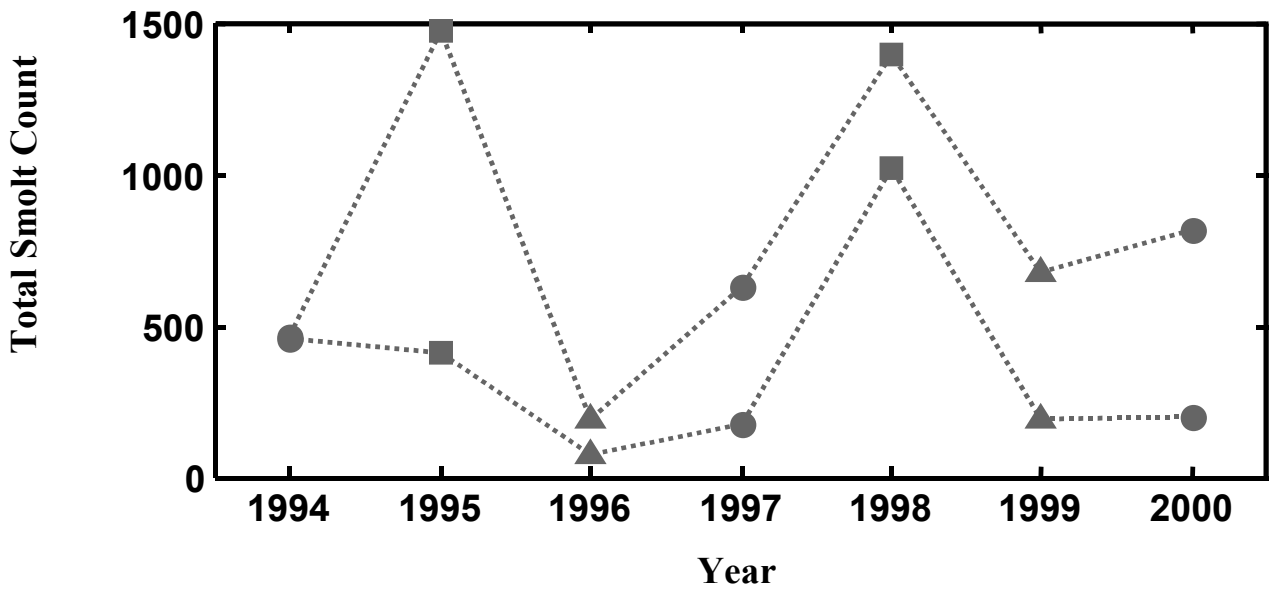


Figure 30. Total smolt counts from downstream migrant traps in West Branch and East Branch of Mill Creek, Del Norte County, from 1994 to 2000. Symbols represent brood lineages. (Data source: Stimson Lumber Company, 2000)

