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A Protocol Using Coho Salmon to Monitor Tongass National Forest Land and Resource Management Plan Standards and Guidelines for Fish Habitat

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Abstract

We describe a protocol to monitor the effectiveness of the Tongass Land Management Plan (TLMP) management standards for maintaining fish habitat. The protocol uses juvenile coho salmon (*Oncorhynchus kisutch*) in small tributary streams in forested watersheds. We used a 3-year pilot study to develop detailed methods to estimate juvenile salmonid populations, measure habitat, and quantitatively determine trends in juvenile coho salmon abundance over 10 years. Coho salmon have been shown to be sensitive to habitat alterations, and we use coho salmon parr as the primary indicator in the protocol. A priori criteria for type I and type II error rates, effect size, and sample sizes for the protocol were derived with estimates of variance computed from the 3-year pilot study. The protocol is designed to detect trends in abundance of coho salmon parr, as well as coho salmon fry and Dolly Varden (*Salvelinus malma*), in small streams managed according to TLMP standards and guidelines and to compare these to trends in unmanaged (old-growth) watersheds. Trends are adjusted to account for statistically significant habitat covariates. This information provides an important element in monitoring land management practices in the Tongass National Forest. The methods we describe may have application to monitoring protocols elsewhere for fish populations and land management practices.

Keywords: Monitoring, coho salmon, Tongass National Forest, watershed management.

Contents

Introduction

The primary emphasis of most monitoring protocols for aquatic habitat in the Pacific Northwest is to gauge the condition of habitat used by anadromous salmon and to assess the effects of human disturbance on watersheds. Johnson et al. (2001) reviewed 429 monitoring protocols that measure habitat conditions commonly associated with salmonid abundance in Oregon, Washington, British Columbia, and the northern Rocky Mountains. They defined a set of essential elements of protocols and used them to recommend a subset of 126 elements. Most of the protocols that were taken from these documents address specific measurements to assess a specific project. None of the protocols assess trends in salmonid populations over time. Five major protocols reviewed by Stolnack et al. (2005) collect data from a range of physical, chemical, and biological features with varying sampling strategies and geographic scales. Most, but not all, provide objective definitions for measurements. All sample fish, but do not specify quantitative measures of abundance over time.

Several monitoring protocols have developed out of large-scale management assessments such as the Northwest Forest Plan for the Pacific Northwest (FEMAT 1993) and the Columbia River basin (USDA FS 1994). More recently, monitoring has been broadened to the watershed and in some instances to the landscape scale (Gallo et al. 2005, Reeves et al. 2003). These and other agency protocols tend to be large, complex, and expensive. They also tend to be difficult to implement. A relatively simple and inexpensive monitoring protocol is more likely to be implemented and sustained than a large, complex, and expensive one. However, well-defined objectives, statistical rigor, quantifiable and repeatable measures, and well-defined methods are critical in a simple and inexpensive monitoring protocol.

A monitoring and evaluation plan is included in the 1997 Tongass Land and Resource Management Plan (TLMP) to assure implementation and effectiveness of the management direction and to measure the achievement of its objectives (USDA FS 1997). Freshwater ecosystems are recognized as an important component of the forest and are part of the monitoring effort. The TLMP standards and guidelines require that fish habitat be managed to ensure that the natural range and frequency of aquatic habitat conditions be either maintained or restored. Chapter 6 of TLMP contains a monitoring and evaluation plan intended to assure that management direction is implemented and objectives achieved for the Tongass National Forest in southeast Alaska.

Well-defined objectives, statistical rigor, quantifiable and repeatable measures, and well-defined methods are critical in a simple and inexpensive monitoring protocol.

The plan identified coho salmon (*Oncorhynchus kisutch*) as a "management indicator species" to monitor the effectiveness of TLMP management standards in maintaining anadromous salmonid habitat. An interagency monitoring evaluation group (IMEG) was convened to assist in the development of guidelines and protocols for monitoring TLMP. In 2002, IMEG recommended the development of a monitoring protocol that used juvenile coho salmon as a "management indicator species" to monitor the effectiveness of TLMP prescriptions for timber harvest.

The concept, background, and literature of "management indicator species" (MIS) were reviewed by Landres et al. (1988). The authors reviewed definitions used by various agencies, including the USDA Forest Service. They provided a "strict" definition that the MIS is a surrogate measure and may have no direct relationship to the cause or factor of interest. In this definition, the species is some measure of environmental quality that affects the biological community and environmental condition. However, under the code of federal regulations (1985), the definition of MIS or "featured species" includes species that have social or economic value. In southeast Alaska, coho salmon have significant social and economic value, and the habitats that support them are of considerable concern during land management planning in the Tongass National Forest.

Van Horne (1983) discussed some of the complicating factors involved with relating animal abundance to habitat quality, including recruitment and trophic requirements that may be unrelated to habitat quality. Van Horne (1983) underscored the importance of using all available information, including precise estimates of abundance and condition of the target species (or group of species), and consistent and repeatable measurements of habitat and physical conditions at as many scales as possible. Similar issues were discussed by Rosenfeld (2003) who pointed out problems of interpreting habitat selection, preference, and requirments. These are important factors that must be accounted for in a monitoring protocol.

The most appropriate target species to assess impacts on freshwater habitat is one that resides in fresh water for all or a substantial portion of its life cycle. The ideal species is one that is widely distributed throughout the affected landscapes and occupies stream habitats that are closely linked to riparian habitat. Coho salmon meet these criteria. Their freshwater residence in most streams of southeast Alaska is usually 1 or 2 years (i.e., two summers) following emergence from the gravel in spring. In the small streams used in the protocol, 2-year residence is more common (Bryant et al. 1996, 1998; Dolloff 1997; Elliot 1976). As a result, coho salmon will be more sensitive to a wider range of land management effects than

species that spawn but do not rear in fresh water, such as chum salmon (*O. keta*) or pink salmon (*O. gorbuscha*).

Juvenile coho salmon are sensitive to natural and anthropogenic disturbances (Meehan 1991). The decline of anadromous salmonids throughout the Pacific Northwest is attributed to widespread habitat degradation, dams, and overfishing (Gregory and Bisson 1997, Nehlson 1997). Numerous authors have shown that juvenile coho salmon respond with varying sensitivity to habitat attributes such as large wood (Bisson et al. 1987), sediment (Everest et al. 1987), and pools (House 1996, Lister and Genoe 1970, Nass et al. 1996, Rosenfeld et al. 2000). Nickelson et al. (1992b) observed positive correlations between juvenile coho salmon density and habitat features such as large wood and pools. Other studies support the findings that changes in physical habitat affect juvenile coho salmon (Bugert et al. 1991, Fausch 1993, Nass et al. 1996, Reeves et al. 1989, Shirvell 1990).

Although the number of smolt migrating from a watershed represents the "bottom line" of freshwater salmon production, the relationship between smolt production and specific management practices is unclear (Bradford et al. 1997). Sharma and Hilborn (2001) found that pools, ponds, and large woody debris (LWD) were good predictors of smolt density, but did not link them to management activities in watersheds. They also observed negative relationships of smolt density with stream gradient and valley slope. Estimation of smolt density is a problem in southeast Alaska where smolt weirs are expensive and difficult to maintain.

Coho salmon juveniles (fry and parr) were selected for the following reasons. They are more likely than adult coho salmon abundance to show a response to management-induced disturbance in small freshwater subbasins where most future timber harvest is likely to occur (Murphy et al. 1986). Coho salmon fry and parr are abundant in small subbasins and tributaries and reside in these small streams for 1 to 2 years in southeast Alaska. They are closely associated with easily identified habitat features such as large wood and pools. The abundance of coho salmon fry (age 0) and parr (age 1+) is easier to estimate than the number of smolt leaving, adult fish returning to a stream, or egg-to-fry survival. In southeast Alaska, escapement is adequate to provide full recruitment of fry to most streams (Halupka et al. 2000); therefore, juvenile coho salmon are more likely to respond to habitat alterations.

The protocol uses juvenile coho salmon as an indicator of effectiveness of the standards and guidelines for watershed management prescribed by TLMP to protect and maintain habitat for salmonids in freshwater. The goal of the monitoring protocol is to determine the trend of the abundance of juvenile coho salmon

The protocol is intended to measure trends in abundance of juvenile coho salmon in streams . . . exposed to timber harvest.

over 10 years or longer in watersheds managed in accordance with the standards and guidelines in TLMP. The protocol is intended to measure trends in abundance (i.e., density) of juvenile coho salmon in streams flowing through forested watersheds that are exposed to timber harvest with TLMP management prescriptions. The response of coho salmon fry and parr to management effects may differ; therefore, trends for each are considered separately (Thedinga et al. 1989). Our objectives are to apply consistent and reliable field methods for collecting fish and habitat data, and provide a statistical design to identify trends in juvenile coho salmon population abundance over a period of 10 or more years with a sample size necessary to detect a defined effect size with specified type I and type II error rates that are set a priori.

The methods in the protocol are designed to provide a quantitative measure of juvenile coho salmon abundance and habitat features that may affect their abundance in response to land management practices. An underlying goal is to provide a practical guide that can be used by field biologists to conduct an effective monitoring program to identify trends in juvenile coho salmonid populations. The sample design, field methods, and estimates for sample sizes for the long-term protocol are based on the results from a 3-year pilot study (Bryant et al. 2005b).

The pilot study estimated population abundance (density), measured habitat features, and examined relationships among management treatments, habitat variables, and geographic features in a set of small streams throughout southeast Alaska. An important part of this study was to apply methods that could be used in the long-term protocol as well as provide a quantitative basis to estimate appropriate statistical power and sample sizes for the long-term protocol. As a part of the study, we identified a set of logistical and administrative requirements needed to conduct the long-term protocol (app. 1). The methods to estimate fish population size (app. 2) and to conduct habitat surveys (app. 3) are adapted from those used in the pilot study.

Methods

The approach to the protocol and sampling strategy is based on results from the pilot study and other studies of juvenile salmon in streams throughout southeast Alaska (Bryant et al. 1998, 2005a, 2005b). The sampling strategy uses forested watersheds that represent watersheds that may be subject to timber harvest. The pilot study used small 2nd- to 3rd-order tributary streams in small subbasins of larger watersheds located from north to south on the Tongass National Forest. These streams are located in areas within the watershed that are most likely to be

exposed to timber harvest in the future under TLMP standards and guidelines. All of the watersheds in the pilot study were located on islands in the southeast Alaska archipelago.

The two management groups used in the protocol are subbasins with no timber harvest (control) and those harvested under TLMP standards and guidelines (treatment). Stream reaches in the control group typically flow through old-growth forests and are dominated by spruce (*Picea sitchensis* (Bong.) Carr.) and hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in their riparian zones. Streams in the control group are selected from the subbasin of watersheds without timber harvest; however, they may be in a land use category available for future timber harvest. Timber harvest may occur downstream from the stream. Stream reaches in the treatment group are drawn from subbasins harvested according to TLMP forest management practices (USDA FS 1997). These require buffers of at least 34 m (100 ft) horizontal distance from the bankfull margin of the stream in addition to other criteria (USDA FS 1997). Streams in a subbasin with timber harvest that occurred before the current forest plan will not be included in the sample.

Site Selection

Distribution of watersheds and sites—
Selection of watersheds and streams within watersheds may be the most difficult task in the monitoring protocol. The first step is to select an array of watersheds available for timber harvest located throughout southeast Alaska that represent the geographic range of the watersheds in the Tongass National Forest. Within these watersheds, streams in subbasins that have had timber harvest that meet current TLMP management criteria are identified as the treatment streams. When possible, timber harvest should have occurred within 3 to 4 years from the start of sampling for the protocol. Treatment subbasins are those that have no timber harvest before TLMP guidelines were implemented. These subbasins are the sample frame for treatment samples. The same process is followed for the control streams where streams are selected from subbasins without timber harvest and with riparian zones of old-growth forest.

A random sample of watersheds, streams, and sample sites that meet the criteria for the monitoring protocol is desirable; however, a simple random sample may not provide the best representation of the sample frame. Differences in fish abundance among geographic locations were identified in the pilot study; therefore, to account for potential differences among locations, equal numbers of treatment and

The criteria . . . are features of small tributary streams . . . that are important rearing habitats.

control streams should be selected within each geographic location. The distribution of timber harvest units and accessibility can influence site selection. Several of the issues affecting sampling populations (watersheds, streams, and sites) over a large geographic area are discussed by Stevens and Olsen (2004). They proposed a rigorous methodology to insure a random sample that is spatially balanced over a large area. It is geographic information system (GIS) and computer intensive, and other, less complex, models may be available.

Criteria for streams—
Criteria used in the pilot study are applied in the protocol. The criteria provide consistency among sample streams and are features of small tributary streams, common throughout southeast Alaska, that are important rearing habitats for juvenile coho salmon. The stream must contain coho salmon parr and fry. Embedded in this is the caveat that the stream should not have downstream obstructions that would impede migration of anadromous salmonids into the stream. Other criteria are as follows.

- The stream should have some upstream spawning area.
- Sample reaches are drawn from either flood-plain (FP) or moderate-gradient (MM) channel process groups (Paustian 1992).
- The average channel bedwidth should be <6 m, but >2 m.
- Within the stream, sample reaches must be free-flowing, single-channel streams. Beaver (*Castor canadensis*) ponds in the channel are avoided. Beaver ponds and side channels may influence the density of juvenile coho salmon.
- The stream is within a watershed network and flows into a clearly identified mainstream channel.
- The stream must be located in forest ecosystems and have forest riparian zones. Although part of the stream may flow through a muskeg, the sample sites should flow through forested riparian area. Streams that flow through muskegs for more than 500 m above a sample reach are likely to influence downstream temperatures and should be avoided.

Sample units are reaches > 100 m within either FP or MM channel process groups in each selected stream. The maximum reach length is determined by the length of stream that can be sampled (i.e., a complete population estimate) in 1 day. The length and number of reaches within each stream depends on the amount of time available to sample the reach and its complexity. The start point of each reach is selected at random. For example, random selection of 1 pool out of 10 identified

upstream from an established point in the stream (i.e., road crossing, tributary junction) may be used as the starting point of the reach. However, reaches in the treatment subbasin should be located adjacent to timber harvest units.

Sample size—

The estimates of sample sizes for the monitoring protocol are derived from variation among coho salmon fry and parr densities observed in the pilot study. Details of the sample size calculations appear in appendix 4. We estimate sample size ranges for two analytic approaches. The first is to detect a trend (annual change in density) over 10 years for each treatment separately; the second is to compare trends in the old-growth (control) and TLMP (harvest) streams. We estimate n, the number of streams necessary to detect a slope (b_1) for the trend equivalent to 5 percent annual change (50 percent total over 10 years) in the mean density of coho fry or parr after 10 years with 80 percent power for an individual treatment, and estimate sample sizes necessary to compare treatment to control trends over 10 years, for a combination of effect sizes and power values. The percentage of annual change defines the effect size in the power analysis. Sample sizes increase when the trends in density on harvest and control streams are compared to one another because two parameters, the TLMP trend and the old-growth trend, are being compared and the variation in both must be considered.

The range of sample sizes needed to detect an annual decrease of 5 percent in fish density in the streams of either the harvest or control group was 5 to 10 streams (app. 4 table 13). A sample size of 10 streams in each treatment provided sufficient precision to fit a linear model with covariates and detect important trends and changes over a 10-year period in a single category of stream (app. 4 table 13). For coho salmon fry in control streams, 10 sample streams gave 80 percent power ($\beta = 0.20$) when $\alpha = 0.10$. For parr and the same criteria, 9 streams were sufficient (app. 4 table 13).

Larger sample sizes are required to detect differences in trends between harvest and control streams at similar levels of α, power, and effect size. Samples of fewer than 10 streams in each treatment may have unacceptable power to detect important differences in trends between treatments (app. 4 tables 14 and 15). Sample size required to achieve >80 percent power to detect a 5 percent difference in trends of coho salmon abundance (i.e., slopes) are generally large (20 or 30 in each group, or between 40 and 60 total streams); however, power "levels out" and does not increase dramatically once 10 to 12 streams are sampled per group. A comparison of trends for coho fry in the harvest and control treatments would require between 20 and 30 streams for each treatment at 80 percent power and $\alpha = 0.10$ (app. 4

table 14). Similar power for parr would be achieved by sampling 15 to 20 streams per group (app. 4 table 15). However, a sample size of 10 to 12 streams in each treatment provided "good" (>0.5) to "large" (≥0.8) power for effect sizes (δ) that range from 0.05 to 0.08 annually for comparisons of fry and parr.

We do not recommend a sample size less than 12 streams per treatment.

Larger sample sizes are statistically more appealing, but are often prohibitive either by cost or logistics (app. 5). During the 3-year pilot study, we were able to sample 21 to 25 streams from July through August with a three-person team (app. 1). The sample size may be increased and the sample time period may be decreased if more than one team is employed. For example, three teams each assigned 12 streams in northern, central, and southern areas of the Tongass National Forest could complete sampling of 36 streams, 18 in the harvest and 18 in the control, in about 36 days. We do not recommend a sample size less than 12 streams per treatment.

Sampling Methods

Fish sampling—

Population estimates for the long-term protocol are made with a four-pass depletion method following procedures described in appendix 1 (Bryant 2000). With the four-pass method, the Capture program computes an estimate using equal probability of capture[1] of each fish in the first and subsequent passes and an estimate where the two probabilities are not equal (White et al. 1982). It then tests for equal capture probability and selects the best estimate. Estimates using the three-pass method are computed only using equal capture probability for all passes. All fish are identified to species and measured for fork length to the nearest millimeter. A subsample representative of the size range is weighed to estimate length-weight relationships.

Estimates are made for each species and coho salmon fry and parr. Fry and parr are separated by length as determined from a length frequency distribution. The number of fish estimated in each sample unit is standardized to density (fish per square meter) where area is computed by multiplying the reach length by the average channel bedwidth. Annual samples from each stream are taken during the same period each year. For example, if Tye Creek is sampled during the second week in July the first year, it is sampled at the same time in following years. The

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[1] Probability of capture is a parameter estimated from the data of the probability of capturing an individual fish during the sample occasion (White et al. 1982: 103).

sample period begins in the second week in July, after all newly emerged fry are recruited into the streams, and continues through late August.

Habitat—

Habitat measurements follow stream survey protocols described for tier III surveys in the Forest Service Stream Survey Handbook for the Alaska Region (USDA FS 2001) and in appendix 3. These include measurements of total stream length surveyed, channel bedwidth, wetted width and length and width of habitat units (pools and fastwater), water depth, length of undercut bank, and counts of large wood. Measurements of stream channel cross section, gradient profile, pebble counts, pH, temperature, and flow are repeated annually for the duration of the study. The habitat survey occurs after fish sampling to decrease disturbance before the population estimate. Electronic thermographs are secured in a deep pool at the beginning of the sampling protocol and downloaded during each sample period to provide a year-round temperature record.

