Little North Fork Noyo Fishery Study, 1992

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ABSTRACT

Burns (1970, 1971, 1972) studied the impacts of logging on salmonid fishes of California's North Coast before, during, and after logging in several watersheds during the late 1960%. Since then, logging has continued under regulations that have become increasingly more protective of aquatic habitat. Despite this additional protection, salmonid populations continued to decline to the point where a number of stocks are considered at-risk (Nehlsen et al. 1991).

During the summer and autumn of 1992, we replicated portions of Burns' work on the Little North Fork of the Noyo River in Mendocino County. At five l00+ m study sites, we estimated aquatic vertebrate populations and measured habitat features: area and volume of water, habitat types, residual pool depth, large woody debris, sediment size distribution, and shade. Further, we document subsequent logging and stream clearing in the drainage.

Newts were captured at one site, but not in numbers sufficient to estimate population size. Yellow-legged frogs were captured in substantial numbers, but only at the downstream-most site. Sculpin were captured at 4 of 5 sites. Pacific giant salamanders, coho salmon, and steelhead rainbow trout were captured at each site. Of the three species captured at each station, dominance as measured either by populations or by biomass differed among sites. While the total salmonid biomass was similar among 1992 and the 1966-69 period, the species composition inverted from primarily coho salmon to primarily steelhead trout.

During the logging activities of Burn's studies, the stream's width increased and depth decreased. By 1992, our data suggests that stream depth had recovered, if not increased, while stream width was intermediate between Burn's pre and post-logging period. Protection from solar insolation (≈ shade canopy) had recovered and was near maximum. Large woody debris was limited and showed evidence of removal. It was often oriented parallel to channel flow and thus had limited channel structuring functions. In addition, the supply of large woody debris appeared likely to

remain restricted into the near future as there was little evidence for recruitment of large material with great longevity. Sediment quality, when measured as percent fines < 0.85 mm, was intermediate to Burns' pre and post-logging data. When expressed by the Fredle index, the 1992 substrate samples estimate 30% and 50% survival-to-emergence for coho and steelhead, respectively. However, the true survival-to-emergence value of the streambed is greater than these values because we did not apply correction factors for wet-sieving or the winnowing of fines caused by the fish's spawning actions.

The only habitat variables that appeared related to salmonid populations were those of the substrate. Plots suggest that steelhead populations followed a negative curvilinear relationship with percent fines. Coho salmon biomass suggests a positive curvilinear relationship with the substrate's geometric mean diameter. Of the factors we evaluated, none clearly could be linked with the inversion of salmonid species. However, Burns did not report on the woody debris dynamics during his period of study, thus we can not make determinations on this parameter of habitat quality.

Whether the inversion in salmonid species composition is a reflection of current habitat conditions within the Little North Fork of the Noyo or due to off-site factors, or simply chance, can not be ascertained from our empirical information. The extended, severe drought seems likely to be an important contributor.

INTRODUCTION

Burns (1970, 1971, 1972) evaluated logging impacts on salmonid habitat and populations in northern California streams during the late 1960's. He investigated watersheds that had been logged including Bummer Lake Creek, South Fork Yager Creek, South Fork Caspar Creek, and Little North Fork Noyo River. His results showed that extensive use of bulldozers on steep slopes or in stream channels can cause excessive erosion which may be detrimental to salmonids. Also he suggested that warming of waters through canopy opening may be a problem. As a result of his studies, Burns recommended a number of measures which might ameliorate impacts including 1) retaining buffer strips to control water temperature effects and sediment input, 2) building roads away from streams, and 3) minimizing the amount of slash that enters a stream. He also suggested that sustained logging and associated road construction over a period of years may not allow a stream or its fishery to recover from logging impacts.

In assessing the impacts of logging to fishery resources, Burns evaluated water quality, water temperature, spawning bed sedimentation (particle size distribution), juvenile salmonid abundance, and insect (fish food) abundance. Each stream was evaluated for three summers; one before, one during, and one after logging.

Since the time of Burns' studies, the Z'berg Negedly Forest Practices Act of 1973 was passed. The resultant California Forest Practices Rules have continued to evolve to protect environmental resources. Many of the Forest Practices Rules' major focus is the protection of aquatic resources and address the three items recommended by Burns.

The California Department of Forestry (Jameson 1989a, Valentine 1992a) proposed a pilot investigation to:

1. Repeat aspects of Burns' earlier studies to determine if there are discernable trends in the parameters he measured, and relate those to timber harvest activities in the drainage since his studies,
2. Develop a database which could be used in the future to continue documenting trends,
3. Collect additional coldwater habitat information beyond that of Burns.

MATERIALS AND METHODS

Study Sites

During 1992, the project was initiated on the Little North Fork Noyo River in Mendocino County, east of Fort Bragg (Fig. 1). The Little North Fork Noyo River drains a 989 ha watershed underlain by Hugo soils and is 16.0 km from the ocean (Burns 1972). Its watershed is dominated by second growth redwood Douglas-fir forests.

In 1992, after field reviewing the entire second and third order "blue-line" extent of the watercourse, we concentrated studies into five ≈ 100 m study reaches (Fig. 1) distributed systematically along the watercourse to capture the range of variability. For the purposes of this report, the study sites are identified by a code starting from the downstream-most site and increasing in an upstream direction; site A-l is near the Little North Fork Noyo River and Noyo confluence, while E-5 is the most upstream site (study reaches may be referenced by number or letter). Site 5-E was at the junction between second and third order sections, and the other sites were in third order portions of the stream. The downstream and upstream end of each study site were marked with flagging and an aluminum tag affixed to nearby woody vegetation.

The criteria we used in establishing all intensive study sites were:

- Gross slope (calculated from the USGS Noyo Hill quad) is less than 3% to ensure that sediment storage reaches are the focus of the analysis.
- Three or more consecutive stream sequences (pools and riffles) or 100 m long, whichever is longer. Our intent in sizing sections in this manner was to encompass most of the stream's

inherent variability in salmonid habitat.

Further considerations which assisted in final siting within the above parameters were:

- Three located (Sites B-l,C-3,5-E; Fig. 1) such that approximately ⅔ and ⅓ will be downstream and upstream, respectively, of the watershed's largest tributaries' inflows. This location promised insight into land management impacts partitioned between the mainstem and the tributaries as affected by area-discharge relationships,
- One (Site A-l, Fig. 1) is located near the mouth of the Little North Fork Noyo River where there are no delineated tributaries on the quad. It was immediately upstream of obvious backwater effects from the Noyo River, as evidenced by sediment accumulations. This location should consolidate the impacts of many of the up-drainage activities,
- One site (Site D-4, Fig. 1) located where the gross slope is the least. This reach was sited to avoid direct tributary influences. It may be prone to sedimentation.

Burns studied a 1,530 m reach of the Little North Fork of the Noyo River in its mid-section (Fig. 1). Along that, he collected his sediment samples systematically. Vertebrate sampling was concentrated into four approximately 100 m reaches, the endpoints of which were permanently established with metal stakes. The reaches' length varied each year due to channel changes resulting from upslope and instream logging practices and hydrology (J.W.Burns, California Coastal Commission, San Francisco, pers. commun.). The exact locations of Burns' four study reaches are unknown, only that they are within the larger reach. Of the study sites sampled in 1992, C-3, D-4, and E-5 are within Burns' study reach, B-2 is marginal, and A-l is well downstream.

Human Modification of the Stream Channel

Logging History.-- Detailed historical records do not exist for logging which occurred prior to 1964. The historical information referenced included Georgia-Pacific Corporation records, aerial photographs, timber inventory plot data, and interviews with current and retired Georgia Pacific employees.

For logging subsequent to 1964, we obtained the annual timber depletion maps maintained by Georgia-Pacific Corporation and transcribed it to the U.S.G.S. 7.5 minute quadrangle maps (Noyo Hill). The harvest areas by year of cut were planimetered and an acreage computed. Silvicultural system and yarding method for harvests prior to 1973 were ascertained from company depletion records and interviews with current and retired Georgia Pacific employees. Silvicultural system and yarding methods for harvest after 1973 were obtained from California Department of Forestry and Fire Protection's timber harvest record files in Santa Rosa and Georgia-Pacific harvest records.

Mapping the Channel. --We sketched each study section along its entire length moving in an upstream direction. The resultant maps are not to scale and only approximate the characteristics and relative dimensions of the channel and near-channel features. Mapping focused on woody debris associated with the channel, the channel banks, near-channel trees, stumps and snags, existing and abandoned roads, skid trails, landings and railroad grades. The habitat typing was conducted separate from the channel illustration, and the types indicated were applied to the illustrations after comparing the illustrations with the typing data.

Unless noted otherwise, objects depicted within and immediately adjacent to the wetted channel are woody debris. Unless noted otherwise, skid trails, roads, and the railroad grade are all abandoned, pre-1973 facilities.

Debris (logjam) Removal .--Debris jam removal, the other major watershed activity which affects channel character, was evaluated using the Department of Fish and Game's project records and evidence mapped during the field studies.

Habitat

Typing. --The study reaches were typed by recording the longitudinal length along the thalweg of habitat types as defined by Flossi and Reynolds (1991). Typing was to Level IV relative to water conditions (low-flow levels) at the time of sampling; i.e., we did not attempt estimate conditions at bankfull or flood-plain flows. Only units greater than the average wetted-width for the entire reach were considered distinct types (Flossi and Reynolds 1991). Habitat is portrayed in pie charts which exhibit the percentage of each site by type at each level. Ratios were calculated using the unit's lengths, not areas.

Quantification. --We measured the dimensions of each habitat type to quantify available habitat. Depth for each unit was the arithmetic average of 5-8 (number depending on length of the unit) random depths along the thalweg. Width for each unit was measured at the location which we visually estimated to be the "average" or "median" width. The values acquired for each unit were then used to calculate surface area and volume of water available as habitat for the entire study section.

The concept of "residual pool" depth (Lisle 1987) is a recent metric of pool depth which is intended to eliminate the effects of stage from depth measurements. "Residual pool" depth is calculated by subtracting the depth of the deepest water as it passes over the pool/riffle crest from the pool's deepest point (to surface of any sediment) found in the pool. Because salmonids are a primary focus of this evaluation and deep pools are relatively more valuable for coho (McMahon 1983), we quantified only residual pools > 30 cm deep. In addition to recording the depth of residual pools, the distance between their deepest points was measured.

Pool quality was rated using the somewhat subjective cover descriptions of Platts et al. (1987: 176). Pool-cover 'was considered:

"abundant" and ranked 1 if instream cover was excellent and most of the perimeter had fish cover;
"intermediate" and ranked 2 if instream cover was moderate and ≈ ½ of the pool perimeter has fish cover; and
"exposed" and ranked 3 if the there is poor instream cover and < ¼ of the perimeter has fish cover.

We measured percent solar radiation blocked (≈ shade canopy) within each reach at 20 m intervals from the stream's center using the July solar arc grid of a Solar Pathfinder. At each point, the percentage of the sun arc blocked by vegetation was determined. The portion of the shade comprised of conifer or deciduous vegetation was estimated.

Large Woody Debris (LWD). -- The dimensions and shape (columnar, conical, slab) of any woody debris larger than 10 cm within the high-water channel was measured, and the presence of apparent influence of the piece on the channel's morphology was noted. Only that portion of a log within the channel was used to calculate the volume of LWD.

Following Cafferata (undated), volume of columnar LWD in m^3 was calculated following the equation:

$$V_c = \frac{\pi (D_1^2 + D_2^2)\ L}{8}$$

where D_1 and D_2 are the end diameters of each of the piece, and L is its length. For conical-shaped LWD, the Volume was calculated following the formula:

$$V_1 = \frac{\pi\ R^2\ L}{3}$$

where R is the radius of the cone's circular bottom and L is the cone's height. Old stumps most commonly took on the conical shape. For slab-shaped LWD, the volume was calculated following the formula:

$$V_s = W * H * L$$

where W is the slabs width, H is its height, and L is its length. Slabs appeared top be from logs shattered during falling or other logging activity.

Substrate.-- We determined particle size distribution following Valentine (1993). To summarize, bulk samples were collected from the thalweg where the water's surface velocity noticeably increased (breaks) as it passed from the tail of a pool into a riffle. A single sample was collected from five pool / riffle breaks in each study reach. Where this sampling location was clearly not suitable for spawning as determined from the substrate's surface conditions, a sample was not taken. Only two samples were moved to the next upstream pool / riffle break for this reason.

Samples were collected using two McNeil samplers (McNeil and Ahnell 1960) with core dimensions of 14.4 cm ID x 13.4 cm and 15.2 ID cm x 15.2 cm, resulting in nominal sample volumes of 2183 and 2780 cm^3, respectively. Samples were wet-sieved (Armour et al. 1983: 31) in the field following Valentine (1993), including a 10 minute settling time for fines (<0.85 mm). Substrate metrics calculated from the samples include percent of the samples passing the 0.85 mm sieve ("fines"), the percent passing the 3.3 mm sieve, the geometric mean, and the Fredle index (Armor et al. 1983). The value passing the 3.3 mm sieve was calculated mathematically using a logarithmic conversion of particle sizes because natural sediments frequently exhibit lognormaldistributions (Platts et al. 1979).

Aquatic Vertebrates

Each study reach was sampled with a Smith-Root Model 12 backpack electrofisher. Sites were fished for two (Site C-3 and Site D-4) or three (all others) passes, depending on the magnitude of decline in captures between the first and second pass (Price and Adams 1982). A subsample of individuals collected were weighed using Pesola spring scales. The size of all individuals was measured using fork length for fishes and snout-vent length for salamanders. Populations of each vertebrate taxa -- with the exception of yellow-legged frogs -- with adequate numbers of representatives captured were estimated in each study reach following the removal depletion strategy and calculated using the software (MicroFish 3.0) of Van Deventer and Platts (1989). Population estimates and biomass were then converted to "density" estimates by dividing them by surface area volume.

Fish/Habitat Relationships

Fish variables were plotted against habitat variables to permit a visual inspection of potential habitat relationships. Because of the small sample size (five stations and one year), we do not apply statistics of association.

RESULTS

In order to evaluate population conditions as near **to their** in-stream bottleneck as possible, the studies proceeded from first performing habitat analysis followed several weeks later by population analysis. Electrofishing was postponed as late in the season as possible. As a result, the four upstream stations were sampled at the extreme low-flow period. Station A-1 was sampled after an early fall storm, and the stage of the water had noticeably increased (≈ 5 cm).

Human Modification of the Stream Channel

Logging *History.* --Georgia-Pacific Corporation records include railroad planning documents for the Little North Fork dated ≈ 1890; the earliest recorded evidence we found of logging related activity in the Little North Fork drainage. Increment cores taken in 1981 from second-growth redwood trees indicate that some of the oldest second-growth stands about 90 years of age in 1992 (Georgia-Pacific Corp. timber inventory plots). Company records indicate that the entire watershed was logged prior to 1920. Most of this early logging approximated clearcutting, but left scattered residual old-growth trees.

Between the early logging and the initial harvest of the second-growth is a long period absent of available logging records. Georgia-Pacific's depletion maps showed that harvest of the second-growth within the drainage was initiated in 1964. This harvest, and all which occurred prior to 1981, employed selection silviculture and was yarded with tractors (Robert Grundman, [Retired] Chief Forester for Union Lumber Company, Fort Bragg, CA, pers. commun.).

Over eighty-five percent of the drainage was logged between 1964 and 1972 (Table 1). Georgia-Pacific% 1975 aerial photographs show this era's logging used a road system located primarily adjacent to the stream system. The channel diagrams (Appendix A) depict those abandoned railroads, truck roads, and skid trails in proximity to the channel. Erosion control facilities are not evident on the abandoned roads and trails immediately adjacent to the channel.

Many of the selectively cut stands within the drainage were logged again, beginning in 1980. Between 1980 and the present, 1809 acres of sapling-sized stands in the Little North Fork drainage have been created and 3514 total acres have been harvested subsequent to the passage of the Z'berg Negedly Forest Practices Act of 1973 (Table 1). Department of Forestry & Fire Protection records show that clearcut areas were usually broadcast-burned to facilitate planting. Subsequent to the original logging of the old-growth, the earliest clearcut was in 1981.

