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FINAL
CRITICAL EROSION LEVEE REPAIR SITES FISH AND HABITAT MONITORING
YEAR-3 (2010) MONITORING REPORT

Prepared for

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Division of Flood Management
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EXECUTIVE SUMMARY

Introduction and Methods

Major levee repairs and emergency levee repairs within the Sacramento River system have been traditionally conducted by the Corps of Engineers through their Sacramento River Bank Protection Project (SRBPP), and the PL84-99 Rehabilitation Programs. ("PL 84-99" refers to federal Public Law 84-99, the Flood and Coastal Storm Emergencies Act). On 24 February 2006, Governor Arnold Schwarzenegger declared a State of Emergency for California's levee system, releasing up to $500 million to repair and evaluate State and Federal project levees. These emergency levee repair funds are now being administered through the existing Corps of Engineers levee repair programs and a new program, the State Erosion Repairs Program. The State Department or Water Resources (DWR) is the lead agency for the State Erosion Repairs Program, while the Corps is the lead agency for the SRBPP and the PL 84-99 Rehabilitation Program.

NMFS issued Biological Opinions (BOs) for the emergency levee repairs covered the Governor's declaration in June 2006 and August 2007; the USFWS issued their BOs in June 2006 and April 2007. The BOs support approval of critical levee repairs at 57 sites (along the Sacramento and Bear rivers; and Steamboat, Sutter, and Cache sloughs). DWR undertook repairs at 21 of the sites, and the Corps undertook repairs at the remaining 36 sites. These sites were identified as "critical", as defined by bank erosion that could threaten the structural integrity of the flood control system, and therefore required immediate work to prevent levee failure during the next flood (Ayres Associates 2007).

The monitoring goals and objectives of this report were formulated to meet the NMFS and USFWS Biological Opinion requirements that post construction repair sites be monitored to evaluate whether "on-site compensations are functioning in a manner that enhances habitat value and offset adverse bank protection effects" (NMFS 2001, 2004, 2006a, 2006b, 2007; USFWS 2004a, 2004b, 2006a, 2006b, 2006c, 2007). This Year-3 report documents the fisheries and habitat feature monitoring and evaluates the results as prescribed in the June 2008 fish and habitat monitoring plan. This report covers the Year-1 (2008) and Year-2 (2009) habitat feature data and the Year-2 (2009) and Year-3 (2010) fisheries data.

When the levees were originally constructed, maintained, and repaired (starting in the mid to late 19th century), mitigation measures were not required, but since the early 1990s, several species of salmonids and the delta smelt (*Hypomesus transpacificus*) have become listed species through the state and federal Endangered Species Acts. Mitigation measures for channel and river bank modifications were designed based on the Standardized Assessment Methodology (SAM). The SAM is a predictive model used to quantify potential impacts to threatened and endangered fish species due to construction of bank revetment and other bank protection measures, and it can also be utilized to assess the fish habitat value of experimental mitigation and compensation measures. The SAM quantifies habitat values in terms of a bank line or area-weighted species response index; habitat variables include bank slope, floodplain inundation ratio, bank substrate size, instream structure, aquatic vegetation, and overhanging shade.

Four experimental levee repair designs were constructed based on SAM results (Table ES-1). The SAM habitat features were measured, and fish presence and abundance using electrofishing and telemetry were estimated at the levee repair sites that incorporate habitat features (n = 13 sites), and at naturalized bank sites[1], where appropriate or available (n = 8 sites). Electrofishing and telemetry studies at the levee repair sites and the naturalized bank sites allowed us to address these study objectives:

1) identify habitat features of levee repair sites that promote fish use, so that repair sites can maximize value for fish and
2) determine if fish use is similar between naturalized sites and levee repair sites.

Monitoring of fish and habitat features for this study was performed for two years following levee repair construction.

Table ES-1. Levee Repair Design Types and Features.

Design Types	Design Features
10:1 Slope design	Tend to have more gradual slopes (10:1) than the other design types and can have benches.
Bench design	Have a bench designed to flood during high flow and high tide events.
Dietl Ditch design	Have an off-channel ditch, parallel to the main channel, designed for aquatic habitat. These ditches are connected to the main channel and are typically inundated.
No Bench design	Typically have steeper slopes (2:1 or 3:1) and do not include a bench

Our data handling and analysis varied from simple descriptive statistics (mean, standard error) to advanced techniques such as generalized linear mixed-effects modeling (GLMM). The survey and statistical methods evolved and improved as we gained greater knowledge in the field, and as we examined results from the first full year of monitoring (2009).

Results and Discussion

Results from this study are presented as those results that 1) allow us to evaluate the study methodology and data analyses, and 2) address the study objectives (Table ES-2).

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[1] Naturalized sites are reference sites used for comparison purposes that have not been engineered and are not rip-rapped; they are dominated by native, naturally established vegetation.

Table ES-2. Study Results Address Study Objectives and Inform our Methodology.

Results Informing Study Methodology	Results Addressing Study Objectives
Instream wood measures better represent fish habitat and fish use when measured using electrofishing-based rather than transect-based methods.	Use of the levee repair sites by juvenile steelhead and larger juvenile Chinook salmon is minimal.
Much of the instream woody material (IWM) at repair sites appears to be placed too high. It may score well based on the SAM, but if not inundated for a long enough time, then its value for fish decreases.	Juvenile Chinook salmon have an association with the Bench /10:1 (with increased Large Woody Material density and depth) and Dietl Ditch levee repair design types. However, the Dietl Ditch repair type also has a strong association with bass predators.
The statistical models were successful in identifying the "best" levee repair design types and features within those types, however, the results of these analyses must be interpreted carefully.	Therefore, based on the existing data, the most beneficial levee repair design type for juvenile Chinook salmon is the Bench/10:1 repair type.
Telemetry results differ considerably comparing upstream of river mile (RM) 20 to downstream of RM 20 of the Sacramento River. A secondary finding was that fish residency was often related to tagged fish release location and date.	Numerous fish habitat features are developing at the repair sites; this is evident after collecting only 2 years of monitoring data. The more gradual slopes that were created at many of these repair sites provide shallow water habitat available for fish.

Models based on summaries/averages of electrofishing-based IWM data fit the data better than those fit directly to these data, indicating a stronger relationship to wood variables at the site scale than at the point scale for larger Chinook salmon juveniles and bass predators. The transect-based IWM measurements were modeled using two years of electrofishing data and all other IWM sampling efforts (not just April 2010); models fit to summaries of electrofishing-based measures generally fit better than those fit to transect-based measures (i.e., SAM's % of bank line and additional transect-based IWM measures jam area and IWM diameter). The implications of these findings are that electrofishing-based wood measures better represent fish habitat and fish use than the transect-based approach used in the SAM.

Much of the IWM at repair sites appears to be placed too high. It may score well based on the SAM, but if not inundated for a long enough time, then its value to fish decreases.

The statistical models were successful in identifying the "best" levee repair design types and features within those types, however, the results must be interpreted carefully. We identified confounding factors and determined that the very habitat features that look to be important in explaining differences in fish behavior are the same features that are also associated with design type; in other words, these habitat features are associated with both design type and fish behavior, complicating interpretation of the effect of design type or habitat feature on fish behavior when both design type and habitat features are included in the models.

A major finding of these analyses is that results differ considerably comparing upstream of river mile (RM) 20 and downstream of RM 20 of the Sacramento River. Some design types (for example, the Dietl Ditch repair type) are primarily at the downstream end of the study area. Some of the differences among habitat features are due primarily to their specific locations on the Sacramento River, which dictated the site designs that could be utilized.

Assessment of levee types and habitat features is complicated by relationships between space (regions and river miles), time (e.g., fish grow and adapt to different habitats), and ecological and physical interactions. Nevertheless, there are certain levee types and habitat features which consistently rank as the best or worst for each species and life stage, and the following statements can be made based on the data collected so far:

Use of the levee repair sites by juvenile steelhead and larger juvenile Chinook salmon is minimal. Based on analysis of the telemetry data, the juvenile steelhead and larger juvenile Chinook salmon (93-218 mm total length, mean 162 mm) are not strongly associated with specific levee design types or habitat features. Many of these fish were likely smolts out-migrating to the sea. Furthermore, juvenile steelhead were rarely captured during electrofishing (a total of 15 captures in 2009 and 2010, ranging from 159 to 270 mm TL with mean of 216 mm), and large juvenile Chinook salmon were not captured during electrofishing surveys (juvenile Chinook salmon in electrofishing surveys ranged from 31-100 mm TL with mean of 53 mm). Inconsistent association between the juvenile steelhead and larger juvenile Chinook salmon and the levee types/habitat features, combined with the fact that these juveniles were rarely captured at the levees, indicates that use of the levees by juvenile steelhead and larger juvenile Chinook salmon is minimal.

Smaller or younger Chinook salmon (≤100 mm total length) may be associated with the Bench 10:1 and Dietl Ditch levee repair design types. The Bench 10:1 design was not strongly associated with juvenile Chinook salmon, but relationships with habitat variables suggest that they could be if there is enough Large Woody Material density at greater depths. With this modification, the Bench/10:1 and Dietl Ditch repair types are associated with juvenile Chinook salmon. However, bass predators are also associated with the Dietl Ditch design, raising concerns about increased Chinook salmon predation at the Dietl Ditch design types.

Therefore, based on the existing data, the most beneficial levee repair type for fry and juvenile Chinook salmon is the Bench/10:1 type with increased Large Woody Material density at greater depth. However, the number of levees sampled in this study was low and the sampling effort likely does not reflect the temporal variation that occurs at these sites. Therefore, future research to increase our knowledge of levee and habitat use by juvenile salmonids and their predators should include increasing electrofishing surveys at more sites within fewer regions (to better distinguish between repair types), and should include repair sites that are not based on using the SAM (standard, rip-rap levees) as an additional control. Future monitoring, especially using telemetry (active and passive) as the technology advances, should generally focus on smaller Chinook salmon (e.g., <100 mm), which appear to have a stronger association with the levees than steelhead or larger Chinook salmon, and their predators.

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1 INTRODUCTION AND BACKGROUND

1.1 Introduction

Routine and emergency repairs within California's Central Valley levee systems have been ongoing since the construction of the levees in the mid to late 1800's. When the levees were originally constructed, mitigation measures were not required, but since then, several species of salmonids and the delta smelt (*Hypomesus transpacificus*) have become listed species through the state and federal Endangered Species Acts. Mitigation measures for channel and river bank modifications have recently been needed and often based on the Standardized Assessment Methodology (SAM). The SAM is a predictive model that attempts to quantify potential impacts to threatened and endangered fish species due to construction of bank revetment and other bank protection measures, and it can also be utilized to assess the fish habitat value of experimental mitigation and compensation measures. The SAM quantifies habitat values in terms of a bank line or area-weighted species response index; habitat variables include bank slope, floodplain inundation ratio, bank substrate size, instream structure, aquatic vegetation, and overhanging shade.