Instream habitat measures in table 1 are standardized by reach length, such as pools per meter, large wood per meter, or proportion of undercut bank where appropriate. Others are computed values, such as average residual pool depth (Lisle 1987) and average substrate size (d_{50}). Most of the variables in table 1 were measured in the pilot study and were included in the stepwise regression to assess relationships with coho salmon (fry and parr) abundance. Significant relationships were observed with some, but not all variables. Nonsignificant variables were retained because relationships appear in other studies and many are part of the tier III stream survey. Furthermore, results from the analysis of the habitat information in the protocol may differ from those in the 3-year pilot study.

Subbasin disturbance was not measured in the pilot study; however, disturbance events that affect the watershed can provide important information with respect to observations of trends in abundance of juvenile coho salmon. These may be estimated from GIS maps. Aerial photography or low-level digital photography may be used, if it is available. Features related to management activities can include percentage of the subbasin that has been harvested, type of harvest (i.e., high lead vs. helicopter), and road density. Landslides and blowdown are two events that can have a substantial effect on streams. Periodic (3-year interval) inventories of these events in the sample watersheds can provide considerable explanatory power of potential trends that may be observed in the protocol. These events may or may not be related to management activities. In most cases, their relationship, or lack thereof, to management activities can be determined.

Table 1—Response variables and potential covariates (instream habitat and other variables) for the long-term monitoring protocol

Variables	Transformations (pilot study)	Units
Response variables		
Density of coho salmon fry	Square root	Number per meter square
Density of coho salmon parr	Log	Number per meter square
Potential covariates		
Time:		
Year sampled		
Month sampled		
Location:		
(North, Central, South)		
Latitude		Decimal
Distance to salt water		Meters
Instream habitat:		
Average residual depth	Log	Meters
Average channel bed width	Log	Meters
Substrate size	Square root	Scale
Proportion of undercut bank		Ratio
Total pieces of large woody debris per meter	Log	Number per meter
Total pools per meter	Log	Number per meter
Biological:		
Density of Dolly Varden	Square root	Number per meter square
Landscape/watershed:		
Water temperature in annual thermal units		°C
Elevation		Meters
Area		Hectares

Analysis

Answers to two primary questions are needed to quantitatively evaluate the effectiveness of TLMP standards and guidelines for coho salmon habitat: (1) Are there observable (i.e., measurable) trends in the abundance of juvenile coho salmon in streams located in watersheds managed in accordance with TLMP prescriptions (i.e., treatment) and, separately, in unmanaged (i.e., control) watersheds? (2) Are there observable differences between trends of juvenile coho salmon abundance in the treatment and control watersheds (i.e., is juvenile coho salmon abundance affected by management treatment)?

These relatively simple questions are complicated by factors that may influence salmonid (juvenile coho salmon) abundance. Salmonid abundance may be influenced by a range of instream habitat variables such as large wood, pools per meter, and average residual depth. If significant relationships between these variables and

salmonid abundance are observed, they are included as covariates in the analysis of trends in salmonid abundance. This adjusts the means of abundance to account for the observed differences in instream habitat variables that influence salmon abundance before testing for an effect of management treatment. Another question is whether trends in these instream habitat variables occur over the monitoring period and, if so, are they related to management treatment. In that case, the test for differences between trends in salmonid abundance based on management treatment is confounded with the trends in instream habitat variables. If the observed difference in trends in instream habitat variables is related to management treatment, we can argue that management treatment is having an effect on salmonid abundance by altering influential instream habitat variables in the stream environment.

Analysis of differences in rates of change attributable to management treatment is based on analysis of covariance. The model determines if the intercepts of both regressions are equal (i.e., are both groups starting at the same value for abundance), if the slopes (rates of change) are equal to zero (i.e., no change in abundance), and if they are equal to one another (i.e., change in abundance is the same for control and treatment). The basic model examines only treatment and nontreatment covariates that have been shown to have an effect on the relationships; therefore, the response and covariate data need to be examined to identify the dominant sources of random variation, a reasonable covariance structure to account for serial correlation, a reasonable model, and finally a model for natural variation that includes treatment effects (McDonald et al. 2006b and app. 6).

We recommend using a linear model after 10 years of monitoring, during which time each stream is visited each year, with transformed data where necessary. The basic model is represented by

$$Y = X_0 \beta_0 + X_1 \beta_1 + \ldots + X_p \beta_p + \varepsilon$$

where Y is the juvenile coho salmon density, X_i are the independent variables in the regression of responses on time, β_i is the rate of change (i.e., trend) in the juvenile coho salmon density per unit change in the variable X_i, p is the number of variables included in the model, and ε are the correlated random errors. The random errors have a correlated structure, as data collected on the same stream through time (longitudinal data) are correlated over the years; i.e., salmonid abundance and habitat measures are related to the previous-year measurements.

For example, a model including elevation and total pools per meter might look like

$$Y = X_1 \beta_1 + X_2 \beta_2 + \varepsilon$$

We recommend using a linear model after 10 years of monitoring.

where Y is the juvenile coho salmon density, X_1 is the elevation, β_1 is the rate of change in the juvenile coho salmon density per unit change in elevation, X_2 is the total pools per meter, β_2 is the rate of change in the juvenile coho salmon density per unit change in total pools per meter, and ε has an AR1[2] autocorrelation covariance structure. The inclusion of the covariates, elevation and total pools per meter, in the model means that there are observed differences in juvenile coho salmon density based on elevation and total pools per meter, so this variation has to be factored out before we can determine if there are observed differences in juvenile coho salmon density based on management treatment. A more complete description of the statistical model can be found in appendix 6.

Instream habitat and other variables—
More than 14 variables are measured as potential covariates in the analysis of trends in salmonid abundance (table 1). They range in scale from the habitat to the landscape and have the potential to influence salmonid populations. Large wood, pool abundance, average residual depth, substrate size, and cross-sectional area are the primary measures of instream habitat that are likely to respond to management treatment. Descriptive statistics that plot annual means and variances (95 percent confidence intervals) of instream habitat and other variables for all streams within a given watershed are useful indicators of trends and can contribute to interpretation of potential trends observed for salmon populations. Trends within and between watersheds over the 10-year monitoring period may be analyzed quantitatively as well.

The number of potentially influential instream habitat and other variables approaches the sample size of streams and makes model development problematic. Relationships among many of the instream habitat variables are not well known, but some studies (e.g., Montgomery et al. 1995) have suggested correlations (e.g., pools and large wood). Correlation analysis (Pearson's correlation coefficient) provides one measure of correlation between variables and can be used to select unique (uncorrelated) variables that may be included in the stepwise regression model used to select significant covariates.

Model selection is performed by backward stepwise elimination. During backwards selection, the statistical significance required for a variable to enter (alpha-to-enter) and leave (alpha-to-exit) the model is set to 0.05. This low alpha identifies

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[2] An AR1 (autoregressive) covariance structure assumes that as more time passes, the measurements will be less correlated with one another. The correlations decay exponentially with time. So, year 1 is correlated with year 2, less with year 3, less still with year 4, etc.

the most important (statistically significant) factors affecting salmon fry and parr density while eliminating the less important factors.

Analysis of trends in salmonid abundance—
The primary analysis is a mixed-effects linear regression model that adjusts treatment effects for both correlation among years and values of covariates. This approach allows us to partition the observed variation in salmonid abundance and separate the variation attributable to the effects of the model covariates (e.g., elevation, location, total pools per meter ...) from the variation attributable to treatment differences (our primary interest). The basic hypothesis of the regression analysis is H_0: $\beta_{treatment} = \beta_{control}$, where the treatment and control trends $\beta_{treatment}$ and $\beta_{control}$ have been adjusted for the values of other covariates. Treatment trends are adjusted for instream habitat and other covariates by virtue of the fact that the multiple regression procedure allows estimation of effects for theoretically identical streams. For example, if fry density is related to stream gradient and a wide range of gradients was observed, the multiple regression model would allow trends in fry density to be estimated for a common gradient value, say 1 percent, and thereby effectively adjust fry densities for gradient. Trends could then be calculated without confounding the estimates with the effects of gradient. All this can be accomplished by simply fitting gradient variables in the model before treatment variables. Mixed-effects regression theory would be employed to estimate and adjust for the covariance of responses through time on a single subbasin, similar to the way that covariance is estimated in standard repeated measures ANOVA procedures. Separate analyses are run for each response variable (coho salmon fry and parr). Each variable (response and instream habitat) is examined for normality and appropriate transformations applied to those with gross departures from normality. In each case, the transformation bringing the data closest to normal is selected. Individual profile plots with average trend lines, cross-sectional plots, and longitudinal plots are also used to examine the relationships between juvenile coho salmon density and individual instream habitat and other variables.[3]

A sample variogram is used to identify the relative importance of the three sources of random error, the between-subject variability (random effects), the within-subject variability (serial correlation) and measurement error (Verbeke and Molenberghs 2000) to assist with the selection of the random error structure. Akaike's Information Criteria corrected for small sample size (AICC) is used to

[3] Patetta, M. 2002. Longitudinal data analysis with discrete and continuous responses. Course Notes. Cary, NC: SAS Institute Inc.

select the best fitting error structure from a variety of biologically appropriate error structures (see Verbeke and Molenberghs 2000).

Analysis of salmonid response to management treatment—
Once a model containing nontreatment covariates (instream habitat and other variables) is selected by the backward stepwise procedure, the treatment and year by treatment interaction effects are added to the model to test for differences in overall trend between treatments (McDonald et al. 2006b). These tests assess the significance of treatment effects after accounting for the cumulative effects of all nontreatment covariates. Statistically, the analysis of treatment and control rates of change is based on analysis of covariance and is illustrated heuristically in figure 1. The model determines whether trends in salmonid abundance in both treatment groups are equal by testing equality of one or more coefficients in the model. The basic model examines harvest and control effects and only those nontreatment effects (instream habitat and other variables from table 1) that have been shown to be related to salmonid abundance.

Other salmonid species—
During the pilot study, Dolly Varden (*Salvelinus malma*) were captured in all streams where coho salmon were captured. Cutthroat trout (*O. clarkii*) and steelhead (*O. mykiss*) were captured in some but not all streams. When these species were captured, population estimates were made following the same methods that were applied to coho salmon. The analysis over the 10-year period that is applied to coho salmon fry and parr can also be applied to Dolly Varden. However, the covariates that influence Dolly Varden need to be analyzed with respect to Dolly Varden. The analysis for Dolly Varden can be used to identify trends between control and treatment watersheds in as much as the abundance estimates are taken from the same sample size and distribution as coho salmon. Such is not the case for cutthroat trout and steelhead because they were not captured in all streams during the pilot study. However, trends can be analyzed for watersheds where population estimates are made. With the inclusion of all species, trends in species diversity may also be observed over the course of the monitoring period.

Subbasin conditions—
Trends of salmonid populations may be in response to management activities or natural disturbance events in the stream subbasin. Disturbance related to management includes road construction (as measured by road length and number of stream crossings), timber harvest (additional area harvested), and slope disturbance (i.e.,

The model determines whether trends in salmonid abundance in both treatment groups are equal by testing equality of one or more coefficients in the model.
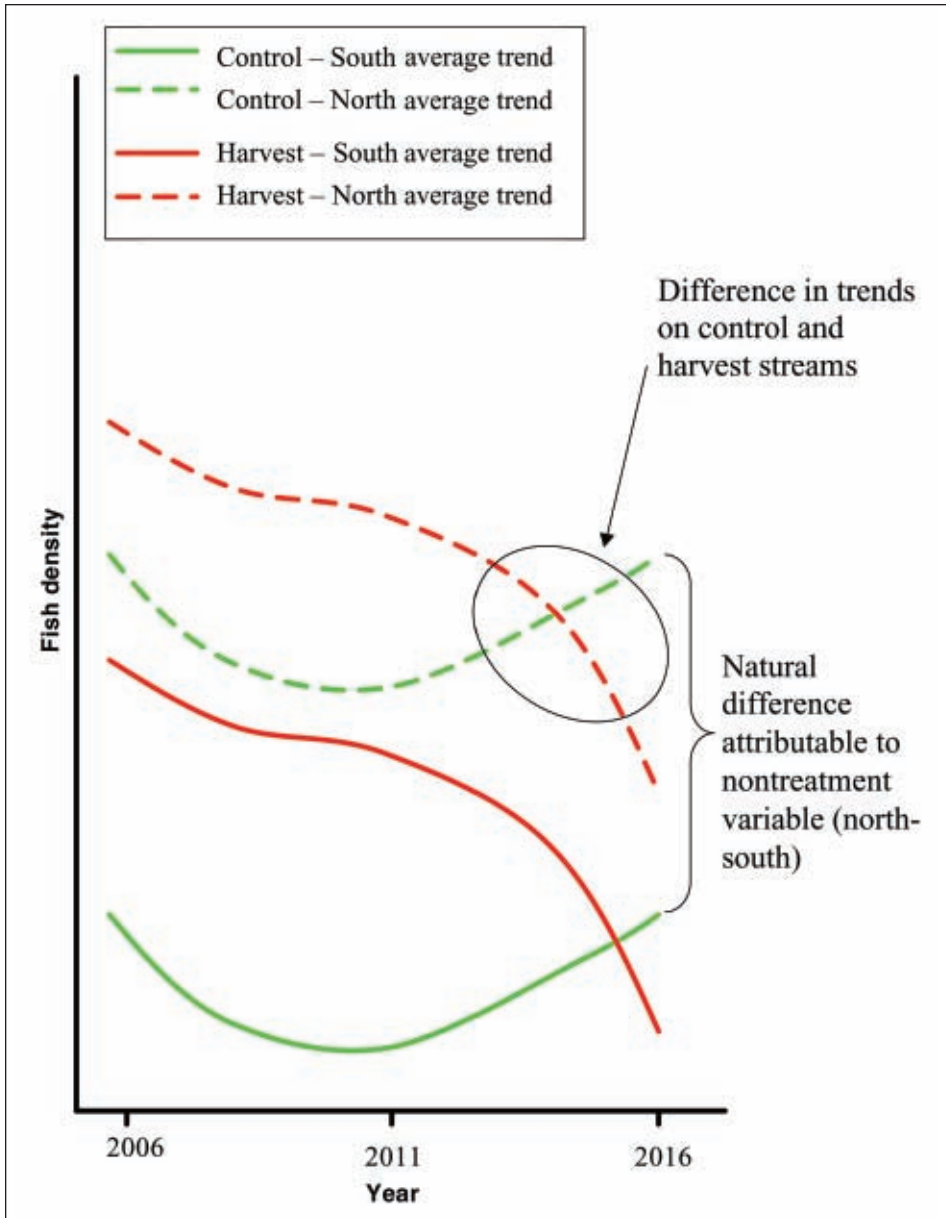
Figure 1—Heuristic representation of the models fit to pilot data and proposed for the monitoring analysis. Models estimate differences caused by natural variation and test for differences in trends among treatment groups. Here, only two locations (north and south) are included and only Tongass Land Management harvest treatments and old-growth control trends are plotted in this figure. In reality, several instream habitat or other variables may be included in the model.

landslides associated with management activities). Landslides and riparian blow-down may be due to either anthropogenic or natural causes. Inventories of land-slides and blowdown in each sample watershed over the course of the monitoring period can help interpret trends in both treatments. Both may result in outliers in

fish population responses, which can be analyzed to determine their effect on the trend analysis. These may be episodic with one event occurring during the monitoring period. The relationship between subbasin conditions and trends in salmon population can be useful to the interpretation of the response to management effects.

Three measures of watershed morphology that may influence distribution and abundance of fish among watersheds were identified by Wissmar and Timm (2006). Relief and ruggedness are important watershed features because they influence the development of stream systems (Patton 1988). Relief (R) is defined as the difference between the highest elevation (m) above a reach and the mean elevation (m) of the stream reach. The ruggedness number (RUG) of a reach, is estimated by multiplying the channel drainage density (km/km^2) by R. Both are related to stream gradient. Drainage density (DD) is an approximate measure of watershed dissection and reflects the competing effectiveness of overland flow and infiltration. Relief (R), ruggedness numbers (RUG) and drainage densities (DD) represent processes that operate over an entire watershed area (Patton 1988). These measures may be used as a separate suite of covariates to determine their effect on fish abundance. Although they were not used in the pilot study, they may be useful indicators of the sensitivity of watersheds and salmonid abundance to management activities.

Discussion

If properly implemented, the methods in the protocol will return reliable estimates of salmonid abundance and consistent measures of habitat. Each sample is a small section of the subbasin in 1 year, which taken in isolation yields only a small amount of information. However, over the period of 10 years, assuming a sample size of 12 streams per treatment, the protocol will yield 240 sample points. In this context, the protocol will provide reasonably precise and, if properly executed, reasonably accurate estimates of salmonid populations and their habitats in managed and old-growth forested watersheds.

Selection of watersheds and the sample streams within these watersheds is critical to the protocol. The criteria provided in the protocol are designed to provide consistency among sample sites. The selection process for the sample frame (i.e., universe) needs to be systematic and to consider the management context of the watersheds. Some of these considerations are timber harvest under TLMP prescriptions, the current management status of the watershed, and its location within the Tongass National Forest. The physical features (i.e., channel process groups) of the streams selected from the sample frame should be consistent between harvest

and control. Furthermore, streams need to be representative of the larger pool of streams that may be subject to timber harvest. However, control watersheds may be located in areas that are not subject to timber harvest, such as old-growth reserves or wilderness areas. An essential part of the protocol is professional experience and knowledge of southeast Alaska watersheds by those involved in establishing the sample frame. Once the watersheds in the sample frame are established, sample sites can be selected through a random process.

Juvenile coho salmon occupy a wide range of habitats, and seasonal use of habitats varies (Bryant 1984, 1988; Bryant et al. 2004b; Dolloff 1987; Elliott and Reed 1974; Nickelson et al. 1992a; Peterson 1982; Swales et al. 1986). For example, they may move from main channel habitats into off-channel habitats, beaver ponds, and small tributaries during the fall (Bramblett et al. 2002, Peterson 1982, Swales and Levings 1989). They also may use lakes as rearing areas (Bryant et al. 1996). However, these habitats are not distributed evenly throughout watersheds and they may not always support juvenile coho salmon during the summer. Access to some of these habitats may vary seasonally. We selected small tributaries (2nd to 3rd order) rather than large streams because juvenile coho salmon are present in small tributaries throughout the year and are usually the most abundant species (Bramblett et al. 2002, Bryant et al. 1991, Dolloff 1983, Elliott 1976).

We suggest that trends in coho parr are the appropriate indicator for the monitoring protocol. Trends in coho salmon parr abundance are more likely than fry to reflect habitat conditions in small streams. Coho salmon parr have completed a full seasonal cycle in fresh water, and those remaining are survivors of summer to fall fry mortality and of over-winter effects. They are larger and usually have established feeding territories. They also tend to occupy habitats that are associated with good cover (i.e., large wood, undercut banks).