Mapping the Channel. --Abandoned railroad grades of the early era of logging follow immediately adjacent the Little North Fork main channel along most of its length (Appendix A). Truck roads and skid trails from the 1964-72 era are still evident **near the** channel (Appendix A).

The channel of the Little North Fork is generally "U" shaped. The high-water banks are nearly vertical and typically under two meters tall. In many places, the stream appears to have eroded through fill material deposited prior to 1973. Logs with sawn ends protrude from the banks in many areas, indicating that fill was placed upon them during the excavation of railroad grades, truck roads, and skid trails. The fill material has been subsequently temporarily stabilized by vegetation. Immediately adjacent to the banks is a narrow flat which lies at the base of steep, timbered slopes. The abandoned logging facilities are vegetated by conifer saplings, riparian hardwoods, grasses and forbs. The slopes are vegetated, except for the currently maintained truck road. The road has a rocked surface and is drained towards an inside ditch with relief culverts.

The timber adjacent to the channel and upon the slopes within the watercourse and lake protection zone (Title 14 CCR Section 916.5, 1991) consists primarily of second-growth redwood, Douglas-fir, and tanoak. Windfalls in the channel area are primarily Douglas-fir, which decomposes rapidly when compared to the wood of old-growth redwood. Most of the woody debris within the channel is old-growth redwood, apparently deposited at least 70 years ago.

Debris (logjam) Removal.--In addition to the logging activities subsequent to 1973, Department of Fish and Game records (Anon. 1984, 1986) show that woody debris was removed from 50 log jams in the channel of the Little North Fork Noyo River over a four year period between 1983 and 1986. The effects of this practice are difficult to determine, because the before and after evaluations were not documented. Jameson (1989b) estimated that log jam removal released approximately 1000 cubic yards of stored sediment within a 10,000 foot reach of the Little North Fork Noyo River. The purpose of the jam removal was to improve salmonid habitat conditions through improved access and enhanced spawning gravels. During removal, logs keyed into the substrate were typically retained, and notches were occasionally cut in keyed logs to facilitate upstream migration over obstructions. During our field work, we observed three notched logs. In two of the three cases, the stream now flows beneath the keyed, notched log.

Habitat

Typing.--When categorized at the most coarse level (Level I), the sample sites ranged from 35 to 56 % pool, and conversely 44 to 65 % riffle (Figs. 2 thru 6). Four of the sites were > 50 % riffle.

At the next more complex level of typing (Level II), 20 to 46% of the sites were comprised of "flatwater" types (Figs. 2 thru 6), a subcategories of riffles. The make-up of each site at the two more complex levels (III and IV) of habitat typing further subdivide the habitat types. Finally, the "all units" graph (Figs. 2 thru 6) displays the habitat types at Level IV without summing units within the same type -- these graphs portray the complexity of the channels as measured by total number of habitat types within the study reach. A trend towards fewer, longer habitat units per study reach is apparent in a downstream direction.

Quantification.- In order to delimit the 1992 study sites at habitat type junctions, the length of the units differed from 100 m (Site B-2) to 107 m (Site E-5) (Table 2). Surface area of the five 1992 sites increased in a downstream direction, and ranged from 196.8 to 235.6 m^2 (Table 2), with an average width of between 1.8 and 2.3 m. From 1966 through 1969, the surface area for the summed study reaches ranged from 600 to 998 m^2 (Table 2, and Table 6[1] of Burns 1972) with an average width of between 1.5 to 2.5 m.

Water volume for the five 1992 sites ranged from 26.7 to 58.5 m^3 and did not follow any observable trend along the watercourse (Table 2). By dividing the volume by the surface area, an average depth for the site is calculated. For the five 1992 sites, site depths averaged from 13.6 to 27.6 cm with no apparent trend along the stream. During 1992, mean residual pool (>30 cm) depth ranged from 31.3 to 56.2 cm and the average distance between the subsequent residual pools greater than 30 cm ranged form 8.3 to 25.0 m for the five 1992 sites.

Pool-cover quality was classified dominantly as "moderate", with a lesser proportion of pools classified as having "poor" cover, and the fewest pools were classified as having "abundant" cover (Fig. 7).

Timing of the shade measurements was late enough such that deciduous vegetation (willows and alders) had initiated leaf drop; however, the amount retained was still substantial. Thus, shade canopy measures are probably somewhat conservative. Percent solar radiation of the July sun arc blocked ranged from 76.7 to 86.8 % (Table 2). Of the vegetation shading the stream during July, coniferous vegetation dominated; although at study site C deciduous forms provided an equal amount of the shade (Table 2).

LWD. -- Large woody debris ranged from 4 to 51 m^3, and averaged 17.7 m^3 (Table 2). While not recorded, the species composition appeared important. Redwood, which probably originated prior to or during the logging activities studied by Burns dominated the in-bed, channel structuring elements and remained sound. Fir and hardwoods were generally small diameter, very weak, and disintegrating. Orientation of LWD relative to the stream's axis was not recorded either. However, much of the instream,

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1 The area measurements of Table 6 in Burns' (1972) are one order of magnitude too high (Burns, pers. commun.).

channel forming elements were oriented parallel to the stream flow. The few elements which were perpendicular to the stream flow were associated with more complex channels (deeper, wider pools) than where materials were parallel to stream flow. Extensive log-jam removal was evidenced by wood chunks thrown above the annual high water channel and by recent-past sediment deposits.

Substrate. --Data tables are provided in Appendix B. Character of the substrate particles varied in a downstream direction. At the upstream study sites, gravels were noticeably more angular and layered than they were in the downstream reaches.

Geometric mean particle size for the five study sites ranged from 5.0 to 8.3 mm (Table 3, Fig. 8). For all sites combined, the geometric mean averaged 7.2 mm. There was no obvious trend along the watercourse (Fig. 8). Variance was extreme at Site 5 (Table 3, Fig. 8), due to a sample (Sample C, Appendix B) being collected from a location with very clean gravels and another (Sample D, Appendix B) which hit clay pockets. Site 5 was immediately downstream of an abandoned truck road crossing which was constructed in 1969. There was no obvious relationship between sites' average geometric mean and their variance (Table 3).

The Fredle Index for the five study sites ranged from 1.3 to 2.4 (Table 3). For all sites combined, the Fredle Index averaged 2.lmm. There was no obvious relationship between a sites' average Fredle Index and its variance (Table 3).

Substrate particles finer than 0.85 mm for the five study sites ranged from 20.8 to 31.2 percent of the samples (Table 3, Fig. 9). For all sites combined, the portion of samples less than 0.85 mm averaged 25.4 percent. The percent of particles less than 0.85 mm appears to be positively related with the variance. The average percentage of substrate made of particles less than 0.85 mm may show a positive trend in an upstream direction.

Wide variation in substrate content is apparent in both the graphical representations of the particle size distributions (Figs. 10 thru 14) and the standard deviations of the means for Dg, the Fredle Index, and the percent fines (Table 3). While the three substrate quality measures are intended to describe the distribution of the substrate, they obviously do so differently as their rank sequence differ, although they are similar. Using site averages, the percent fines plotted against geometric means (Fig. 15) suggests a negative relationship, but with substantial scatter.

Aquatic Vertebrates

Eight species were captured during the electrofishing operations: Pacific giant salamander *(Dicamptodon tenebrosus,* formerly *D. ensatus* [Good 1989]), rough-skinned newt *(Taricha granulosa)*, yellow-legged frogs (*Rana boylei*), coho salmon *(Oncorhynchus kisutch),* steelhead trout *(Oncorhynchus mykiss),* prickly and coastrange sculpin *(Cottus asper and C. aleuticus*), and three-spine stickleback *(Gasterosteus aculeatus).*

Vertebrate species were not uniformly distributed. Newts were located on only one study site, and population estimates were not possible. Numerous stickleback (population estimate 47 [Table 4]) populated study site A-l, but no other site. Yellow-legged Frogs were captured during electrofishing only from station A-l, although few (<15) were observed early in the season along the reach during project reconnaissance level-work. Frog population was not estimated at A-l because they readily escaped the holding tank during passes, violating assumptions of the depletion method.

Because of the low total number of captures, the sculpin species were grouped and population estimates for sculpin apply to the genus. Sculpin were present in 4 of 5 stations at populations between 1 and 11 individuals, being absent only form station C-2 (Table 4).

Pacific giant salamanders were common at all sites, and at two sites (D-4 and E-5) were the most numerous vertebrate taxa. Population estimates ranged from 28 to 151 per study site (Table 4).

Study site populations for the four lOO+ m study sites were estimated (Table 4) in 1992 between 29 to 91 for steelhead trout (Fig. 16) and from 3 to 102 for coho salmon (Fig. 17). In order to make our estimates more comparable to those of Burns (1972), two measures of abundance were calculated. When measured in density (number of fish per m^2 of water surface area), the 1992 samples averaged 0.13 coho salmon / m^2 (range 0.3 - 0.8) and 0.28 steelhead / m^2 (range 0.15 - 0.41) (Table 5). As biomass, coho salmon averaged 3.72 kg/ha (range 0.91 - 11.16) and steelhead averaged 15.07 kg/ha (range 10.33-24.48) (Table 6).

Condition factors ranged from 0.84 to 1.47 for coho salmon and 0.91 to 1.42 for steelhead (Table 7). Site A-l was the lowest for both species, while the point estimates for all other sites were greater than 1.0.

Fish / Habitat Relationships

Scatter-plots of different measures of salmonid abundance against most measures of habitat quality produced no figures with obvious trends. Visual inspections of site mean values for biomass did not suggest relationships with water surface area (Fig. 18), water volume (Fig. 19), mean residual pool depth (Fig. 20), mean site depth (Fig.. 21), large woody debris (Fig. 22) for either salmonid species. Two measures of substrate condition, the geometric mean and the percent fines did not suggest any trends in the biomass of sculpin nor the Pacific giant salamander (Fig. 23 and 24).

Scatter-plots of substrate characteristics suggested possible relationships with salmonid abundance. While the biomass of coho salmon showed extensive scatter when plotted against the stations' percent fines, that for steelhead suggested a negative curvilinear relationship (Fig. 25). A similar, but looser, relationship is suggested between the percent of fines and steelhead density (Fig. 26). The results differ when the substrate condition is expressed by its geometric mean (Fig. 27 and 28). Steelhead biomass and density show substantial scatter while those for coho suggests a positive curvilinear relationship. Both biomass and density for coho salmon begin to increase at a geometric mean diameter about 7.5 mm.

Scatter-plots of steelhead and coho condition factors did not suggest a relationship with the percent of fines (Fig. 29) nor with the geometric mean particle size (Fig. 30).

DISCUSSION

The early logging along the north coast of California (prior to ≈ 1920) yarded logs to a railroad line with bull teams and steam yarders (Jackson 1975, Caranco and Labbe 1979). This type of yarding, probably representative of the Little North Fork of the Noyo River, typically deposited large quantities of soils and woody debris into watercourses. Subsequent to that period, the common logging practice was to skid logs and construct both roads and landings within or immediately adjacent to stream channels. This practice was that used in the Little North Fork of the Noyo River (Burns 1972). Further, Burns (1972) describes the practice of bull-dozing of slash from the stream channel following the logging.

The regulation of forest practices in California has undergone continuous change since 1973, and to ascertain the provisions of regulation which applied to each logging operation in the Noyo watershed would be difficult. Major provisions of California's forest practice regulation in place since 1974 regulate stream protection, equipment use, erosion control, road construction and maintenance.

Unlike the logging of the period between 1964 and 1972, more recent operations included some new road construction at or above the mid-slope to facilitate cable-skyline yarding of slopes over 55 percent and to shorten skidding distances. Based upon a comparison of timber harvest plan records and 1975 aerial photos, many miles of pre-1973 skid trails and truck roads in the Little North Fork Noyo watershed have been abandoned. Our field examination found most of these abandoned facilities were vegetated and erosion from them was relatively uncommon, except at old instream roads and landings. The fills beneath these in-stream facilities continue to erode as channel alignment and gradient approach new equilibria.

Our five study sites covered a broad range of logging-related disturbance. One site included a reach where the stream had cut down through an instream landing constructed in 1969, one site was downstream of a landslide that was probably activated by upslope roading of the early 1970's, and all sites exhibited old roadbeds or crossings. The channel diagrams (Appendix A) depict those abandoned railroads, truck roads, and skid trails in proximity to the channel.

In addition to the impacts of timber harvest, evidence of recent (± 10 years old) log jam removal was common. Some of the impacts of timber harvesting (excessive sediment inputs) and log jam removal (remobilized instream sediment) are similar, and this study can not segregate these impacts.

During Burns'(1972) studies, the total (summed) length of four ≈ 100 m study areas differed from 399 mto 424 m. The starting and end points were fixed; the difference in length was the result of intervening meander (Burns, pers. commun.). Average widths during Burns' study increased, presumable due to the logging activities. However, from 1966 to 1969, the average depth ranged from 15.2 to 9.1 cm, with a trend toward becoming more shallow after timber harvest (Table 2).

During 1992, habitat typing revealed that the pool / riffle ratio was approximately even, tending slightly toward riffles. Conventional interpretation is that a ratio of 1 to 1 is optimum, although studies comparing fish abundance among streams have shown the measure to have low precision; i.e., within studies, highest salmonid abundance is sometimes in study sections more divergent from this value than in other study sections (Platts et al. 1983:10). "Ideal" conditions are difficult to define and are likely to vary in response to a number of parameters (MacDonald et al. 1991). A preponderance of riffles may imply an excessive increase of coarse sediment or a reduction in large woody debris, although there is little information on the response of habitat types to management activities (MacDonald et al. 1991). The best use of pool riffle abundance may be to monitor stream's response to habitat alteration over a longer time frame.

Our methods for quantifying habitat types differed from those used by Burns (1971). Opposed to recording length, width, and depth of each habitat type as we did, others have taken measures (width, depth) along systematically, or otherwise placed transects perpendicular to stream flow. Burns (1971) placed "...from 30 transects in stream sections less than 1 km long...," so we assume that 30 transects were used to measure his 0.399 to 0.424 km long study sites, and the design of their placement (systematic, random, etc.) is not reported. Therefore, while Burns' and our studies measure the same characteristics of the streams, they do so in different ways and comparison of the results must recognize those differences. For example, we calculated average depth for each unit from several readings along the thalweg (the deepest portion of the longitudinal profile) while perpendicular transects normally record depths at pre-set distances across the channels' wetted-width. Therefore, our methods may tend to compute a greater "average depth" than those of Burns. On the other hand, because we measured each habitat unit of greater length than the average wetted width while transects placed either systematically, randomly, or selectively may miss habitat types or over sample-others, our average depth may tend to be slightly less or more than if calculated by transect methods.

Prior to logging activities in 1966, the average depth was nearly 15 cm; in 1968, 24 months after initial road construction and 12 months after gully logging the average depth dropped to 12 cm; and in fall of 1969, immediately after second road construction, the average depth was 9 cm. Burns (1972) tables note the decline in average depth even though the measured flow for each study year increased (first it doubled from 1966 to 1968, then the 1969 value was more than triple the 1966 flow). Concomitantly with shallowing, the channels widened (Table 2). The average depth in the 1992 study sites was 21.1 cm (Table 2), and the range of depths falls entirely above Burns' pre-logging value. Thus, the changes (becoming more shallow) in the physical condition of the stream observed by Burns appear to have recovered by 1992. The initial shallowing may have been due to the gully logging and other stream operations by bulldozers. Even in 1992, the high-water channel along much of the watercourse appears to be the width of a bull-dozer blade, and the low flow-channel meanders weakly within. The salmonid population response from pre to post-logging (Burns 1972) may have been due to these changes in physical habitat (becoming more shallow), increased discharge and thus probably average velocity, or an interaction between these variables, as well as such factors as gravel quality (Burns 1970).