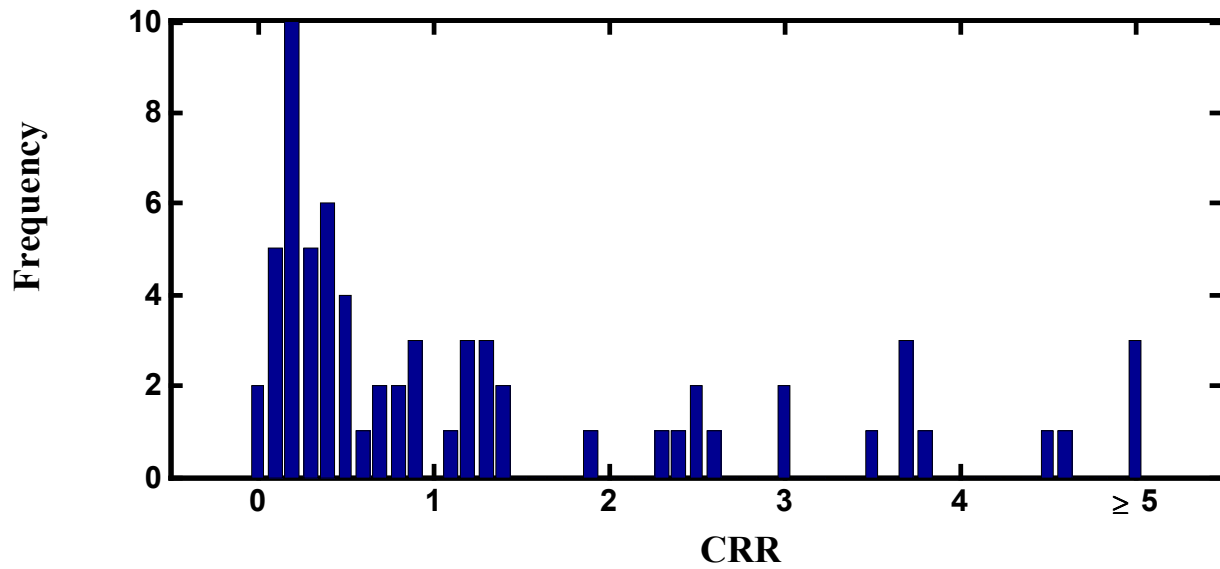


Figure 31. Frequency distribution of cohort replacement rates CRR for streams and rivers in the Southern Oregon/Northern California Coasts ESU indicating a significantly ($p = 0.0278$) higher likelihood of numbers decreasing with time. Values less than 1 indicate a decline in the abundance index from time t to time $t+3$.

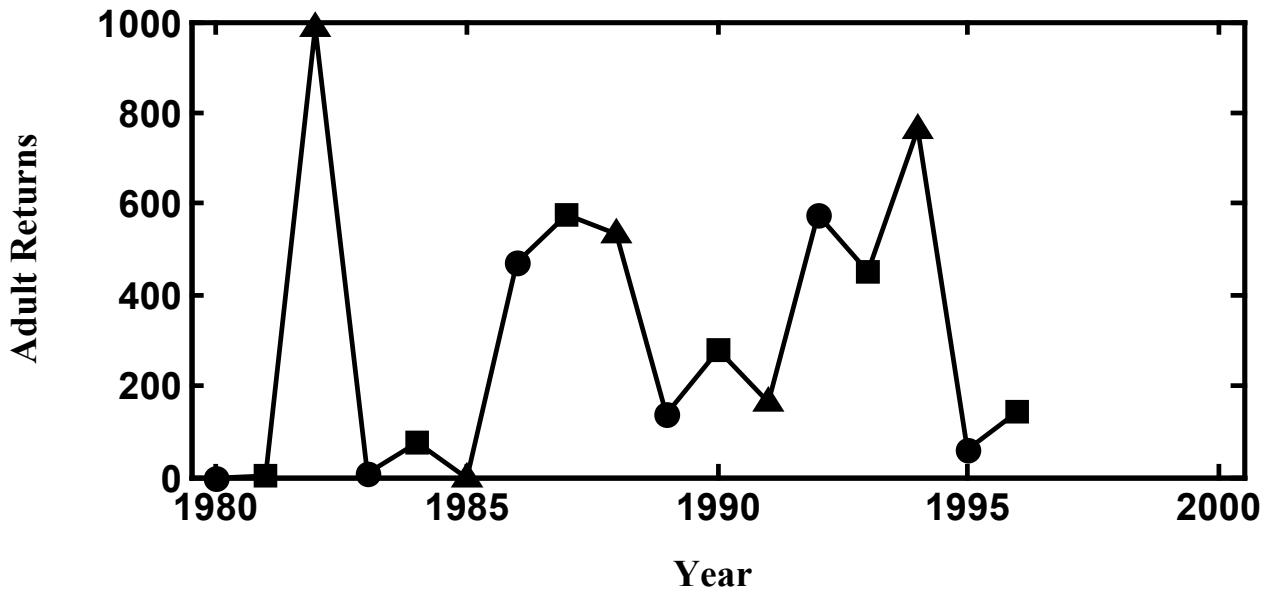


Figure 32. Adult coho salmon returns to Warm Springs Hatchery on Dry Creek (Russian River), Sonoma County, from 1980 to 1996.