Trends in coho salmon fry may also be a useful indicator of management effects as well. Coho salmon fry are abundant throughout most small streams in southeast Alaska. Most streams in southeast Alaska are fully stocked with coho salmon fry. Population estimates taken during midsummer usually reflect the peak abundance of fry. By mid-June fry have emerged and dispersed from spawning locations and occupy nearly all pools or low-velocity habitats regardless of quality. Time of sampling within the season may be an important covariate if fry experience high mortality over the summer sampling period. A decreasing trend in fry abundance over years may indicate decreasing habitat quality or lower recruitment into the stream. This may be the result of lower escapement to the stream or a decline in egg-to-fry survival. Smaller escapements may be the result of higher

harvest rates, lower marine survival, a combination of both, or a downstream barrier. Environmental factors such as temperature extremes or freshets may be responsible. Habitat factors that increase fine sediment deposition will decrease egg-to-fry survival. Upslope disturbance from landslides or poorly designed roads can contribute high amounts of sediment. Several of these effects, which are identified as covariates, are sampled and analyzed. A trend of decreasing substrate size is an indication of infiltration of fine sediment into the streambed. Other factors, such as marine survival and escapement, may be inferred from other sources. For example, estimates of harvest rates and escapement are available from management reports by the Alaska Department of Fish and Game. However, consistent differences in trends between the treatment and control would suggest that habitat issues may be related to management practices.

Juvenile coho salmon may move during the fall in southeast Alaska and the Pacific Northwest (Bramblett et al. 2002, Cederholm and Scarett 1983) and coho salmon parr that are found in a particular reach may or may not have been there as fry. It is reasonable to assume that they are likely to stay in habitats that offer some protection from adverse conditions such as high fall/winter flows and will return to and survive in stream reaches with conditions that have adequate flows and cover. The monitoring protocol will not determine fry-to-parr survival, but trends in abundance should reflect the ability of the reach, as a representative part of the watershed, to support coho salmon. If conditions deteriorate in the stream or elsewhere in the subbasin, recruitment into the reach is likely to decline.

Selection of criteria for statistical significance is somewhat arbitrary, particularly type I error where $\alpha = 0.05$ (Johnson 1999). Selection of effect size is an important determinant for sample size and type II error rates. As the effect sizes decreases, the statistical power decreases when the type I error rate remains the same. Although a trend of 5 percent per year may appear to be a "small" effect, an effect size of 50 percent over 10 years may be considered fairly large and of biological significance. Many of the issues of setting statistical criteria for monitoring studies are discussed by Bryant et al. (2004a) and many of the references cited therein.

Setting the effect size at 5 percent annually is used as part of the analysis to determine sample size and statistical power; however, it is highly unlikely that a change, if detected, will be constant from year to year. Furthermore, a linear model may not provide the best fit for the observed results during the 10-year period. However, trends may be detected by using the linear model as illustrated in the three scenarios in figure 2. The hypothetical data for the treatment streams illustrate three scenarios with two significant trends and one where significant trends are not

Although a trend of 5 percent per year may appear to be a "small" effect, an effect size of 50 percent over 10 years may be considered fairly large and of biological significance.

observed. In each case, the data response varies from year to year and not in a strict linear manner. Nonlinear models may be applied to improve the regression fit; however, linear models in these scenarios are adequate for managers to detect trends in abundance.

We include statistically significant covariates in our analysis of trends to account for differences that may be external to management effects and to reduce variation among samples. Relationships between observations of fish abundance and disturbance either natural or anthropogenic may be established through statistical relationships between response variables (coho salmon fry or parr abundance) and a suite of covariates (habitat measures). These measures are an important part of identifying and understanding trends in abundance.

Often disturbance events (natural and anthropogenic) do not lend to rigorous statistical analysis. They are difficult to replicate, and acquiring before and after samples is undependable. They are often not easily predicted in time and space. For example, certain terrains may be more prone to landslides, but when and where they will occur is uncertain. Large-scale events tend to be infrequent, often occurring over decades or longer. When they do occur, they tend to cause outliers. In the case of a large landslide that flows through a tributary stream, an abrupt decline in fish abundance relative to previous years may occur. In the other extreme, a newly created beaver pond in the system may result in a spike in juvenile coho salmon abundance. Outliers have been used to identify unique characteristics among salmon stocks (Halupka et al. 2000) and may provide similar insight into management effects and response of fish populations.

A range of techniques can be used to identify outliers. Box and whisker plots are an easy graphical method. Diagnostic tools available for general linear mixed-model validation include residual analysis, outlier detection, influence analysis, checking model assumptions, and leverage analysis. When outliers are detected, the first part of the process is to insure that the data are correct and that there are no recording or "clerical" errors. The next step is to insure that the methods of collection were consistent and not biased. Examples of this type of problem are extreme weather conditions (i.e., high flows during the sample period), incomplete sampling, or interference in sampling by external events (i.e., bears pulling the traps). Once the validity of the sample has been established, then an investigation of reasonable explanations may proceed. A generalized approach to the analysis is to begin at the reach scale and proceed upward to the landscape scale, using information collected in conjunction with the monitoring process. When outliers at several locations occur in a single year, then more global effects may be responsible (marine conditions, extreme seasonal events).
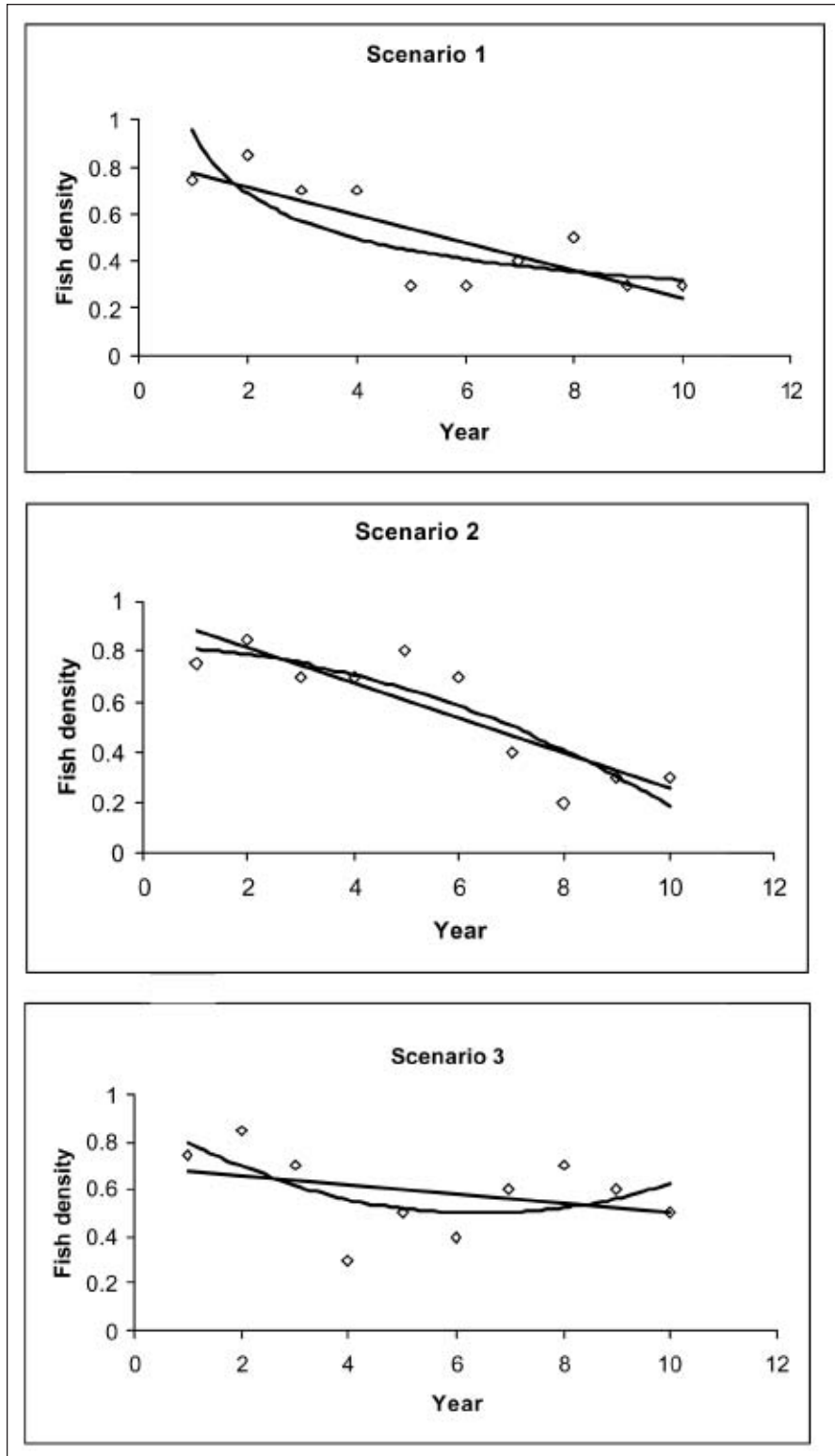
Figure 2—An illustration of three possible outcomes of the regression analysis of trends in the treatment watersheds.

Whether to retain or discard the sample from the analysis depends, in part, on the results of the analysis. In some instances, an outlier may have an inordinate effect on the outcome of the results. An outlier may or may not be related to a management activity. Identification of the cause and the decision to retain or discard the sample depends upon the circumstances, the causes, and its influence on the results. However, they cannot be ignored.

The focus of this protocol is to identify trends of juvenile coho salmon abundance in small streams. However, other information is also collected, and potentially useful metrics can be derived from the samples to examine trends within and between control and treatment watersheds. The same analytic methods used for abundance may be applied to certain other variables. The ratio of parr to fry with fry offset by 1 year (P_i/F_{i-1}) may be useful, where P_i = parr density in year i and F_{i-1} = fry density in year i-1. The ratio describes the potential effect of fry abundance on the following year parr abundance. Because fish may move into and out of the sample reach, it is not an estimate of over-winter survival. Fry and parr biomass may be computed from population estimates and weights derived from length-weight relationships and substituted for density in the analysis. These are more complex response variables with unknown variances; therefore, a separate power analysis is required to determine type II error rates.

The protocol is narrowly focused to evaluate the response of juvenile coho salmon to the management prescriptions in TLMP. The protocol incorporates a wide range of measurements that can be used to evaluate management effects in the watersheds. It is designed to return quantitative results using methods that are consistent from year to year and among management treatments. Furthermore, it can be incorporated into a broad-scale monitoring effort that includes a wider range of resources within selected watersheds. A decreasing trend in fish abundance provides managers with a symptom that can be used in conjunction with other indicators drawn from scales that range from the instream habitat to landscape-scale effects (i.e., habitat fragmentation, road density, etc.) to determine potential causes and to craft alterations in management direction. Similarly, a constant or increasing trend, although a good sign for fish, does not remove the need to monitor both managed and unmanaged watersheds in the future. Conditions and environments may change in unpredictable ways. Among the more ominous is the potential for climate change, which may change management criteria. Future timber harvest of old-growth forest will reduce the number of intact watersheds (i.e., cumulative effects). Management prescriptions that are adequate in the present environment may not be so in the future.

A decreasing trend in fish abundance . . . can be used in conjunction with other indicators . . . to determine potential causes and to craft alterations in management direction.

Vesely et al. (2006) recommended some key elements for monitoring protocols. Among these are a pilot study to establish estimates for sample sizes, effect size, and power analysis. They also included selection criteria for and the definition of the target population (response variable), and identification of potential stressors (covariates). These were incorporated into the coho monitoring protocol. The pilot study used in the development of this protocol provided field verification of the methods used to obtain population estimates, habitat measurements, and statistical analysis of a short-term data set comparable to that in the long-term study. The protocol addresses a specific need identified in TLMP (MIS monitoring for forest planning) and provides an example of an application of a generalized design for other monitoring protocols. It will provide managers with quantitative measures of juvenile coho salmon populations (and associated species) and a set of habitat measures that can be used to evaluate forest management practices that may affect salmonid populations.

Acknowledgments

English Equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	0.0394	Inches (in)
Centimeters (cm)	.394	Inches (in)
Meters (m)	3.28	Feet (ft)
Meters	1.094	Yards
Kilometers (km)	.621	Miles
Square kilometers (km^2)	.386	Square miles
Hectares (ha)	2.47	Acres
Grams (g)	.0352	Ounces
Liters	.265	Gallons (gal)
Milliliters	.0338	Ounces (oz)

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Appendix 1: Administrative and Logistical Requirements

The administrative and logistical requirements for field projects in southeast Alaska are unique compared to elsewhere. Most fieldwork is done in remote locations where access is by float plane or boat. Travel to and from sample sites may be in vehicles on logging roads, or by foot, boat, or helicopter. Accommodations may be primitive, and forgotten items are not easily replaced. Equipment and supply lists are important. Bears and flying are considerations for southeast Alaska. Safety is an important part of the fieldwork, and training requirements such as aviation safety, first aid, and cardiopulmonary resuscitation (CPR) are critical. Logistical support may be available only from Forest Service ranger districts in outlying locations. Permits are required from the Alaska Department of Fish and Game to capture and handle fish. The purpose of this appendix is to provide the basics of many of these requirements.

Safety

Harsh weather and terrain, flying, boating, and bears impose unique safety considerations for work in Alaska. As a result, the U.S. Forest Service, Alaska Region has an extensive and mandatory training program for all employees. An extensive training schedule begins usually by mid-April and continues through June to accommodate seasonal employees. Some of the requirements and details may change from year to year, but some core requirements are aviation safety, safety in bear country, rifle training, CPR, and first aid.

Fieldwork in southeast Alaska can be hazardous, and, as a result, a Job Hazard Analysis (JHA) specific to the work to be performed must be prepared. The JHA identifies the project, location, specific tasks, hazards associated with the task, and safety procedures that can be implemented to avoid injury. An example is shown in figure 3. The form is typically prepared by the crew leader and first-level supervisor. Tasks and hazards listed in the JHA make appropriate topics for weekly safety "tailgate" sessions.

Coordination

State of Alaska

A Fish Resource Permit (for scientific/educational purposes) from the Alaska Department of Fish and Game is required to capture fish for research or monitoring

U.S. Department of Agriculture Forest Service	1. WORK PROJECT/ACTIVITY	2. LOCATION	3. UNIT
JOB HAZARD ANALYSIS (JHA) References-FSH 6709.11 and -12 (Instructions on Reverse)	Coastal Grid Inventory	Coastal Alaska	AFSL
	4. NAME OF ANALYST	5. JOB TITLE	6. DATE PREPARED
	Chris Teutsch	Safety Officer	3/31/2003

7. TASKS/PROCEDURES	8. HAZARDS	9. ABATEMENT ACTIONS Engineering Controls * Substitution * Administrative Controls * PPE
*Backcountry Travel *	Disorientation	Retrace steps to last known point. Stay with partner. Consult map and gps. Use FM handheld radio, or satellite phone if you need outside assistance.
*Backcountry Travel *	Lost	Follow the same directions as outlined in the Disorientation section. Use radio, cell phone, or satellite phone for directions. Follow the seven steps for survival: 1. Recognition, 2. Inventory, 3. Shelter, 4. Signals, 5. Water, 6. Food, 7. Play. Remember that the international distress signal for help is three separate signs, such as three separate fires, shooting three flares, or transmitting three repeater signals over the radio. If you expect a rescue party to find you, make yourself as visible as possible. Stay in the open, Stay together in one spot, utilize your orange flight suit, orange field vest, flagging, or any other kind of markings such as forming S.O.S. letters on the ground with whatever is on hand.
*Backcountry Travel *	Exposure	Keep a set of dry, clean clothes with you. In the event of becoming wet and chilled, you will be able to change into something dry. Drink plenty of fluids through out the day. Stay with your partner. Field clothes should include rain gear, wool cap, mittens, long underwear, polypro. jacket. Keep your survival gear accessible. Follow the seven steps for survival outlined in the Lost Section.
*Backcountry Travel *	Bear Encounters	Familiarize yourself with USFS & ADF&G bear safety pamphlet: Bears and You. Always give bears the right of way. Avoid surprising bears by making noise, especially in dense brush. Carry approved firearms and/or bear repellent spray, and know how to use them effectively.
*Backcountry Travel *	Contaminated Water	Avoid drinking directly from any stream, lake, or spring water in non-emergency situations. Carry enough water for your trip, or if need be, sterilize by boiling, filtration, or chemical treatment (iodine) before consuming.

10. LINE OFFICER SIGNATURE	11. TITLE	12. DATE

Previous edition is obsolete

JHA Instructions (References-FSH 6709.11 and .12)

The JHA shall identify the location of the work project or activity, the name of employee(s) writing the JHA, the date(s) of development, and the name of the appropriate line officer approving it. The supervisor acknowledges that employees have read and understand the contents, have received the required training, and are qualified to perform the work project or activity.

Blocks 1, 2, 3, 4, 5, and 6: Self-explanatory.

Block 7: Identify all tasks and procedures associated with the work project or activity that have potential to cause injury or illness to personnel and damage to property or material. Include emergency evacuation procedures (EEP).

Block 8: Identify all known or suspect hazards associated with each respective task/procedure listed in block 7. For example:

  a. Research past accidents/incidents

  b. Research the Health and Safety Code, FSH 6709.11 or other appropriate literature.

  c. Discuss the work project/activity with participants

  d. Observe the work project/activity

  e. A combination of the above

  a. Engineering Controls (the most desirable method of abatement). For example, ergonomically designed tools, equipment, and furniture.

  b. Substitution. For example, switching to high flash point, non-toxic solvents.

  c. Administrative Controls. For example, limiting exposure by reducing the work schedule; establishing appropriate procedures and practices.

  d. PPE (least desirable method of abatement). For example, using hearing protection when working with or close to portable machines (chain saws, rock drills portable water pumps)

  e. A combination of the above.
copy of the JHA as justification for purchase orders when procuring PPE.

Blocks 11 and 12: Self-explanatory.

Emergency Evacuation Instructions (Reference FSH 6709.11)

Work supervisors and crew members are responsible for developing and discussing field emergency evacuation procedures (EEP) and alternatives in the event a person(s) becomes seriously ill or injured at the worksite.

Be prepared to provide the following information:

  a. Nature of the accident or injury (avoid using victim's name).

  b. Type of assistance needed, if any (ground, air, or water evacuation)

  c. Location of accident or injury, best access route into the worksite (road name/number). identifiable ground/air landmarks.

  d. Radio frequency(s).

  e. Contact person.

  f. Local hazards to ground vehicles or aviation.

  g. Weather conditions (wind speed & direction, visibility, temp).

  h. Topography.

  i. Number of person(s) to be transported

  j. Estimated weight of passengers for air/water evacuation.

The items listed above serve only as guidelines for the development of emergency evacuation procedures.

JHA and Emergency Evacuation Procedures Acknowledgment

SIGNATURE	DATE	SIGNATURE	DATE
Work Leader			

Figure 3—Example of a Job Hazard analysis form.