We found that pools greater than 30 cm residual depth were nearly always associated with large woody debris, either in the form of logs or in-place stumps. The few other residual pools resulted from tributary inflows, standing trees, or in one case soil apparently well anchored by the roots of herbaceous and shrubby vegetation. Pool cover quality was generally moderate to low as many pools were the result of a single root-wad or few pieces of LWD. Burns (1972) did not quantify woody debris nor pool depths, so comparisons are speculative. However, Burns did note that bulldozers were used to remove logging debris in the streams he studied. This action probably removed large woody debris other than that generated by the logging.

As for habitat typing, the average distance between the deepest points of 5 successive residual pools may provide an indicator of the status of sediment dynamics in the stream system. Its use is limited to time trend analysis.

Although not providing data, Burns (1972) noted that "...selective removal of timber along the stream opened the forest canopy and undoubtedly increased stream temperatures." We did not record stream temperature; however, "shading" during the critical summer months was nearly 100%. The "solar-pathfinder" does not measure "canopy" in the traditional sense. That is, it does not measure vegetative obstruction to vertical projections, the common application for wildlife and forestry (Hays et al. 1981, Husch et al. 1972). Rather, it measures solar insolation along the sun's arc which may substantially differ from vertical and approach horizontal at the horizons. In addition, it does not measure percent of the sky shaded, but measures the percent solar radiation blocked during a user-defined time period. "Canopy closure" and "solar radiation blocked" differ in that the percent of solar radiation (a measure of heating ability) is greater for a given angle of the sun's arc during mid-day than it is for the same angle during other portions of the day. In streams where increased water temperature is the focus of concern, the solar pathfinder should be superior to other common tools (e.g., densiometers). However, where other parameters of fish habitat are provided by near-stream vegetation -- invertebrate foods or inputs of vegetative matter -- the solar pathfinder may be inferior to other tools. Nevertheless, the dense canopy we measured in 1992 showed that thermal heating in the late summer period was probably inconsequential and that, within the limits of Burns statement, had recovered in the intervening 23 years.

In 1992, large woody debris was limited to a few isolated, small log jams. Recent (± 10 year-old) log jam removal was evident. LWD was most commonly oriented such that it did not collect and meter the sediments' movement downstream, develop plunge or scour pools, nor sort sediments across the channel bottom. The tree species mix of recent additions was biased toward small trees and species with rapid deterioration rates, suggesting they would do little in the short-term to restore the apparent shortage. A few recent large redwoods had fallen and spanned the watercourse; however, their incorporation into the channel will take some time and thus they risk being yarded during future timber harvest.

We selected the substrate composition sampling scheme because it repeated the functional locations sampled by Burns. Also, it samples locations preferred for redd construction by spawning salmonids (Bjornn and Reiser 1991).

Like Burns, we did not apply two corrections to the sediment samples. One correction sometimes applied accounts for the differential water retention among the different particle size fractions. This factor becomes significant at particles sizes less than 4 mm. A second correction sometimes applied adjusts for the winnowing of fines from the substrate when salmonids construct a redd, a factor which Chapman (1988) describes as "substantial." Thus the proportion of substrate which is fine sediments differs between the general channel bottom and that of a redd. We chose not to apply corrections to our samples because 1) Burns (1970, pers. commun.) did not, 2) correction values for water retention are substrate-type specific, and 3) the cleansing that results from spawning is widely variable (Kondolf 1988).

Burns (1972) found that the percent of substrate comprised of particles less than 0.85 mm averaged 20.0 prior to timber harvest activities and jumped to greater than 30 % after harvest (Table 3 [taken from Table 7 of Burns 1972], Fig. 9). While Burns (1972) showed a statistically significant increase in fines from pre- to post-logging years, our 1992 average (n = 24) falls between Burn's pre-logging and post-logging values. The 1992 average did not differ significantly from any of Burns' samples (Fig. 9). This suggests some recovery of fines in the substrate at the pool riffle crests.

We have collected other sediment information from the Little North Fork Noyo River. In 1991, three stations on Little North Fork Noyo River averaged fines of 18, 10.5, and 26% (n = 4 each), for a reach average of 21.5% (n = 12) (Valentine 1992b). After the wet winter of 1992-93, we sampled station 3-C during July. The average (n = 4) percent passing the 0.85 mm sieve averaged 15.8 (sd = 5.0), Dg averaged 8.9 (SD = 1.9), and the Fredle index averaged 3.6 (SD = 1.4) (Valentine unpubl. data).

The fact that the level of fines was as low as it was despite and extended, multi-year drought and ongoing timber harvest is surprising. The slightly lower percent fines for 1991 [Valentine (1992b)] relative to 1992 (this study) may be the result of random error associated with the location of the sampling stations, wide variability common in sediment sampling, and / or drought-induced accumulation of fines in the stream bed. We noted fine roots in many of the 1992 sediment samples, indicating that recent winter stream flows had been insufficient to move the gravels. The root network may help trap and hold fine sediments in the substrate. The improved sediment condition observed from limited 1993 sampling suggests that the effects of sediment buildup during the drought were reversed by the wet winter. In fact, the 1993 samples exhibited lower concentrations of fines than did Burns' (1970) pre-logging values.

When plotted on the survival to emergence graph (Fig. 31) of Lotspeich and Everest (1981), the Fredle index for the 1992 study average predicts ≈ 31% survival for coho eggs while that for steelhead is predicted at ≈ 50%. The Fredle index of individual samples ranged from a low of 0.2 to 7.3, translating into virtually 0 % survival to emergence for both coho salmon and steelhead to > 80 % and 90%, respectively. This analysis suggests that the survival-to-emergence quality of spawning habitat may have been limiting. However, the values we derived must be considered the minimum because 1) we did not apply a correction factor in the analysis for differential adherence of water to particles between sizes, 2) we did not correct for the winnowing of fines from the substrate which occurs when fish construct redds, and 3) the samples were collected in summer (and during a drought), well after spawning and during which time sediments could accumulate. In addition, we did not collect our samples from redds, but from locations where the literature suggest salmonids prefer to spawn.

Site A-l was the only station where we captured yellow-legged frogs and stickleback. It differed from the other sites in at least three respects: the base level of the channel was wider, there was more grassy vegetation within the base-level of the channel, and the canopy directly above it was more open. These, or some other factors, may have enabled stickleback and yellow-legged frogs to inhabit this study reach but not the others.

Burns (1972) reported population sizes estimates for his approximately 400 m study sections at between 698 coho salmon before timber harvest and 255 after operations, whereas steelhead numbers changed from 19 to 29 over the same period (Table 4, Figs 16 and 17). When expressed in density, coho salmon declined from 1.15 to 0.26 fish / m^2 from the pre- to the final Yost-logging sample, and steelhead remained unchanged at 0.03 / m (Table 5). Standing crop changes were similar; coho salmon declined from 24.36 kg/ha prior to logging to 7.15 kg/ha after harvest while steelhead biomass dropped 3.66 kg/ha to 1.73 kg/ha (Table 6).

Total salmonid biomass was similar between Burns' and our studies (Fig. 32). Values of total salmonid biomass at Stations A-l and B-2, downstream of Burns' study sites, were similar to Burns' 1966 pre-logging value. Sites C-3, D-4, and E-5 which were within Burns' study area had values similar to those of Burns' post-logging samples. However, an obvious difference between the two sample periods is that the species composition is inverted; i.e., steelhead made up 80% of the 1992 sample but only 17% of the 1966-1969 samples (averaged).

Most habitat measures did not show a clear relationship to salmonid biomass or population. This may be due to our sites not spanning the range of a habitat feature across which salmonid populations respond. Examples may include pool depth or woody debris loading. Alternately, salmonid populations may have been below levels which caused these factors to be limiting. A third explanation includes the possibility that some unmeasured factor was controlling populations to a greater degree than those we measured.

The only habitat measures which appeared related to the abundance of salmonids were those connected to particle size distribution. If these findings are more than chance, clearly the geometric mean and the percent fines measure different aspects of the substrate because coho and steelhead responded to them differently. These two measures differ primarily in that "percent fines" concentrates on a small portion of the sample, while the geometric mean and the Fredle Index account for the size distribution of the entire sample. Due to the time lapse between fry emergence and our sampling, the relationships between salmonid abundance and the measures of particle size are not likely due to fish association with nearby, past redds. If the relationship is biologically real, it is likely related to (an)other factor(s): better cover provided for fry in the interstitial spaces; perhaps minor water quality variations; or most likely, greater food production from cleaner gravels (Bjornn and Reiser 1991).

The inversion of the salmonid& species composition from primarily coho salmon to primarily steelhead between study periods has several possible explanations. Our results shed little light in regards to instream habitat character, with the possible exception of large woody debris conditions. The logging activities observed by Burns resulted in changes in the physical habitat condition, exemplified by the decline in average depth and increased fines in the substrate. Within the limits of our studies, these changes appear to have recovered. Debris removal may have enhanced access to the watershed, but may have retarded recover in terms of channel development.

The modifications of physical habitat may have caused changes in the salmonid populations mediated through narrow habitat preferences. Bugert et al. (1991) found that coho salmon selected relatively deep areas of small streams, whereas steelhead were more evenly spread regardless of water depth. They also found in laboratory channels (Bugert and Bjornn 1991, in Bugert et al. 1991) that subyearling steelhead used riffles and slopes from riffle to pool more than did coho salmon. Moyle et al. (1989) and Moyle and Yoshiyama (1992) suggests that pools > 1 m deep are important habitat features of coho salmon streams. No pools matching that description were present in the 1992 study sites, nor were any observed during the stream field-reconnaissance which covered > 50 % of the study reach. The character of pools during Burns' study was not disclosed, but his average depths did not suggest deep pools.

Alternatively, changes in the species composition may have been indirect through altering the predator-prey or competition dynamics of the biological community (non-salmonid as well as salmonid). Bjornn and Reiser (1991) reported that channel characteristics caused population shifts between steelhead and other salmon species. Data from this study are too sparse to evaluate this possibility. Changes in community composition among coexisting salmonids after harvest has been reported from western Washington (Bisson and Sedell 1984) and Oregon (Reeves et al 1993). Both studies suggest that the changes were the result of simplification of the habitat, largely related to changes in the abundance of large woody debris. Competition, either for food or space may maintain the initial shift induced by logging-related habitat changes despite a return to the intial habitat conditons.

Timber harvest remains one of the most visible uses of watersheds inhabited by California's north coast salmonids and is considered by some to be an important land-use activity limiting anadromous salmonids. Many other factors other than timber harvest such as over-fishing, marine environment changes, hatchery impacts on genetics and disease transmission, and other land uses may also have roles in limiting salmonid populations and species composition (Higgins et al. 1992, Kaczynski and Palmisano 1992).

A factor which seems very important in controlling salmonid populations is the continued and prolonged drought. This study was initiated after an extended drought (Fig. 33). The Palmer Drought Severity Index (PDSI) is often considered an index of meteorological drought. However, as Alley (1984) points out, its derivation incorporates precipitation, evaporation, and soil moisture -- all of which are determinants of hydrologic drought. Mean monthly values of the Palmer drought severity index hovered between the "critical" level (-3) and the extreme level (-4) for months prior to the initiation of this field work. Drought conditions can influence the juvenile salmonid populations in the streams in innumerable ways through both inland habitat conditions, access of spawners, smoltification, and offshore habitat. Lack of rain, especially during the early-to-mid winter period may have differentially affected spawning access to streams or the suitability of the spawning and rearing environment.

Another explanation of the inversion is chance; that is, populations of the different salmonid species may naturally fluctuate enough that the relative proportions of each species in Burns' and our studies fall within the range of natural variation should we have information of adequate time spans.

Because at a coarse level, steelhead and coho have similar habitat needs (cool, clear water; clean gravels; spawning access; rearing habitat), the fact that the salmonid biomass is similar between study periods suggests that at that at this level of resolution, recent land-uses in the Little North Fork Noyo River appear not to have been destructive to the "cold-water fishery habitat? If this is true, then factors which affect the species differentially may be fruitful subjects of study when attempting to identify those important in the decline of coho salmon (both marine and inland).

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LITERATURE CITED

Alley, W.M. 1984. The Palmer Drought Severity Index: Limitations and Assumptions. J. Climate and Applied Meteorology 23:1100-1109.

Anonymous. 1984. Fish Habitat Completion Form. Department of Fish & Game, Region 3. Yountville, CA.

_____ 1986. Fish Habitat Completion Form. Department of Fish & Game, Region 3. Yountville, CA.

Armour, C.L., K.P. Burnham, and W.S. Platts. 1983. Field Methods and Statistical Analyses for Monitoring Small Salmonid Streams. U.S. Fish & Wildl. Serv. FWS/OBS-83/33. 200 pp.

Bisson, P.A., and J.R. Sedell. 1984. Salmonid Populations in Streams in Clearcut vs. Old-growth Forests of Western Washington. PP 121-129 In W.R. Meehan, T.R. Merrell, Jr., and T.A. Hanley (Eds) Fish and Wildlife Relationships in Old-growth Forests. Amer. Inst. Fish. Res. Biologists.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Pages 83-138 In W.R. Meehan (Ed.), Influences of Forest and rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19.

Bugert, R.M., T.C. Bjornn, and W.R. Meehan. 1991. Summer Habitat Use by Young Salmonids and Their Responses to Cover and Predators in a Small Southeast Alaska Stream. Trans. Amer. Fish. Soc. 120:474-485.

Bugert, R.M., T.C. Bjornn. 1991. Habitat Use by Steelhead and coho salmon and Their Responses to Predators and Cover in Laboratory Streams. Trans. Amer. Fish. Soc. 120:486-493.

Burns, J.W. 1970. Spawning bed sedimentation studies in Northern California Streams. Calif. Fish & Game 56(4):253-270.

_____ 1971. The carrying capacity for juvenile salmonids in some northern California streams. Calif. Fish & Game 57(1):44-57.

_____ 1972. Some effects of logging and associated road construction on Northern California Streams. Trans. Amer. Fish. Soc. 101(l): 1-17.

Cafferata, P. undated. Large Woody Debris Loading: Hare Creek. Unpubl. photocopy. California Department of Forestry. Sacramento, CA. 1 pp.

Caranco, l., and J.T. Labbe. 1979. Logging the Redwoods. The Claxton Printers, Ltd. Caldwell, ID. 142 pp.

Chapman, D.W. 1988. Critical Review of Variables Used to Define Effects of Fines in Redds of Large Salmonids. Trans Amer. Fish. Soc. 117:1-21.

Flossi, G. and F. L. Reynolds. 1991. California salmonid stream habitat restoration manual. California Department of Fish & Game. Sacramento, CA. Various pagination + appendices.

Good, D.A. 1989. Hybridization and cryptic species in Dicamptodon (Caudata: Dicamptodontidae). Evolution 43(4):728-744.

Hayes, R.L., C. Summers, and W. Seitz. 1981. Estimating Wildlife Habitat Variables. USDI Fish & Wildlife Service. FWS/OBS-81/47. 111 pp.

Higgins, P., S. Dobush, and D. Fuller. 1992. Factors in Northern California Threatening Stocks with Extinction. Unpubl. Photocopy. Humboldt Chapter, Amer. Fish. Soc. Arcata, CA. 26pp.

Husch, B., C.I. Miller, and T.W. Beers. 1972. Forest Mensuration (Sec. Ed.). John Wiley & Sons. New York. 410 pp.

Jackson, F. 1975. Big River Was Dammed. Miller Print Company. Mendocino (?), CA. 138 pp.

Jameson, M. 1989a. Juvenile Salmonid Population, Sediment Restudy. Unpubl. Memo to Ted Wooster. Calif. Dept. Fish & Game, Region 3. Yountville, CA. 2 pp.

Jameson, M. 1989b. Inspection of Little North Fork Noyo River (l-89-674 MEN). Unpub. Memorandum to Len Theiss. Calif. Dept. Forestry & Fire Prot. Santa Rosa, CA. 5pp.

Kaczynski, V.W., and J.F. Palmisano. 1992. A Review of Management and Environmental Factors Responsible for the Decline and Lack of Recovery of Oregon's Wild Anadromous Salmonids: Summary and Conclusions. Unpubl. Rept. prepared for Oregon Forest

Industries Council. Salem Oregon. 60 pp.