This report documents the monitoring of the emergency levee repairs' mitigation measures; we measured the SAM habitat variables listed above and conducted electrofishing and fish telemetry studies. (Running of the SAM model using the habitat features measurements will be performed by others.) The monitoring occurred at four levee repair designs (Table 1-1; Appendix A).

Table 1-1. Levee Repair Design Types and Features.

Design Types	Design Features
10:1 Slope design	Tend to have more gradual slopes (10:1) than the other design types and can have benches.
Bench design	Have a bench designed to inundate during high flows and tide events.
Dietl Ditch design	Have an off-channel ditch, parallel to the main channel, designed for aquatic habitat. These ditches are connected to the main channel and are typically inundated.
No Bench design	Typically have steeper slopes (2:1 or 3:1) and do not include a bench

Fish presence and abundance using electrofishing and telemetry were estimated at: 1) recently constructed levee repair sites that incorporate habitat features, and 2) naturalized bank sites[2], where appropriate or available. Monitoring at the repair sites and the naturalized bank sites allowed us to compare the efficacy of the repair sites' habitat improvements to that of the natural bank sites. Monitoring of fish and habitat features for this study has been performed for three years following construction.

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[2] Naturalized sites have not been engineered and are not rip-rapped; they are characterized by vegetation that has been allowed to develop.

In June 2008, H. T. Harvey & Associates (2008) prepared a fish and habitat monitoring plan for the Department of Water Resources (DWR), the US Army Corps of Engineers (Corps), the National Marine Fisheries Service (NMFS), the US Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG), to meet the monitoring goals and objectives determined by the Technical Task Group (8 February 2008). The monitoring goals and objectives were formulated to meet NMFS and USFWS Biological Opinion requirements that the data evaluate whether "the various experimental … on-site compensations are functioning in a manner that enhances habitat value and offsets adverse bank protection effects" (NMFS 2001, 2004, 2006a, 2006b, 2007; USFWS 2004a, 2004b, 2006a, 2006b, 2006c, 2007).

This Year-3 report documents the fisheries and habitat feature monitoring and evaluates the results as prescribed in the June 2008 fish and habitat monitoring plan. This report covers the Year-1 (2008) and Year-2 (2009) habitat feature data and the Year-2 (2009) and Year-3 (2010) fisheries data. All agency comments received on drafts of this report and responses to these comments are provided in the report's last Appendix (Appendix K).

The overall objectives of this study are to identify habitat features of levee repair sites that promote fish use, so that repair sites can maximize value for fish, and to determine if fish use is similar between naturalized sites and levee repair sites. We based our evaluations on field observations and professional judgment, measurements of habitat features, electrofishing surveys and telemetry, and statistical analyses.

1.2 Background

On 24 February 2006, Governor Arnold Schwarzenegger declared a State of Emergency for California's levee system, releasing up to $500 million to repair and evaluate State and Federal project levees. These levee repairs are being conducted under three main programs: the State Erosion Repairs Program, the Sacramento River Bank Protection Project (SRBPP), and the PL84-99 Rehabilitation Program. ("PL 84-99" refers to federal Public Law 84-99, the Flood and Coastal Storm Emergencies Act). The State Department or Water Resources (DWR) is the lead agency for the State Erosion Repairs Program, while the Corps is the lead agency for the SRBPP and the PL 84-99 Rehabilitation Program.

The SRBPP was originally authorized under the Flood Control Act of 1960 (Public Law 86-645) with the purpose of protecting the levees and flood control facilities on the Sacramento River from the delta at Collinsville at river mile (RM) 0, to Chico Landing at RM 194. Mitigation was not required for much of the initial work occurring in the 1960s and 1970s, under the SRBPP, however, with the listing of several species of salmonids and delta smelt, mitigation is now required. Mitigation measures for channel and river bank modifications have recently been designed based on the Standardized Assessment Methodology (SAM).

The SAM model systematically compares species responses to habitat features that may be affected by bank protection projects; it is particularly useful in supporting consultations with NMFS and USFWS on Endangered Species Act (ESA) listed fish species, as well as those listed under the Pacific Fishery Management Council's Salmon Fishery Management Plan. The SAM assumptions and model variables were developed to be adapted and validated through data gained from monitoring and experimentation within the SRBPP. Constructed habitat features must be monitored to validate whether the overall long-term habitat effects of the projects are beneficial, as determined by the SAM. In general, the SAM quantifies habitat values in terms of a bank line or area-weighted species response index; the index is calculated by combining quantified habitat feature data with relevant species/life stage. Habitat variables include bank slope, floodplain inundation ratio, bank substrate size, instream structure, aquatic vegetation, and overhanging shade. Using habitat feature data and fish species response models, the SAM model is used to quantify changes in species response from current conditions (for example, prior to repair construction) to projected future "with" or "without" project conditions.

NMFS issued Biological Opinions (BOs) for the levee repairs and mitigation measures in June 2006 and August 2007; the USFWS issued their BOs in June 2006 and April 2007. The BOs included critical levee repairs at 57 sites (along the Sacramento and Bear rivers, and Steamboat, Sutter, and Cache sloughs). DWR undertook repairs at 21 of the sites, and the Corps undertook repairs at the remaining 36 sites. These sites were identified as "critical", as defined by bank erosion that could threaten the structural integrity of the flood control system, and therefore required immediate work to prevent levee failure during the next flood (Ayres Associates 2007). Additional sites may be added based upon future levee repair work by DWR or the Corps. Vegetation establishment and maintenance of the repair sites' habitat features were being performed by others, as contracted by the Corps, Reclamation Board, and/or DWR, for a three-to-five year period.

The terms and conditions to minimize the incidental take associated with construction and monitoring of the levee repair sites is provided in several BOs prepared by NMFS and USFWS (NMFS 2001, 2004, 2006a, 2006b, 2007; USFWS 2004a, 2004b, 2006a, 2006b, 2006c, 2007). This monitoring effort has the potential to affect adversely several special-status fish species including Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU), Central Valley steelhead Distinct Population Segment (DPS), Central Valley spring-run Chinook salmon ESU, the North American green sturgeon southern DPS, the delta smelt, longfin smelt, and others. Thus, the BOs cover incidental take that could occur with this monitoring effort at the selected repair and natural sites.

As described in the BOs, the required monitoring includes evaluating habitat features that are incorporated into the critical levee repair sites for ten years. The recently completed critical levee repairs and constructed habitat features include:

- riprap and/or riprap mixed with soil to protect the toe and upper slopes of the bank;
- berms at the mean summer water level to provide aquatic habitat during higher river stages in winter and spring;
- instream woody material (IWM) installed for aquatic instream structure and hydraulic refuge; and
- live pole cuttings, container plantings, and grasses to stabilize the bank and provide riparian and shaded riverine aquatic habitat.

The riprap provides structural bank and levee protection, while the constructed habitat features will support habitat use by fish and other aquatic and terrestrial organisms.

2 STUDY AREA DESCRIPTION

The Sacramento River originates on the slopes of Mount Eddy in the Trinity Mountains within the Klamath Mountain Range (Thompson 1961). It joins with the McCloud and Pit rivers at Lake Shasta to form the largest river in California, with a drainage basin approximately 335 mi (540 km) long and 168 mi (270 km) wide (Larsen and Greco 2002). The Sacramento River basin climate is Mediterranean with mean annual rainfall of 36 in (914 mm) and average temperatures ranging from 54°F (12°C) in January to 88°F (31°C) in July (Domagalski et al. 2000). The Sacramento River system flows are regulated by dams built for water supply and flood control, which have stabilized and altered flow regimes, changing the river's erosion and sediment transport characteristics (Mount 1995).

The planning area for the SAM extends from the lower Sacramento River near Collinsville at RM 0 to Chico Landing at RM 194, and includes the lower reaches of the American River (RM 0–23), Feather River (RM 0–61), Yuba River (RM 0–11), and Bear River (RM 0–17); portions of Three Mile, Steamboat, Sutter, Miner, Georgiana, Elk, and Cache sloughs are also included (Figure 2-1). These floodways comprise part of the comprehensive flood management improvements that have been developed along the lower 175 mi (281 km) of the river's east bank, the lower 185 mi (298 km) of the west bank, and along the lower reaches of the river's major tributaries (Stillwater Sciences and Dean Ryan Consultants 2004). Behind the present day project levees, access to the Sacramento River floodplains is limited by overflow weirs (Moulton Weir, Colusa Weir, Tisdale Weir, Fremont Weir, and Sacramento Weir) and bypasses (Sutter, Yolo, and Butte).

Downstream of Colusa at RM 143, the river becomes narrower, deeper, and has more gradual gradient; it exhibits finer substrate, and is confined by levees on both sides (SRAC 2003). In these reaches, the riparian vegetation tends to consist of discontinuous narrow bands of riparian vegetation along the levees (Table 2-1). The soils along these reaches are primarily composed of Colombia and Sycamore series (SRAC 2003).

The lower reaches of the Sacramento River (1A and 1B) along RM 0-80 run past the City of Sacramento to the Delta (Stillwater Sciences and Dean Ryan Consultants 2004). Here, the majority of the river is narrowly confined by large levees. The riparian vegetation tends to consist of discontinuous narrow bands of riparian vegetation along the levees (Table 2-1). The soils along these reaches are primarily composed of Colombia and Sycamore series (SRAC 2003). A portion of the reach (RM 0 to approx. RM 30) is tidally influenced. The middle reach of the Sacramento River extends from RM 80, near the Feather River confluence, north towards RM 143 near Colusa (Reach 2; (Stillwater Sciences and Dean Ryan Consultants 2004). The channel is generally less narrow than along the lower reaches; however the river is confined within levees. A few relict stands of riparian vegetation occur on sands deposited over the riprapped banks. The levees along the uppermost reach from RM143-194 (Reach 3) are generally setback and spaced wide enough to allow for river migration (Stillwater Sciences and Dean Ryan Consultants 2004). In areas not fortified with riprap or other erosion control features, the meandering river forms cut banks, gravel bars, and associated floodplains. Sparse remnant stands of riparian forest occur along the upper reach and early successional species establish on alluvial deposits.