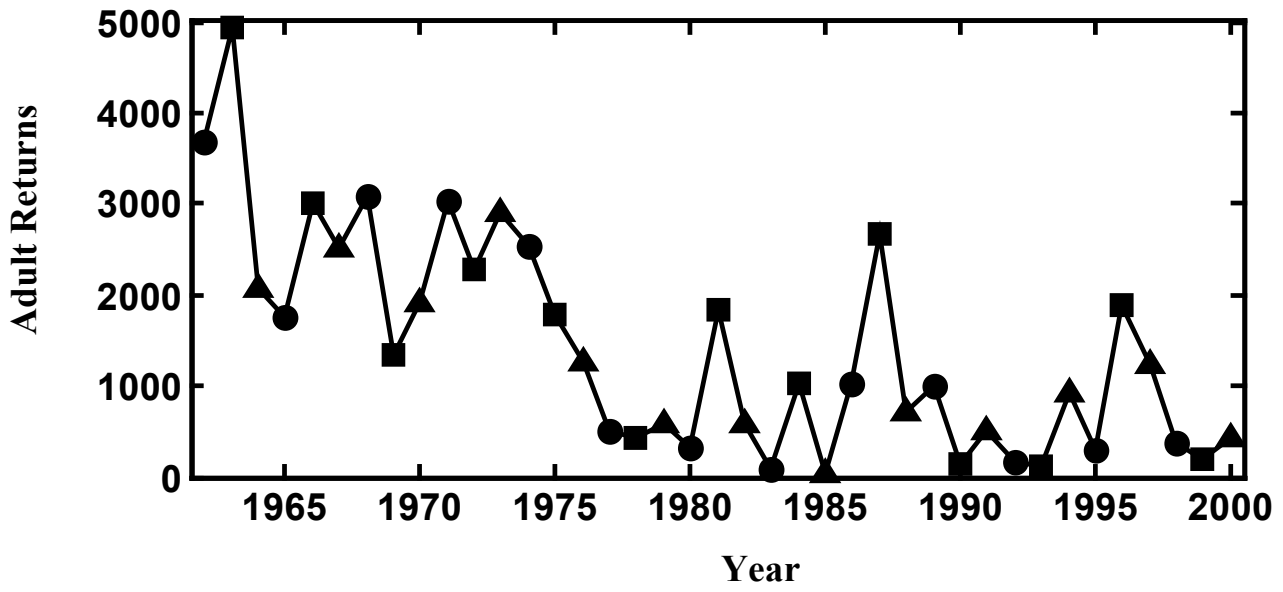


Figure 33. Adult coho salmon returns to Noyo Egg Collecting Station, Mendocino County, from 1965 to 2000.

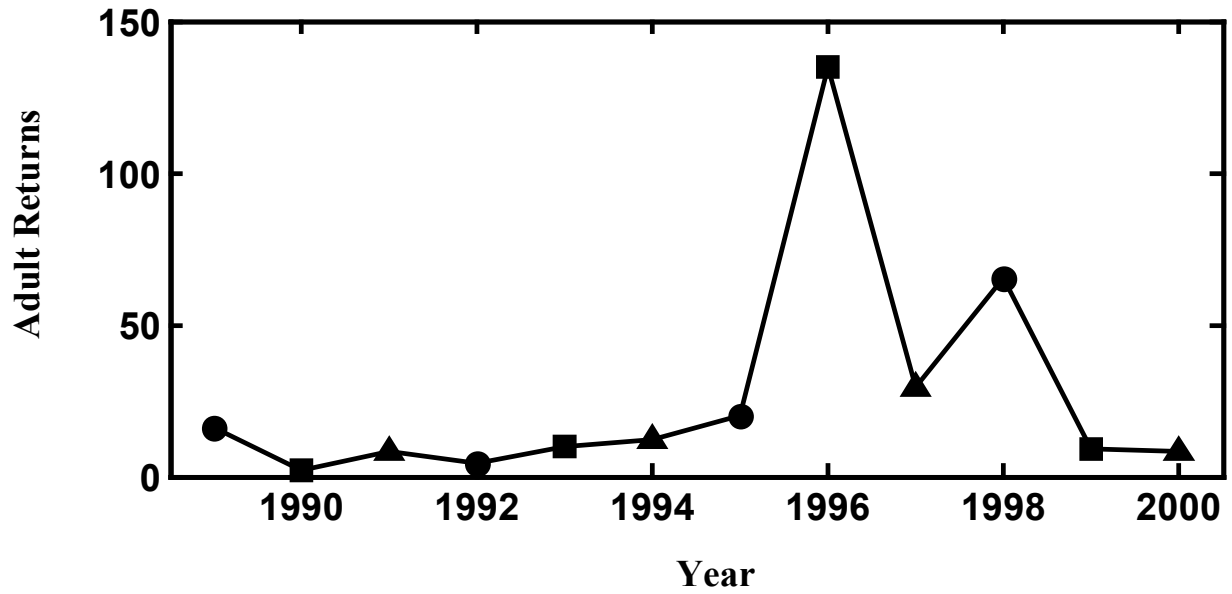


Figure 34. Adult coho salmon returns to Rowdy Creek Hatchery, De Norte County, from 1989 to 2000.