Kondolf, G.M. 1988. Salmonid Spawning Gravels: A Geomorphic Perspective on Their Size Distribution, Modification by Spawning Fish, and Criteria for Gravel Quality. PhD Dissertation. Johns Hopkins Univ. Baltimore, MD 396 pp.

Lisle, T.E. 1987. Using "Residual Depths' to Monitor Pool Depths Independently of Discharge. USDA For. Serv. Res. Note PSW-394. 4 pp.

Lotspeich, F.B., and R.H. Everest. A New Method for Reporting and Interpreting Textural Composition of Spawning Gravels. USDA For. Serv. Res. Note PNW-369. 11 pp.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. US EPA 910.9-91-001. Seattle, WA. 166 pp.

McMahon, T.E. 1983. Habitat suitability index models: Coho salmon. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.49. **29pp**.

McNeil, W.J., and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size or spawning bed materials. U.S. Fish & Wildl. Serv., Spec. Sci. Rpt. Fish. # 469. 15 pp.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish Species of Special Concern of California. California Dept. Fish & Game. Inland Fisheries Division. Rancho Cordova, CA. 222 pp.

_____ and R.M. Yoshiyama. 1992. Fishes, Aquatic Diversity Management Areas, and Endangered Species: A Plan to Protect California's Native Aquatic Biota. The California Policy Seminar. University of California. Berkeley, CA. 222 pp.

Nehlsen, N, J. E. Williams, and J.A. Lichatowich. 1991. Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. Fisheries 16(2): 4-21.

Platts, W.S., M. A. Shirazi, and D. H. Lewis. 1979. Sediment particle sizes used by salmon for spawning with methods for evaluation. EPA-600/3-79-043. US EPA, Environ. Res. Lab., Corvallis OR. 33 pp.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA For. Serv. Gen. Tech. Rep. INT-138. 70pp.

_____ C. Amour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L.

Nelson, J.R. Sedell, J.S. Tuhy. 1987. Methods for Evaluating Riparian Habitats With Applications to Management. USDA For. Serv. Gen. Tech. Rep. INT-221. 177 pp.

Price, D.G. and J.R. Adams. 1982. A fishery resource sampling methodology for small streams. Pacific Gas & Electric Co., Dept. Eng. Res. Rep. 420-81.141. 49 pp.

Reeves, G.H., F.H. Everest, and J.R. Sedell. 1993. Diversity of Juvenile Anadromous Salmonid Assemblages in Coastal Oregon Basins with Different Levels of Timber Harvest. Trans. Amer. Fish. Soc. 122:309-317.

Valentine, B.E. 1992a. Proposed fishery and habitat evaluation project. Unpubl. Memo to "Interested Parties." On file. California Department of Forestry, Reg. 1. Santa Rosa, CA. 10 pp.

_____ 1992b. Sediment samples on Little North Fork of the Noyo River and Pudding Creek; Reference THPs 1-91-441, 442, 443 MEN. Unpubl. memo to T. Osipowich. On File at CA Dept. Forest., Reg. 1. Santa Rosa, CA. 16 PP.

_____ 1993. Stream substrate quality for salmonids: guidelines for sampling, processing, and analysis. (Perpetual draft--October 13, 1993). California Dept. Forestry and Fire Protection. Sanat Rosa, CA. 20 pp.

Van Deventer, J.S., and W.S. Platts. 1989. Microcomputer Software System for Generating Population Statistics From Electrofishing Data--User's Guide for MicroFish 3.0. USDA For. Serv. Gen. Tech. Rep. INT-254. 29 PP-

Table 1. Area (acres) logged by year, silvicultural system, and yarding method.

YEAR	SEL	THI	CC	SHS	SHR	STS	STR	TOT	CABL	TRAC
1964	103							103		
1966	201							201		
1967	928							928		
1968	357							357		
1969	220							220		
1970	63							63		
1971	170							170		
1972	27							27		
SUBTL	2069							2069		2069
1973										
1974										
1975										
1976	56							56		
1977										
1978										
1979										
1980	120							120		
1981	520		23					543		
1982	69							69		
1983	26		19	115				160		
1984			155	261		69		485		
1985	143	86						229		
1986			218	45	20			283		
1987			297	29	119			445		
1988		11	55	132	35		67	300		
1989		57	80	26	99			262		
1990	19	17	315		120			471		
1991	47		7					54		
1992			37					37		
SUBTL	857	85	1349	694	393	69	67	3514	1406	2108
TOTAL	**2926**	**85**	**1349**	**694**	**393**	**69**	**67**	**5583**	**1406**	**4177**

SEL=SELECTION;THI=THIN;CC=CLEAR-CUT;SHS=SHELTERWOOD SEED STEP;SHR=SHELTERWOOD REMOVAL;STS=SEED TREE SEED STEP;STR=SEED TREE REMOVAL;CABL=CABLE SKYLINE YARDING;TRAC=TRACTOR/SKIDDER YARDING

NOTE: THE SUBTOTAL FOLLOWING 1972 INDICATES THE TIMING OF MAJOR REGULATORY CHANGES IN LOGGING PRACTICES

NOTE: Approx. 1809 ACRES OF SAPLING STANDS HAVE BEEN CREATED SINCE 1980

NOTE: SELECTION CUTTING IN STREAM PROTECTION ZONES WITHIN NON-SELECTION SILVICULTURAL AREAS WAS NOT INCLUDED IN THE TABLE.

Table 2. Physical conditions of the habitat in Little North Fork Noyo River at 5 ≈ 100 m study reaches in 1992, and at four summed reaches (total ≈ 400 m) reaches in three years, 1966-1969.

Reach: Year	Site Length m	Surface Area m^2	Volume m^3	Mean Pool Depth cm	Mean Inter-pool distance m	Mean Site Depth[a] cm	Mean Site Width[a] m	Shade Canopy Total %	Shade Canopy Conifer %	Shade Canopy Decid. %	LWD Vol. (m^3)
A-1:92	104	235.6	44.7	44.5	15.6	19.0	2.3	81.0	70.0	30.0	51
B-2:92	100	222.6	40.6	37.5	13.5	18.2	2.2	86.8	66.7	33.3	4
c-3:92	105	215.1	58.5	56.2	18.6	27.2	2.0	78.7	50.0	50.0	15
D-4:92	102	197.5	54.6	40.6	8.3	27.6	1.9	76.7	57.5	42.5	12
E-5:92	107	196.8	26.7	31.3	25.0	13.6	1.8	85.0	89.2	10.8	7
Mean[c]	103.6	213.5	45.0	42.0	16.2	21.1	2.1	81.6	66.7	33.3	17.7
SD	2.7	16.6	12.5	9.3	6.2	6.1	0.2	6.1	4.2	14.8	18.9
n	5	5	5	5	5	5	5	5	5	5	5
1966	**399**	**609**	93			**15.3**	**1.5**				
1968	**399**	998	**122**			**12.2**	**2.5**				
1969	**424**	994	**91**			9.2	**2.3**				

a: **Site depth and width are "averages" calculated by dividing the volume measurements by the surface area measurements and the unit length, respectively.**

b: **Shade canopy for conifers and deciduous is the proportion of the total shade provided by those groups.**

c: **Summary statistics for the 1992 period only.**

Table 3. Summary of particle size distribution of substrate samples from the Little North Fork Noyo River in 1992 and 1967-1969 (Burns 1970).

Study Reach	Mean (sd)				n
	D_g (mm)	Fredle Index	< 0.85 mm (%)	< 3.3 mm[a] (%)	
A-l	8.3 (3.2)	2.4 (2.2)	22.5 (7.5)	33.3 (10.7)	5
B-2	7.6 (1.6)	2.4 (1.3)	20.8 (4.6)	27.8 (6.5)	5
c-3	7.1 (1.9)	2.3 (1.8)	24.4 (5.8)	29.2 (9.7)	5
D-4	5.0 (2.1)	1.3 (0.9)	31.2 (14.8)	39.5 (15.4)	5
E-5	8.2 (6.4)	2.2 (2.9)	29.1 (14.9)	40.3 (19.0)	4
1992 Total	7.2 (3.5)	2.1 (1.9)	25.4 (10.9)	33.7 (12.7)	24
1966	-[b]		20.0 (5.8)	-	27
1968			31.0 (8.9)	42.1 (10.5)	8
1969			33.3 (15.4)	44.4 (14.6)	16

[a] Values for the 1992 period calculated as described in text; values for 1966-1969 from Burns (1970).
[b] "-" indicates value not determined by Burns (1972).

a:sed_tab1

Table 4. Population Estimates for study site (95% confidence interval) of vertebrates captured in Little North Fork Noyo River at 5 ≈ 100 m study reaches in 1992, and at four summed reaches (total = 400 m) reaches in three years, 1966-1969.

Reach: Year	Total Salmonid	Coho Salmon	Steelhead Trout	Sculpin (spp.)	Stickle-back	Pacific Giant Salamander
	Population Size (95% Confidence Interval)					
A-1:92	**193**	**102** (97-109)	**91** (86-99)	6 **(6-6)**	**47** (41-58)	**68** (63-76)
B-2:92	**99**	8 **(8-8)**	**91** (86-98)	**-**	**-**	**31** (24-48)
c-3:92	**55**	7 **(7-8)**	**48** (46-53)	5 **(5-8)**		**28** (19-57)
D-4:92	**53**	3 **(3-3)**	**50** (50-51)	**11** (11-13)		**151** (133-169)
E-5:92	**58**	**29** (29-30)	**29** (29-30)	**1** **(1-1)**		**44** (36-61)
Mean [c]	**91.60**	**29.80**	**61.80**	**4.60**	**9.40**	**64.40**
SD	**59.78**	**41.61**	**27.89**	**4.39**	**21.02**	**50.91** 53.20
n	5	5	5	5	5	5
1966		**698** (672-724)	**19** (11-27)			
1968		**403** (390-416)	**29** (23-35)			
1969		**255** (238-272)	**25** (24-26)			

a: A **"-"** for 1992 samples means the species was not captured in that reach.
b: A "-" for 1966-1969 indicates that the data was not present in Burns (1972) in a form which allowed comparison.
c: Summary statistics for the 1992 period only.

A:TABLE_N

Table 5. Density (n/m^2) of vertebrates captured in Little North Fork Noyo River at 5 ≈ 100 m study reaches in 1992, and at four summed reaches (total ≈ 400 m) reaches in three years, 1966-1969.

	Density ($\#/m^2$)					
Reach: Year	Total Salmonid	Coho Salmon	Steelhead Trout	Sculpin (spp.)	Stickle-back	Pacific Giant' Salamander
A-1:92	0.8	0.43	0.39	0.03	0.20	0.29
B-2:92	0.4	0.04	0.41	- [a]		0.14
c-3:92	0.3	0.03	0.22	0.02		0.13
D-4:92	0.3	0.02	0.25	0.06		0.76
E-5:92	0.3	0.15	0.15	0.01		0.22
Mean [c]	0.42	0.13	0.28	0.02	0.04	0.31
SD	0.24	0.18	0.11	0.02	0.09	0.26
n	5	5	5	5	5	5
1966	**1.18**	**1.15**	**0.03**	- [b]	-	-
1968	**0.43**	**0.4**	**0.03**	-	-	-
1969	**0.29**	**0.26**	**0.03**	-	-	-

a: **A "-" for 1992 samples means the species was not captured in that reach.**
b: **A "-" for 1966-1969 indicates that the data was not present in Burns (1972) in a form which allowed comparison.**
c: **Summary statistics for the 1992 period only.**

A:tab_dnst

Table 6. Biomass (kg/ha) of vertebrates on Little North Fork Noyo River from five ≈100 m reaches in 1992 and four summed reaches (total ≈ 400 m) in three years, 1966-1969.

	BIOMASS (kg/ha)					
Reach: Year	Total Salmonids	Coho Salmon	Steelhead Trout	Sculpin (spp.)	Stickle- back	Pacific Giant Salamander
A-l:92	27.21	11.16	16.04	1.95	2.12	23.30
B-2:92	25.79	1.30	24.48			30.46
C-3:92	14.32	1.35	12.88	1.30		8.55
D-4:92	11.24	0.91	10.33	2.43		37.67
E-5:92	15.50	3.86	11.64	0.30		10.57
Mean[c]	18.79	3.72	15.07	1.20	0.42	22.11
SD	7.22	4.32	5.67	1.04	0.95	12.55
n	5	5	5	5	5	5
1966	**24.36**	**20.7**	**3.66**		-	-
1968	**11.39**	9.66	**1.73**	-	-	-
1969	**9.29**	7.15	2.14	-	-	-

a: **A "-" for 1992 samples means the species was not captured in that reach.**

b: **A "-" for 1966-1969 indicates that the data was not present in Burns (1972) in a form which allowed comparison.**

c: **Summary statistics for the 1992 period only.**

Table 7. Salmonid condition factors, Little North Fork Noyo River from five ≈100 m reaches in 1992.

Reach: Year	Condition Factor Coho	Condition Factor Steelhead
A-1:92	0.84	0.91
B-2:92	1.47	1.15
C-3:92	1.18	1.04
D-4:92	1.34	1.42
E-5:92	1.21	1.17
1966	-[a]	
1968		
1969		
Mean	1.21	1.14
SD	1.44	1.33
n	5	5

[a] **Values were not provided by Burns (1971, 1972).**

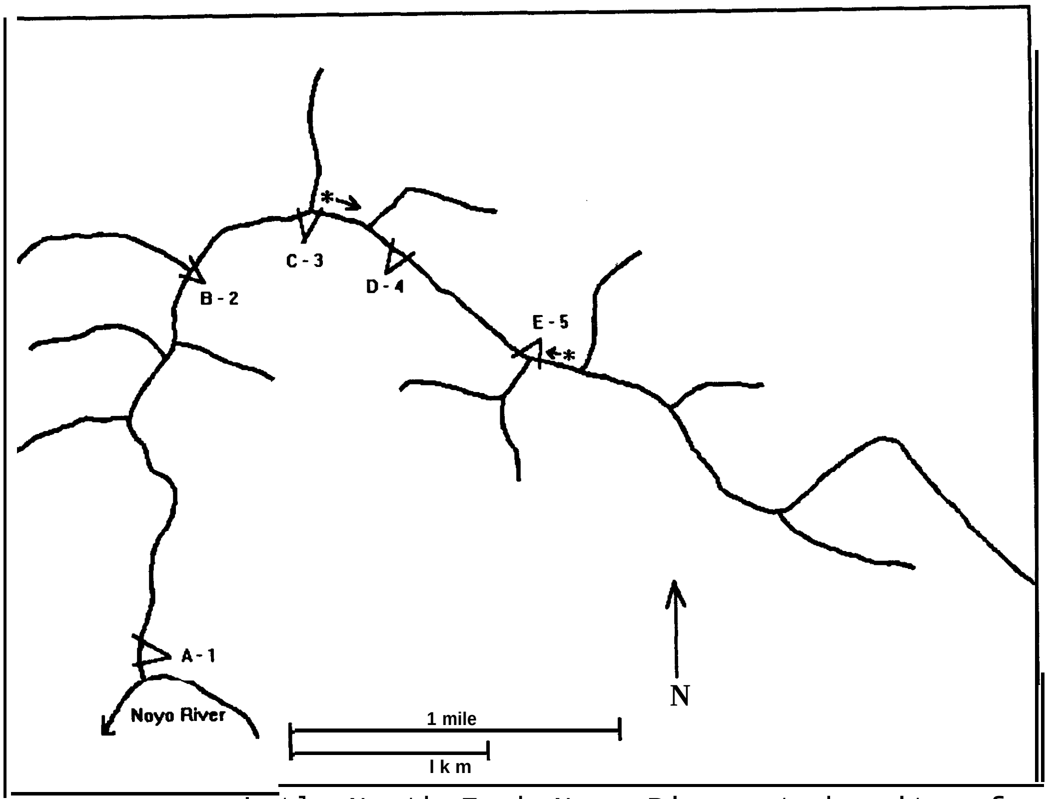

Figure 1. Little North Fork Noyo River study sites for 1992 are indicated with an alpha-numeric identifier in an **upstream** direction. Approximate limits of Burns' (1972) study reach is between *→ and ←*.