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STATE OF ALASKA
DEPARTMENT OF FISH AND GAME
333 RASPBERRY ROAD
ANCHORAGE, ALASKA 99518-1599

Permit No. SF-2005-079

Expires 12/31/2005

FISH RESOURCE PERMIT
(For Scientific/Educational Purposes)

This permit authorizes _Mason D. Bryant_ (whose signature is required on page 2 for permit validation)
person
of _USDA Forestry Sciences Laboratory_ at _2770 Sherwood Lane Suite 2A, Juneau, AK 99801_
agency or organization   address

to conduct the following activities from _April 20, 2005_ to _December 31, 2005_ in accordance with AS 16.05.930:

Purpose: 1) Evaluate coho salmon monitoring protocols. 2) Determine movement patterns of Dolly Varden and cutthroat trout in high-gradient streams

Location: 1) Coho monitoring protocols: Chichagof Island, Admiralty Island, Kupreanof Island, Kuiu Island, Prince of Wales Island. 2) Dolly Varden and cutthroat trout movement in high-gradient streams: Hobo2 Creek, Mitkof Island

Method of Capture: 1) Minnow traps. 2) Minnow traps and weir trap. (see **Permit Stipulations** section).
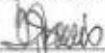
Species Collected and Final Disposition: 1) Any species and number of fish may be captured, recorded for length, weight, and then released live at the site of capture. 2) Any species and number of fish may be captured, recorded for length and weight, and then released live at the site of capture. All fish >60 mm fork length may be marked with PIT tags.

-Continued on Back-

REPORT DUE _January 31, 2006_ . The report shall include species, numbers, dates, and locations of collection and disposition, and if applicable, sex, age, and breeding condition, and lengths and weights of fish. The report shall also include other information as may be required under the permit stipulations section.

GENERAL CONDITIONS, EXCEPTIONS AND RESTRICTIONS

1.   This permit must be carried by person(s) specified during approved activities who shall show it on request to persons authorized to enforce Alaska's fish and game laws. This permit is nontransferable and will be revoked or renewal denied by the Commissioner of Fish and Game if the permittee violates any of its conditions, exceptions or restrictions. No redelegation of authority may be allowed under this permit unless specifically noted.

2.   No specimens taken under authority hereof may be sold or bartered. All specimens must be deposited in a public museum or a public scientific or educational institution unless otherwise stated herein. Subpermittees shall not retain possession of live animals or other specimens.

3.   The permittee shall keep records of all activities conducted under authority of this permit, available for inspection at all reasonable hours upon request of any authorized state enforcement officer.

4.   Permits will not be renewed until detailed reports, as specified above, have been received by the department.

5.   UNLESS SPECIFICALLY STATED HEREIN, THIS PERMIT DOES NOT AUTHORIZE the exportation of specimens or the taking of specimens in areas otherwise closed to hunting and fishing; without appropriate licenses required by state regulations; during closed seasons; or in any manner, by any means, at any time not permitted by those regulations.

Fish Resource Permit Coordinator
Division of Sport Fish

for Director
Division of Sport Fish

4-29-05
Date

Figure 4—Example of fish resource collection permit for scientific and educational purposes required for fish sampling.

projects. Permits are issued through the Division of Sport Fish and are issued annually. It identifies the primary investigator and others who will participate in the sampling procedures, purpose of the project, location, methods of capture, and the

target species and their disposition (fig. 4). A report of collecting activities is required within 30 days following the expiration of the permit before a new permit will be issued.

Ranger Districts

In most locations, ranger districts will provide the primary logistical support base for sampling operations. A letter to the district ranger explaining the purpose and goals of the project, what will be done, and how many people will be involved should be sent annually before the field season begins. Requests for logistical support such as housing in bunkhouses or vehicles should be submitted as soon as schedules are set and well in advance of the field season. It is important to follow up requests a few weeks in advance of planned trips.

Personnel and Equipment

Personnel

Having a trained crew familiar with conditions in southeast Alaska facilitates the work. Everyone in the crew may not have this experience; therefore, an experienced crew leader capable of training and working with field crews is important for efficiency and safety. A minimum crew of three people, one designated as the crew leader, was able to sample five streams during a 10-day sample period for the 3-year pilot study (table 2). A crew leader provides supervision for the crew, insures that vehicle arrangements and bunkhouse reservation are in place, prepares grocery and supply lists, and insures that all required field equipment is packed and loaded. The crew leader also arranges for field purchases in advance (i.e., procures credit card information). Individual crew members are responsible for their personal commercial air tickets, packing field gear, grocery shopping, and preparation of grocery lists. The crew leader insures that all members have completed required safety training, conducts "tailgate" safety sessions, and insures that safety protocols are followed. The crew leader coordinates contract flights with Forest Service dispatch and insures that daily check-in is made while in the field.

Equipment and Supplies

Fish population sampling and the habitat survey are separate activities and have separate equipment requirements. Both are conducted on the same stream reach but as independent activities. The most effective method to insure that all necessary equipment is on site is to maintain an equipment check list.

Table 2—Sample work schedule for 10-day work period to accomplish fish population and habitat sampling for the monitoring protocol

Day	Tasks
Day 1	Pack sampling gear and personal gear and travel to work site. Grocery shop and prepare bait for minnow traps.
Day 2	Travel to stream site and complete 4-pass depletion for population estimate.
Day 3	Travel to stream site and complete 4-pass depletion for population estimate.
Day 4	Complete habitat survey and cross sections on reaches previously sampled for fish populations.
Day 5	Travel to stream site and complete 4-pass depletion for population estimate.
Day 6	Travel to stream site and complete 4-pass depletion for population estimate.
Day 7	Complete habitat survey and cross sections on reaches previously sampled for fish populations.
Day 8	Travel to stream site and complete 4-pass depletion for population estimate.
Day 9	Complete habitat survey and cross sections on reach previously sampled for fish populations, clean camp and pack sampling gear and personal gear.
Day 10	Travel to Juneau, back up data, clean and repair sampling gear, complete timesheets, and travel vouchers.

The list in table 3 was used for the fish sampling part of the short-term pilot study. Important elements are the data recording equipment—an automatic data recorder with a formatted data sheet, a laptop computer, and associated hardware and extra batteries—fish sampling gear—minnow traps with 3.1 mm mesh (1/8 in), holding pens, buckets, dip nets, bait, and measuring equipment to obtain fork lengths (nearest millimeter) and weights (nearest 0.1 g).

Equipment required for stream habitat surveys is listed in table 4. The laptop computer may be used for both the fish population sampling and habitat survey. It is used to download and back up data collected each day in the field and resides at the field camp. The list for safety and maintenance equipment in table 5 provides for basic needs. Details for first aid kits and survival gear are generally available and may be modified to meet individual and local needs.

Table 3—Equipment list for fish population sampling

Equipment to capture and hold fish
    Minnow traps 1/8-in (3.1 mm) wire mesh (30 to 50)
    Spare clips and parachute cord for minnow traps
    Holding pen (net 1/8-in [3.1 mm] mesh)
    Blocknets (10- to 20-ft [5 to 10 m] with 5- to 15-mm mesh beach seines work well)
    Buckets, one 1-gallon, two 4- to 5-gallon
    Prepared bait packets with salmon eggs (180 to 200 per stream)
    Pack frames for minnow traps (20 to 40 traps will fit on a frame)
    Bungee cords (5 to 10) to secure traps to pack frames
Equipment to handle and measure fish
    Ms-222/ clove oil
    Aquarium style dip nets (3 to 4)
    Measuring boards (in mm)
    Electronic balance accurate to 0.1 g with extra batteries
    Scale envelopes and acetate strip for the scales
Equipment to record data
    Automatic data recorder such as Husky FEX2[1] with pre-programmed data sheet with
      backup batteries, and data storage
    Laptop computer (maybe same one used for backup of habitat survey
      data and usually is not taken to the field)
    Cable link to laptop computer
    Write-in-the-rain notebooks and pencils
Miscellaneous equipment and supplies
    Fish identification keys
    Blue/white flagging (to mark begin and end points on reach)
    Permanent waterproof ink markers (sharpie markers)
    Brass wire for trap repair
    Shoe goo (boot repair)
    Tweezers
    Day pack

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Table 4—Equipment list for stream habitat surveys

Supplies for stream location
    Maps and photos (U.S. Geological Survey [USGS] maps and aerial photos and
      ortho-photos) handheld global position system, extra batteries
    Permanent metal signs (to mark stream section if needed)
Equipment to measure stream habitat
    Fiberglass measuring tapes: One 100-m; two 30-m reels
    Electronic or laser distance measurers with extra batteries
    Compass
    Stadia rod (metric) with level
    Meter stick to measure depth
    Hand level (Abney) or auto level
    Tripod (if using an auto level)
    Survey stakes or pins
    Hip chain (metric)
    Extra hip chain string with extra string (approximately 1500 m)
    Gravelometer
    Digital flow meter or top-setting rod and current meter
    Thermometer
    Calculator
    pH meter
Equipment to record data
    Automatic data recorder such as Husky FEX21 with pre-programmed data sheet,
      with backup batteries, and data storage (i.e., flash disk) and instruction sheets for
      electronic data entry
    Habitat data sheets (waterproof) or hand-held computer data sheet
    Field notebooks
    Laptop computer (maybe same one used for backup of habitat survey data and usually
      is not taken to the field)
    Cable link to laptop computer
    Write-in-the-rain notebooks and pencils
    Hand counter for instream counts of wood debris or pebble counts
    Waterproof digital camera, extra rechargeable batteries
    Pencils, waterproof marking pens, extra pencil leads.
Miscellaneous equipment and supplies
    A copy of the habitat survey protocol
    Definitions of habitat
    Schematics of channel type classification system
    Maps and photos (USGS and GIS)
    Field instructions (e.g., this manual)
    Survey rebar, two pieces per stream
    Handsaw, brush cutter, or bow saw
    Blue and white flagging
    Hammer (for rebar)
    Nails

Table 5—Equipment list for safety and equipment maintenance

Safety and communication
    Field first aid kit (group and personal)
    Insect repellent
    Leather gloves
    Radio, with channel list, extra batteries, and charger
    Satellite phone (optional)
    Cell phone
    Waders
Maintenance and repair equipment
    Leatherman/pocket knife
    Duct tape
    WD-40
    Small tool kit with wrenches, pliers, electrical tape, vise grip, screwdrivers
    Paper towels
Bear country
    Rifle (.375 HH) with carrying case
    One box of bullets and field carrying case
    Cleaning kit

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Appendix 2: Fish Sampling Methods

The purpose of this appendix is to provide methods to conduct population estimates for the monitoring protocol. The equipment required for sampling is given in appendix 1, table 3. The removal method described in Bryant (2000) proved to be an effective method to estimate the number of juvenile coho salmon (*Oncorhynchus kisutch*) and associated species in stream reaches during the short-term pilot study. One of the primary advantages was that population sampling could be completed in 1 day for a sample site. Minnow traps are an effective capture method for juvenile coho salmon, Dolly Varden (*Salvelinus malma*), and other juvenile salmonids in southeast Alaska streams. (Bloom 1976, Dolloff 1987, Elliott 1976)

Preparation

Minnow traps with 3.1-mm (1/8-in) mesh are required to effectively capture coho salmon fry, which may escape or become trapped in larger sized mesh. About 2 m of parachute cord is attached to each minnow trap. Colored flagging attached to the end of the cord makes it more visible and easier to find when set in the stream. All traps should be inspected before taken to the field and each time they are used to insure that they have clips and are not broken.

Salmon eggs, which may be obtained from various fish processors, are used as bait. The eggs are sterilized with betadyne. Borax is added as a preservative and slow-release activator that helps release the egg scent at a controlled rate. The salmon eggs are soaked in a 1:100 betadyne to water solution for 10 minutes. After soaking, the eggs (skeins) are drained and the skeins are rolled in borax. These can be frozen in bulk, usually 1-gal plastic bags, and thawed for later use.

About 1 to 2 tablespoons of eggs are used for each trap. The small amount of eggs is placed into a 2-oz whirlpak. After the whirlpak is closed, it is perforated with a pointed dissecting needle or scalpel. Use care not to over-perforate the whirlpak (the goal is to allow the scent to move through the water column slowly and prevent fish from eating the eggs). The bait may be prepared while the eggs are frozen, but should be thawed before they are used. The bait packets can be stored in a ziplock or spill-proof bag and frozen or refrigerated if they are not going to be used immediately. Egg preparation can be a messy task, and use of rain gear and disposable gloves is recommended.

Sufficient egg packs need to be prepared before sampling. Bait is replaced after each sampling occasion (i.e., each time a trap is set and recovered). If four

sampling occasions are used for a sample reach and 40 traps are set, then 4 x 40 = 160 bait packs are required for the reach.

Sampling Procedure

During the initial sampling period, the stream reach is marked and its location recorded using a global positioning system (GPS). The starting point for the reach is selected by randomly choosing a pool 1 to 10 pool-riffle sequences from a known starting point, such as a road crossing, tributary junction, or other landmark. This establishes the permanent sample reach for the monitoring period. The reach is marked with permanent markers—metal stakes and signs attached to trees—and temporary markers such as blue and white flagging for ease in locating the site. The reach should be at least 100 m long; a longer section may be used if it can be adequately sampled for a population estimate in 1 day.

Trapping Fish

Before the traps are set, block nets (usually 6.2-mm [¼-in]-mesh beach seines) are set on either end of the reach to prevent fish moving into or out of the sample reach. A sufficient number of traps should be set to saturate the stream reach. The objective is to capture as many fish as possible, and the density of traps set can vary depending on the complexity of the reach and stream conditions. For example, two to three traps may be set in a complex pool, whereas, one trap may be set in a scour pool in the middle of a riffle section 2 to 4 m long. Traps should be counted before they are set and after they are picked up at the end of the last sample session for the reach to insure that none are left in the stream.

The time the first trap is set is the start time for each sample occasion. The traps are left in the water for at least 60 minutes and no longer than 90 minutes. The traps are picked up in the order in which they were set. If two people set traps, each person should begin with the traps that they set. As the traps are picked up, fish are removed from the trap and placed in a bucket. The bait is replaced with a fresh pack, and the trap is returned to the same location in which it was set. This is important to insure equal sampling effort over all sampling occasions.

After the traps are set for the first time, a central location where fish can be processed is selected and set up. A holding pen for fish is required to retain fish alive and in the stream for the duration of the sampling procedure. The holding pen should be placed outside of the sample reach. Metadata should be entered on the data sheets before recording fish data, and data sheets should be prepared to receive data when fish from the first sample occasion are retrieved. The balance for taking

weights is set up and calibrated at this time. Buckets with water and anesthetic solution are prepared before fish are collected. Water and anesthetic solution may need to be refreshed at various points during the procedure.

After fish are retrieved from each sample occasion, they are identified by species and measured to the nearest mm (fork length). Fish are identified by sample occasion on the data sheet. A subsample of about 20 percent are weighed. The subsample should be distributed over all size groups. It will be used to determine length-to-weight relationships. Scale samples may be taken to verify age distribution. After fish are processed from each sample occasion, they are placed in a holding pen and are not returned to the stream until all traps from the last sample occasion are retrieved. After the last sample occasion has been completed, all fish are returned to the stream. It is a good idea to disperse them more or less evenly over the length of the reach.

Data and Analysis

All fish data must be associated with a metadata file that provides, at a minimum, the location identified by GPS, date and time, method of capture, last names of crew, and weather and air and water temperature (table 6). In the list of the data collected on each fish captured in the pilot study (table 7), the TrapHdrID entry matches the metadata associated with the sample reach (table 6). In the fish data sheet, each row is associated with an individual fish captured. In the example data shown in table 7, the fish was a coho salmon that was captured during the first capture occasion. It was 56 mm long (fork length) and weighed 2.1 g. No scale was taken and it was released alive. The exception to the "one row, one fish" entry may occur when a large number of fish (usually coho salmon fry) are captured and time precludes measuring each fish. To reduce handling, the first 100 fish in a year class are measured, after which the rest of the fish are identified by species and size class (i.e., coho fry) and counted. The total number of fish counted is entered in the COUNT column and the size class, for example, coho salmon fry (COF), is entered in the size class column.

The data for variables listed in table 7 must be summarized for computation of the population estimates. The estimate is computed from the total number of fish captured in each sample occasion. Estimates are made for coho salmon fry (COF) and parr (COP) separately. The fish captured in each sample occasion are summed by species (and, in the case of juvenile coho, by age group) for each stream reach (table 8). Coho salmon fry and parr are separated on the basis of length frequency distribution of all fish from the 10-day sample period, and usually for midsummer

Table 6—Example of entries for metadata for the stream reach

Variable name	Description	Example of data entered
TrapHdrID	Unique identifier for stream and sample type. CM =coho monitoring; F= fish; 53 =data set 53.	CMF53
Date	Month/day/year	6/16/2005
MRDC	Type of population estimate (mark-recapture or depletion)	DEPLETION
Stream	Name of stream	SWITZER
Site	Location within stream	Reach 1
Stream-reach code	Unique identifier for stream and reach	SWIT1
LatLong	GPS latitude and longitude	N 58 21' 47.3" W 134 30' 2.7'
ChannelType_2001	Channel type (Paustian 1992)	MM1
Air Temperature C	Temperature at start of sample	15
Water Temperature C	Temperature at start of sample	7
Stage	Qualitative estimate of bankfull stage	MOD =Moderate
TrapsSet	Number of traps set in reach	38
Length of Set	Length of time trap set	1HR
Length	Length of the sample reach (meters)	157.4
Weather	General description of weather	PC = Partly cloudy
Gear	Type of gear used to capture fish	MINTRAP=minnow traps
RecorderID	Name of person recording data	HELLER
Crew1	Name of crew member	GREEN
Crew2	Name of crew member	TRUESDELL
Crew3	Name of crew member	WRIGHT
TrapHdrComments	Comments on events affecting sample	PINKS IN STREAM

Table 7—Example of entries for fish data

Variable name	Description	Example
TrapFshID	Identifies unique fish	
TrapHdrID	Code to associate metadata	CMF53
PASS_NUM	Number of sample occasion for depletion estimate; 1, 2, 3, or 4	1
SP	Species of fish	CO
FL	Fork length of fish in mm	56
MWT	Weight of fish to nearest 0.1g	2.1
SCALE	Enter Y if scale is taken	
MORT	Enter 1 if fish is dead or dies during sample procedure	
COUNT	Enter integer number of total number of fish (identified by species) that were counted without further processing. Used when overwhelming number of coho fry are captured.	
SIZECLASS	Used in association with COUNT. For example, enter fry (COF) or parr (COP) depending on the group counted	
TrapFishComments	Comments associated with the particular fish	

Table 8—Example of data summary used to estimate population numbers by reach/stream using the removal method

Stream	Species	Sample occasion			
		1	2	3	4
		Number of fish captured			
Ancient Creek	COF	88	54	66	53
	COP	15	8	4	4
	CT	10	4	2	0
	DV	11	3	4	2
Beach Creek	COF	64	25	16	4
	DV	64	25	16	4
Cedar Creek	COF	85	15	10	5
	COP	12	2	0	0
	DV	5	3	2	1
Double Park Creek	COF	107	70	40	25
	COP	38	5	4	3
	CT	11	3	3	0
	DV	32	12	7	6

COF = Coho salmon fry; COP = coho salmon parr; CT = cutthroat trout;
DV = Dolly Varden; SH = steelhead.

the separation occurs at about 60 mm. Figure 5 provides an example. Population estimates are computed from the number of fish captured in each sample occasion.