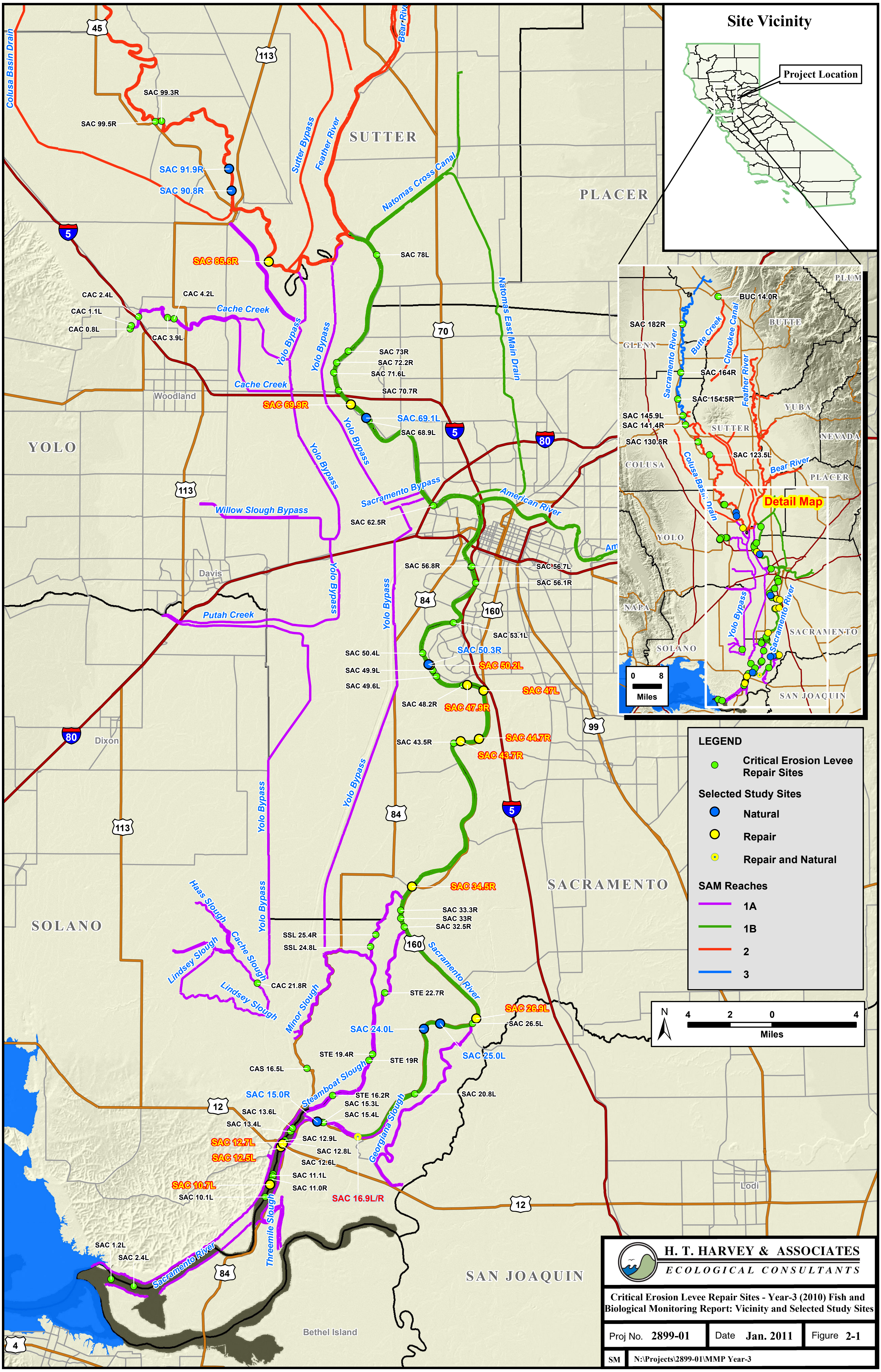
Table 2-1. Common Riparian Plant Species Found along Sacramento River Downstream of RM 143 (SRAC 2003).

Common Name	Scientific Name
Fremont cottonwood	*Populus fremontii ssp. fremontii*
valley oak	*Quercus lobata*
Goodding's black willow	*Salix gooddingii*
box elder	*Acer negundo var. californicum*
arroyo willow	*Salix lasiolepis*
narrow-leaved willow	*Salix exigua*
California black walnut	*Juglans californica var. hindsii*
Oregon ash	*Fraxinus latifolia*
blue elderberry	*Sambucus mexicana*
coyote brush	*Baccharis pilularis*
Himalayan blackberry	*Rubus discolor*
wild rose	*Rosa californica*
Mugwort	*Artemisia douglasiana*
Horseweed	*Conyza Canadensis*
California wild grape	*Vitis californica*
Santa Barbara sedge	*Carex barbarae*
California Dutchman's pipe	*Aristolochia californica*

Based on the differences in reach geomorphology and vegetation as described above (and in further detail in Stillwater Sciences and Dean Ryan Consultants 2004), four reach designations of the Sacramento River were considered in the SAM:

- Reach 1a: from Collinsville to (near) Isleton (RM 0-20)
- Reach 1b: from (near) Isleton to Verona (RM 20–80)
- Reach 2: from Verona to Colusa (RM 80–143)
- Reach 3: from Colusa to Chico Landing (RM 143-194)

The majority of the levee repairs occurred in Reaches 1a and 1b, with fewer in Reaches 2 and 3. The monitoring sites for this study included existing completed repair sites and naturalized sites between RM 10.7 and 91.9 on the Sacramento River (that is, within Reaches 1a, 1b, and 2). Reach 3 was not considered for this study for logistical reasons. We selected monitoring sites focusing on the original 57 critical repair sites constructed in 2006 and 2007, the Brannan Andrus Levee Maintenance District (BALMD) sites constructed in 2007, and naturalized sites within the study reach.



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Critical Erosion Levee Repair Sites - Year-3 (2010) Fish and Biological Monitoring Report: Vicinity and Selected Study Sites

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3 MONITORING OBJECTIVES

The overall objectives of this study are to:

1) identify habitat features of levee repair sites that promote fish use, so that repair sites can maximize value for fish and
2) determine if fish use is similar between naturalized sites and levee repair sites.

3.1 Objective of Habitat Features Monitoring

The primary objective for the habitat feature monitoring is to quantitatively describe and compare the habitat features located at various seasonal water elevations at the selected bank protection and at naturalized, reference sites[3]. These habitat features include bank slope, floodplain inundation ratio, bank substrate size, instream structure, aquatic vegetation, and overhanging shade. These data were collected using a repeatable survey design and in a format that can be used to evaluate focus fish species response in the SAM model.

3.2 Objectives of Fish Monitoring

The primary objective of fish monitoring is to determine fish species utilization at 1) recently constructed levee repair design sites and naturalized sites, and 2) at specific habitat features present within those sites.

Specific fish monitoring objectives include:

- Evaluate fish use based on electrofishing surveys at selected naturalized and repaired sites. The electrofishing data were used to determine salmonid and bass predator presence at sites.
- Evaluate juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) outmigration behavior using telemetry to compare residency time at repaired versus naturalized sites.

4 METHODS

Sampling consisted of calculating and measuring habitat features, electrofishing, and tracking fish using telemetry. Habitat features were characterized using the methods described in the Final Standard Assessment Methodology (SAM) for the SRBPP (Stillwater Sciences and Dean Ryan Consultants 2004); additional measures of instream woody material were also conducted.

The statistical methods employed varied from relatively simple descriptive statistics (mean, standard error) to more advanced techniques such as generalized linear mixed-effects modeling (GLMM). The survey and statistical methods evolved and improved as we gained greater knowledge in the field, and as we examined results from the first full year of monitoring (2009).

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[3] The term “reference sites” was frequently used in agency discussions. In this report, the terms “reference sites” and “naturalized sites” are synonymous.

We elected to employ a 3-step approach to evaluate differences due to design type and relationships with habitat features. The four levee repair design types exhibited many and various habitat features important to fish (e.g., IWM and overhanging shade). Simple comparisons of fish presence/absence to design type may indicate relationships between fish and design type, but such comparisons would not identify which habitat features (singly or in combination) within the four levee repair designs were attractive or used by fish. We wish to understand whether fish respond to 1) the levee repair design types, 2) the specific habitat feature(s) within sites, or 3) some combination of both design and habitat features. Our approach consisted of the following 3-step process:

1) Develop a statistical model that indicates whether fish use significantly differs due to design type. Habitat features are not accounted for in this step, but important spatial and temporal variables are identified; these variables are independent of design type and habitat features. Examples of this latter group of variables include "region" of river or month of sampling.
2) Develop a statistical model that indicates statistically significant relationships between fish use and habitat features; design types are not accounted for in this step.
3) Develop a statistical model that is similar to the model in Step 2, except that it includes design type, key habitat features, and important variables reflecting spatial and temporal variability.

Detailed descriptions of the statistical methods are presented below.

4.1 Site Selection

In 2008, a site selection process was completed to determine the long-term study sites for this fish and habitat monitoring study. Existing information was used to compile a comprehensive master list of potential repair sites and of naturalized sites for site selection. Within Reaches 1a, 1b, and 2, naturalized sites were initially selected from the revetment database (Stillwater Sciences and Ayres Associates, Inc. 2007). Information was obtained on naturalized and repair site characteristics from the following sources:

- DWR and Corps repair site designs and personal communications,
- the revetment database (Stillwater Sciences and Ayres Associates, Inc. 2007),
- repair site post-construction SAM result data obtained from DWR and the Corps,
- the agency field trip and meeting 7-8 February 2008, and
- initial March 2008 field monitoring effort 17-21 March 2008.

All repair and naturalized sites were categorized and stratified based on site-specific characteristics.

The site selection process factored in a number of variables including SAM reach designations, geomorphic setting, repair type, bank slope, floodplain inundation, bank substrate size, recent repair sites with constructed habitat features (i.e., more gradual slopes, off-channel ditches, benches), recent repair sites without habitat features (i.e., no benches, no riparian or wetland habitat, no IWM, etc.), and relatively undisturbed natural bank sites. The use of these variables was discussed in an 8 February 2008 monitoring meeting with DWR, Corps, NMFS, USFWS, and CDFG. Setback levee repairs and sites located in Reach 3 were not included in this study for logistical reasons. The list of repair sites included 22 sites in Reach 1a, 29 sites in Reach 1b and 9 sites in Reach 2. Region was an additional variable used to describe river segments identified by clusters of study sites or proximity by river mile, and were identified as: Knights Landing (RM 85 to 95), Garcia Bend (RM 40 to 70), Ko-ket (RM 24 to 35), and Rio Vista (RM 10 to 20).

The result of this selection process was the provisional selection of a subset of sites. Sites from the sloughs (for example, Steamboat or Cache sloughs) were not selected to minimize extraneous variability and to focus on comparing naturalized versus repaired sites. Sites were selected to balance effort among river reaches and to ensure efficient data collection (for example, access from boat launching sites was considered). Site access is critical to stationary telemetry gear maintenance and data acquisition. Sites that met reach and access criteria were explored using non-metric multidimensional scaling ordination to ensure that the sites ultimately selected for sampling exemplified a wide range of ecological characteristics (for example, scant to abundant large woody debris). In addition, sites were selected to ensure sufficient separation so that passive telemetry would be effective in identifying tagged fish at specific sites.