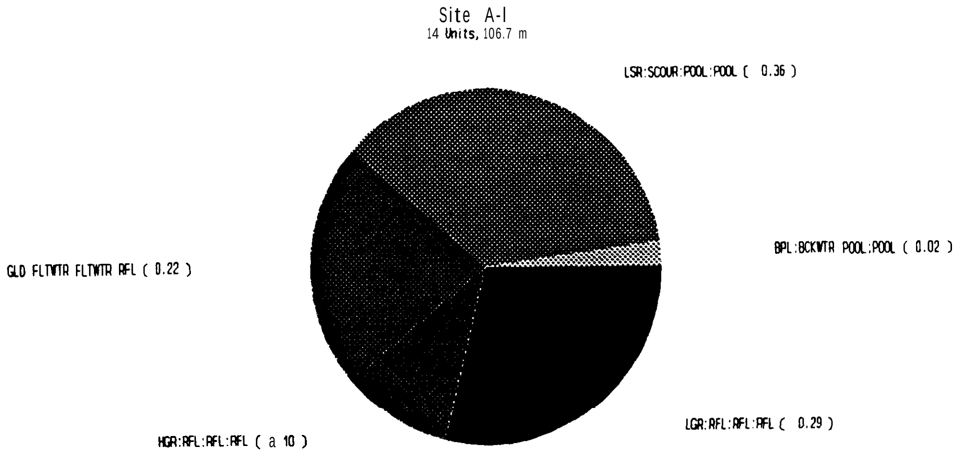

Figure 2. Length of **habitat types** at four hierarchical levels of classification (Flosi & Reynolds 1991) for Site A-l, Little North Fork Noyo River, 1992.

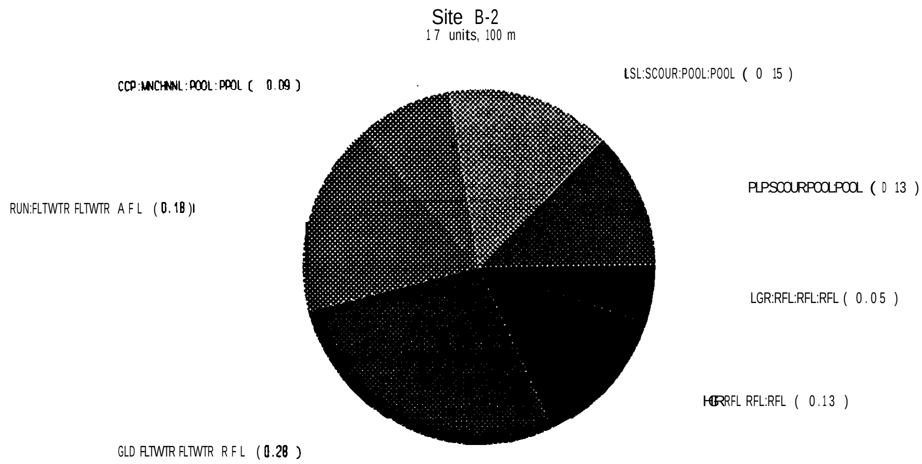

Figure 3. Length of habitat **types** at four hierarchical levels of classification (Flosi and Reynolds 1991) for Site B-2, Little North Fork Noyo River, 1992.

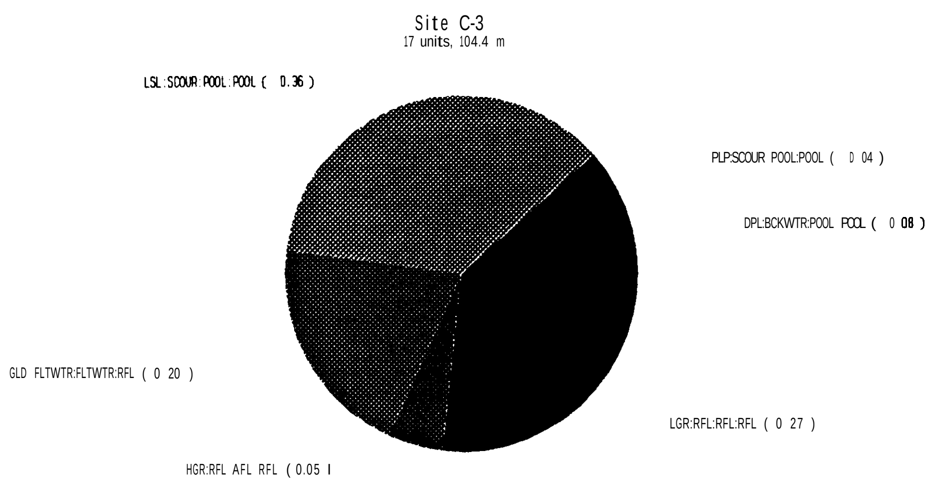

Figure 4. Length of habitat types at hierarchical four levels of classification (Flosi & reynolds 1991) for Site C-3, Little North Fork Noyo River, 1992.

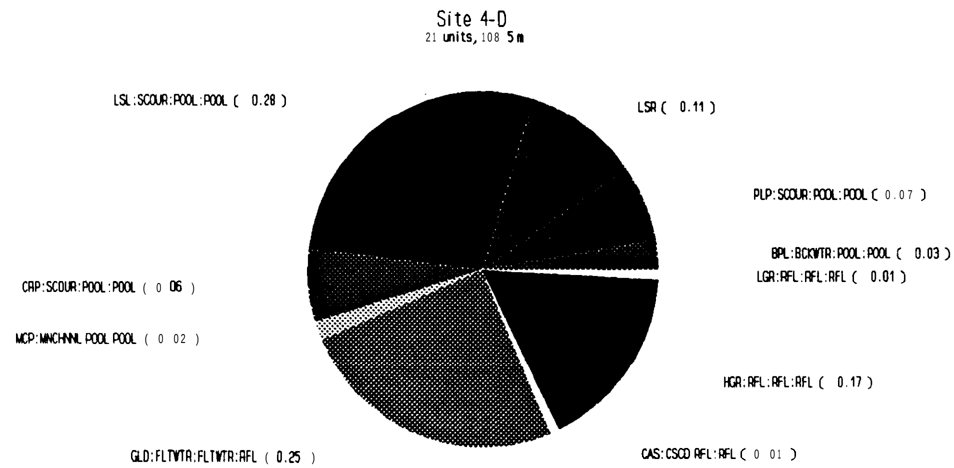

Figure 5. Length of **habitat types** at four hierarchical levels of classification (Flosi & Reynolds 1991) for Site D-4, Little North Fork Noyo River, 1992.

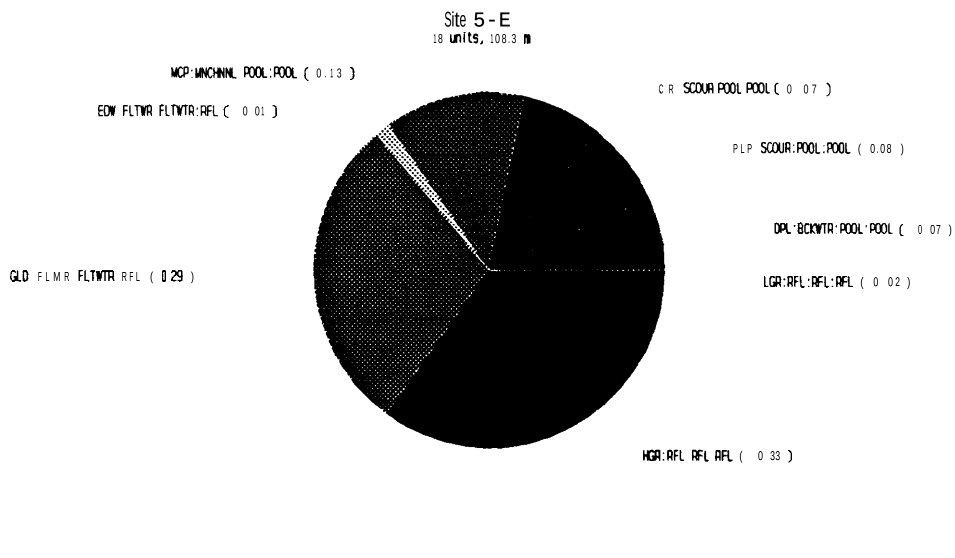

Figure 6. Length of **habitat types** at four hierarchical levels of classification (Flosi & Renolds 1991) for Site E-5, Little North Fork Noyo River, 1992.

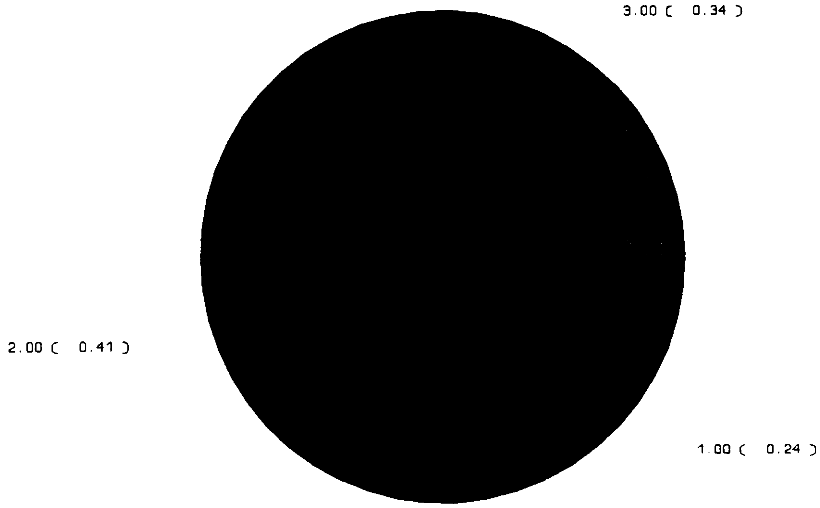

Figure 7. Pool quality ratings for all pools in five study reaches, Little North Fork Noyo River, 1992. See text for code definitions.

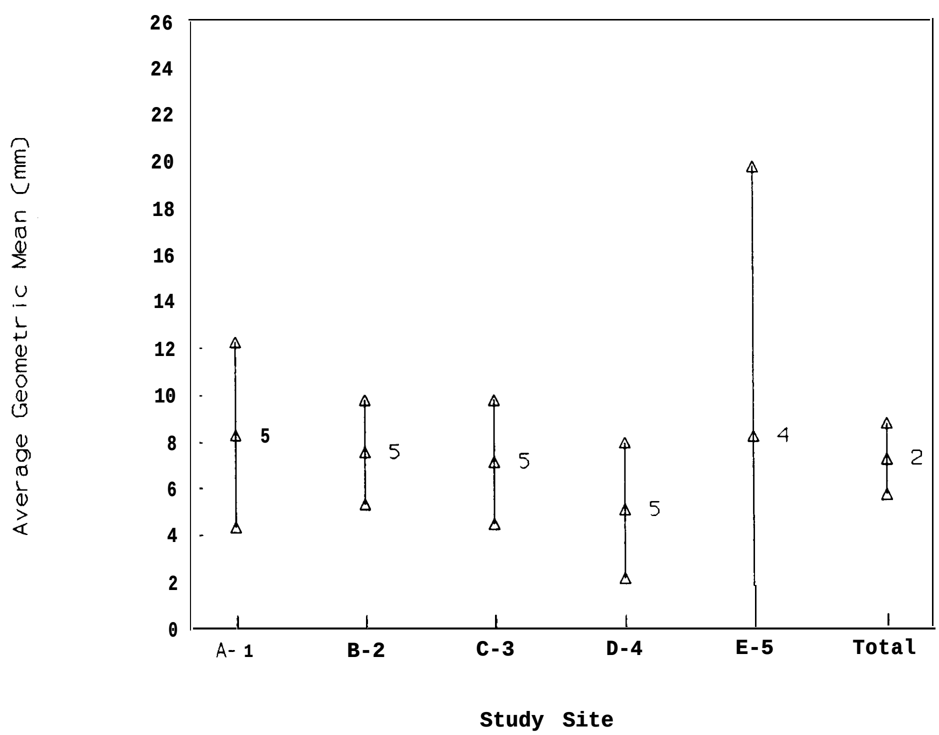

Figure 8. Average geometric mean (and 95% confidence intervals) for gravel samples at five study sites, and all sites combined, on the Little North Fork Noyo River, 1992. Sample size is identified adjacent to the mean.

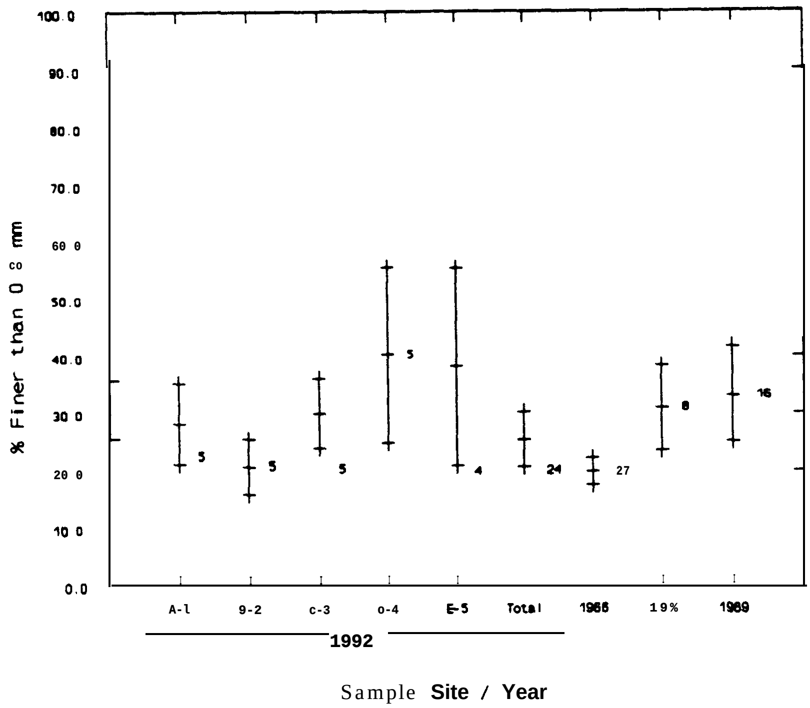

Figure 9. Mean, **95%** confidence interval, and sample size of percent of substrate less than 0.85 mm from 5 study sites for 1992, and for samples from 1966-69 (Burns 1970).

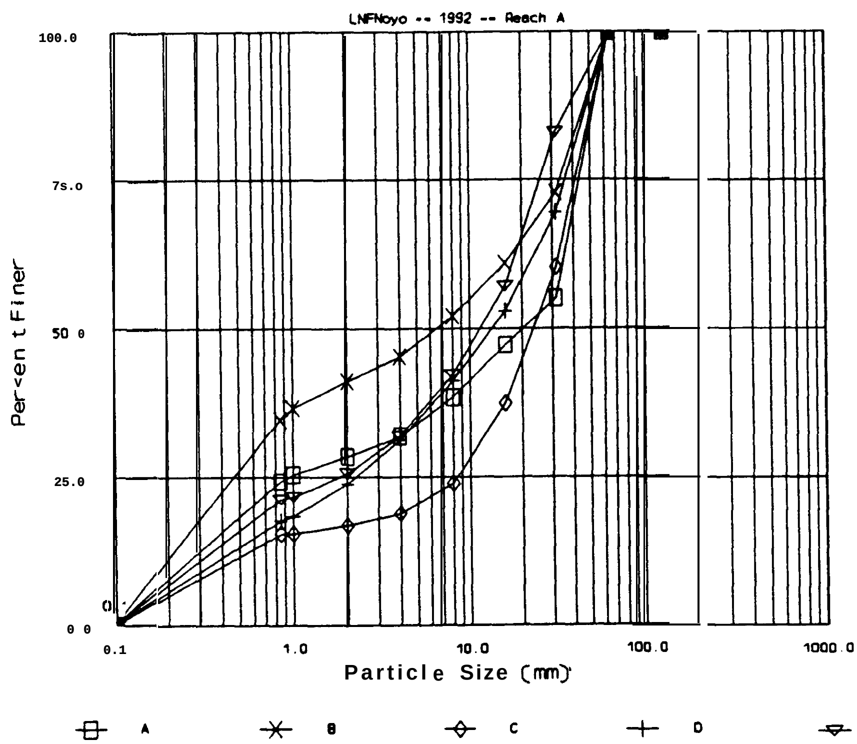

Figure 10. Particle size distribution for study site A-1, Little North Fork Noyo River, 1992.