Population estimates for the pilot study were computed using the Capture program described in White et al. (1982). They discussed the assumptions and details of the methods and provided several examples of its use. The generalized removal method provides a test of constant capture probability (the probability of capturing any given fish during the sample occasion) among sample occasions (n) when n >3 and was used for the pilot study for all instances where n >3; however, in most cases, a constant capture probability could be used. More recent versions of the program are available at www.warnercnr.colostate.edu/~gwhite/software.html. The site provides a wide range of population dynamics models and large set of programs. The Generalized Removal Program is embedded in the Capture program, which may be found on the Web site and downloaded at no cost. Contacts for the program and an interactive version, 2Capture, are also provided.

The version of Capture used in the pilot study was a FORTRAN-based program and requires a specific data input format (fig. 6). The first line in figure 6 is the title and identifies the specific location, site, and species (and any other information) for the sample site. It is enclosed in single quotes. The second line identifies the specific program used to compute the estimate; in this case it is "Population Removal," which is the generalized removal method. The third line gives the number of sampling occasions; in this case, four sample occasions (i.e.,
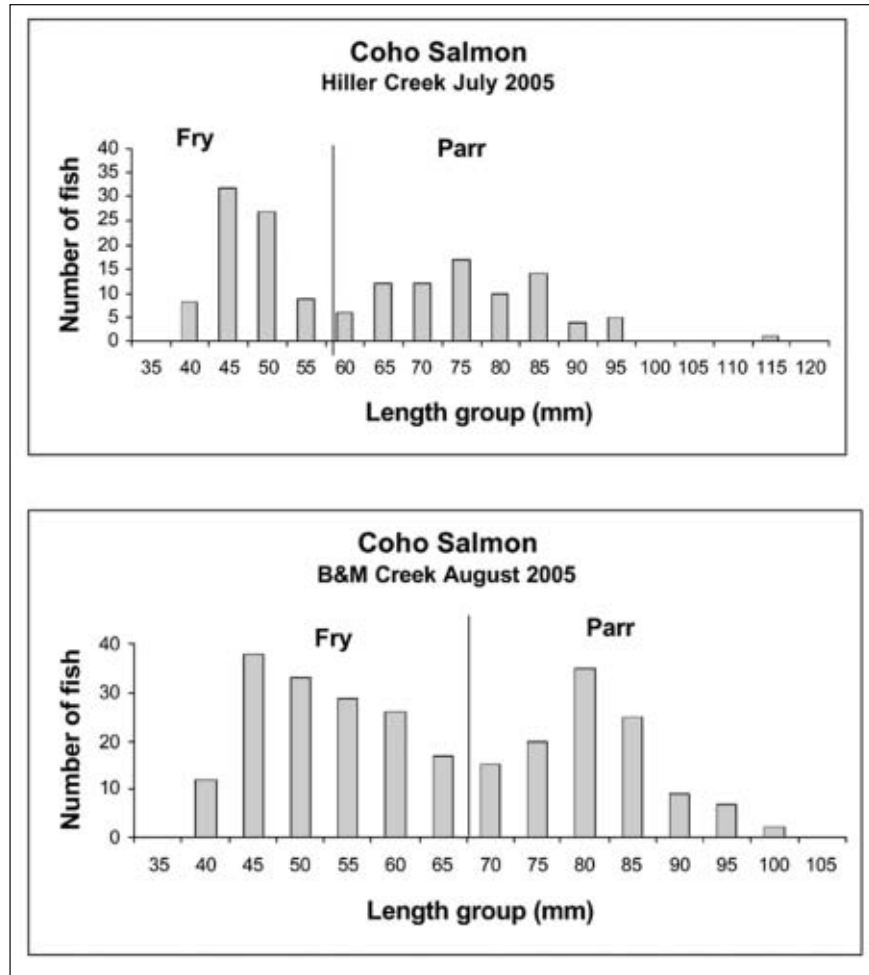
Figure 5—Examples of length frequency distributions used to separate coho salmon fry and coho salmon parr.

traps were set four times) were made in the reach. The last line is the number of fish captured in each removal sample. When four sample occasions are used, the assumption of equal probabilities of capture between the first occasion and subsequent occasions is tested.

The output from the program shown in figure 7a and b provides the results from the Capture program. In the output example, k = 1 for equal probability of capture (p-bar) for all sample occasions and k = 2 for p-bar not equal. In the example for Trap Creek CCA2 Pool 2 COP, Chi square tests that p-bar are equal, and $\chi^2 = 0.0398$ and is less than $\alpha = 0.10$; therefore, the assumption of equal p-bar between the first and later sample occasions is rejected and the estimate for k = 2 of 108 fish is used (fig. 7a). The 95-percent confidence interval is skewed and ranges from 96 to 176. In the example for Trap Creek CCA5 Pool 11 COP, $\chi^2 =$

```
Title='Trap Creek CCA2 Pool 2
COP'
Task Read Population Removal
4
56 14 15 7
Title='Trap Creek CCA5 Pool 11
COP'
Task Read Population Removal
4
15 11 5 4
End
```

Figure 6—Example of data input for Capture
program producing output shown in figure 7.

0.7496; therefore, the assumption of p-bar equal between sample occasions is not rejected, and the estimate for k = 1 of 39 fish is used (fig. 7b).

The probability of capture (p-bar) is derived from the number of fish captured in each successive capture event and is an estimate of the independent probability of capturing an individual fish (White et al. 1982). It also represents the precision of the estimate. As p-bar increases, the range of the 95-percent confidence interval decreases. It also indicates how well the removal method worked for that particular sample effort. In some cases, the number of fish captured during successive sample occasions may not decrease,[1] in which case an estimate can not be computed and is listed as a "failure" in the output. These clearly can not be included in the analysis. Less clear is the problem of estimates that may have large confidence intervals. During the pilot study, estimates that returned values of p-bar < 0.25 were excluded from the analysis and were treated as missing values, as were those that "failed." Over the course of the study, less than 10 percent of the estimates were excluded. Careful execution of the sampling protocol and attention to the assumptions of the method can minimize missing data.

---

[1] Failures can be the result of incomplete sampling of a section (i.e., not enough traps, or traps improperly set), recruitment of new fish between sampling occasions, or any other of a number of causes that violate the assumptions of the removal method (see White et al. 1982).

```
Mark-recapture population and density estimation program
Program version of 30 Jun 1992      2-Oct-**
Trap Creek CCA2 Pool 2 COP

Population estimation with variable probability removal estimator.
See M(bh) or removal models of the Monograph for details.

Occasion      j=  1  2  3  4
Total caught  M(j)=   0  56  70  85  92
Newly caught  u(j)=   56  14  15  7

k   N-hat  SE(N)  Chi-sq.  Prob.   Estimated p-bar(j),j=1,..., 4

1   96.28   3.23    6.45 0.0398  0.528 0.528 0.528 0.528
2   108.40  16.6    1.67 0.1963  0.517 0.315 0.315 0.315


Population estimate is     108 with standard error   16.5797

Approximate 95 percent confidence interval     96 to      176

Profile likelihood interval     94 to greater than     2160

Histogram of u(j)


Frequency    56  14  15   7
-----------------------------------
Each * equals   6 points

    54      *
    48      *
    42      *
    36      *
    30      *
    24      *
    18      *        *
    12      *    *    *
     6      *    *    *    *
-----------------------------------
```

Figure 7a—Sample output of population estimate with four capture occasions and unequal probabilities of capture using data in figure 6.

```
Mark-recapture population and density estimation program
Program version of 30 Jun 1992      2-Oct-**

Trap Creek CCA5 Pool 11 COP

Population estimation with variable probability removal estimator.
See M(bh) or removal models of the Monograph for details.


Occasion       j=  1  2  3  4
Total caught   M(j)=  0  15  26  31  35
Newly caught   u(j)=  15  11  5  4

k    N-hat  SE(N) Chi-sq.  Prob.   Estimated p-bar(j),j=1,..., 4

1    39.25  4.31    0.58 0.7496  0.412 0.412 0.412 0.412
2    37.25  3.40    0.70 0.4044  0.403 0.503 0.503 0.503


Population estimate is      39 with standard error    4.3116

Approximate 95 percent confidence interval      36 to      57

Profile likelihood interval      35 to      62

Histogram of u(j)




Frequency    15  11  5  4
------------------------------------
Each * equals   2 points

    16     *
    14     *
    12     *   *
    10     *   *
     8   *   *
     6   *   *   *
     4   *   *   *   *
     2   *   *   *   *
```

Figure 7b—Sample output of population estimate with four capture occasions and equal probabilities of capture using data in figure 6.

The next step is to create a data set from the population estimates that can be merged with the habitat data. The first step in the process is to screen the data and insure that all entries are correct. The population estimates are standardized for all reaches by converting them to density estimates. The population estimate is divided by the total area of the reach. Total area is computed by multiplying the reach length by the average channel bed width. An effective method to merge the fish density data with the habitat data is to create a common stream and reach code for each data set. The files can be merged on the common stream reach code into one data set.

Appendix 3: Habitat Survey Methods

The variables measured and methods used in the stream surveys in the pilot study and those for this protocol are described in the Fish and Aquatic Stream Habitat Survey in the *Aquatic Ecosystem Management Handbook* (USDA FS 2001). The variables and methods used in the handbook evolved from extensive field testing to insure consistency and repeatability. Other considerations included their potential influence on salmon distribution and abundance, and relative ease in collection. The stream habitat survey methodology used for this protocol are from the tier III survey in the handbook. The purpose of this appendix is to describe the measurements used in this protocol and how to collect the habitat data for the protocol.

Preparation

Most of the methods used in the protocol are relatively straightforward; however, all members of the field crew need to be familiar with the methods in the Fish and Aquatic Stream Habitat Survey (FSH) and know how to apply the methods described in this appendix. Each crew member must know how to read metric tapes and stadia rods, and operate the other instruments such as handheld geographic positioning systems (GPS), flowmeter, Abney level, and electronic data collector. Each crew member needs to know how to use and enter data on the data sheets, either paper or electronic, used in the survey.

Practice sessions using all equipment in the field by the entire crew are critical. We recommend a minimum of two practice sessions for each of the required segments of the habitat survey using all the equipment necessary for all the parts of the survey (cross section, pebble count, pH, flow, and habitat). This is a good time to test all of the equipment. It is important that all crew members are familiar with proper care and maintenance of the equipment and that it is checked each time before a field trip.

Most of the equipment listed in table 4 are common measuring or recording implements. Tapes, stadia rods, and distance measuring equipment are all metric. As much as possible, all electronic equipment should be waterproof. The gravelometer is a unique piece of equipment and is used to determine substrate size. The gravelometer is a template with square holes of common sieve sizes (usually 8 to 128 mm) that is used as a hand-sieving device to sort particles in the field (fig. 8) (Petrie 1998). Substrate is measured by passing the individual particle through the smallest possible opening in the template.
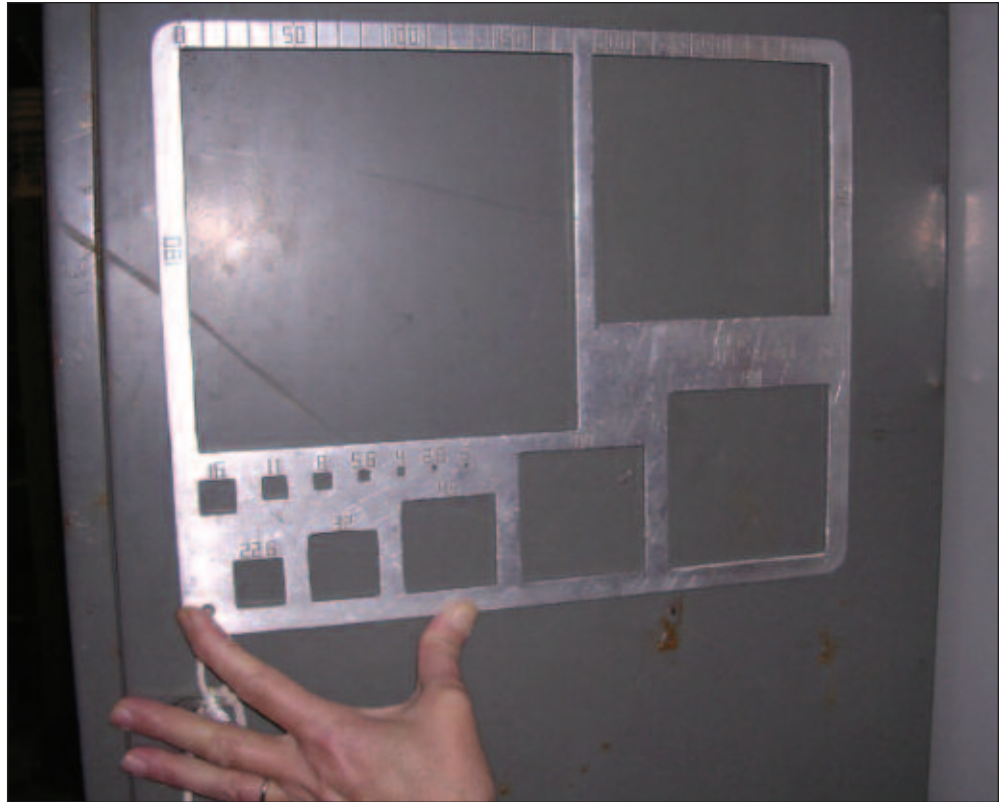
Figure 8—The gravelometer used to determine particle size during stream habitat survey (USFS photo).

Conducting the Survey

The start and end points of the sample reach are identified and marked before fish are sampled and are in place before the habitat survey begins. The start and end points are marked with "permanent" stakes that can be identified throughout the monitoring period. The survey is done at moderate or low-flow stages. In general, begin the habitat survey at the downstream end of the site. Working upstream decreases the turbidity that may obscure underwater wood pieces or mask pool tail crests.

The habitat survey is like a slow-moving parade up the stream. The first step in habitat survey is to measure at least three channel bed widths within the site that are at least five channel bed widths apart. For example, if the first channel bed width is 5 m across, then the next measurement will be at least 25 m from the first one. One crew member attaches one end of a hip chain to a secure object at the start point of the survey to record reach distance along the thalweg (lowest point of the channel) of the stream. Metadata are recorded and criteria for pools and large

wood are determined. As the survey progresses upstream, the crew determines the habitat type. The length, widths, depths (for pools), dominant substrate, large wood pieces, key large wood pieces, wood clusters, and presence of disturbance or other unusual features are recorded. Cross-section measurements and pebble counts can be completed concurrently with the stream measurements if there are enough people in the crew, otherwise they are completed at the end of the survey.

In the pilot study, we found that assigning the same job to one person for an entire stream survey improves consistency. For example, always have the same person record data, measure undercut bank, and count large wood for an entire site. The data recorder begins the survey by entering the metadata for the site.

The Data

Metadata

Metadata consist of the stream name, date, channel type, and location from GPS (latitude and longitude), water and air temperature, average channel bed width, minimum residual depth for pools, person recording information and members of the crew, flow, pH (optional), and, in the remarks section, buffer width and other relevant information. The minimum residual pool depth and average channel bed width are calculated from the three channel bed width measurements made by the crew on the day of survey as the metadata are entered. A sample paper data sheet for tier III survey includes definitions for data in each column (fig. 9).

Channel bed width is the distance between the bottom of the left bank and the bottom of the right bank. It is important to measure the initial channel bed width at a place where the channel is straight and the banks are nearly vertical with no undercut bank. After the first measurement, the crew proceeds into the survey area to collect at least two more measurements that are at least five channel bed widths apart. The average channel bed width (ACBW) is computed from the average of three (or more) channel bed width measurements (table 9). The ACBW is then used for calculating minimum residual depth (MRD) and size classes for key pieces of large wood. The ACBW multiplied by 0.01 m + 0.15 m is the MRD criteria for pools. For example, if the ACBW width is 5 m, then MRD is (5 m x 0.01 m) + 0.15 = 0.20 m.

All pieces of wood at least 0.10 m in diameter and 1 m long that are in the water or within bankfull are tallied. Key pieces of wood are a special case of the large wood count. Key piece size is adjusted for ACBW of the stream (table 10). In our example of a stream with ACBW of 5 m, a key piece of wood is any piece

Figure 9—Sample data sheet used to record habitat data for tier III habitat surveys.

Table 9—Habitat measures (covariates) derived from stream habitat survey

Habitat variable	Abbreviation	Units	Computation
Average residual depth	ARD	Meters	Σ (pool maximum depth - pool tailcrest depth)/ number of pools
Average channel bed width	ACBW	Meters	Σ (channel bed widths)/number of measurements
Width-to-depth ratio	WD	Scaleless	Bankfull width/hydraulic depth
Substrate size	d_{50}	Scale	Substrate diameter value corresponding to the 50th percentile of the cumulative frequencies of the substrate measured
Proportion of undercut bank	PUCB	Scale	Σ undercut bank length/length of survey
Total pieces of large woody debris (TLWD) per meter	LWDM	Number per meter	TLWD/length of survey
Total pools (TPOOL) per meter	POOLM	Number per meter	TPOOL/length of survey

Table 10—Large wood key piece categories based on average channel bed width

Channel bed width	Piece diameter	Piece length	Rootwad diameter
		Meters	
0.0 - 4.9	0.30	> 3.0	>1
5.0 – 9.9	0.30	> 7.6	>3
10.0 - 1 19.9	0.60	> 7.6	>3
> 20.0	0.60	> 15	>3

greater than 0.3 m in diameter and 7.6 m in length or a rootwad greater than 3 m in diameter. Total wood count includes key pieces.

Streamside buffers are designated by width from the stream channel to adjacent timber harvest units. They include 0 width (no buffer), < 30 m, 30 to 60 m, > 60 m, and no harvest. The buffer width is measured for either or both banks depending on timber harvest. Buffer width should be determined from the edge of the bankfull channel or side channel to the stump.

Temperatures are recorded in Centigrade. Long-term monitoring may include year-round automatic temperature recorders. Several brands are available and contain sufficient memory to record data for a year.

Stream Data

Six habitat types are used in the tier III habitat survey, three pool types and three fastwater types (table 11). Most pools are scour pools and most fastwater units are riffles. Pools are separated from fastwater habitat units by three criteria. A habitat unit must meet all three criteria to be recorded as a pool. Pools have a unique hydraulic control, depth criteria (MRD), and minimum size (>ACBW x 0.1).

Table 11—Stream habitat units used in tier III stream surveys

Macro-scale	Meso-scale (tier III)
Pool	Backwater
	Scour
	Slough
Fastwater	Glide
	Riffle
	Cascade

Source: USDA FS 2001.

Use the hip chain to determine length of all habitat units. Note the hip chain distance for the start of the unit and proceed upstream. Keep the hip chain as close to the thalweg as possible by attaching the string to vegetation or debris in the channel near the thalweg. Record the hip chain distance at the end of the habitat unit. Wetted widths are measured for all habitat units. Fastwater wetted width is measured at the top and bottom. Pool average wetted width requires one or more measurements. Irregularly shaped pools need at least two widths. Maximum and pool tail crest depths are recorded for each pool. Maximum pool depth is located by probing around the pool until the deepest point is located. Pool tail crest depth is the maximum depth along the pool tail normally (not always) at the thalweg.