In 2008, a 4-day reconnaissance boat trip and follow-up field investigation with DWR was completed to select the final 21 monitoring sites. Each site was visited in the field and information on passive telemetry feasibility, channel morphology, site design, and habitat features was collected. A study segment was chosen for each site, recorded with GPS points, and photographed. The boat field reconnaissance was attended by fisheries and restoration ecologists and the project's biostatistician to ensure all elements of the monitoring were carefully considered and the statistical power of the study design maximized. Following the reconnaissance trip, the final sites were selected in coordination with the biostatistician and agency group, to ensure a study design that could address the goals and objectives of the project. It should be noted that the final sites selected for monitoring changed slightly during installation of monitoring transects. The final list of selected monitoring sites for habitat feature and fish monitoring is provided in Table 4-1 and Figure 2-1. These sites were monitored through the entire monitoring program.

Table 4-1. Final Selected Monitoring Sites at Levee Repair and Naturalized Sites.

Site	SAM Reach	Region	Repair or Natural	Study Segment Length (ft)	Repair Design Type	DWR/Corps	Tidal vs. Non-tidal (RM 32)
10.7L*	1a	Rio Vista	Repair	302	Dietl Ditch	DWR	Tidal
12.5L*	1a	Rio Vista	Repair	183	bench	DWR	Tidal
12.7L*	1a	Rio Vista	Repair	648	bench	DWR	Tidal
15.0R*	1a	Rio Vista	Natural	450	natural	N/A	Tidal
16.9R*	1a	Rio Vista	Natural	450	natural	N/A	Tidal
16.9L*	1a	Rio Vista	Repair	167	10:1 slope	Corps	Tidal
24.0L	1b	Ko-ket	Natural	600	natural	N/A	Tidal

Site	SAM Reach	Region	Repair or Natural	Study Segment Length (ft)	Repair Design Type	DWR/Corps	Tidal vs. Non-tidal (RM 32)
25.0L	1b	Ko-ket	Natural	600	natural	N/A	Tidal
26.9L	1b	Ko-ket	Repair	449	Dietl Ditch	Corps	Tidal
34.5R	1b	Ko-ket	Repair	493	Dietl Ditch	Corps	Non-tidal
43.7R	1b	Garcia Bend	Repair	633	10:1 slope	Corps	Non-tidal
44.7R	1b	Garcia Bend	Repair	656	10:1 slope	Corps	Non-tidal
47.0L	1b	Garcia Bend	Repair	622	10:1 slope	Corps	Non-tidal
47.9R	1b	Garcia Bend	Repair	657	10:1 slope	Corps	Non-tidal
50.2L	1b	Garcia Bend	Repair	615	no bench	Corps	Non-tidal
50.3R	1b	Garcia Bend	Natural	450	natural	N/A	Non-tidal
69.1L	1b	Garcia Bend	Natural	600	natural	N/A	Non-tidal
69.9R	1b	Garcia Bend	Repair	701	no bench	DWR	Non-tidal
85.6R	2	Knights Landing	Repair	619	no bench	DWR	Non-tidal
90.8R	2	Knights Landing	Natural	600	natural	N/A	Non-tidal
91.9R	2	Knights Landing	Natural	600	natural	N/A	Non-tidal

* Electrofishing was not conducted at these sites due to restrictions associated with delta smelt.

4.2 Measurement of Habitat Features

Habitat conditions were characterized using the methods described in the Final Standard Assessment Methodology (SAM) for the SRBPP (Stillwater Sciences and Dean Ryan Consultants 2004), with some additional measuring of instream structure added to better characterize the structure of the wood that the fish are utilizing. Habitat conditions were characterized at selected sites for each season using available data, existing models, and field surveys. Habitat feature monitoring fieldwork for the 2008 season was completed 11-15 August, 25-28 August, and 18 September. Habitat feature field work for the 2009 season was completed by H. T. Harvey & Associates on 25-27 August, 9-11 September, 2 October, and 6-8 October. Additional instream wood surveys were conducted by boat on 15-7 April 2010 during the time when electrofishing data were collected. Habitat feature data were also collected in 2010 and will be compared to the 2011 fisheries data. Surveys were completed by land or boat, depending on accessibility with repair sites generally completed on land and natural sites by boat. The following are descriptions of the methods used to estimate values for each habitat variable.

4.2.1 Water Surface Elevations

Estimates of average fall, winter, spring, and summer water surface elevations for each selected monitoring site were determined by DWR and H. T. Harvey & Associates using computed seasonal gage data from available DWR and United States Geological Survey (USGS) gages, interpolated computed seasonal average water surface elevations, field indicators, and field calculations where needed. In 2008, the locations of average low (summer/fall) and high (winter/spring) seasonal shoreline elevations were used to establish permanent transects at each selected site. These elevations roughly correspond to the range of water surface elevations that could occur during the period of fish sampling. Data on substrate size, instream structure, aquatic vegetation, and shade were collected at each selected site along these two permanent transects. Data collected along the average high (winter/spring) shoreline elevation were used for both winter and spring season values; data collected along the average low (summer/fall) shoreline elevation were used for summer and fall season values. Some selected monitoring sites (those downstream of RM 32) are influenced more by tidal fluctuations than by seasonal changes in flow elevation. Accordingly, instead of using seasonal water surface elevations, mean high and mean low tidal elevations were used to determine transect locations for the habitat feature analysis in these locales. Monitoring data were collected along these same permanent transects in both 2008 and 2009 and will be collected along these same transects in the future. Water surface elevations are strongly correlated with river mile.

4.2.2 Wetted Areas

The wetted area is the water surface area (in square feet) for each season under analysis (Stillwater Sciences and Dean Ryan Consultants 2004). The wetted area was estimated for the selected monitoring sites for each season by calculating the wetted surface area of the river, measured from the centerline of the river to the seasonal shoreline elevation. The wetted area for sites that are tidally influenced was estimated using the mean high and mean low tidal elevations. Wetted area values were calculated by DWR in 2008; these values will be used in analyses throughout the monitoring program.

4.2.3 Shoreline Length

The shoreline length (in feet) of the study segment was measured at each selected monitoring site in the field during habitat feature monitoring in 2008. These values will be used in the analysis throughout the monitoring program. Shoreline length was used to standardize various habitat variables to control for differences in the length of the sites selected for this study.

4.2.4 Bank Slope

Bank slope represents near shore shallow water habitat availability for focal fish species (Stillwater Sciences and Dean Ryan Consultants 2004). The SAM uses the average change in channel width with respect to depth (dW/dH) for each season under analysis to accommodate changes in water surface elevation. The bank slope was calculated for each selected monitoring site, for each season under analysis. Some of the selected monitoring sites are influenced more by tides than by seasonal changes in water surface elevation; for these sites, the bank slope was calculated using the mean high and mean low tidal conditions. Bank slope values were calculated by DWR in 2008. These values will be used in analyses throughout the monitoring program.

4.2.5 Floodplain Inundation Ratio

The floodplain inundation ratio represents floodplain habitat availability, which is important for focal fish species juvenile life stages (Stillwater Sciences and Dean Ryan Consultants 2004). In the SAM, the floodplain inundation ratio (unitless) is a ratio of the total wetted surface area at a 2-year flood recurrence probability (Q2) to the reach-average wetted surface area during winter or spring. The floodplain inundation ratio was calculated for the average spring/winter water elevation using GIS software. The mean high tidal elevations were used for those selected monitoring sites that are influenced more by tides than season. Floodplain inundation ratio values were calculated by DWR in 2008. These values will be used in analyses throughout the monitoring program.

4.2.6 Bank Substrate Size

Bank substrate is an important factor in determining predation risk and growth for almost all life stages of the focal fish species in the SAM (Stillwater Sciences and Dean Ryan Consultants 2004). The bank substrate size (in units of inches) was characterized for each selected site at and directly below/under each permanent transect. A percentage of each substrate size category was estimated for each transect using substrate size categories adapted from the *SAM Users Manual* (Stillwater Sciences and Dean Ryan Consultants 2004). Some of the categories in the *SAM Users Manual* were grouped into larger size categories for this study (Table 4-2).

Table 4-2. Substrate Size Categories.

Size Class	Size (in) in Diameter
Large Boulders	>20
Medium Boulders	20 - 12
Small Boulders	<12
Large Cobbles	>10
Medium Cobbles	10 - 6
Small Cobbles	<6
Gravel	2.5 - 0.08
Sand	0.08 - 0.01
Silt/Clay	0.01
Erosion Control Blanket[1]	0.01

[1] Substrate category added by H. T. Harvey & Associates.

4.2.7 Aquatic Vegetation

Aquatic vegetation represents hiding cover and invertebrate food production base for the focal fish and their predators (Stillwater Sciences and Dean Ryan Consultants 2004). Aquatic vegetation included floating, submerged, and emergent aquatic vegetation. Live riparian vegetation that was partially submerged seasonally was considered aquatic vegetation, but annual upland species were not considered aquatic vegetation. Aquatic vegetation data were collected in the field and values were estimated for each season at each selected monitoring site.

Along the permanent transects, the percent of shoreline with aquatic vegetation coverage was determined using the point-intercept method, as recommended in Appendix E of the *SAM Manual* (Stillwater Sciences and Dean Ryan Consultants 2004). Presence/absence of aquatic vegetation was determined at each point and directly below/under that point perpendicular to the line toward the water in both 2008 and 2009. Thirty regularly spaced points were established along the permanent transects at each selected site. Mean percent of shoreline with aquatic vegetation coverage was calculated for each season at the selected sites. Aquatic vegetation data were collected in August and September for both summer/fall and winter/spring values, but values were reduced by 40% for the winter/spring values to account for seasonal senescence of the vegetation.

4.2.8 Overhanging Shade

Shade represents hiding cover and food availability for the focal fish species in the SAM (Stillwater Sciences and Dean Ryan Consultants 2004). Shade included riparian canopy and any other vertical obstruction that provided shade above the seasonal bank line at midday. Overhanging shade data were collected in the field and values were estimated for each season at each selected monitoring site in both 2008 and 2009.

The percent of shoreline with overhanging shade coverage was determined using the point-intercept method, as recommended in Appendix E of the *SAM Manual* (Stillwater Sciences and Dean Ryan Consultants 2004) along the 2 permanent transects. Presence/absence of overhanging shade was determined at each point and below the elevation of that point perpendicular to the line toward the water. Thirty regularly spaced points were established along the permanent transects at each selected site. Mean percent of shoreline with overhanging shade coverage was calculated for each season at the selected sites. Overhanging shade data were collected in August and September for both summer/fall and winter/spring values, but values were reduced by 40% for the winter/spring values to account for seasonal leaf senescence.

4.2.9 Photo-Documentation

Each selected site was photographed from 2 to 6 permanent photo points established at the sites, in 2008 and 2009. Selected photographs of the sites are presented in Appendix B. The entire set of photographs will be furnished upon request.