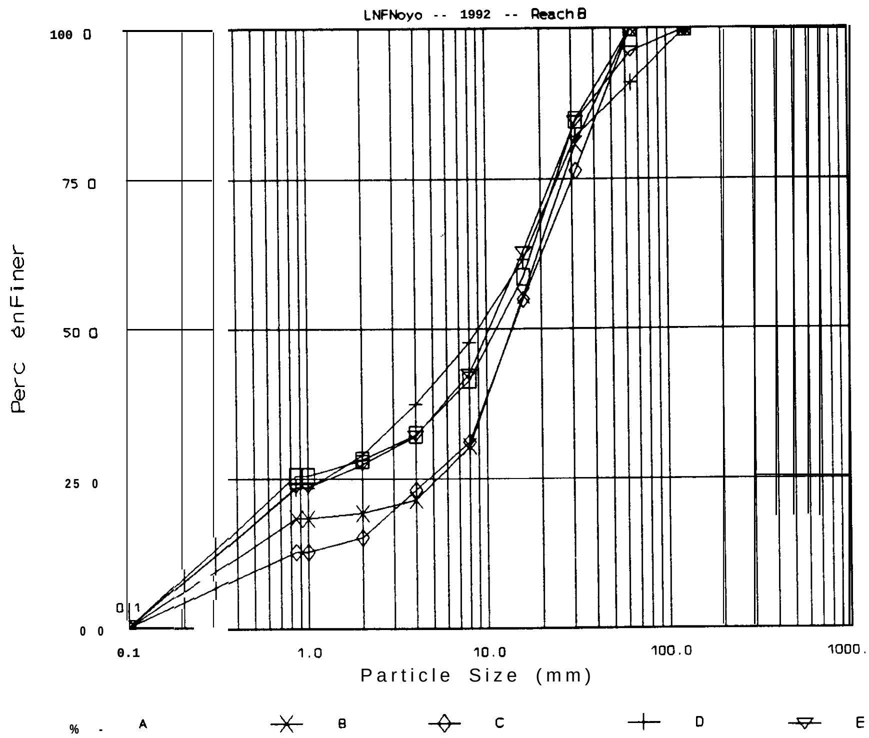

Figure 11. Particle size distribution for study site B-2, Little North Fork Noyo River, 1992.

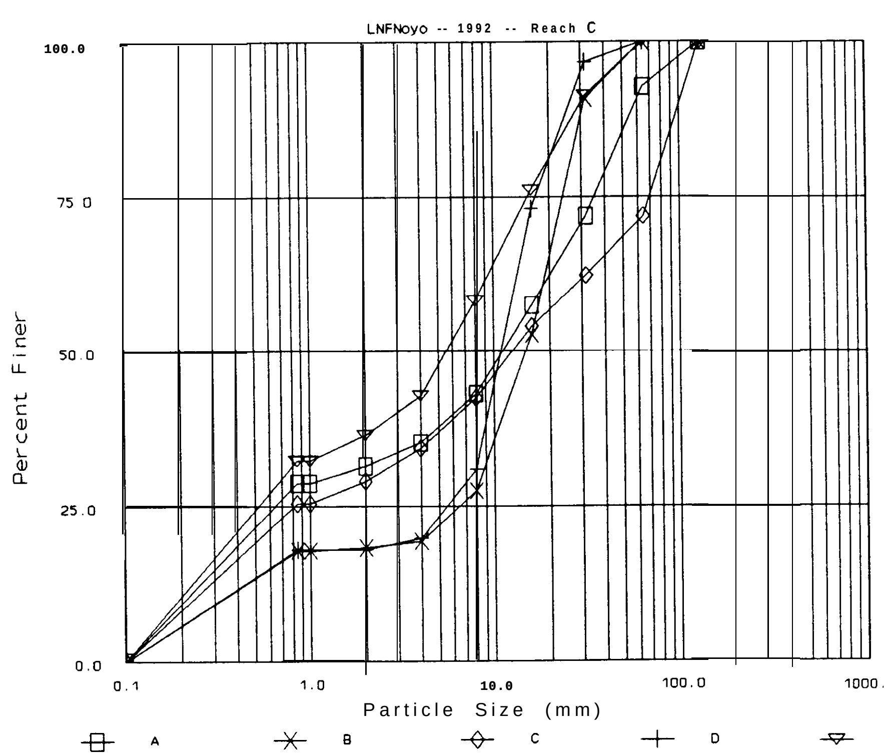

Figure 12. Particle size distribution for study site C-3, Little North Fork Noyo River, 1992.

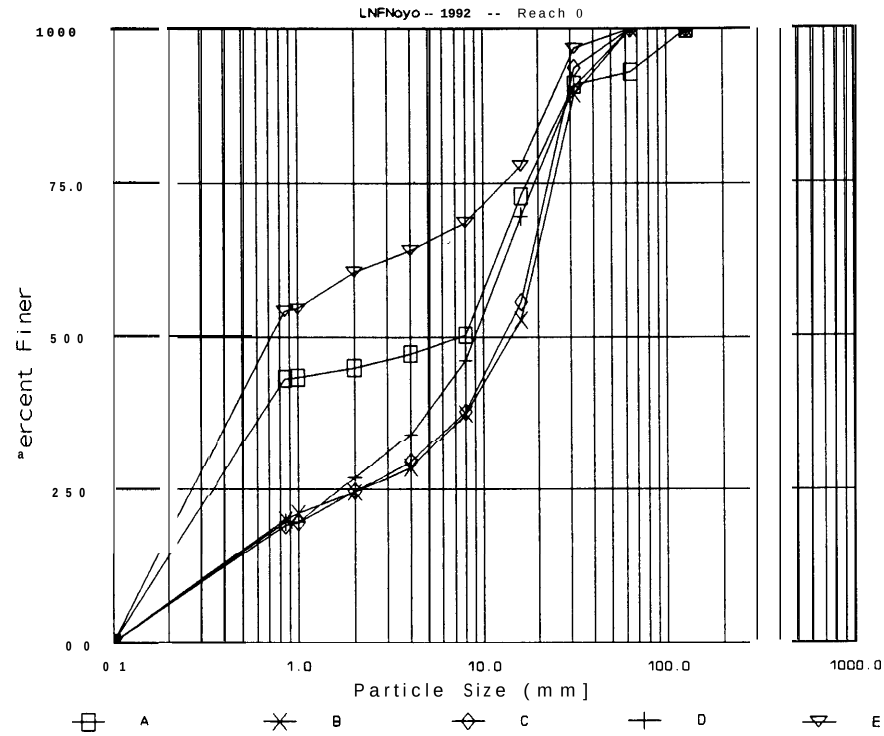

Figure 13. Particle size distribution for study site D-4, Little North Fork Noyo River, 1992.

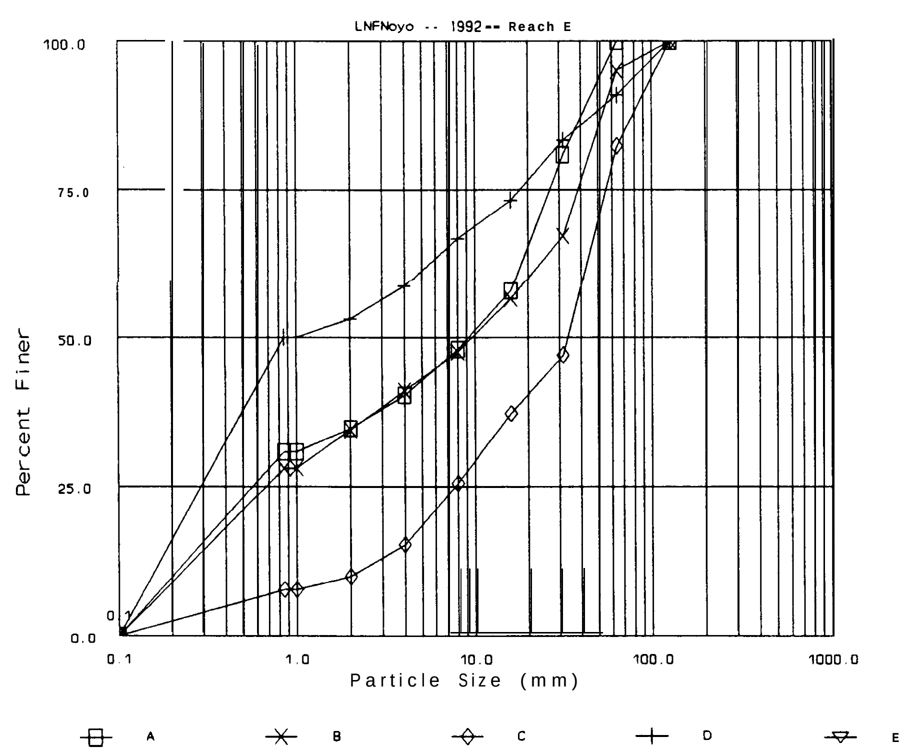

Figure 14. Particle size distribution for study site E-5, Little North Fork Noyo River, 1992.

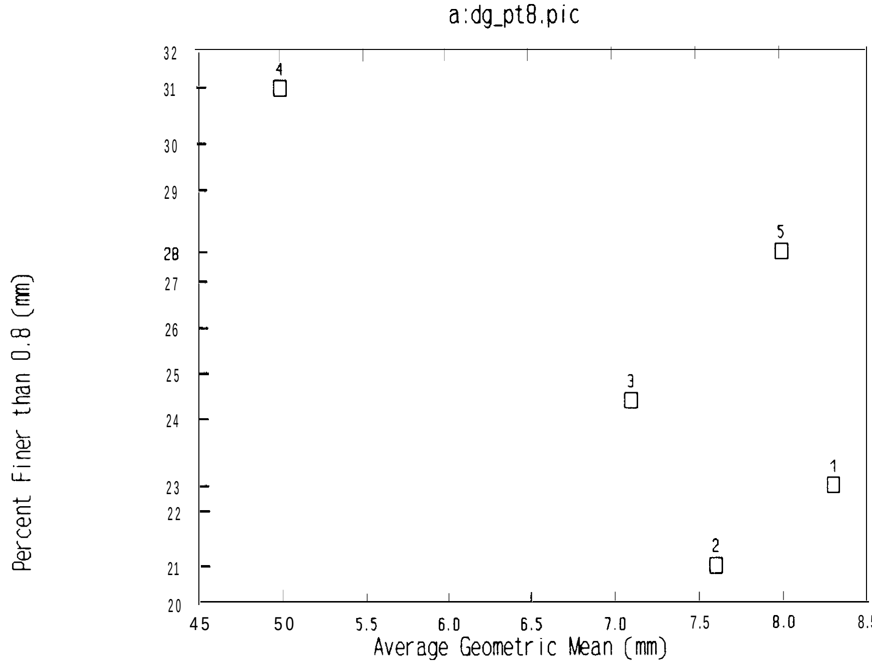

Figure 15. Scatter diagram of percent of the substrate finer than 0.85 mm plotted against geometric mean.

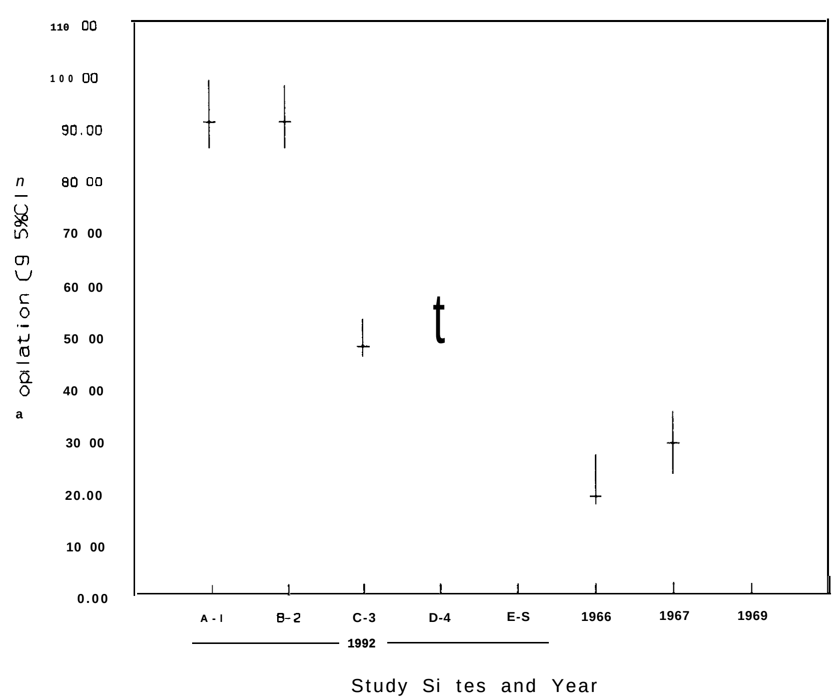

Figure 16. Population estimates and 95% confidence intervals for Steelhead Trout at five study reaches, 1992, and for 1966-69 (Burns 1972).

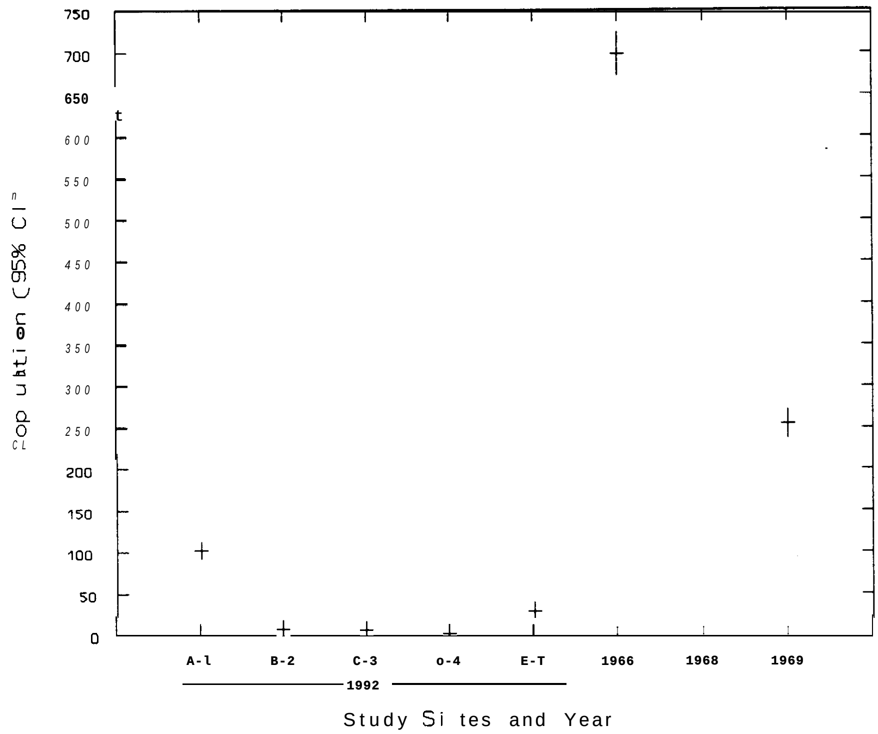

Figure 17. Population estimates and 95 % confidence limits for coho salmon at 5 five study reaches in 1992, and for 1966-69 (Burns 1972).