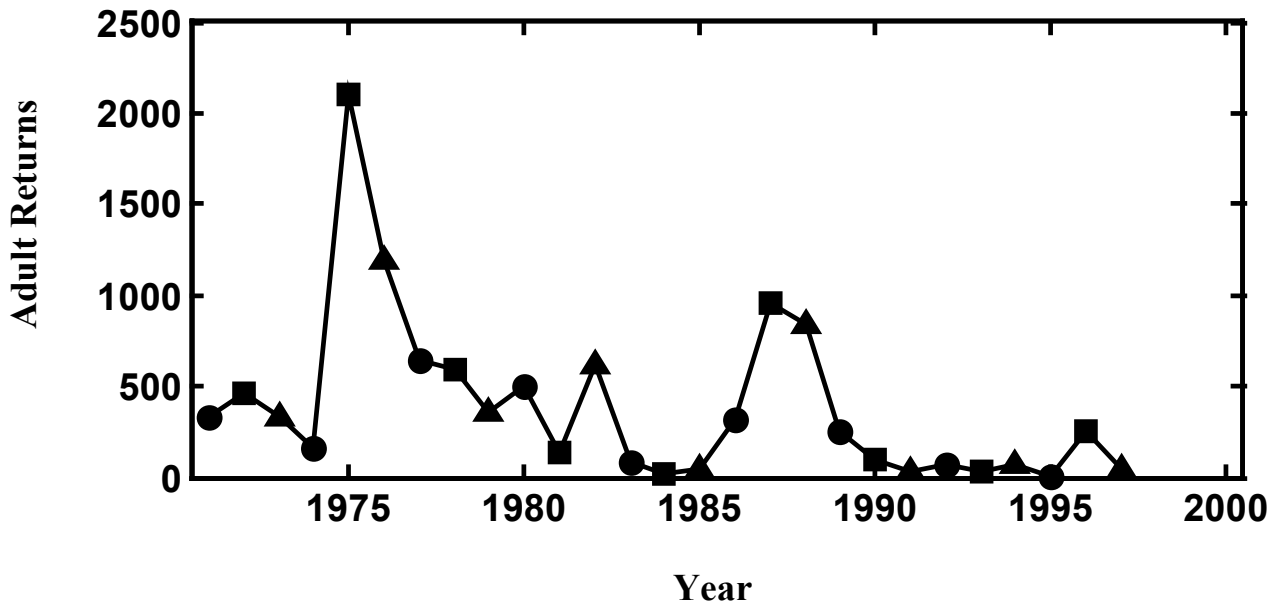


Figure 35. Adult coho salmon returns to Mad River Hatchery, Humboldt County, from 1971 to 1997.