4.3 Instream Structure and IWM Measurements

Instream structure and IWM were measured in various ways:

1) Percent of shoreline with instream structure coverage (unitless), measured along a transect, as recommended in Appendix F of the *SAM Manual* (Stillwater Sciences and Dean Ryan Consultants 2004),
2) Estimates of the jam size, number, and area at or below the higher elevation shoreline transect at each site (also measured along a transect), and

3) IWM density, IWM size, and IWM in/out of water, measured during electrofishing at sampled points within a site.

Instream wood was characterized at sites in 2008 and 2009 during transect surveys described in 1) and 2) above; these surveys were conducted independent of electrofishing surveys. The transect-based instream wood measurements were taken at the shoreline, and therefore generally describe instream wood that may not be inundated during electrofishing. In contrast, 3) above describes IWM measurements that were taken at the points electrofished in April 2010; these spatially explicit measurements were based on visual observations of IWM in and above the water.

In the SAM, instream structure represents possible hiding and resting cover for focal fish species and their predators (Stillwater Sciences and Dean Ryan Consultants 2004). Instream structure includes natural sources of instream wood, but also other structural elements such as pump intakes, docks, and any other submerged structures that provide flow deflection or hiding cover. Instream structure does not include live bank vegetation or wood pieces smaller than 10 cm in diameter, but includes fascines (bundles of live willow cuttings) anchored perpendicular to the bank. Instream structure data were collected in the field along transects during habitat feature monitoring, and values were estimated for each season at each selected monitoring site.

The percent of shoreline with instream structure coverage (unitless) was determined along transects, as recommended in Appendix F of the *SAM Manual* (Stillwater Sciences and Dean Ryan Consultants 2004). Percent of shoreline was quantified along the 2 permanent transects located at the average low (summer/fall) and high (winter/spring) shoreline elevations as described above. Transects were located at the mean high and mean low tidal elevations for the sites that are influenced more by tides than seasonal changes in water surface elevation. Notes were also taken to determine if the instream structure was installed as part of the repair design or if the wood was recruited. Thirty regularly spaced points were established along the permanent transects at each selected site. Mean percent of shoreline with instream structure coverage was calculated for each season at the selected sites in both 2008 and 2009.

Although data were collected along transects as recommended by SAM, to accurately reflect the variability of instream structure between sites and to better characterize wood that could be used as fish habitat, additional data were collected along the transects. This additional data included estimates of jam size, number, and area present at or below the higher elevation shoreline transect at each site; these data were also collected in both 2008 and 2009.

During the 2010 electrofishing surveys, we noted that the IWM measures along transects may not be as closely related to fish abundance from electrofishing, as would IWM measured at the electrofished points. Therefore, during electrofishing in April 2010, we also measured IWM at the electrofishing points; these measurements were IWM density, IWM size, and IWM in/out of water (Table 4-3). IWM density class was estimated by visual observation at the start of each electrofishing point; the observation was focused on IWM visible below the surface of the water within a 10 ft diameter circle, the approximate range of electrofishing effectiveness. IWM size was the most common size class observed at the point. IWM in/out of water was classified at each point; if IWM was submerged beyond sight, probing of the IWM below the water with net handles was used to help assess IWM in/out of water. In addition, submerged vegetation was measured at electrofishing points as a binary variable, with “yes” denoted if there was >10% of the area of an electrofishing point covered with plant material that was providing instream cover, including submerged riparian vegetation and shrubs (i.e., blackberries), and aquatic plants.

Table 4-3. IWM Measures during Electrofishing.

IWM Measures at Electrofishing Points	Classifications of IWM Measured
IWM Density Class	None Low (<25%) Medium (25 to 50%) High (>50%)
IWM Size Class	<4 inches 4 to 8 inches >8 inches
IWM In/Out Water	>50% submerged >50% above the surface Floating

In summary, IWM was characterized along transects in 2008 and 2009, and at sampled electrofishing points during electrofishing in 2010 (Table 4-4).

Table 4-4. Summary of IWM Measures along Transects and during Electrofishing.

SAM-based IWM Measure along Transects (2008, 2009)	Additional IWM Measures along Transects (2008, 2009)	IWM Measures during Electrofishing (2010)
% IWM of bankline (SAM variable)	jam area number of IWM pieces IWM diameter	IWM density IWM size IWM in/out of water

4.3.1 Use of IWM Measured along Transects and during Electrofishing with the Electrofishing Data, in the Generalized Linear Modeling

IWM data collected along transects and during electrofishing allowed us to analyze whether fish could be responding differently to habitat variables at two spatial scales. The transect IWM measures are representative of a larger area of river/stream bank. The electrofishing IWM measures are representative of much smaller areas of river/stream bank. For example, for smaller fish such as Chinook salmon fry and juveniles, there may be stronger relationships with IWM measured at the electrofishing points than along transects. Conversely, larger fish such as bass predators may be more likely to respond to IWM measured along transects than at the electrofishing points. Therefore, for our generalized linear modeling, we analyzed relationships between IWM measured along transects and at electrofishing points. These modeling techniques are described in Section 4.5.1.

4.4 Fish Sampling

To evaluate specific habitat use by juvenile salmonids and predator fish species, electrofishing and passive telemetry surveys were conducted. These methods complement each other; electrofishing surveys provide information on fish assemblages and habitat-specific fish use at selected sites, whereas passive telemetry of tagged fish provides information on individual fish behavior at monitored sites “24/7” over several months. In addition, several water quality parameters were measured during electrofishing surveys.

4.4.1 Electrofishing

The USFWS determined that boat electrofishing was not allowed at sites downstream of RM 20 because of the increased potential to injure, harm or kill delta smelt. Electrofishing was conducted at sites upstream of RM 20 using a boat-mounted electrofishing unit. Monitoring design was based on studies that have evaluated salmonid habitat use in large mainstem rivers by Beechie et al. (2005) and Tiffan et al. (2006).

Each selected site upstream of RM 20 was electrofished during daylight hours from a boat held as stationary as possible, using a grid-point sampling system. Due to safety issues and difficulty in seeing the fish, night surveys were not conducted. A pulsed DC, Smith-Root GPP 5.0 electrofisher with a single 28-cm-diameter ring anode mounted on each of two telescoping fiberglass poles was used. The voltage, pulse rate and amperage were determined in the field with CDFG personnel experienced in electrofishing in the delta (Curtis Hagen, CDFG) on 21 October 2008; various combinations of voltages, pulse rates, and amperages were evaluated on fish catches and fish condition to select the settings used for this study (500 V, 60 pulses/s, 60 A).

Each sampling point included an area of approximately 20 m^2; this estimate of area accounts for movement due to the downstream drift of the boat during sampling. Grid-point spacing ranged from 10 m at small sites to 25 m at large sites, and 15 points were typically sampled at each site. Grid-point spacing was first determined by the need to maintain independence between points (hence all spacing was ≥10 m), and secondarily by the length of the site. Electrofishing at the first grid-point was unlikely to disturb the fish at the second grid-point. Fish were collected at each grid point by turning the electrofisher on for 10 s, off for 5 s, and back on for 10 s, until no additional fishes were stunned. Stunned fish were retrieved with dip nets, and species and lengths recorded. Missed fish (stunned and seen, but not netted) were also recorded and classified to species and approximate size.

The exact location of sampling relative to the bank varied somewhat among points within a site, typically ranging from between 1 to 5 m from the shoreline. An attempt was made at each site to shock areas with adequate depths (>0.5 ft) as close to the shoreline as possible. Depth ranges were relatively consistent among sampled points. Spacing relative to the bank was consistent among sites and design types, with the exception of Dietl Ditch. Distance from the bank at Dietl Ditch was by necessity greater than for other design types, because it was not possible to sample the off-channel ditch itself; instead, sampling along the main channel at the outside of the ditch or at the inlets connecting the ditch with the main channel. These sites were sampled at approximately 5 to 7 m from the shoreline. The catchability of fish here probably did not differ from the other design types, given that depth conditions at these electrofishing points were similar to those sampled for the other design types. Other habitat features that may affect catchability are discussed later in the text.

Sites were electrofished three times between late January and April in 2009 and 2010 to capture out-migration peaks of fall-run, late fall-run, spring-run, and winter-run Chinook salmon and steelhead (Snider and Titus 2000, Williams 2006a); a January effort in 2009 was aborted before all sites were sampled, due to low number of captures and excessively high flows. Typically, 3 to 5 sites were sampled per day until all sites were sampled during a given sampling effort. Specific timing of sampling within the winter/spring window was based on 1) detection of fish at the Knights Landing outmigrant trap (Appendix C), and 2) the objective of sampling during multiple points in time within the out-migrant season.

4.4.2 Telemetry

Deployment of telemetry receivers and tagging of juvenile steelhead are described in H. T. Harvey & Associates and PRBO Conservation Science (2010). In 2010, telemetry receivers (Figure 4-1) were deployed at 18 study sites by H. T. Harvey & Associates and at three study sites by Bud Abbott (Table 4-5) on 17 December 2009; receivers operated until 13 May 2010. Data were not available for the entire period of record for station 69.1L, due to the inability to retrieve the receiver (i.e., a water-logged tree rolled or drifted over the top of the receiver and could not be moved). Chinook and steelhead were released from December 2009 to March 2010 (Table 4-5).

The receivers were placed closer to shore than to mid-channel, generally as near to the bank as possible, given the need for sufficient water depth to keep the receiver and the buoys below the surface. The distance from the bank to the receiver ranged from 4 to 34 meters. Range detection tests indicated that the average detection distance for V9 transmitters (with a consistence of 80% or better) was just over 200 meters, but results varied with location and environmental conditions. For an illustration of receiver deployment methodology, please see H. T. Harvey & Associates and PRBO Conservation Science 2010.

H. T. Harvey & Associates also participated in the California Fish Tracking Consortium (CFTC), an allied group of researchers using acoustic telemetry to study fish movement patterns, and pooling equipment and data resources. Other members of the CFTC released tagged fishes in the Sacramento River mainstem and tributaries. Some of these releases had the potential to encounter our array of receivers, and, by accessing the CFTC database, we were able to identify tags detected by our array. The CFTC database identified (at a minimum) the species originally implanted with the tag, release date, release location and the researcher(s) responsible.