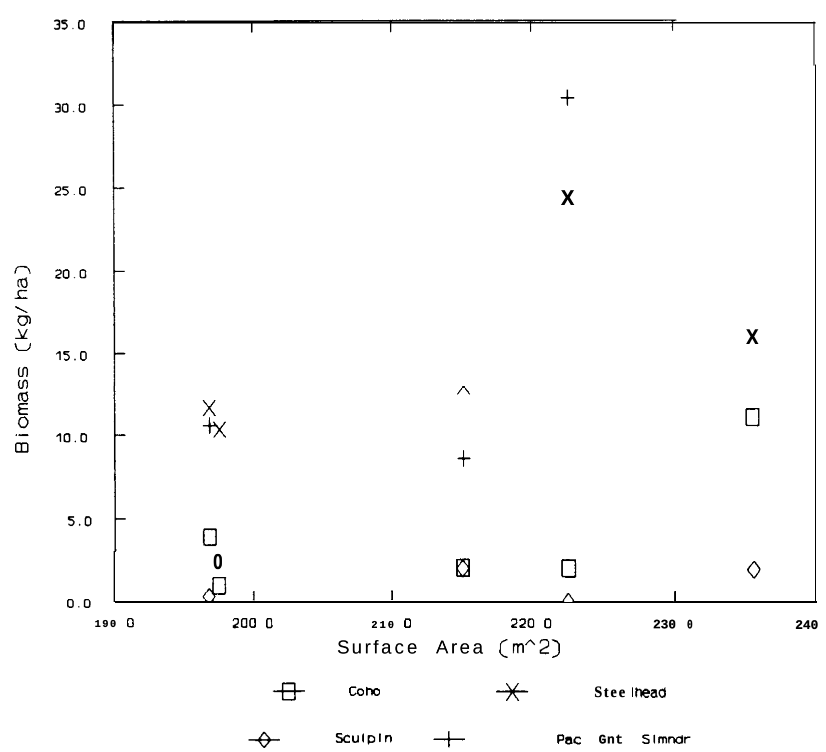

Figure 18. Scatter plot of standing crop plotted against stream surface area for 4 species caught at 5 study sites, 1992.

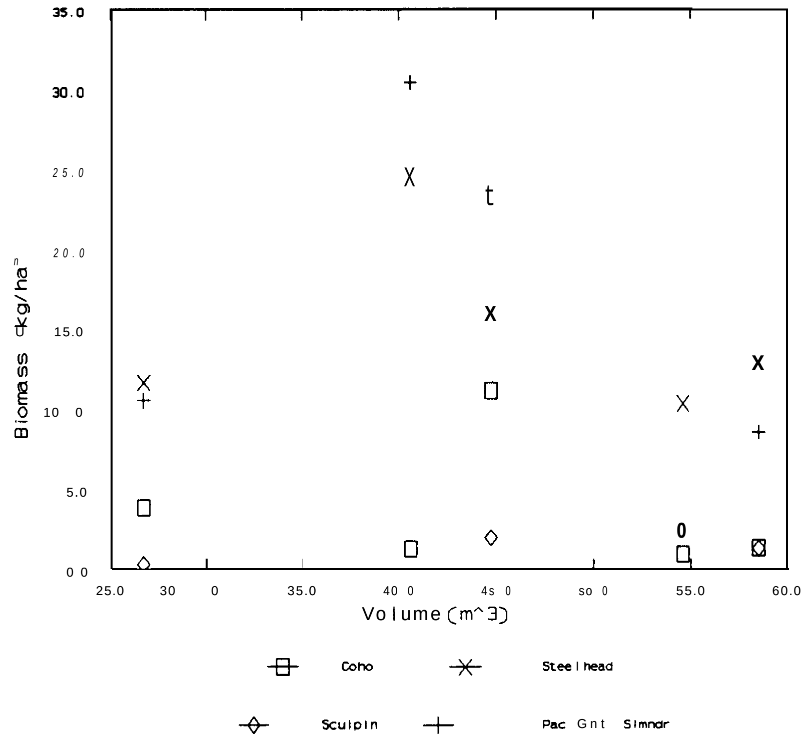

Figure 19. Scatter plot of standing crop of four species against volume of water at five study sites, 1992.

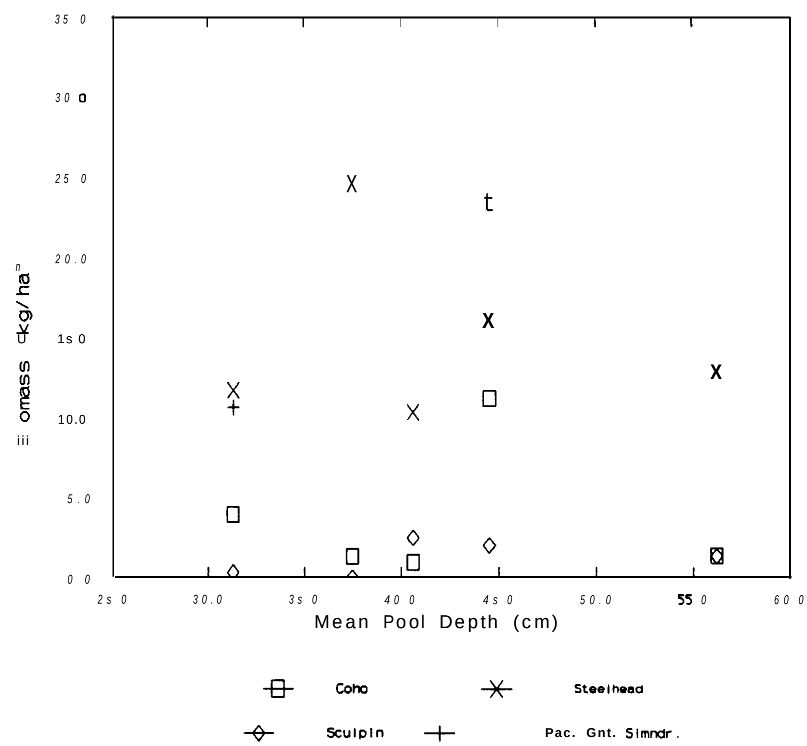

Figure 20. Scatter plot of standing crop of four species against mean depth of residual pools for five study sites, 1992.

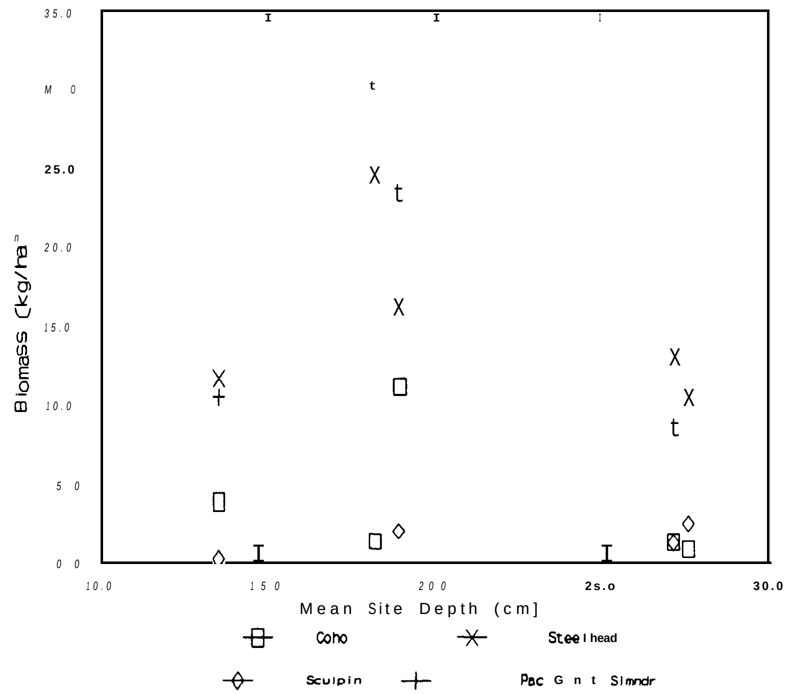

Figure 21. Scatter plot of the standing crop of four species against the mean site depth of five study sites, 1992.

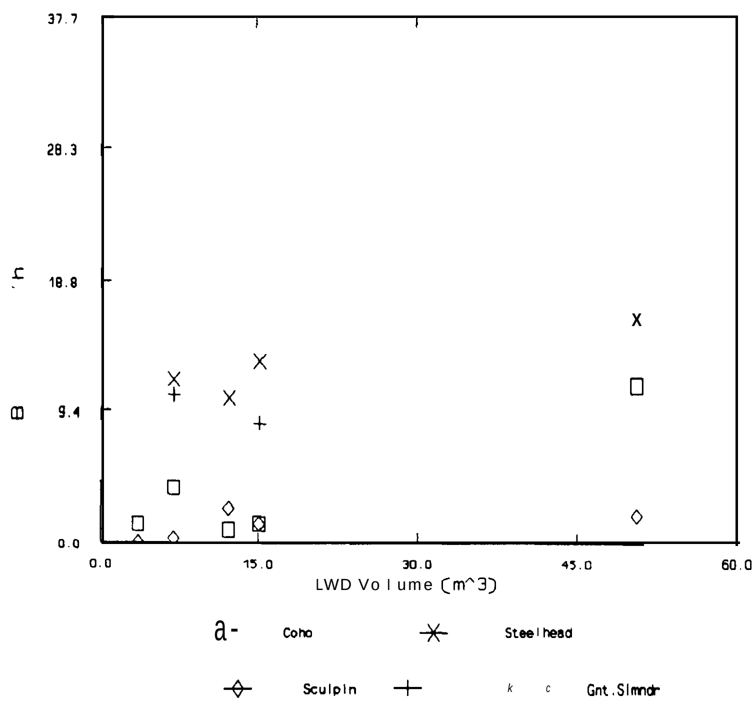

Figure 22. Scatter plot of the standing crop of 4 species against the volume of large woody debris in five study sites, 1992.

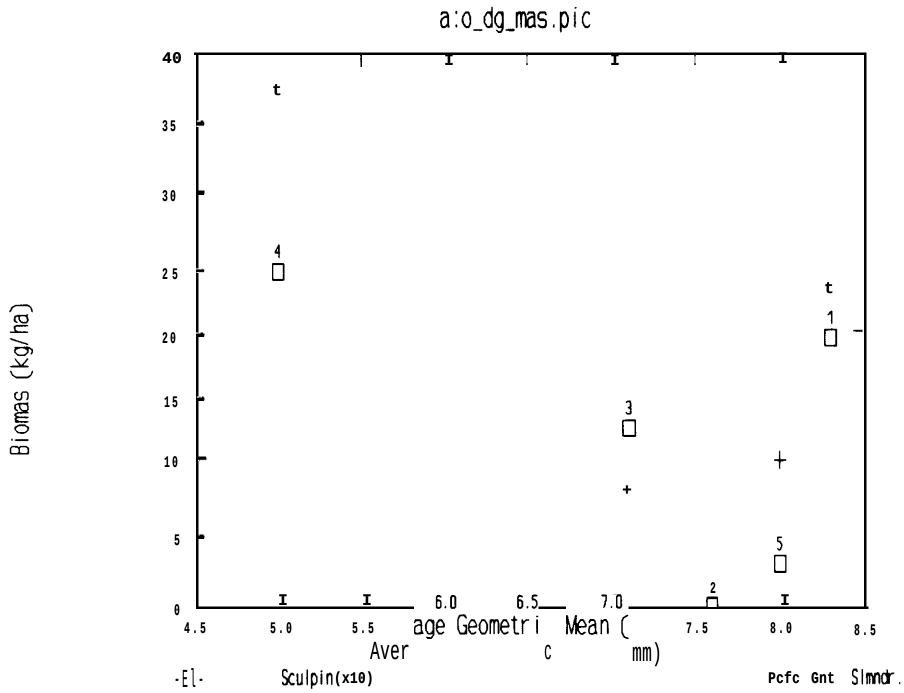

Figure 23. Scatter plot of the standing crop of sculpin and Pacific Giant Salamander against the substrate's geometric mean particle size at five study sites, 1992.

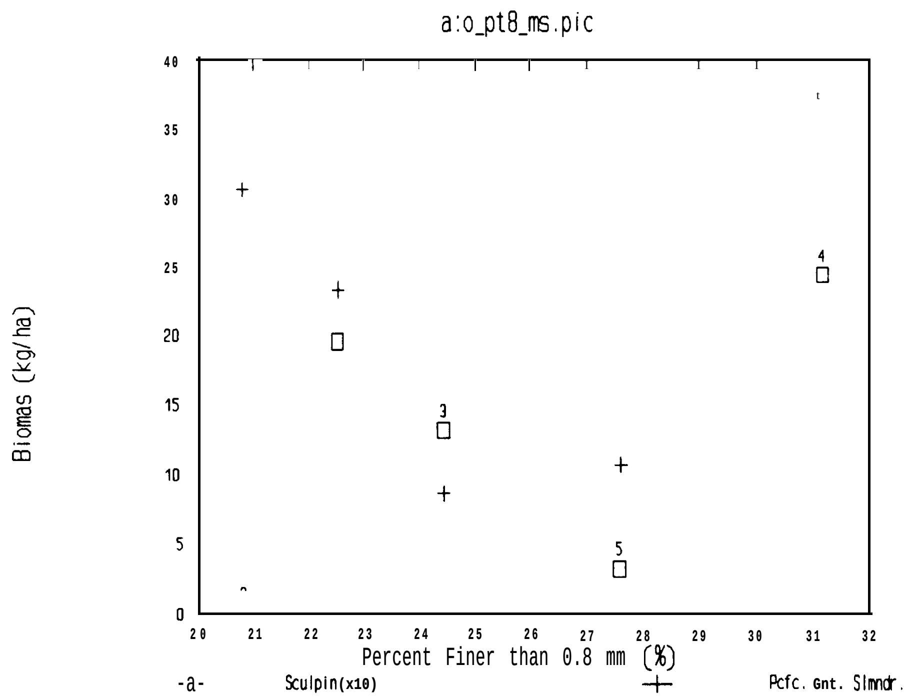

Figure 24. Scatter plot of the standing crop of sculpin and Pacific Giant Salamander against the percent of fines for 5 study sites, 1992.

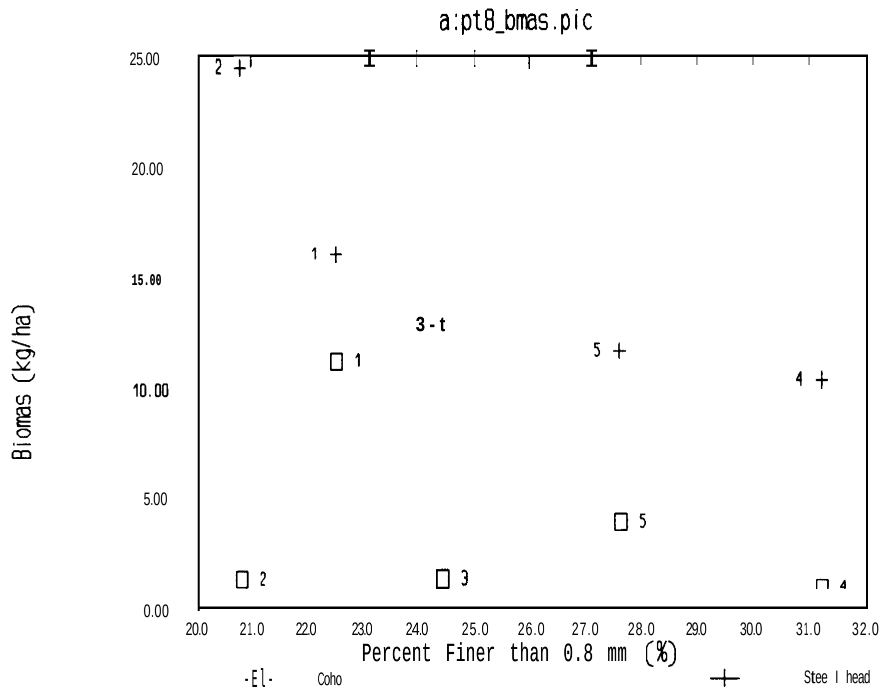

Figure 25. Scatter plot of the standing crop of Coho salmon and Steelhead Trout against the percent fines at five study sites, 1992.