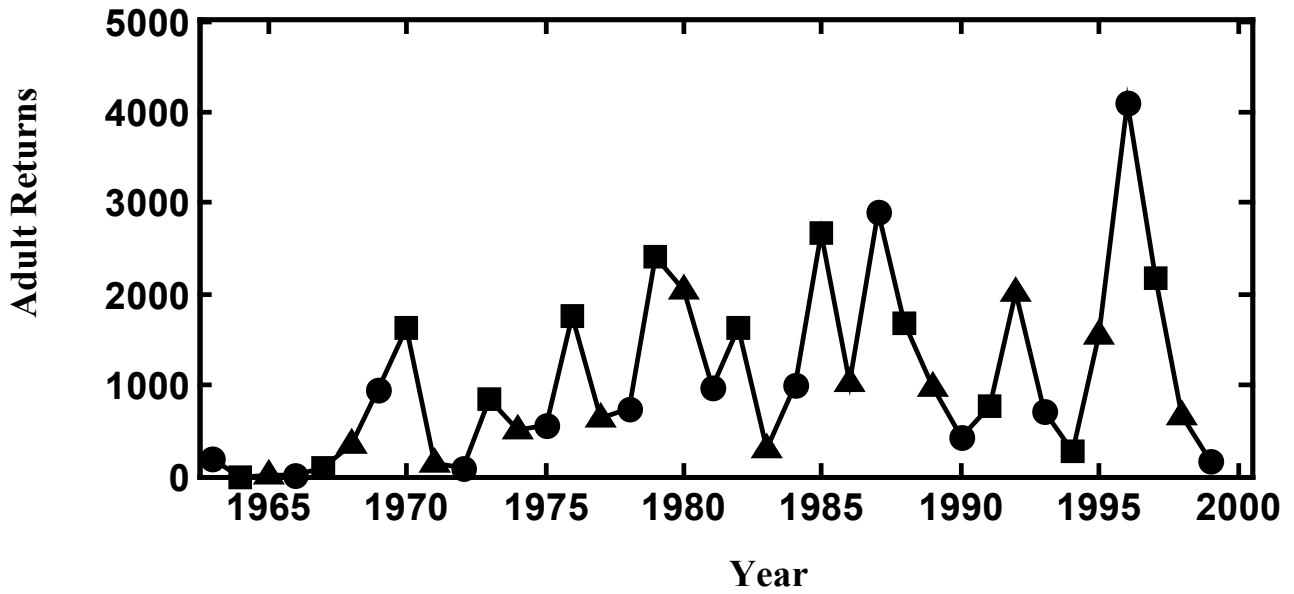


Figure 36. Adult coho salmon returns to Iron Gate Hatchery (Klamath River), Siskiyou County, from 1963 to 1999.

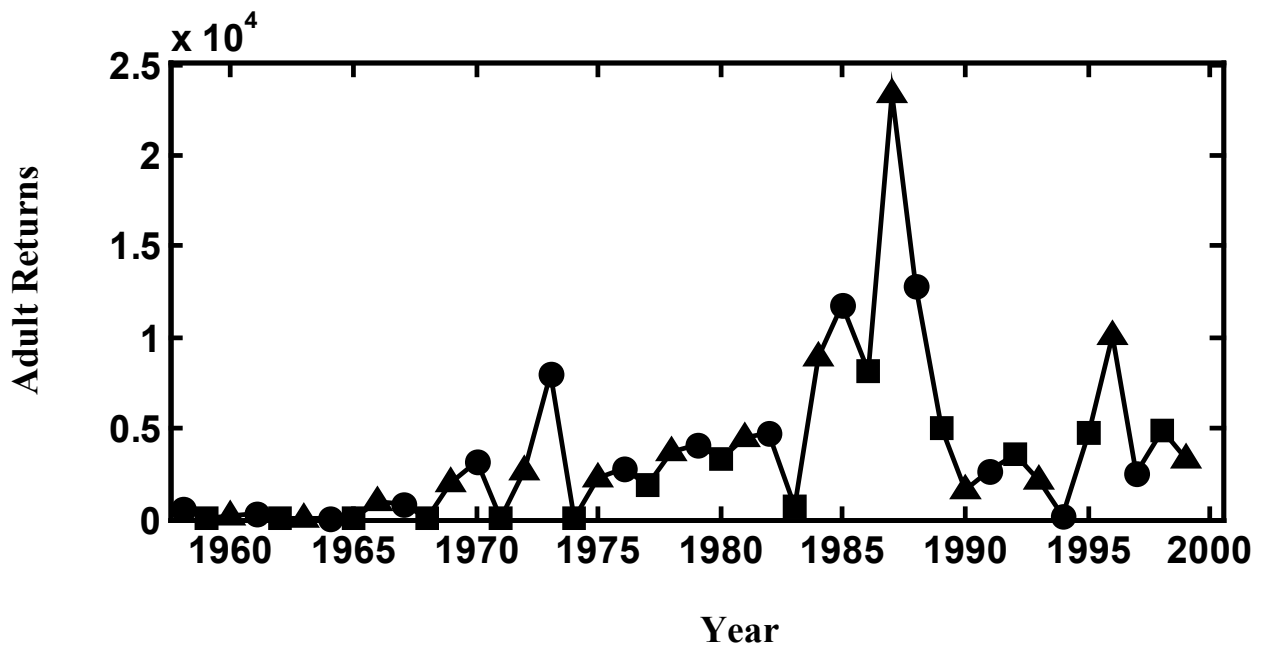


Figure 37. Adult coho salmon returns to Trinity Hatchery, Trinity County, from 1963 to 1999.

TABLES

Table 1. Geographical regions used to aggregate data for logistic regression analysis of presence-absence data. Regions are arranged north to south, as described in the text.