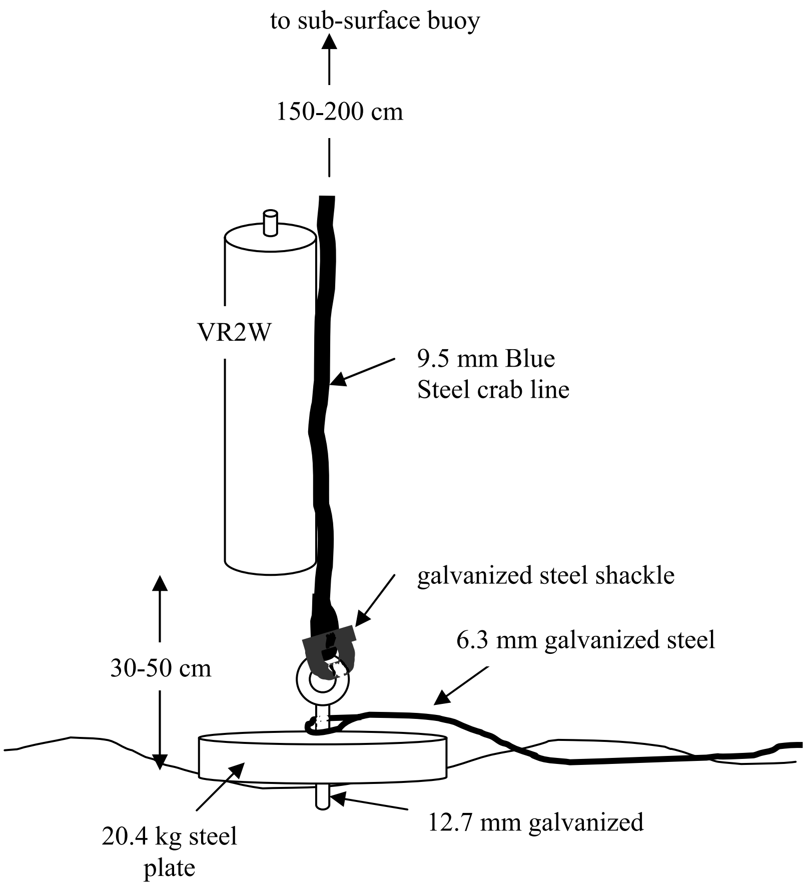

Figure 4-1. Passive Telemetry Receiver Schematic.

Table 4-5. Location, Date, and Size at Release (mm) for Tagged Chinook Salmon and Steelhead Juveniles Released in the Mainstem Sacramento River from December 2009 to March 2010.

Species	RM	Location	Date Released	# Release	Fork Length (mm)		
					Mean	SD	Range
Chinook	69	Elk Landing	30-Jan-10	249	177.8	12.5	144-206
Chinook	69	Elk Landing	05-Feb-10	248	176.6	14.8	93-200
Chinook	73	Elverta Road	28-Jan-10	100	163.7	8.9	150-190
Chinook	100	Knights Landing	27-Jan-10	100	163.7	8.8	150-185
Chinook	169	Butte City Boat Ramp	15-Dec-09	51	155.7	9.2	137-174
Chinook	169	Butte City Boat Ramp	06-Jan-10	51	150.4	10.1	135-174
Chinook	200	Irvine Finch Boat Ramp	15-Dec-09	51	153.0	10.6	135-176
Chinook	200	Irvine Finch Boat Ramp	06-Jan-10	51	151.2	10.5	135-174
Chinook	258	Jelly Ramp	15-Dec-09	51	152.0	10.6	135-173

Species	RM	Location	Date Released	# Release	Fork Length (mm)		
					Mean	SD	Range
Chinook	258	Jelly Ramp	06-Jan-10	51	152.5	10.1	135-174
Chinook	282	Battle Creek Weir	16-Dec-09	120	147.9	7.7	135-160
Steelhead	69	Elk Landing	30-Jan-10	249	222.4	18.8	108-266
Steelhead	69	Elk Landing	05-Feb-10	250	223.8	16.6	132-277
Steelhead	69	Elk Landing	09-Mar-10	20	206.8	24.0	167-243
Steelhead	169	Butte City Boat Ramp	17-Dec-09	50	192.0	13.4	161-217
Steelhead	169	Butte City Boat Ramp	07-Jan-10	50	194.0	21.6	157-228
Steelhead	200	Irvine Finch Boat Ramp	17-Dec-09	50	197.3	18.7	155-232
Steelhead	200	Irvine Finch Boat Ramp	07-Jan-10	50	199.4	22.3	155-235
Steelhead	258	Jelly Ramp	17-Dec-09	50	197.2	19.3	157-238
Steelhead	258	Jelly Ramp	07-Jan-10	50	197.0	18.5	157-234

4.5 Analysis of Fish Data

Our 3-step approach to analyzing the fish and habitat features data was applied to both the electrofishing and telemetry data. To review, this 3-step approach is:

1) Develop a statistical model that indicates whether fish use significantly differs due to design type. Habitat features are not accounted for in this step, but important spatial and temporal variables are identified; these variables are independent of design type and habitat features. Examples of this latter group of variables include “region” of river or month of sampling.
2) Develop a statistical model that indicates statistically significant relationships between fish use and habitat features; design types are not accounted for in this step.
3) Develop a statistical model that is similar to the model in Step 2, except that it includes design type, key habitat features, and important variables reflecting spatial and temporal variability.

This approach allowed us to discern differences in fish use due to design type, and to identify statistically significant relationships with habitat features. Further, the approach allows us to identify and control for those features or variables that may affect the dependent variable (for example, sampling year) but that are not directly related to design type or habitat features. Additional details of the 3-step statistical modeling approach are given below (see text box).

3-Step Statistical Modeling Approach

For example, in Step 1, a potential generalized linear mixed model could be:

Y = region + Year + region x Year interaction + **design type** + random effect of Site.

Where **Y** = presence or absence (a binary variable, 1 or 0), and residuals follow a binomial distribution.

Such a model is described in detail by Zuur et al. (2009). Variables in **bold red** are of greatest interest to us, because they can indicate whether there are statistically significant differences in fish use due to design type. Habitat feature variables are not accounted for here, because at least some are likely to be confounded with design type, and the goal of this step is to identify differences in the dependent variable due to design type (Monitoring Objective 2). The variables in blue are spatial and temporal variables that are statistically significant (these are also categorical variables), but that are of less intrinsic interest; these variables are included in the model and controlled for in order to reduce the amount of unexplained variance in the dependent variable and thus improve our ability to identify and quantify the variables of interest.

In Step 2, the following is an example of a generalized linear mixed model:

Y = region + Year + region x Year interaction + **habitat features** + random effect of Site

Where **Y** = presence or absence (1 or 0), and residuals follow a binomial distribution.

As in the previous example, the variables in bold red are of greatest interest because they indicate the relationship between the presence/absence of the fish and statistically significant habitat variables (these are quantitative variables), regardless of design type. Essentially, Step 2 tries to identify which habitat variables are most important to fish. As described above, the variables in blue are the spatial and temporal variables that are being controlled for; in this case however, controlling for these variables increases confidence in our assessment of the significance of the relationships with habitat variables rather than design type. Note, the same spatial and temporal variables are included in both Step 1 and Step 2.

Based on the examples in Steps 1 and 2, an example model for Step 3 is:

Y = region + Year + region x Year interaction + **design type** + **habitat features** + random effect of Site

Where **Y** = presence or absence (1 or 0), and residuals follow a binomial distribution.

This is similar to the model in Step 2, except that it now includes design type in addition to the habitat feature variables.

Numerous interpretations can be drawn from the 3-step statistical modeling approach; important interpretations can be summarized (Table 4-6).

Table 4-6. Interpretations of Habitat Features and Design Types Possible from 3-step GLM Approach.

Significant in Step 1	Significant in Step 2	Significant in Step 3	Interpretation
yes		yes	If design type is significant in both Step 1 and Step 3, this would indicate a very strong effect due to design type. Differences between the design types could vary between the steps, though in Step 3 design type could be confounded with habitat features; therefore, differences in Step 1 are more reliable for evaluating design type differences.
yes		no	If design type is significant in Step 1 but not Step 3, this should not be interpreted as "design type is unimportant", but rather that differences in fish use relative to design type can be accounted for by differences in associated habitat variables. Such a result would provide important insights in understanding why fish might respond differently to different design types.
no		yes	If design type is not significant in Step 1 but is in Step 3, this would indicate that, were one to control for all the habitat variables included in the Step 3 model, then we would expect variation in fish use to differ among design types.
no		no	If design type is not significant in either Step 1 or Step 3, then we would conclude that there is no difference in fish use among design types.
	yes	yes	Habitat variables that are significant in Steps 2 and 3 are variables whose effect is manifest over and above differences among design types. We can infer that even given a specific design type, differences in fish use can be expected given variation in that variable.
	yes	no	Habitat variables that are significant in Step 2 but not in Step 3 are variables whose effect is confounded with design type. Nevertheless, identification of such variables is informative because these are variables that contribute to differences in fish use among design types.
	no	no	Habitat variables that are not significant in Step 2 are not included in Step 3, and therefore cannot be significant in Step 3. These habitat variables do not appear to influence fish use.

During each step, variables were dropped one at a time, and likelihood ratio tests were used to compare successive models. Likelihood ratio tests are frequently used to compare the maximum likelihood of two nested statistical models; if the test indicates that the models are significantly different (defined as $p<0.05$), then the more complicated model (i.e., with more variables) fits the data significantly better than the simpler model (i.e., with fewer variables). In Step 1, spatial and temporal variables were dropped and design type retained regardless of significance, because design type is critical to our objectives. In Step 2, the spatial and temporal variables identified in Step 1 were included with potential habitat variables, with habitat variables being dropped as appropriate. In Step 3, design type was included in the model, along with all the variables retained in the final model of Step 2. Habitat variables were again dropped as appropriate. Likelihood ratio tests with $p>0.10$ led to the variable being removed; otherwise it was retained. Variables leading to a likelihood ratio test result of $p<0.05$ were considered significant and $p>0.10$ not significant. Results were considered to be inconclusive when $0.05<p<0.10$.

We used R software (RDCT 2009) to conduct all analyses. The statistical software R allows for use of different statistical packages tailored for numerous statistical methods, including all those used in this report.

4.5.1 Electrofishing Data Analyses

Analyses were applied using fish data collected at electrofishing points and habitat data used to characterize the sites. Note that all bench sites were downstream of RM 20, so this design type category was not included in the electrofishing analyses.

Electrofishing data from 2009 and 2010 were analyzed using two approaches for each species/life stage of interest (i.e., Chinook fry, Chinook juveniles, bass predators): 1) analysis “by month” and 2) analysis combined across months. We conducted analyses “by month” to specifically identify differences between design types and relationships with habitat features at a given point in time. The “by month” analyses provided an assessment of differences between months; the disadvantage in “by month” analyses is that they have less statistical power to discern differences due to design type or relationships with habitat variables. Electrofishing data that were combined “across months” have more statistical power due to increased sample size, but interpretation can become more difficult if interactions terms are added to account for differences due to months. Results from the “by month” analyses can help us select appropriate interaction terms to be included in the “across month” analyses, and lend some clarity for interpretation. For example, if the “by month” analysis indicated that IWM size differed between months, an interaction between IWM size and month could be included in the “across month” habitat model, along with other biologically relevant interaction terms.