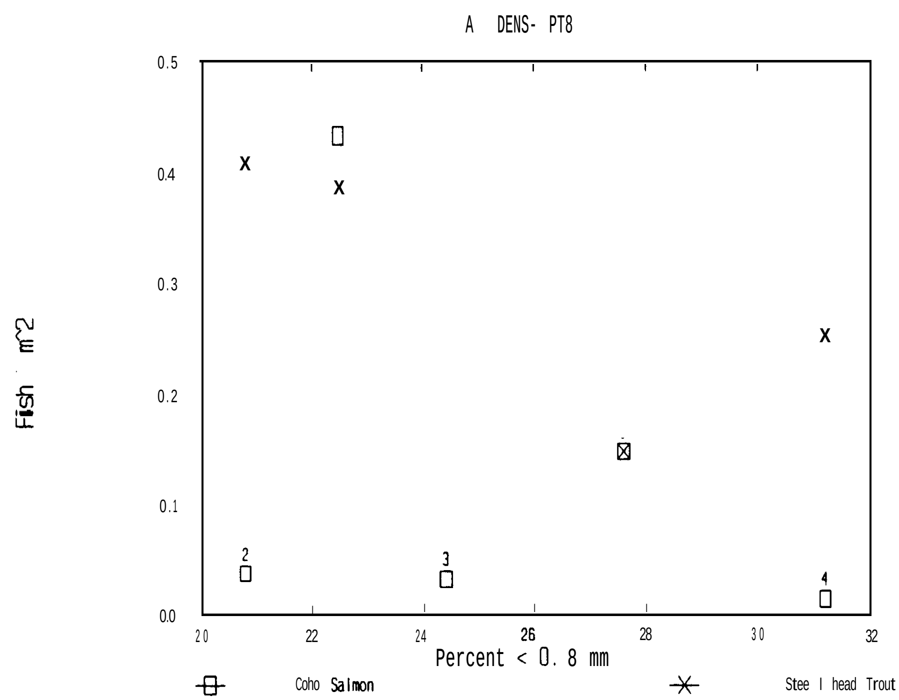

Figure 26. Scatter plot of the density of Coho Salmon and Steelhead Trout against the percent of fines at five study sites, 1992.

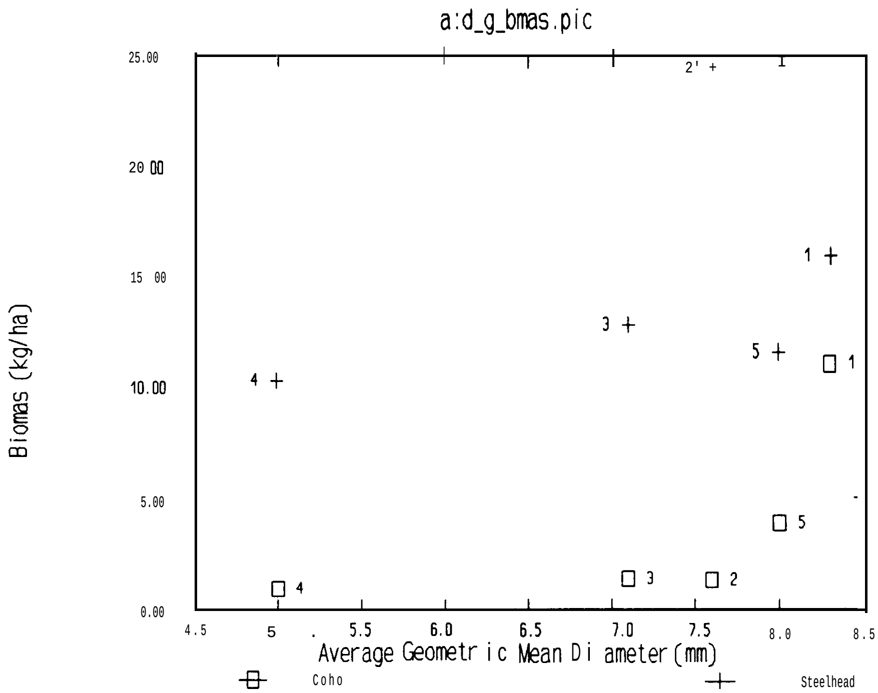

Figure 27. Scatter plot of the standing crop of Coho Salmon and Steelhead trout against the geometric mean diameter of the substrate at five study sites, 1992.

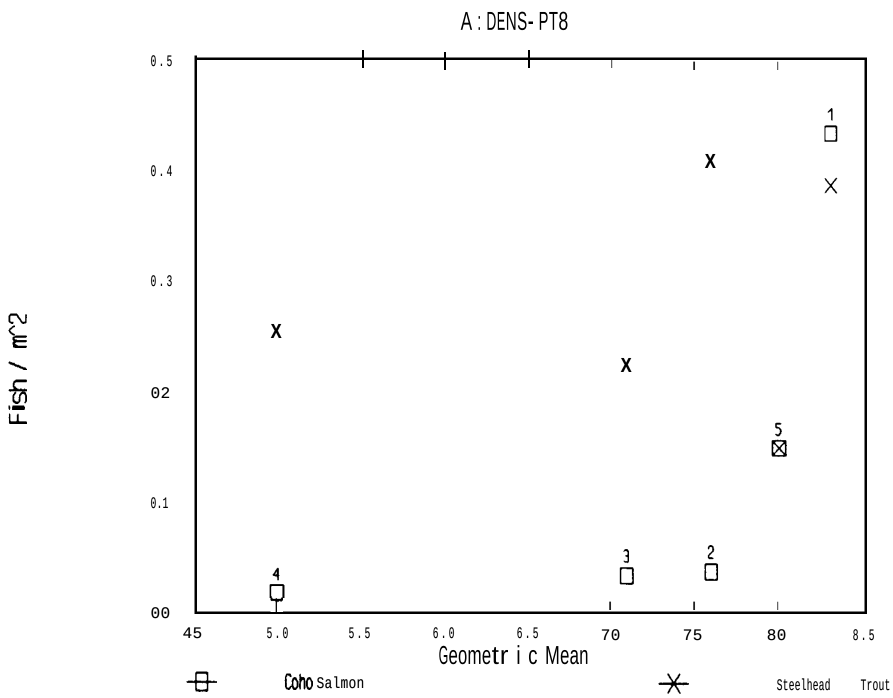

Figure 28. Scatter plot of the density of Coho Salmon and Steelhead Trout against the geometric mean particle size of the substrate at five study sites, 1992.

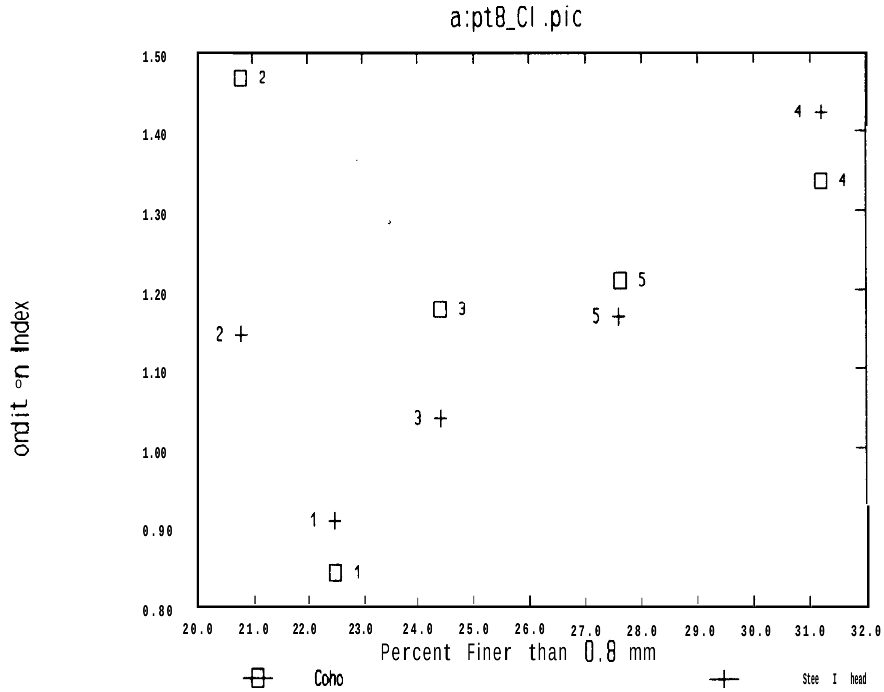

Figure 29. Scatter plot of salmonid condition indices against the percent of fines (<0.85 mm) in the substrate for five study sites, 1992.

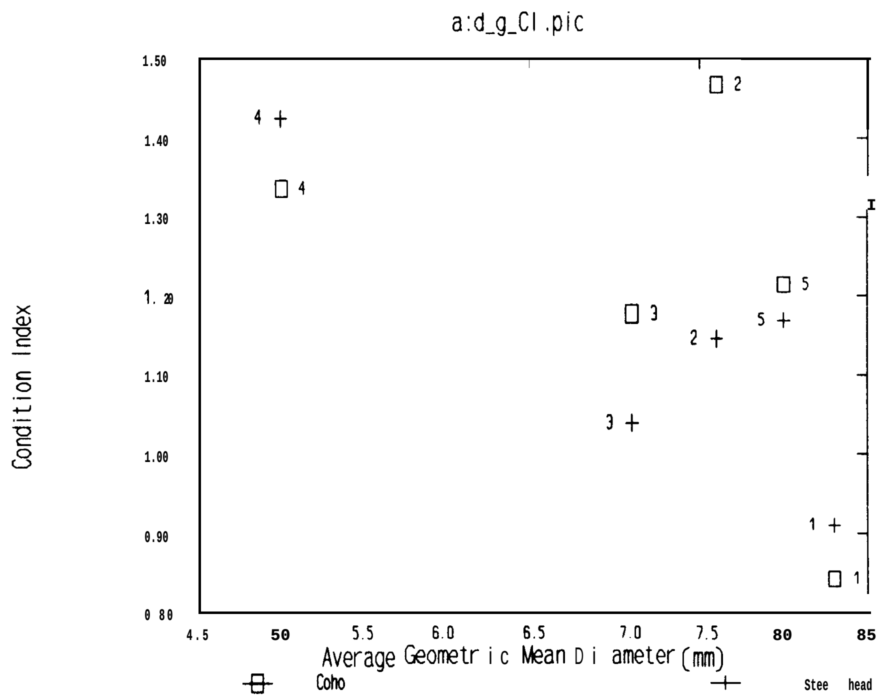

Figure 30. Scatter plot of salmonid condition indices against the substrate's geometric mean at five study sites, 1992.

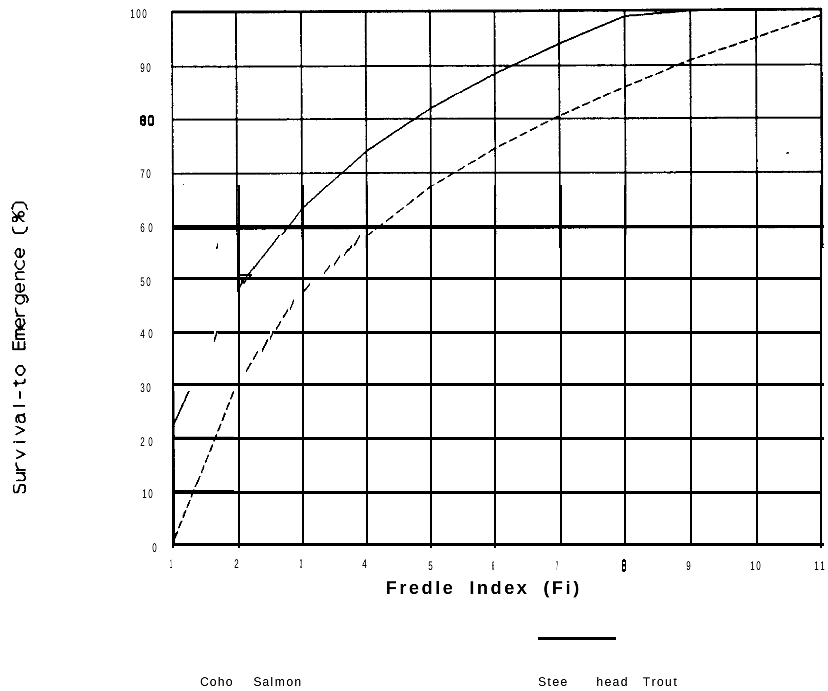

Figure 31. Percent survival to emergence for coho and steelhead against the Fredle Index. Averages for 1992 plotted on the curves. Graph adapted from Lotspeich and Everest (1981).

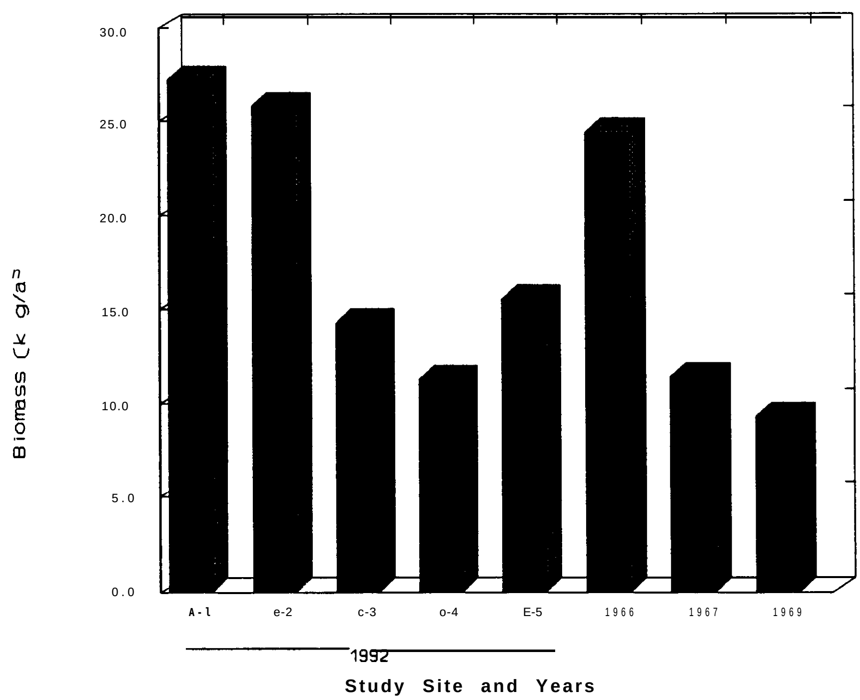

Figure 32. Standing crop (kg/ha) for five study sites, 1992, and for 1966-69 (Burns 1972). Darker zones represent coho, lighter zones represent steelhead.

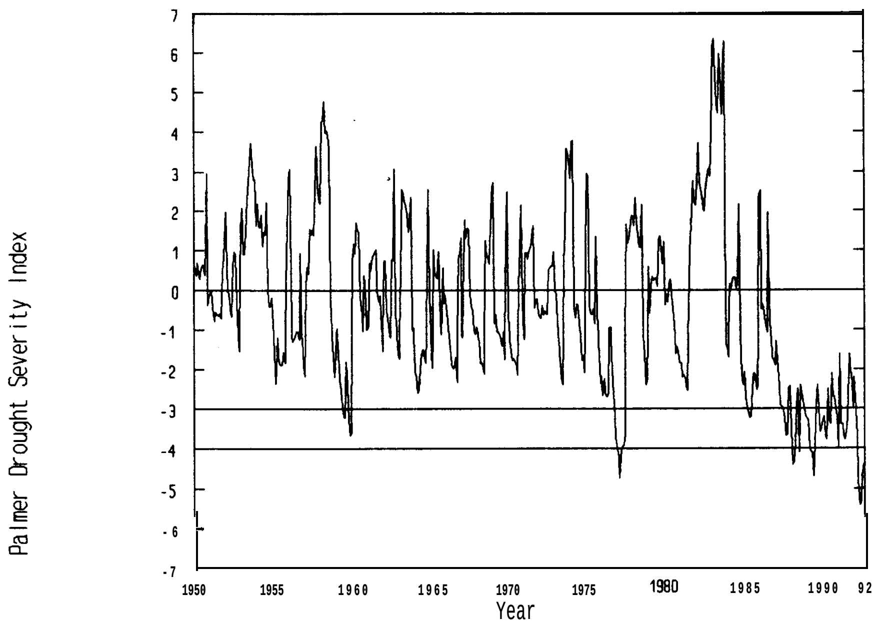

Figure 33. Monthly Palmer Drought Severity Index for the North Coast of California since 1950. Conditions considered "severe" (≤ -3) and "extreme" (≤ -4) drought conditions are indicated by horizontal lines.