Dominant substrate is estimated by choosing the most common pebble size in the habitat unit and determining that size with the gravelometer (fig. 8). The size of the smallest hole the pebble will pass through is recorded.

All pieces of wood within the water or bankfull area of the channel that meet the minimum size criteria (0.1 m diameter and 1 m or greater in length) are tallied. For further criteria on living or dead standing trees and rootwads see the FSH handbook (USDA FS 2001). Key pieces, size determined by average channel bed width, are counted in total large wood and also in a separate category (table 10). Tier III survey also requires a tally of wood clusters. A wood cluster is where five or more wood pieces are all touching. The two categories of clusters are 5 to 9 pieces touching or 10 or more pieces touching.

Undercut bank is measured in whole meters for both banks of the stream whether wet or dry. The undercut bank must be >0.30 m deep and >1 m long to qualify (fig. 10).

Disturbance of the streambank is noted during the habitat survey. The location of the disturbance (left or right facing downstream), type, and length is recorded. The five categories of disturbance are blowdown or windthrow, eroding bank, road, mass movement, and "other" (fig. 9). In some areas, extensive blowdown may
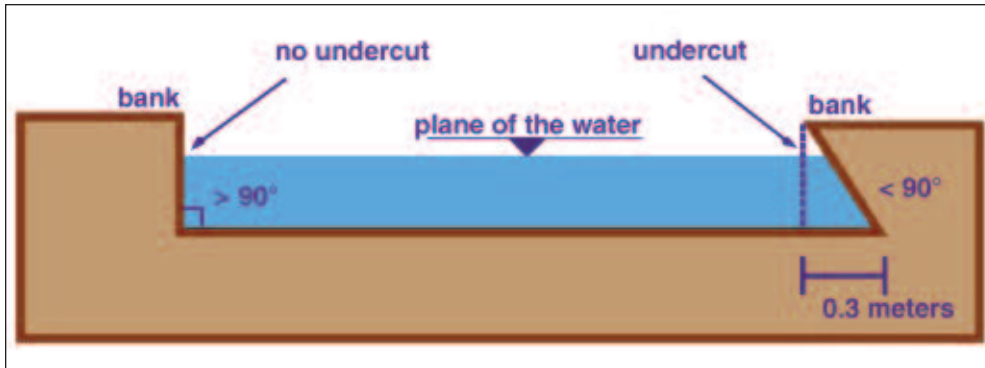
Figure 10—Diagram of stream cross section showing criteria for undercut banks (USDA FS 2001).

occur. The information would be recorded as right, left, or both banks, BD for blowdown, and total length of stream affected. Disturbance may extend over multiple habitat units.

Side channels are also surveyed if they fall within the long-term monitoring reach. Side channels are defined as channels connected to the main channel that receive flow from the main channel and are not within bankfull of the main channel. All of the measurements made in the main channel are also taken in the qualifying side channels. The column for location on the data sheet is noted as SC (side channel) to differentiate from the main channel habitat units.

The total length of the habitat survey is the total distance along the stream thalweg. Length of stream is determined by subtracting the first distance on the hip chain (0 m) from the final distance. This distance is used to standardize the comparison of pool and wood counts among streams.

A complete habitat survey also includes a cross section and pebble count. It is critical to choose the best site possible for the cross section within the study area. It is permanently marked so that future cross sections can occur in the same location. The pebble count occurs at the cross section. The FSH handbook describes the necessary procedure in detail (USDA FS 2001). The minimum information needed from the cross section is bankfull depth and thalweg depth. Pebble counts must include 100 pieces of substrate.

Width-to-depth ratio is calculated from the cross-sectional area data. Maximum depth is taken at bankfull (USDA FS 2001: 12), and thalweg and width is measured at bankfull: width-to-depth ratio = bankfull width / maximum bankfull depth. The Alaska Region (Region 10) suggests the use of the WinXSPro software for precise calculations (Hardy et al. 2005).

Substrate d_{50} is calculated from the pebble count that occurs at the same location as the stream cross section. It is the substrate diameter value corresponding to the 50th percentile of the cumulative frequencies of the substrate measured. For each pebble count, a sample size of 100 particles is generally sufficient to consistently measure the median grain size (d_{50}) of a specific gravel patch or graph the cumulative frequency distribution (Harris 2005). A cumulative frequency distribution can be computed and graphed by using a published spreadsheet program such as "Size-ClassPebbleCountAnalyzer2001.xls" (Potyondy and Bunte 2002). There are also copyrighted and some freely distributed spreadsheet templates on the internet.[1] To compare numerous sites and successive years of data, graph the summaries in box and whisker plots. Examples of cumulative frequency distribution curves and box and whisker plots may be reviewed in Kondolf (2000).

The habitat survey is summarized and seven parameters are calculated from the survey data. They are pools per meter, substrate d_{50}, total large wood pieces per meter, total key large wood pieces per meter, width-to-depth ratio, residual pool depth/average channel bed width, and pool length per meter (table 9). Substrate d_{50} is calculated from the pebble count. Width-to-depth ratio is calculated from the cross-sectional area data with WinXSPro software.

Large wood, key pieces, and pool length are summed and divided by total survey length to calculate total large wood pieces per meter, total key large wood pieces per meter, and pool length per meter. Pools per km is the total number of pools identified divided by total survey length in kilometers. Residual pool depth is calculated by subtracting the pool tail crest depth from the maximum pool depth. All of the pool residual depths are then averaged and divided by the average of all of the channel bed widths taken during the survey. Pool spacing was dropped from Region 10 summary analyses.

The crew leader checks the data every day for accuracy and completeness. Then data are backed up either electronically or (if paper) copied. When using an electronic data recorder, transfer the daily files to another computer and make a backup copy on disk or external memory stick. When the paper data are correctly formatted, check for typos or omissions.

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[1] Size-Class Pebble Count Analyzer V1 2001.xls by John Potyondy and Kristin Bunte http://www.stream.fs.fed.us/publications/PDFs/Size-ClassPebbleCountAnalyzer2001.xls (September 13, 2007).
PebbleSort, Particle Size (Ptxsize). (Lehre 1993)
www.humboldt.edu/~geology/courses/geology531/531_macros_templates_index.html (October 5, 2007).
The reference reach spreadsheet Version 2.2 L by Dan Mecklenburg:
http://www.dnr.ohio.gov/soilandwater/water/streammorphology/ (October 5, 2007).

Data and Analysis

The data must be associated with the metadata for each stream survey reach. Both the metadata and the survey data are screened to insure that all entries are correct and to identify outliers. The habitat data file with the seven variables listed in table 9 can be merged with the fish density data by using a common stream and reach code for each data set.

If the data will be transferred to a regional or national database, the formats and definitions must be consistent with the larger database. This will be easier if the data sheets (paper or electronic) are initially prepared to ensure compatibility with the larger database.

Quality Assurance and Quality Control (QA/QC)

A well-trained crew is the basic element for data that are accurate and consistent. A 2-week training period with an experienced trainer worked well for the pilot study. During this period, the crew conducted repetitive stream surveys and several iterations of fish population sampling, to include field identification of fish species. In the pilot study, the trainer was an individual with several years of experience designing and conducting stream habitat surveys. The reference for stream habitat surveys is FSH handbook (USDA FS 2001).

Although habitat variables used in the protocol are measurable, are well-described in the FSH handbook, and most have been shown to be reasonably consistent Roper et al. (2002), periodic checks can provide an assessment of consistency. Throughout the season, a duplicate survey of a subsample of the streams in the monitoring set will provide a consistency check. The second survey is best conducted by an independent crew if more than one crew is used in the monitoring effort. If a single crew is used for the season, the second survey may be done by different crew members. For example, the person recording the data would do the measurements for the second survey. There are no set criteria for consistency comparisons; however, relatively simple statistical tests (i.e., t-test) may be applied to determine if significant differences occur between crews. Comparison of results during the season may identify inconsistencies that can be corrected through additional training or better definitions of criteria. Persistent inconsistencies may indicate that the habitat measure is not reliable.

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Appendix 4: Statistical Power Analysis

This appendix contains methods and results of the power analyses designed to estimate number of streams needed in each treatment group to achieve 80 percent power.

Sample size (number of streams) required to detect a 5-percent annual trend with 80-percent power is based on testing the hypothesis H_0: $\beta_1 = 0$ versus the one-sided alternative H_1: $\beta_1 < 0$ in the following linear regression: $y_i = \beta_0 + \beta_1 x_i$, where y_i is fish density and x_i is year. Errors in this regression model were assumed to be correlated through time if they occurred on the same stream. Sample sizes were the same if we had tested H_1: $\beta_1 > 0$. Trend is detected if the null hypothesis of no trend is rejected in favor of H_1.

Assuming σ^2 is known, the null hypothesis H_0: $\beta_1 = 0$ will be rejected if the statistic $\mathbf{t} = \hat{\beta}_1 / \sigma_{\beta,n}$ is less than the $(1-\alpha)^{\text{th}}$ quantile of a T distribution with $m = (10n - 2)$ degrees of freedom where n = sample size and 10 is the number of years. The standard deviation of trend, $\sigma_{\beta,n}$, is the square root of the second diagonal element in the variance-covariance matrix,

$$\sigma_{\beta,n} = \sqrt{\sigma^2 \, (\underset{\sim}{X}' \underset{\sim}{R}^{-1} \underset{\sim}{X})^{-1}}$$

where $\underset{\sim}{R}$ is the (block diagonal) correlation matrix for observations measured on the same stream through time. Streams were assumed to be independent. The correlation between observations made in consecutive years was estimated as the lag 1 autocorrelation in densities observed during a separate 18-year study of a stream on Prince of Wales Island. Assuming this lag 1 autocorrelation was ρ, the correlation of observations separated by k ($k \geq 1$) years was assumed to be ρ^k.

Assuming the random variable $\hat{\beta}_1$ follows a non-central T distribution with mean $\Delta = (0.05) \overline{Y}$ (= observed annual change of 5 percent of the original mean density) and variance $\sigma^2_{\beta,n}$, we calculate sample size as the smallest n such that

$$\Pr\left[\frac{\hat{\beta}_1}{\sigma_{\beta,n}} < t_{m,0.1}\right] = \Pr\left[\frac{\hat{\beta}_1}{\sigma_{\beta,n}} - \frac{\Delta}{\sigma_{\beta,n}} < t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}}\right] = \Pr\left[T_m < t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}}\right] = 0.8$$

where T_m follows a central T distribution with m degrees of freedom, and $t_{m,0.1}$ denotes the critical value in a central T distribution corresponding to a test of size alpha = 10 percent (Pr indicates probability within the parentheses). Letting $t_{m,0.8}$ denote the value of the central T distribution such that 80 percent of its area is to the left, sample size to obtain 80 percent power is calculated as the smallest value of n satisfying

$$t_{m,0.1} - \frac{\Delta}{\sigma_{\beta,n}} = t_{m,0.8} \, .$$

Note that n denotes the number of streams in a given treatment and the "total sample size" is $10n$ after 10 years. The estimate of residual error carries $m = 10n - 2$ degrees of freedom. The above analysis is conducted for the harvest treatment (TLMP) and an old-growth control (OG).

Testing for a significant difference in the trends (slopes) between two treatments of streams is more difficult because two parameters are involved. We define OG to be the reference (control) and determine the sample sizes necessary to detect a difference between OG trend and the trend on the TLMP treatment. This analysis fitted separate linear regressions (of the above form) to data from OG and TLMP streams. Assuming true slope on OG streams is β_{OG} and true slope on TLMP streams is β_T, this method tested for a difference in slopes using a t-test procedure. Although primary interest is in comparison of TLMP treatment to the OG control, recommended sample sizes will be appropriate for comparing any pair of the treatment combinations.

For example, if the slope of the OG control is 0.0 and the trend of the TLMP treatment is a decrease of 5 percent per year (equal to -0.05 ($\overline{Y}_{TLMP}$) coho fry per square meter per year), then we simulate the sample size required to declare an effect of this magnitude to be significant with 80 percent power. Sample sizes to detect a difference in trend assuming the slope in the OG treatment = 0.0 will be approximately equal to sample sizes to detect an effect of the same magnitude assuming nonzero slope in the OG treatment. We choose to frame the problem assuming 0.0 trend in OG because interpretation of the difference in slopes is easier in this case.

The same theory cited above can be used with slight modification to compute power to detect a significant difference in trend between TLMP and OG. The standard deviation of density on OG and TLMP streams is estimated separately as the square root of the second diagonal element in the variance-covariance matrix,

$$\sigma_{\beta,n} = \sqrt{\sigma^2\, (\underset{\sim}{X}'\underset{\sim}{R}^{-1}\underset{\sim}{X})^{-1}}$$

where $\underset{\sim}{X}$ contained only the intercept and year effects for the appropriate streams, and $\underset{\sim}{R}$ was the same correlation matrix as above. Assuming OG and TLMP streams are sampled independently, the variance of the difference in two slope parameters, e.g., ($\hat{\beta}_{OG} - \hat{\beta}_T = \beta_\delta$), is the sum of the variances $\sigma_d = (\sigma_{\beta OG,n} + \sigma_{\beta T,n})$ with $m = 2(10)n - 4$ degrees of freedom. Assuming the difference ($\beta_\delta = \beta_{OG} - \beta_T$) follows a non-central T distribution with mean Δ (= desired change in slope) and variance $\sigma_d = (\sigma_{\beta OG,n} + \sigma_{\beta T,n})$, we calculate sample size as the smallest n such that

$$\Pr\left\{\frac{\beta_\delta}{\sigma_d} < t_{m,0.1}\right\} = \Pr\left\{\frac{\beta_\delta}{\sigma_d} - \frac{\Delta}{\sigma_d} < t_{m,0.1} - \frac{\Delta}{\sigma_d}\right\} = \Pr\left\{T_m < t_{m,0.1} - \frac{\Delta}{\sigma_d}\right\} = 0.8$$

where T_m follows a central T distribution with m degrees of freedom. Sample size was calculated as the value of n satisfying

$$t_{m,0.1} - \frac{\Delta}{\sigma_d} = t_{m,0.8}$$

when $t_{m,0.8}$ denotes the value of the central T distribution such that 80 percent of its area is to the left.

Power Analysis Results

The variance estimates for densities obtained from TLMP streams and OG streams in the 3-year pilot study appear in table 12. The range of sample sizes to detect a decrease of 5 percent in fish density on streams of one treatment group or the other is between 5 and 10 streams (table 13). These numbers assumed 10 years of sampling, a one-tailed test with $\alpha = 0.10$, and an annual correlation of 0.15.

Sample sizes increase when the trends of coho salmonid fry and parr abundance in the TLMP treatment and OG control are compared relative to each other (tables 14 and 15). Sample sizes for testing slope difference were computed assuming an annual correlation of 0.15. Sample sizes are larger because two parameters, each with its own variance, are being compared. The difference of two independent parameters has more variance than either of the two individual parameters, and larger variances in turn require larger sample sizes to detect a significant effect size. For example, the estimated power to detect a decreasing trend of $\delta = 5$ percent or $\Delta = (0.05)(0.0779) = (0.0039$ coho parr per square meter per year) on TLMP streams assuming 0.0 trend on old-growth streams is 0.84 with $n = 20$ streams in each treatment (40 total streams) (table 15).

Sample size to achieve >80 percent power to detect a 5 percent difference in slopes for fry is 30 streams in each group (60 total), and 20 streams in each group for parr (40 total) (tables 14 and 15). However, the sample sizes needed to achieve appreciable power for a given percentage difference "level out" at much fewer streams. In other words, sample sizes from 10 to 12 streams per group (20 to 24 streams total) achieved reasonable power (>50 percent) to detect a difference in slopes of 5 percent to 8 percent, and increases in sample size beyond that did not result in dramatic increases in power (boxed values in tables 14 and 15).

Table 12—Density (fish per square meter) and variance values used for calculating sample sizes presented in table 13

| Input | Coho fry | | Coho parr | |
	Old-growth (control)	Post-TLMP (harvest)	Old-growth (control)	Post-TLMP (harvest)
Xbar	0.41505	0.30807	0.09542	0.07786
var.obs	0.05830	0.02093	0.00293	0.00101

Note: No outliers were excluded from the data. Variances were estimated as ordinary variance about the mean (i.e., slope = 0.0). Variances should be conservative relative to variances in final mixed linear models fitted to data after 5 or 10 years of monitoring. TLMP = Tongass land management plan.

Table 13—Sample sizes necessary to achieve the goal of 80 percent power to detect a 5 percent annual decline in mean coho density

| Correlation | Coho fry | | Coho parr | |
	Old-growth (control)	Post-TLMP (harvest)	Old-growth (control)	Post-TLMP (harvest)
-0.3	<5	<5	<5	<5
-0.15	7	<5	6	<5
0	8	5	8	<5
0.15	10	6	9	<5
0.3	12	7	11	6

Note: Values are for a single stream over 10 years using a one-tailed test with $\alpha = 0.10$ assuming means and variance are equal to those reported in table 12, which are thought to be conservative. Highlighted values correspond to correlation of 0.15 derived from annual pairs of density estimates over of 18 years in a stream on Prince of Wales Island. Other values investigate the effects of autocorrelation on sample size. Old-growth = control; TLMP = harvest under TLMP standards and guidelines.