The 3-step approach described previously was employed to determine differences due to design type and to establish relationships between fish presence/absence and habitat features. We assume that presence of Chinook salmon fry is indicative of habitat preferences. The details of the model fitting that occurs at each of the 3 steps are as follows:

1) A generalized linear model (GLM) was fit to the data to determine key variables;
2) Then, a generalized linear mixed model (GLMM) was employed to model the random effect of site (i.e., to account for the fact that several points were sampled within each site)

Generalized linear mixed models belong to a class of models termed "mixed-effects models", which allow for modeling variation due to random effects (i.e., effects reflecting correlated observations associated with grouping of observations) (Pinheiro and Bates 2004, Zuur et al. 2009). If ignored, the random effects potentially interfere with interpretation of the effects of greatest interest to the experiment. In our case, the effects of greatest interest were the effects of design type, spatial and temporal variables, and habitat features. We used mixed effects models because several electrofishing points were sampled from each site, and therefore shared the same values for habitat features that were quantified at the site level. We expect that electrofished points within a site will be more similar to each other (after accounting for habitat features) than will points at different sites. We accounted for the correlated variation in fish use among points within a site by incorporating the random effect. If random effects are not adequately accounted for, the coefficients and standard errors estimated for fixed effects may be biased (Mullen and Birkeland 2008). All mixed-effects modeling was conducted using the R-specific statistical package "lme4" (Bates and Maechler 2009).

4.5.1.1 Analysis by Month

For January/February 2010, March 2010, and April 2010, we applied the 3-step approach outlined previously. We assumed a binomial distribution to model presence/absence of fish at a point. The species and life stages that we analyzed were Chinook salmon fry (defined as <55 mm FL), Chinook salmon juveniles (>55 mm FL), and bass predators (>115 mm FL, based on Nobriga and Feyrer 2007); these life stages and species were selected because they are most germane to the objectives and are of greatest interest to managers.

As part of Step 1, we modeled the presence/absence of a species/life stage at electrofishing points as the dependent variable, along with all possible spatial and temporal variables, which included:

- Region
- Year
- Region x Year (an interaction term)
- Design Type
- Design Type x Year (another interaction term)

In Step 1, we developed two models. The first was a model that did not include the design type interaction with year (Design Type x Year) term; the main purpose of this model was to discern those differences due to design type that are consistent across years, thus meeting a key study objective. The secondary purpose was to identify key spatial and temporal variables to be used in Step 2. The second model's purpose was to determine the key spatial and temporal variables to be used in Step 3. Region was a variable used to describe river segments identified by clusters of study sites or proximity by river mile, and were identified as: Knights Landing (RM 85 to 95), Garcia Bend (RM 40 to 70), Ko-ket (RM 24 to 35), and Rio Vista (RM 10 to 20).

For Step 2, we developed a model that included key spatial and temporal variables identified in Step 1's first model, in addition to the following habitat variables:

- % shade (of bankline)
- Average depth, point-specific
- % emergent vegetation, point-averaged
- IWM diversity, point-based
- Bank slope
- % boulder/cobble substrate
- Dominant IWM size, point-based
- Average large woody material (LWM), defined as IWM >4 inches in diameter, point-averaged
- Interaction between Average depth and the following variables:
    - IWM diversity
    - % boulder/cobble
    - Dominant IWM size
    - Average LWM density
- Interaction between Dominant IWM size and Average LWM density

IWM diversity was characterized as the number of unique IWM classes (defined by the combination of IWM density, IWM size, and IWM in/out water) per site standardized by the number of points sampled. Average LWM density was based on the number of points that had pieces of IWM >4" diameter within each density class (i.e., none, low (<25%), medium (25 – 50%), and high (>50%)); using the midpoint of each density class (i.e., 12.5%, 37.5%, and 75%), we took the average of these density values across all points within the site. Dominant IWM size was simply the most common size class at a site; the midpoint of this class was used as the value in the analyses.

We decided to use "summer" measures for SAM variables, because the lower elevation transect at which these variables were measured was more likely to be inundated during the sampling period than the higher elevation transect where "winter" measures were made. Though there were likely some changes between years, the changes in IWM measures and aquatic vegetation do not appear to be substantial based on the qualitative comparison of habitat features, suggesting that the changes for IWM/LWM and emergent vegetation between years would also be relatively minor.

Step 2 interaction terms were based on relationships that we thought were biologically reasonable. We limited the number of interactions due to potential problems with model overparameterization; we prioritized variables that were most likely to be influential. Interactions with depth were considered, due to likely different habitat use as depth increases. For example, shallower lower velocity habitat is more likely used by fry or juvenile Chinook salmon for rearing, whereas deeper water is more likely to be used for migration. Therefore, one might expect stronger relationships between juvenile catch and habitat variables in shallower water, and potentially no relationship with these variables in deeper water. In addition, we considered a potential interaction between wood size and density; it seemed quite possible that there could be a threshold of wood size where density becomes important; conversely, it also seems possible that there could be a threshold of wood density where size becomes more or less important.

In Step 3, regional interactions that were biologically reasonable were also considered. There was particular interest in evaluating whether IWM measures and habitat use with depth would also differ depending on the nature of use, i.e., migration vs. rearing. Therefore, we included the following variables:

- Region x Average depth
- Region x IWM diversity
- Region x Dominant IWM size
- Region x Average LWM density

Other regional interactions were also considered, although overparameterization becomes an issue with the inclusion of several interaction terms. These chosen variables were considered of greatest interest to us and most likely to be important to fish.

4.5.1.2 Combined Analyses

Combined analyses (in which we combined data from months) were similar to the analyses by month, as described above, except that the data analyzed consisted of multiple months. To account for this, we included a "Month" term in addition to specific interaction terms with "Month." The additional terms (in addition to those fit in the by Month analyses) initially fit in Step 1 were then:

- Month
- Month x Design type
- Month x Year

The combined analyses used data from the months appropriate for that life stage/species. Analysis for Chinook salmon juveniles was based on data from March and April, whereas analysis for Chinook salmon fry was based on data from January/February and March. Analysis for bass predators was based on data from January/February, March, and April.

4.5.1.3 Comparison of IWM Measured along Transects and during Electrofishing

We used the transect-based and electrofishing-based IWM measures and the electrofishing presence/absence data for two comparisons. First, we compared the relationships of fish presence/absence to the transect IWM measures versus the electrofishing IWM measures (attempting to answer, "do the electrofishing presence/absence data create better statistical models with the transect-based or electrofishing-based IWM measures?"); this comparison was based on data from both years. Second, we did a similar comparison but attempted to answer, "do the electrofishing presence/absence data create better models with IWM measures representative of smaller or larger scales?" For this second comparison, we were limited to data collected during April 2010.

For the first comparison, we used presence/absence fish data from 2009/2010 with transect-based IWM measures from 2008/2009, and with averaged or summarized electrofishing-based IWM measures (Table 4-7); the reason we averaged or summarized the electrofishing-based IWM data was to expand the comparison beyond a single sampling effort (April 2010, when electrofishing-based IWM measures were taken). Ultimately, this comparison was used to guide the choice of IWM variables to use for the GLM and GLMM analyses of the electrofishing data.

For the second comparison, we used presence/absence fish data from April 2010 with 1) IWM measured during electrofishing, 2) averaged or summarized electrofishing-based IWM measures, and 3) transect-based IWM measures (Table 4-7). As discussed above, these IWM measures characterize IWM at larger (i.e., site scale, used to characterize the site) and smaller spatial scales (i.e., point scale, at electrofishing points). This second comparison allows us to investigate whether effects of spatial scale can be discerned.

Table 4-7. Summary of Data and Measurements Used in Analyses of IWM Data.

Question:	Spatial Scale Investigated	IWM Measurement Type	IWM Data Analyzed	Fish Data Analyzed
1) Does the electrofishing presence/absence data create better statistical models with the transect-based or electrofishing-based IWM measures?	Larger (Site)	Average of electrofishing-based measures	April 2010	2009/2010
		Transect-based	2008/2009	2009/2010
2) Does the electrofishing presence/absence data create better models with IWM measures representative of smaller or larger scales?	Smaller (Point)	Electrofishing-based	April 2010	April 2010
	Larger (Site)	Average of electrofishing-based measures	April 2010	April 2010
	Larger (Site)	Transect-based	2009	April 2010

Therefore, in the models we related the presence/absence of Chinook salmon juveniles and bass predators to:

1) electrofishing-based IWM measures that were averaged or summarized to characterize the larger spatial scale (addressing first and second questions)
2) transect-based IWM measures characterized at the larger spatial scale (addressing first and second questions)

3) electrofishing-based IWM measures characterized at the smaller spatial scale (addressing second question only)

Both questions were answered by using the first 2 steps of the 3-Step approach outlined above, with the focus being on identifying key IWM measures. Because of this focus, Step 1 was conducted to determine key spatial and temporal variables only; design type comparisons were not evaluated.

We used AIC (Akaike Information Criterion) as a measure of overall model fitness to compare models. The AIC is a way of assessing model fitness by penalizing increasing numbers of model terms (Akaike 1974). In addition, we reviewed whether there were differences in the significant relationships identified for each set of variables.

4.5.2 Telemetry Data Analyses

The telemetry data collected from 2009 and 2010 were analyzed using methods similar to 2009 (i.e., GLM/hurdle, see H. T. Harvey & Associates and PRBO Conservation Science 2010); however, because we desired to evaluate relationships with IWM, we conducted two separate analyses:

1) Fit a statistical model to the habitat data that included the newly measured electrofishing-based emergent vegetation and IWM variables collected during the April 2010 electrofishing survey; this analysis was by necessity restricted to the upper 3 regions, because no sites downstream of RM 20 were electrofished.
2) Fit a statistical model to the habitat data from 2008 and 2009 for all regions, which only includes transect-based IWM measures (and does not include electrofishing-based habitat measures)

Analysis # 2 included assessment of interaction terms. Interaction terms were of interest, particularly with respect to how habitat use may have varied between the wide, tidally influenced river downstream of RM 20, and sites evaluated upstream of RM 20.

A key difference between the 2009 and 2009/2010 analyses is the way that residence time was characterized; we characterized residence time in terms of days in 2009 (i.e., values were rounded to the nearest day), but in the 2009/2010 analysis, we characterized residence time in terms of hours. Based on graphical analysis of the residence time data (see Section 5.4.1, Figure 5-19), a threshold of one hour of residence time was more consistent with the idea of a fish remaining at a site than a threshold of at least one day of residence time. In addition, the use of hours rather than days gives greater temporal resolution for the analyses.

Telemetry data consisted of detection records for individually tagged hatchery fish released by other groups within the CFTC (juvenile steelhead and juvenile Chinook salmon); tagged fish were detected at receivers deployed at 20 of the 21 study sites (one receiver, at RM 69.1, was not retrievable). Data consisted of the time of detection and the tag ID for acoustically tagged steelhead and Chinook salmon. These data were analyzed to quantify residence time for Chinook salmon and steelhead. Residence time of a tagged fish was estimated as the difference between the first and last times of detection of that tag at a given site; therefore, it was possible for an individual fish to be associated with multiple estimates of residence times if it was detected at more than one site. Analyses of telemetry data consisted of distributions of residence times for each site, in addition to generalized linear model (GLM) analyses of residence time in relation to habitat variables and levee design type (including natural sites).