ESU/County	Watershed Group	Geographical Index
<i>Southern Oregon/Northern California ESU</i>		
Del Norte	Coastal	1
	Smith River	2
	Klamath River	3
Humboldt	Coastal	4
	Redwood Creek	5
	Mad River	6
	Eel River	7
	Mattole river	8
<i>Central California Coast ESU</i>		
Mendocino	Coastal	9
	Ten Mile River	10
	Noyo River	11
	Big River	12
	Navarro River	13
Sonoma	Coastal	14
	Gualala River	15
	Russian River	16
Marin	Coastal	17
San Francisco Bay	Coastal	18
San Mateo	Coastal	19
Santa Cruz	Coastal	20
Monterey	Coastal	21

Table 2. Percent of surveyed streams in the historic range of coho salmon with coho salmon present for four time intervals: 1989-1991, 1992-1994, 1995-1997, and 1998-2000. Results are summarized by ESU and county at the mouth of the stream or river system.

County	Number of Streams with Historical Presence	1989-1991				1992-1994				1995-1997				1998-2000				
		Number Surveyed ¹	Coho Present ²	Coho Absent ³	No Data	Number Surveyed ¹	Coho Present ²	Coho Absent ³	No Data	Number Surveyed ¹	Coho Present ²	Coho Absent ³	No Data	Number Surveyed ¹	Coho Present ²	Coho Absent ³	No Data	
<i>Southern Oregon/Northern California Coasts ESU</i>																		
Del Norte	Coastal	12	0	-	-	12	1	100%	0%	11	1	100%	0%	11	6	83%	17%	6
	Smith R.	52	5	80%	20%	47	16	69%	31%	36	35	63%	37%	17	14	43%	57%	38
	Klamath R.	189	62	95%	5%	127	105	90%	10%	84	61	70%	30%	128	72	69%	31%	117
Humboldt	Coastal	46	9	100%	0%	37	8	100%	0%	38	13	92%	8%	33	22	86%	14%	24
	Redwood Cr.	23	3	100%	0%	20	10	90%	10%	13	13	69%	31%	10	11	91%	9%	12
	Mad R.	23	2	100%	0%	21	1	100%	0%	22	4	100%	0%	19	4	100%	0%	19
	Eel R.	205	50	60%	40%	155	77	82%	18%	128	64	89%	11%	141	30	67%	33%	175
	Mattole R.	49	5	60%	40%	44	10	60%	40%	39	17	88%	12%	32	21	76%	24%	28
ESU Total		599	136	81%	19%	463	228	85%	15%	371	208	78%	22%	391	180	69%	27%	419
<i>Central California Coast ESU</i>																		
Mendocino	Coastal	74	15	53%	47%	59	37	51%	49%	37	47	60%	40%	27	47	47%	53%	27
	Ten Mile R.	18	10	20%	80%	8	13	31%	69%	5	14	71%	29%	4	13	54%	46%	5
	Noyo R.	25	3	67%	33%	22	11	82%	18%	14	17	82%	18%	8	18	56%	44%	7
	Big R.	23	1	0%	100%	22	14	21%	79%	9	16	81%	19%	7	13	23%	77%	10
	Navarro R.	28	1	0%	100%	27	15	27%	73%	13	17	65%	35%	11	16	44%	56%	12
Sonoma	Coastal	11	0	-	-	11	0	-	-	11	0	-	-	11	0	-	-	11
	Gualala R.	15	1	0%	100%	14	4	0%	100%	11	6	0%	100%	9	4	0%	100%	11
	Russian R.	46	1	100%	0%	45	9	78%	22%	37	20	45%	55%	26	14	7%	93%	32
Marin	Coastal	16	3	100%	0%	13	5	100%	0%	11	12	83%	17%	4	10	80%	20%	6
San Francisco Bay	Coastal	6	0	-	-	6	0	-	-	6	1	0%	100%	5	0	-	-	6
San Mateo	Coastal	5	0	-	-	5	1	100%	0%	4	5	20%	80%	0	3	67%	33%	2
Santa Cruz	Coastal	9	0	-	-	9	3	67%	33%	6	5	60%	40%	4	6	50%	50%	3
Monterey	Coastal	2	0	-	-	2	0	-	-	2	2	0%	100%	0	0	-	-	2
ESU Total		278	35	46%	54%	243	112	48%	52%	166	162	61%	39%	116	144	44%	56%	134

¹ Total number of streams surveyed at least once within the three-year interval

² Percentage of surveyed streams where coho were present in one or more years during the interval

³ Percentage of surveyed streams where coho were absent in all years of survey during the interval