Table 14—Power to detect a slope difference (d) for a range of sample sizes for coho salmon fry

	Sample size																		
δ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	30	40	50
	Power to detect a slope difference																		
0.20	0.672	0.885	0.960	0.987	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.19	0.641	0.860	0.947	0.980	0.993	0.997	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.18	0.608	0.831	0.929	0.971	0.988	0.995	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.17	0.574	0.799	0.907	0.957	0.981	0.992	0.996	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.16	0.540	0.763	0.879	0.940	0.970	0.985	0.993	0.997	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.15	0.505	0.723	0.847	0.916	0.955	0.976	0.987	0.993	0.997	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.14	0.470	0.680	0.808	0.886	0.933	0.961	0.978	0.987	0.993	0.996	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000
0.13	0.436	0.635	0.764	0.849	0.904	0.940	0.963	0.977	0.986	0.991	0.995	0.997	0.998	0.999	0.999	1.000	1.000	1.000	1.000
0.12	0.402	0.587	0.715	0.804	0.867	0.910	0.939	0.960	0.973	0.982	0.988	0.992	0.995	0.997	0.998	1.000	1.000	1.000	1.000
0.11	0.369	0.537	0.660	0.752	0.820	0.870	0.906	0.933	0.952	0.966	0.976	0.983	0.988	0.992	0.994	0.999	1.000	1.000	1.000
0.10	0.337	0.487	0.602	0.693	0.763	0.818	0.861	0.894	0.920	0.939	0.954	0.965	0.974	0.980	0.985	0.997	1.000	1.000	1.000
0.09	0.306	0.437	0.542	0.627	0.698	0.755	0.802	0.841	0.872	0.898	0.918	0.935	0.948	0.959	0.967	0.990	0.999	1.000	1.000
0.08	0.277	0.389	0.480	0.558	0.625	0.682	0.730	0.772	0.808	0.838	0.864	0.886	0.904	0.920	0.933	0.973	0.996	0.999	1.000
0.07	0.250	0.342	0.419	0.487	0.547	0.600	0.647	0.689	0.726	0.759	0.789	0.814	0.837	0.857	0.875	0.937	0.985	0.996	0.999
0.06	0.224	0.297	0.360	0.416	0.467	0.514	0.556	0.595	0.630	0.663	0.693	0.720	0.746	0.769	0.790	0.870	0.953	0.983	0.994
0.05	0.201	0.256	0.305	0.348	0.389	0.426	0.461	0.494	0.525	0.554	0.582	0.608	0.632	0.655	0.676	0.767	0.881	0.941	0.971
0.04	0.179	0.218	0.253	0.285	0.315	0.343	0.369	0.394	0.419	0.442	0.464	0.485	0.505	0.525	0.544	0.628	0.754	0.840	0.897
0.03	0.159	0.184	0.207	0.228	0.248	0.266	0.284	0.301	0.318	0.333	0.349	0.364	0.378	0.392	0.406	0.470	0.578	0.665	0.735
0.02	0.140	0.154	0.167	0.178	0.190	0.200	0.210	0.220	0.229	0.238	0.246	0.255	0.263	0.271	0.279	0.316	0.383	0.443	0.496
0.01	0.124	0.127	0.132	0.136	0.141	0.145	0.149	0.153	0.156	0.160	0.163	0.166	0.169	0.172	0.175	0.190	0.215	0.238	0.259

Note: Sample sizes necessary to detect a given difference $\Delta = \delta \times$ (mean density) in the trend (slopes) of coho **fry** density in harvested (Tongass Land Management Plan [TLMP]) streams relative to trend on old-growth (control) streams after 10 years. Sample size = n streams per year per treatment. $\overset{\circ}{\delta}$ = percentage of difference in slope between TLMP streams and control streams. Boldface values are all those with power greater than 0.800. Highlighted fields indicate the minimum sample size necessary to detect the given slope difference with 80 percent power. Boxed fields indicate samples sizes where power "levels out" and achieves >50 percent power to detect a difference in slopes from 5 to 8 percent.

Table 15—Power to detect a slope difference (d) for a range of sample sizes for coho salmon parr

	Sample size																		
δ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	30	40	50
									Power to detect a slope difference										
0.20	0.749	0.934	0.983	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.19	0.718	0.916	0.976	0.993	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.18	0.685	0.894	0.965	0.989	0.996	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.17	0.649	0.867	0.951	0.982	0.994	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.16	0.612	0.835	0.931	0.972	0.989	0.996	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.15	0.574	0.799	0.907	0.957	0.981	0.992	0.996	0.998	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.14	0.535	0.758	0.875	0.937	0.968	0.984	0.992	0.996	0.998	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.13	0.496	0.712	0.837	0.909	0.950	0.973	0.985	0.992	0.996	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.12	0.457	0.662	0.791	0.872	0.923	0.954	0.972	0.984	0.990	0.994	0.997	0.998	0.999	0.999	1.000	1.000	1.000	1.000	1.000
0.11	0.418	0.609	0.738	0.826	0.886	0.925	0.951	0.969	0.980	0.987	0.992	0.995	0.997	0.998	0.999	1.000	1.000	1.000	1.000
0.10	0.380	0.554	0.679	0.770	0.837	0.884	0.919	0.943	0.960	0.972	0.981	0.987	0.991	0.994	0.996	0.999	1.000	1.000	1.000
0.09	0.343	0.497	0.614	0.705	0.775	0.830	0.871	0.903	0.927	0.946	0.959	0.970	0.978	0.983	0.988	0.997	1.000	1.000	1.000
0.08	0.308	0.441	0.546	0.632	0.702	0.760	0.807	0.845	0.876	0.901	0.921	0.937	0.950	0.960	0.969	0.991	0.999	1.000	1.000
0.07	0.275	0.385	0.476	0.554	0.620	0.677	0.725	0.767	0.803	0.833	0.859	0.882	0.900	0.916	0.930	0.971	0.995	0.999	1.000
0.06	0.245	0.333	0.407	0.473	0.531	0.583	0.629	0.671	0.708	0.741	0.771	0.797	0.821	0.842	0.860	0.926	0.980	0.995	0.999
0.05	0.216	0.283	0.341	0.393	0.441	0.484	0.525	0.562	0.596	0.628	0.657	0.685	0.710	0.733	0.755	0.840	0.934	0.974	0.990
0.04	0.190	0.238	0.280	0.318	0.354	0.387	0.418	0.447	0.475	0.502	0.527	0.551	0.574	0.596	0.616	0.706	0.829	0.903	0.945
0.03	0.166	0.197	0.225	0.250	0.274	0.296	0.317	0.337	0.357	0.376	0.394	0.411	0.428	0.445	0.461	0.534	0.653	0.743	0.811
0.02	0.145	0.161	0.177	0.191	0.204	0.217	0.229	0.240	0.251	0.262	0.272	0.282	0.292	0.302	0.311	0.355	0.434	0.503	0.564
0.01	0.126	0.130	0.136	0.142	0.147	0.152	0.156	0.161	0.165	0.169	0.173	0.177	0.180	0.184	0.188	0.204	0.235	0.262	0.288

Note: Sample sizes necessary to detect a given difference $\Delta = \delta \times$ (mean density) in the trend (slopes) of coho **parr** density in harvested (Tongass Land Management Plan [TLMP]) streams relative to trend on old-growth (control) streams after 10 years. Sample size = n streams per year per treatment. δ = percentage of difference in slope between TLMP streams and control streams. Highlighted fields indicate the minimum sample size necessary to detect the given slope difference with 80 percent power. Boldface values are all those with power greater than 0.800. Highlighted fields indicate the minimum sample size necessary to detect the given slope difference with 80 percent power. Boxed fields indicate samples sizes where power "levels out" and achieves >50 percent power to detect a difference in slopes from 5 to 8 percent.

Appendix 5: Estimated Annual Budget to Conduct the Coho Monitoring Protocol

Implementation of the coho monitoring protocol will be in two phases. Phase 1 will include hiring employees to lead and develop the project, locating 12 to 15 treatment sites and an equal number of paired control sites, and purchasing the necessary equipment.

Phase 2 will be the actual fish population and stream habitat monitoring. Monitoring will occur annually at each site for 10 years. The preliminary budget is developed with the assumption that monitoring will be completed by a combination of ranger district and Tongass National Forest employees (SO). A permanent Tongass National Forest employee will travel to each district throughout the summer and pair up with two district employees for monitoring all sites on that district and then move on to the next district. This scheme will help insure continuity and consistency between the districts and over the years.

Phase 1

SO project administrator (30 days x $400/day)	$12,000
SO field leader for site identification (80 days x $250/day)	$20,000
Geographic information system (GIS) assistance (10 days x $350/day)	$3,500
District bio/hydro (1 employee/district x $250/day x 2 days/site x 30 sites)	$15,000
Helicopter to visit potential sites (15 hrs x $1000/hr)	$15,000
Travel and per diem (6 trips x $800/trip)	$4,800
Sampling equipment	$6,000
Total (FY07 dollars)	**$76,300**

Phase 2 (annual costs)

SO project administrator (20 days x $400/day)	$8,000
SO field leader for field data collection (130 days x $250/day)	$32,500
District biologists (2 employees/district x $250/day x 2 days/site x 30 sites	$30,000
District project administration (2 days x 6 districts x $350/day)	$4,200
Helicopter (15 hrs x $1000/hr)	$15,000
Replacement equipment	$500
Field subsistence ($26/day x 60 days)	$1,560
Annual total (FY07 dollars)	**$91,760**

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Appendix 6: Statistical Analysis of the Relationship Between Salmon Abundance and Management Treatments

Data collected on the same stream are correlated over years (i.e., a correlated error structure). The model will be applied to detect trends in the mean density over time. The linear model assumed in year 10 is:

$$\underset{\sim}{Y} = \underset{\sim}{X}\underset{\sim}{\beta} = \underset{\sim}{e}$$

where $\underset{\sim}{Y}$ is the $n \times 1$ vector of measured densities of fish sorted such that the responses from each stream appear in order together, $\underset{\sim}{X}$ (the design matrix) is the $n \times p$ matrix of independent variables in the regression of responses on time, $\underset{\sim}{\beta} = [\beta_0 \ \beta_1 \ldots \beta_p]'$ is the vector of coefficients, and $\underset{\sim}{e}$ is a $n \times 1$ vector of correlated random errors. Here, n is total sample size equal to the number of streams sampled in each treatment group times number of treatment groups times number of years. Assuming the second column of $\underset{\sim}{X}$ contains the visit designation (i.e., year); the coefficient β_1 is the rate of change (or trend) in the density of fish per year. Other coefficients ($\beta_2 \ldots \beta_p$) measure the effect of important measured covariates.

SAS Code for Analysis of Pilot Data

```
*******************************************************************************
*******;
*******************************************************************************
*******;
* MIXED MODELS FOR COHO FRY DENSITY - NO INTERACTIONS - ALPHA = 0.05 - WITH DV - BW;
*******************************************************************************
*******;
*******************************************************************************
*******;
* select covariance structure using saturated mean model;
ods output clear;
ods listing close;
ods output fitstatistics(match_all persist=proc)=modstat;
title 'MIXED MODELS FOR COHO FRY - with DV - SELECT COVARIANCE STRUCTURE - BW - ALPHA
=0.05';
%macro modelfrycv (type=,);
proc mixed data=in.fishhabtrans method=REML ic;
        class year treatment location stream;
        model fryt=year location latdec distsaltw elevation ph ardtlog cbwtlog d50t pucb
                         tlwdmtlog tkpm tpoolsmtlog dvt;
        repeated year / subject=stream(treatment) type=&type local; run;
%mend;
%modelfrycv (type=UN);
%modelfrycv (type=SIMPLE);                              * Convergence criteria met but final
hessian is not
                                                                positive
definite.;
%modelfrycv (type=TOEP);                                * Convergence criteria met but final
hessian is not
                                                                positive
definite. A linear combination of covariance
                                                                parameters
is confounded with the residual variance.;
%modelfrycv (type=TOEPH);
%modelfrycv (type=AR(1));
%modelfrycv (type=ARH(1));
%modelfrycv (type=ARMA(1,1));                   * Convergence criteria met but final hessian
is not
                                                                positive
definite. A linear combination of covariance
                                                                parameters
is confounded with the residual variance.;
ods listing;
data model_fit_cov;
        length model$ 7 type$ 6;
        set modstat(in=un)
                modstat1(in=simple)
                modstat2(in=toep)
                modstat3(in=toeph)
                modstat4(in=ar)
                modstat5(in=arh)
                modstat6(in=arma);
        if substr(descr,1,2) = '-2' then type = '-2logL';
        if substr(descr,1,3) = 'AIC' then type = 'AIC';
        if substr(descr,1,4) = 'AICC' then type = 'AICC';
        if substr(descr,1,3) = 'BIC' then type = 'BIC';
        if simple then model = 'simple';
        if ar then model = 'ar(1)';
        if arh then model = 'arh(1)';
        if arma then model = 'arma(1,1)';
        if un then model = 'un';
        if toep then model = 'toep';
        if toeph then model = 'toeph';
run; proc print data=model_fit_cov; run;
data model_fit_aicc;
```

```
        set model_fit_cov;
        if type = 'AICC'; run; proc print data=model_fit_aicc; run;
goptions reset=all;
proc gplot data=model_fit_cov;
        plot value*model = type;
        symbol1 value=star color=blue;
        symbol2 value=circle color=red;
        symbol3 value=dot color=green;
        title 'Model Fit Statistics by Covariance Structure';
run; quit;
* Using REML, AICC is calculated using a sample size of n-p, where p is the number of
fixed
  effects (plus intercept);


* SELECT ARH(1) FOR COVARIANCE STRUCTURE;


* MODEL SELECTION WITH BACKWARDS STEPWISE LINEAR REGRESSION WITH ALPHA-TO-ENTER AND
  ALPHA-TO-LEAVE BOTH SET AT 0.05 - USE REML - ELIMINATE INTERACTIONS FIRST;
title 'MIXED MODELS FOR COHO FRY - with DV - ALPHA=0.05 - SELECT MEAN STRUCTURE';
%macro modelfrymean (expvar=,);
proc mixed data=in.fishhabtrans method=REML;
        class year treatment location stream;
        model fryt=&expvar / solution ddfm=kr;
        repeated year / subject=stream(treatment) type=ARH(1) local; run;
%mend;
%modelfrymean(expvar=year location latdec distsaltw elevation ph ardtlog cbwtlog d50t
pucb tlwdmtlog
                        tkpm tpoolsmtlog dvt );
* drop tkpm;
%modelfrymean(expvar=year location latdec distsaltw elevation ph ardtlog cbwtlog d50t
pucb tlwdmtlog
                        tpoolsmtlog dvt );
* drop pucb - see if can add anything back in - NO;
%modelfrymean(expvar=year location latdec distsaltw elevation ph ardtlog cbwtlog d50t
tlwdmtlog
                        tpoolsmtlog dvt );
* drop ardtlog - see if can add anything back in - NO;
%modelfrymean(expvar=year location latdec distsaltw elevation ph cbwtlog d50t tlwdmtlog
                        tpoolsmtlog dvt );
* drop d50t - see if can add anything back in - NO;
%modelfrymean(expvar=year location latdec distsaltw elevation ph cbwtlog tlwdmtlog
                        tpoolsmtlog dvt );
* drop latdec - see if can add anything back in - NO;
%modelfrymean(expvar=year location distsaltw elevation ph cbwtlog tlwdmtlog tpoolsmtlog
dvt );
* drop tpoolsmtlog - see if can add anything back in - NO;
%modelfrymean(expvar=year location distsaltw elevation ph cbwtlog tlwdmtlog dvt );
* drop tlwdmtlog - see if can add anything back in - NO;
%modelfrymean(expvar=year location distsaltw elevation ph cbwtlog dvt );
* drop year - see if can add anything back in - NO;
%modelfrymean(expvar=location distsaltw elevation ph cbwtlog dvt );
* drop ph - see if can add anything back in - NO;
%modelfrymean(expvar=location distsaltw elevation cbwtlog dvt );
* drop distsaltw - see if can add anything back in - NO;
%modelfrymean(expvar=location elevation cbwtlog dvt );
*********************************************************************************
*******;
*********************************************************************************
*******;
* FINAL HABITAT MODEL;
*********************************************************************************
*******;
*********************************************************************************
*******;
title 'FINAL HABITAT MODEL FOR COHO FRY - with DV - ALPHA=0.05 - BW';
proc mixed data=in.fishhabtrans method=REML;
        class year treatment location stream;
        model fryt = location elevation cbwtlog dvt
                        / solution outpm=fryout ddfm=kr;
        repeated year / subject=stream(treatment) type=ARH(1) local; run;
```

```
****************************************************************************************
*******;
****************************************************************************************
*******;
* FINAL MODEL FOR COHO FRY DENSITY - NO INTERACTIONS - ALPHA = 0.05 - WITH DV - BW
  ADD IN TREATMENT EFFECT - NO TREATMENT EFFECT;
****************************************************************************************
*******;
****************************************************************************************
*******;
proc mixed data=in.fishhabtrans method=REML;
        title 'FINAL HABITAT MODEL FOR COHO FRY - with DV - ALPHA=0.05 - BW - TEST FOR
TREATMENT EFFECT';
        class year treatment location stream;
        model fryt = location elevation cbwtlog dvt
                / solution outpm=fryout ddfm=kr;
        repeated year / subject=stream(treatment) type= ARH(1) local r rcorr;
        contrast 'Central with North' location 1 -1 0;
        contrast 'Central with South' location 1 0 -1;
        contrast 'North with South' location 0 1 -1; run;
****************************************************************************************
*******;


****************************************************************************************
*******;
****************************************************************************************
*******;
* MIXED MODELS FOR COHO PARR DENSITY - NO INTERACTIONS - ALPHA = 0.05 - WITH DV - BW;
****************************************************************************************
*******;
****************************************************************************************
*******;
ods output clear;
ods listing close;
ods output fitstatistics(match_all persist=proc)=modstat;
title 'MIXED MODELS FOR COHO PARR - ALPHA = 0.05 - WITH DV - BW - SELECT COVARIANCE
STRUCTURE';
%macro modelparrcv (type=,);
proc mixed data=in.fishhabtrans method=REML ic;
        class year treatment location stream;
        model parrtlog = year location latdec distsaltw elevation ph ardtlog cbwtlog d50t
                                    pucb tlwdmtlog tkpm tpoolsmtlog dvt;
        repeated year / subject=stream(treatment) type=&type local; run;
%mend;
%modelparrcv (type=UN);                                 * Convergence criteria met
but final hessian is not
                                                                   positive
definite. A linear combination of covariance
                                                                   parameters
is confounded with the residual variance.;
%modelparrcv (type=SIMPLE);                             * Convergence criteria met but final
hessian is not
                                                                   positive
definite.;
%modelparrcv (type=TOEP);                               * Convergence criteria met but final
hessian is not
                                                                   positive
definite. A linear combination of covariance
                                                                   parameters
is confounded with the residual variance.;
%modelparrcv (type=TOEPH);                              * did not converge;
%modelparrcv (type=AR(1));
%modelparrcv (type=ARH(1));                             * did not converge;
%modelparrcv (type=ARMA(1,1));
ods listing;
data model_fit_cov;
        length model$ 7 type$ 6;
        set modstat(in=un)
                modstat1(in=simple)
                modstat2(in=toep)
```

```
                modstat3(in=ar)
                modstat4(in=arma);
        if substr(descr,1,2) = '-2' then type = '-2logL';
        if substr(descr,1,3) = 'AIC' then type = 'AIC';
        if substr(descr,1,4) = 'AICC' then type = 'AICC';
        if substr(descr,1,3) = 'BIC' then type = 'BIC';
        if simple then model = 'simple';
        if ar then model = 'ar(1)';
        if arma then model = 'arma';
        if toep then model = 'toep';
        if un then model = 'un';
run; proc print data=model_fit_cov; run;
data model_fit_aicc;
        set model_fit_cov;
        if type = 'AICC'; run; proc print data=model_fit_aicc; run;
goptions reset=all;
proc gplot data=model_fit_cov;
        plot value*model = type;
        symbol1 value=star color=blue;
        symbol2 value=circle color=red;
        symbol3 value=dot color=green;
        title 'Model Fit Statistics by Covariance Structure';
run; quit;
* Using REML, AICC is calculated using a sample size of n-p, where p is the number of
fixed
  effects (plus intercept);

* SELECT AR(1) FOR COVARIANCE STRUCTURE;

* MODEL SELECTION WITH BACKWARDS STEPWISE LINEAR REGRESSION WITH ALPHA-TO-ENTER AND
  ALPHA-TO-LEAVE BOTH SET AT 0.05 - USE REML ;
title 'MIXED MODELS FOR COHO PARR - ALPHA = 0.05 - WITH DV - BW - SELECT MEAN STRUCTURE';
%macro modelparrmean (expvar=,);
proc mixed data=in.fishhabtrans method=REML;
        class year treatment location stream;
        model parrtlog =&expvar / solution ddfm=kr;
        repeated year / subject=stream(treatment) type=AR(1) local; run;
%mend;
%modelparrmean(expvar=year location latdec distsaltw elevation ph ardtlog cbwtlog d50t
pucb tlwdmtlog
                        tkpm tpoolsmtlog dvt );
* drop ardtlog;
%modelparrmean(expvar=year location latdec distsaltw elevation ph cbwtlog d50t pucb
tlwdmtlog
                        tkpm tpoolsmtlog dvt );
* drop tkpm - see if can add anything back in - NO;
%modelparrmean(expvar=year location latdec distsaltw elevation ph cbwtlog d50t pucb
tlwdmtlog
                        tpoolsmtlog dvt );
* drop latdec - see if can add anything back in - NO;
%modelparrmean(expvar=year location distsaltw elevation ph cbwtlog d50t pucb tlwdmtlog
                        tpoolsmtlog dvt );
* drop tlwdmtlog - see if can add anything back in - NO;
%modelparrmean(expvar=year location distsaltw elevation ph cbwtlog d50t pucb tpoolsmtlog
dvt );
* drop cbwtlog - see if can add anything back in - NO;
%modelparrmean(expvar=year location distsaltw elevation ph d50t pucb tpoolsmtlog dvt );
* drop distsaltw - see if can add anything back in - NO;
%modelparrmean(expvar=year location elevation ph d50t pucb tpoolsmtlog dvt );
* drop location - see if can add anything back in - NO;
%modelparrmean(expvar=year elevation ph d50t pucb tpoolsmtlog dvt );
* drop d50t - see if can add anything back in - NO;
%modelparrmean(expvar=year elevation ph pucb tpoolsmtlog dvt );
* drop pucb - see if can add anything back in - NO;
%modelparrmean(expvar=year elevation ph tpoolsmtlog dvt );
* drop ph - see if can add anything back in - NO;
%modelparrmean(expvar=year elevation tpoolsmtlog dvt);
*************************************************************************************
*******;
*************************************************************************************
*******;
```

```
* FINAL HABITAT MODEL;
*******************************************************************************
*******;
*******************************************************************************
*******;
title 'FINAL HABITAT MODEL FOR COHO PARR - ALPHA = 0.05 - WITH DV - BW';
proc mixed data=in.fishhabtrans method=REML;
        class year treatment location stream;
        model parrtlog = year elevation tpoolsmtlog dvt
                                / solution outpm=parrout ddfm=kr;
        repeated year / subject=stream(treatment) type=AR(1) local; run;
*******************************************************************************
*******;
*******************************************************************************
*******;
* FINAL MODEL FOR COHO PARR DENSITY - ADD IN TREATMENT EFFECT;
*******************************************************************************
*******;
*******************************************************************************
*******;
proc mixed data=in.fishhabtrans method=REML;
        title 'FINAL HABITAT MODEL FOR COHO PARR - ALPHA = 0.05 - WITH DV - BW - TEST FOR
TREATMENT EFFECT';
        class year treatment location stream;
        model parrtlog = year elevation tpoolsmtlog dvt treatment year*treatment
                    / solution outpm=parrout ddfm=kr;
        repeated year / subject=stream(treatment) type=AR(1) local r rcorr; run;
*******************************************************************************
*******;


*******************************************************************************
*******;
*******************************************************************************
*******;
* COHO FRY DENSITY MODEL VALIDATION;
*******************************************************************************
*******;
*******************************************************************************
*******;
ods html;
ods graphics on;
title 'MODEL ASSESSMENT FOR COHO FRY DENSITY HABITAT MODEL';
proc mixed data=in.fishhabtrans method=REML boxplot;
        ods output Influence=fryinfl;
        class year treatment location stream;
        model fryt = location elevation cbwtlog dvt
                                / solution outpm=fryout ddfm=kr influence(iter=2 estimates)
residual;
        repeated year / subject=stream(treatment) type=ARH(1) local; run;
ods graphics off;
ods html close;
goptions reset=all;
title;
* residual plots to look for outliers and patterns;
proc gplot data=fryout;
        title;
        plot StudentResid*(pred year location elevation cbwtlog dvt
                            ) / vref=0;
        symbol v=star c=blue; run; quit;
* none evident;
* histogram of the residuals to check for normality;
proc univariate data=fryout;
        title 'Frequency Distribution';
        var StudentResid;
        histogram / normal; run;
proc univariate data=fryout;
        title 'Normal Probability Plot';
        var StudentResid;
        qqplot / normal; run;
* residuals are not grossly abnormal;
```

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```
* look for potential outliers;
proc rank data=fryout groups=100 out=percentiles;
        var StudentResid;
        ranks percentile; run;
proc print data=percentiles noobs split='*';
        where percentile=0 or percentile=99;
        var stream year location distsaltw ph ardtlog cbwtlog d50t tkpm dvt;
        title 'Streams with Outlying Coho Fry Densities'; run;
* no outliers;
* influence - stream level;
* restricted likelihood (overall influence on analysis);
data new;
        a=quantile('CHISQ',0.95,5);
        b=quantile('CHISQ',0.90,5);
        c=quantile('CHISQ',0.85,5);
        d=quantile('CHISQ',0.80,5);
        e=quantile('CHISQ',0.75,5);
run; proc print data=new; run;
proc gplot data=fryinflstr;
        title;
        axis1 order = 0 to 15 by 1 offset=(0) label=(angle=90 h=1.5 f=swiss 'Restricted
Likelihood Distance');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot rld * stream / vaxis=axis1 vref=12.55 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* mdffits (effect on parameter estimates);
proc gplot data=fryinflstr;
        title;
        axis1 order = 0 to 1 by 0.1 offset=(0)label=(angle=90 h=1.5 f=swiss 'MDFFITS');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot mdffits * stream / vaxis=axis1 vref = 0.845 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=fryinflstr;
        title;
        axis1 order= 0 to 10 by 1 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot covratio * stream / vaxis=axis1 vref = 0.464, 1, 1.536 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black; run; quit;
* RMSE (effect on fitted and predicted values);
data fryinflstrpress;
        set fryinflstr;
        pressbt = press*press;
        rmsebt = rmse*rmse;
        pressrmse = sqrt(press/56);
        pressrmsebt = sqrt(pressbt/56);
        diffrmse = pressrmse - rmse;
        diffrmsebt = pressrmsebt-rmsebt;
        absdiffrmsebt = abs(diffrmsebt); run; proc print; run;
proc gplot data=fryinflstrpress;
        title;
        axis1 order = -0.15 to 0.15 by 0.05 offset=(0)label=(angle=90 h=1.5 f=swiss 'RMSE
- PRESS RMSE');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot diffrmse * stream / vaxis=axis1 vref=0 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
proc gplot data=fryinflstrpress;
        title;
        axis1 order = -0.04 to 0.04 by 0.02 offset=(0)label=(angle=90 h=1.5 f=swiss j=c
'RMSE - PRESS RMSE' j=c '(#/square meter)');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot diffrmsebt * stream / vaxis=axis1 vref=0 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
proc means data=fryinflstrpress alpha=0.05;
        var absdiffrmsebt;
        output out=temp n=n mean=mean stderr=se uclm=upper lclm=lower; run; proc print;
run;

* influence - observation level;
```

```
* restricted likelihood (overall influence on analysis);

data new;
        a=quantile('CHISQ',0.95,5);
        b=quantile('CHISQ',0.90,5);
        c=quantile('CHISQ',0.85,5);
        d=quantile('CHISQ',0.80,5);
        e=quantile('CHISQ',0.75,5);
run; proc print data=new; run;
proc gplot data=fryinfl;
        title;
        axis1 order = 0 to 15 by 1 offset=(0) label=(angle=90 h=1.5 f=swiss 'Restricted
Likelihood Distance');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot rld * index / vaxis=axis1 vref=12.55 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* dffits (effect on parameter estimates);
data temp; set fryinfl; absdffits = abs(dffits); run;
proc gplot data=temp;
        title;
        axis1 offset=(0)label=(angle=90 h=1.5 f=swiss 'DFFITS');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot absdffits * index / vaxis=axis1 vref = 0.845 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=fryinfl;
        title;
        axis1 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot covratio * index / vaxis=axis1 vref = 0.464, 1, 1.536 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* leverage (undue influence in tails of the regression model);
goptions reset=all;
proc gplot data=fryinfl;
        title;
        axis1 order = -0.05 to 0.75 by 0.1 offset=(0)label=(angle=90 h=1.5 f=swiss
'Leverage');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot leverage * index / vaxis=axis1 vref=0, 0.357 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;

* influence on covariance parameters - stream level;
* restricted likelihood (overall influence on analysis);

* Cook's D (effect on parameter estimates);
proc gplot data=fryinflstr;
        title;
        axis1 order= 0 to 2.75 by 0.25 offset=(0)label=(angle=90 h=1.5 f=swiss 'Cook''s D
- Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot mdffitscp * stream / vaxis=axis1 vref = 0.071 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=fryinflstr;
        title;
        axis1 order= 0 to 3 by 1 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO -
Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot covratiocp * stream / vaxis=axis1 vref = 0.464, 1, 1.536 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black; run; quit;

* influence on covariance parameters - observation level;
* restricted likelihood (overall influence on analysis);

* cooksD (effect on parameter estimates);
data temp; set fryinfl; abscookDcp = abs(cookdcp); run;
proc gplot data=temp;
```

```
        title;
        axis1 order = 0 to 2 by 0.5 offset=(0)label=(angle=90 h=1.5 f=swiss 'Cook''s D -
Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot abscookdcp * index / vaxis=axis1 vref = 0.071 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=fryinfl;
        title;
        axis1 order = 0 to 2 by 0.5 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO -
Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot covratiocp * index / vaxis=axis1 vref = 0.464, 1, 1.536 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
%let comma= +(-1) "," ;
data _NULL_;
        file  "C:\Documents and settings\mbstahl\my documents\projects\usfs\tongass
coho2\reports\model\fryinflstr table.csv";
        set fryinflstrpress;
        if _N_ =1 then put
"stream,obs,rld,mdffits,covratio,pressrmsebt,rmse,cookdcp,covratiocp";
        put   stream &comma nobs &comma rld &comma mdffits &comma covratio &comma
pressrmsebt &comma rmse &comma cookdcp &comma
                        covratiocp &comma; run;
%let comma= +(-1) "," ;
data _NULL_;
        file  "C:\Documents and settings\mbstahl\my documents\projects\usfs\tongass
coho2\reports\model\fryinfl table.csv";
        set fryinfl;
        if _N_ =1 then put
"index,student,rld,dffits,covratio,leverage,cookdcp,covratiocp";
        put   index &comma student &comma rld &comma dffits &comma covratio &comma
leverage &comma
                        cookdcp &comma covratiocp &comma; run;
*****************************************************************************************
*******;


*****************************************************************************************
*******;
*****************************************************************************************
*******;
* COHO PARR DENSITY MODEL VALIDATION;
*****************************************************************************************
*******;
*****************************************************************************************
*******;
ods html;
ods graphics on;
title 'MODEL ASSESSMENT FOR COHO PARR DENSITY HABITAT MODEL';
proc mixed data=in.fishhabtrans method=REML boxplot;
        ods output Influence=parrinfl;
        class year treatment location stream;
        model parrtlog = year elevation tpoolsmtlog dvt
                                / solution outpm=parrout ddfm=kr influence(iter=2 estimates)
residual;
        repeated year / subject=stream(treatment) type=AR(1) local; run;
ods graphics off;
ods html close;
goptions reset=all;
title;
* residual plots to look for outliers and patterns;
proc gplot data=parrout;
        title;
        plot StudentResid*(pred year location elevation cbwtlog dvt
                                ) / vref=0;
        symbol v=star c=blue; run; quit;
* none evident;
* histogram of the residuals to check for normality;
```

```
proc univariate data=parrout;
        title 'Frequency Distribution';
        var StudentResid;
        histogram / normal; run;
proc univariate data=parrout;
        title 'Normal Probability Plot';
        var StudentResid;
        qqplot / normal; run;
* residuals are not grossly abnormal;
* look for potential outliers;
proc rank data=parrout groups=100 out=percentiles;
        var StudentResid;
        ranks percentile; run;
proc print data=percentiles noobs split='*';
        where percentile=0 or percentile=99;
        var stream year location distsaltw ph ardtlog cbwtlog d50t tkpm dvt;
        title 'Streams with Outlying Coho Fry Densities'; run;
* no outliers;
* influence - stream level;
* restricted likelihood (overall influence on analysis);
data new;
        a=quantile('CHISQ',0.95,5);
        b=quantile('CHISQ',0.90,5);
        c=quantile('CHISQ',0.85,5);
        d=quantile('CHISQ',0.80,5);
        e=quantile('CHISQ',0.75,5);
run; proc print data=new; run;
proc gplot data=parrinflstr;
        title;
        axis1 order = 0 to 15 by 1 offset=(0) label=(angle=90 h=1.5 f=swiss 'Restricted
Likelihood Distance');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot rld * stream / vaxis=axis1 vref=12.55 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* mdffits (effect on parameter estimates);
proc gplot data=parrinflstr;
        title;
        axis1 order = 0 to 1 by 0.1 offset=(0)label=(angle=90 h=1.5 f=swiss 'MDFFITS');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot mdffits * stream / vaxis=axis1 vref = 0.791 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=parrinflstr;
        title;
        axis1 order= 0 to 10 by 1 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot covratio * stream / vaxis=axis1 vref = 0.531, 1, 1.469 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black; run; quit;
* RMSE (effect on fitted and predicted values);
data parrinflstrpress;
        set parrinflstr;
        pressbt = press*press;
        rmsebt = rmse*rmse;
        pressrmse = sqrt(press/56);
        pressrmsebt = sqrt(pressbt/56);
        diffrmse = pressrmse - rmse;
        diffrmsebt = pressrmsebt-rmsebt;
        absdiffrmsebt = abs(diffrmsebt); run; proc print; run;
proc means data=parrinflstrpress alpha=0.05;
        var absdiffrmsebt;
        output out=temp n=n mean=mean stderr=se uclm=upper lclm=lower; run; proc print;
run;
proc gplot data=parrinflstrpress;
        title;
        axis1 order = -0.5 to 0.5 by 0.1 offset=(0)label=(angle=90 h=1.5 f=swiss 'RMSE -
PRESS RMSE');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot diffrmse * stream / vaxis=axis1 vref=0 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
```

```
proc gplot data=parrinflstrpress;
        title;
        axis1 order = -1 to 1 by 0.2 offset=(0)label=(angle=90 h=1.5 f=swiss j=c 'RMSE -
PRESS RMSE' j=c '(#/square meter)');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot diffrmsebt * stream / vaxis=axis1 vref=0 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;


* influence - observation level;
* restricted likelihood (overall influence on analysis);

data new;
        a=quantile('CHISQ',0.95,5);
        b=quantile('CHISQ',0.90,5);
        c=quantile('CHISQ',0.85,5);
        d=quantile('CHISQ',0.80,5);
        e=quantile('CHISQ',0.75,5);
run; proc print data=new; run;
proc gplot data=parrinfl;
        title;
        axis1 order = 0 to 15 by 1 offset=(0) label=(angle=90 h=1.5 f=swiss 'Restricted
Likelihood Distance');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot rld * index / vaxis=axis1 vref=12.55 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* dffits (effect on parameter estimates);
data temp; set parrinfl; absdffits = abs(dffits); run;
proc gplot data=temp;
        title;
        axis1 order = 0 to 1 by 0.1 offset=(0)label=(angle=90 h=1.5 f=swiss 'DFFITS');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot absdffits * index / vaxis=axis1 vref = 0.791 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=parrinfl;
        title;
        axis1 order = 0 to 3 by 0.5 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot covratio * index / vaxis=axis1 vref = 0.531, 1, 1.469 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black; run; quit;
* leverage (undue influence in tails of the regression model);
goptions reset=all;
proc gplot data=parrinfl;
        title;
        axis1 order = 0 to 0.75 by 0.25 offset=(0)label=(angle=90 h=1.5 f=swiss
'Leverage');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot leverage * index / vaxis=axis1 vref=0, 0.313 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;


* influence on covariance parameters - stream level;
* restricted likelihood (overall influence on analysis);

* Cook's D (effect on parameter estimates);
proc gplot data=parrinflstr;
        title;
        axis1 order= 0 to 2.75 by 0.25 offset=(0)label=(angle=90 h=1.5 f=swiss 'Cook''s D
- Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
        plot mdffitscp * stream / vaxis=axis1 vref = 0.0625 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=parrinflstr;
        title;
        axis1 order= 0 to 3 by 1 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO -
Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Stream');
```

```
        plot covratiocp * stream / vaxis=axis1 vref = 0.531, 1, 1.469 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black; run; quit;

* influence on covariance parameters - observation level;
* restricted likelihood (overall influence on analysis);

* cooksD (effect on parameter estimates);
data temp; set parrinfl; abscookDcp = abs(cookdcp); run;
proc gplot data=temp;
        title;
        axis1 offset=(0)label=(angle=90 h=1.5 f=swiss 'Cook''s D - Covariance
Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot abscookdcp * index / vaxis=axis1 vref = 0.0625 haxis=axis2;
        symbol v=dot c=black i=needle; run; quit;
* covratio (effect on precision of estimates);
goptions reset=all;
proc gplot data=parrinfl;
        title;
        axis1 order = 0 to 2 by 0.5 offset=(0)label=(angle=90 h=1.5 f=swiss 'COVRATIO -
Covariance Parameters');
        axis2 label=(h=1.5 f=swiss 'Deleted Level of Observation');
        plot covratiocp * index / vaxis=axis1 vref = 0.531, 1, 1.469 lvref=(2 1 2)
haxis=axis2;
        symbol v=dot c=black; run; quit;
%let comma= +(-1) "," ;
data _NULL_;
        file  "C:\Documents and settings\mbstahl\my documents\projects\usfs\tongass
coho2\reports\model\parrinflstr table.csv";
        set parrinflstrpress;
        if _N_ =1 then put
"stream,obs,rld,mdffits,covratio,pressrmsebt,rmsebt,cookdcp,covratiocp";
        put  stream &comma nobs &comma rld &comma mdffits &comma covratio &comma
pressrmsebt &comma rmsebt &comma cookdcp &comma
                        covratiocp &comma;      run;
%let comma= +(-1) "," ;
data _NULL_;
        file  "C:\Documents and settings\mbstahl\my documents\projects\usfs\tongass
coho2\reports\model\fryinfl table.csv";
        set fryinfl;
        if _N_ =1 then put
"index,student,rld,dffits,covratio,leverage,cookdcp,covratiocp";
        put  index &comma student &comma rld &comma dffits &comma covratio &comma
leverage &comma
                        cookdcp &comma covratiocp &comma; run;
*************************************************************************************
*******;
```