4.5.2.1 Generalized Linear Model Analysis

Generalized linear model analyses were used to detect differences in residence time between levee design types and to determine key habitat variables that are related to residence time, for juvenile Chinook salmon and steelhead. We applied the 3-step approach outlined for electrofishing data analyses, using likelihood ratio tests to drop variables from the model one-at-a-time until the model only included variables with $p<0.10$. Data included estimated residence times and spatial and temporal variables in addition to design type and habitat variables associated with each site. Residence time was calculated using all telemetry data except for records associated with evidence of a shed tag, mortality, or predation.

Spatial and temporal variables related to the release and individual fish were included to better estimate and evaluate the coefficients for variables of interest (i.e., for key habitat variables and design type). Spatial variables included release location and region (river segments identified by clusters of study sites or proximity by river mile). Region was an additional variable used to describe river segments identified by clusters of study sites or proximity by river mile, and were identified as: Knights Landing (RM 85 to 95), Garcia Bend (RM 40 to 70), Ko-ket (RM 24 to 35), and Rio Vista (RM 10 to 20). Temporal variables included the year of detection, date of release, the first date of detection at a site, and measured discharge at Verona (USGS and DWR operated gauging station) during the first day of residency at a site. In addition, we included a temporal variable to indicate whether the first detection at a site occurred during day or night, since this could influence the decision to stay at a site.

Design type consisted of four categories: 1) 10:1 and bench designs; 2) No bench design; 3) Dietl Ditch design; and 4) natural sites. The 10:1 and bench repair designs were combined into one category because similar design features were observed in the field and sample size was considered. The sample size for the bench repair design was small (n=2) and there was little distance between the two sites (sites 12.5L and 12.7L), therefore it was desirable to combine this design type with another.

First, we fit a statistical model to habitat variables for sites upstream of RM 20; the habitat variables that were selected were based on 2009 analyses (H. T. Harvey & Associates and PRBO Conservation Science 2010) and newly added IWM variables measured at the point scale in April 2010. The newly added IWM variables took the place of previously used IWM measures (i.e., jam area per ft2, IWM diameter, and number of IWM pieces per ft), since use of these newly added variables appeared to result in superior model fit (see Section 5.2.3.1). The primary purpose of this analysis was to examine relationships with these IWM measures and secondarily to help further examine the differences in the relationships with habitat variables between sites upstream of RM 20 (upper 3 regions) and sites downstream of RM 20 (lowermost region). The habitat variables (based on data collection in summer of 2008 and 2009) in this telemetry analysis were:

- % shade (of bankline) during the previous summer
- % boulder/cobble substrate during the previous summer
- bank slope during the previous summer
- IWM diversity measured April 2010
- Average LWM density measured April 2010
- IWM dominant size measured April 2010
- % emergent vegetation measured April 2010

Second, we fit a statistical model to the habitat data for all sites including those downstream of RM 20, but only included the habitat variables in common with the telemetry analysis done for 2009 data (H. T. Harvey & Associates and PRBO Conservation Science 2010). This analysis was critical for examining differences in relationships with habitat variables between sites upstream of RM 20 and sites downstream of RM 20. Habitat variables included in this telemetry analysis were measured during the previous summer and included:

- % shade (of bankline) during summer
- % boulder/cobble during summer
- bank slope during summer
- IWM diameter
- jam area per ft (i.e., the jam area divided by the survey length along the river).

We also modeled interaction terms one at a time, as an additional part of Step 2. This was to evaluate interaction terms without the influence of too many variables at once. For instance, with so many variables in the model, the effect of an important interaction could be missed, if there was confounding with another variable. The following possible interactions were considered in the second telemetry analysis:

- Reach:IWM diameter
- Reach:jam area per ft

For this second telemetry analysis, "Reach" consisted of two categories: 1) downstream of RM 20 and 2) upstream of RM 20. Due to potential differences in habitat use (i.e., rearing vs. migration), we suspected that there could be differences in relationships with key habitat components between these two reaches, due to the lower reach (downstream of RM 20) being a wide tidally influenced segment of river, in contrast to the more confined upper reach. Although other interactions between habitat variables and reach seemed biologically possible, we selected those of greatest interest that also are likely to be the most important biologically, to avoid model overparameterization (see text box for details). In determining the initial model for Step 3, all significant interaction terms were then fit to the model simultaneously, and likelihood ratio tests were used to drop model terms that were no longer significant.

Handling "zero data" in the GLM framework

Within the GLM framework, a two-component model was used to help account for the large number of zeroes in the residence time dataset and the potential for model overdispersion, using function "hurdle" (Zeileis et al. 2008) within the "pscl" package (Jackman 2008) for R; see Zuur et al. 2009 for discussion. The hurdle function allows the fitting of zero data separately from fitting non-zero data. That is, 0 vs. non-zero is fit with a binomial model (where non-zero means that residence time was 1 h or greater); a negative binomial model was used for the values of residence time greater than zero (i.e., the positive non-zero component), The positive non-zero component (typically termed the "truncated count component" by statisticians, i.e., Zeileis et al. 2008, Zuur et al. 2009) is referred to as the "non-zero" component throughout the text to avoid confusion with use of the term "count."

The "zero vs. non-zero" component (0 vs. values greater than zero) and non-zero component (residence time of 1 hr or more) of the GLM models for the telemetry data address two subtle but distinct aspects of fish behavior and their ecological response to the study sites. This approach allowed us to explore the ways in which fish appear to have potentially interacted with a site, where the environmental features were, presumably, influential in terms of behavior. The "zero vs. non-zero" component models 'presence' versus 'absence' where the two conditions were defined as follows: Zero or 'absent' fish were those whose elapsed time from first detection to last was less than an hour (<1 hour); all those whose elapsed time was greater than 1 hour were understood to be 'present.'

The distinction based on an elapsed time of more or less than 1 hour was based on preliminary analysis of the distribution of hours for all fish in the dataset (see Section 5.4.1), which suggested that the vast majority of residence times during the first day are less than one hour, and that extremely few residence times exist between 1 and 3 h; in other words, there is a break in the data that suggest some change in behavior associated with individuals that are staying vs. leaving quickly. The use of this threshold provides a means for differentiating between fish that were clearly spending appreciable amounts of time within the detection range of a given receiver and therefore likely influenced by the local environment versus those fish that may instead have had a more transitory relationship to a given site. The non-zero portion of the GLM hurdle models the residency duration of the 'present' fish that are more likely to be influenced by their environment.

This 'two component' approach requires that we characterize the response of fish to the different design types and the various spatial, temporal and habitat variables used in this study in terms of two separate processes. For evaluating presence/absence of fish, the fish response is understood in terms of the probability that a fish will remain at a site (for at least 1 h) versus passing through or departing from a site. The non-zero component was used to interpret fish response in terms of residency duration for fish that remain at a site for at least 1 h (i.e., residency duration is equivalent to the amount of time a fish is assumed to have spent within detection range of a receiver). The division of fish response into these two separate processes is supported by literature which suggests that downstream movement can be characterized by holding and moving states (Steel et al. 2001). Patterns in movement based on our telemetry data support the Steel et al. (2001) hypothesis that fish migration behavior consists of moving and holding components. Within the context of our GLM efforts, the "zero vs. non-zero" component models whether a fish is continuing to move or making the transition from moving to holding (i.e., staying vs. going), whereas the non-zero component models the duration of holding (i.e., residency duration).

Results for habitat variables in Step 2 or 3 can differ between the two components of the model (i.e., stay vs. go, and residency duration). If a variable is significant for only one component, or its coefficient has the same sign (i.e., either both positive or both negative) for both components, then the interpretation is straightforward (Table 4-8). If the variable is not significant in either component, the result is again straightforward. However, if the variable is significant for both components, but the signs of the coefficients conflict, the interpretation is more complicated. Although the net effect of such an outcome may be slightly positive or negative, we assumed that the effect was essentially cancelled and did not report this result in the text; the full model output is presented in Appendix G.

Table 4-8. Interpretation Based on All Possible Outcomes for Habitat Variables in Step 2 or 3 of the Telemetry GLM Analyses. Signs for the Coefficients Are Indicated by + for Positive and – for Negative Relationships.

Staying vs. Going	Residency Duration	Interpretation
Significant, +	Significant, +	Important, report
Significant, +	Significant, -	Functionally cancel, not reported
Significant, -	Significant, -	Important, report
Significant, -	Significant, +	Functionally cancel, not reported
Not significant	Significant, + or -	Important, report
Significant, + or -	Not significant	Important, report
Not significant	Not significant	Not important

4.6 Water Quality Measurements

Water quality parameters were measured during electrofishing surveys. The parameters measured were velocity, temperature, conductivity, salinity, and turbidity. A Marsh-McBirney Portable Flo-mate Flowmeter Model 2000 electromagnetic velocity sensor was used to measure the water velocity at each site. Water depth of the velocity reading was measured off of demarcations on the rod used to mount the sensor. Flow velocity was taken in ft/s and converted to cm/s. A YSI Model 30 Handheld Meter was used to measure temperature (Celsius), conductivity (µs/cm) and salinity (ppt) measurements at each site. A Secchi disk was used to measure turbidity at each site. The disk was lowered into the water column on a rope, and the greatest depth (cm) at which the disk could be observed was recorded. All instruments were calibrated per manufacturer's specifications prior to use.

5 RESULTS AND IMPLICATIONS FOR LEVEE DESIGN

5.1 Results of Habitat Features Monitoring

Values for water surface elevation, wetted area, study segment shoreline length, bank slope, and floodplain inundation ratio for selected repair and natural monitoring sites are presented in Appendix D (Table D-1). These data were originally developed in 2008 and are assumed to be constant for the purposes of this study. The habitat features of interest are bank substrate size, overhanging shade, aquatic vegetation, and instream woody material. Instream woody material is evaluated in its own section (Section 5.3).

Locations of average low (summer/fall) and high (winter/spring) seasonal shoreline elevations were used to establish permanent transects at each selected site (i.e., Low Elevation Transects and High Elevation Transects). These elevations roughly correspond to the range of water surface elevations that could occur during time when fish monitoring occurred (December through May).

A number of comparisons are made for many of the habitat features, between natural and repair sites, and between the four levee repair design types. Our comparisons are based on data collected, as well as descriptive statistics performed on the habitat features measured. In most cases, the simple statistics confirm our professional field assessments but not at a statistical level of significance. We report our observations and the statistical calculations. We augment comparisons based on statistical tests with those of professional observation because of the small sample size and, therefore, low statistical power (Nur et al. 1999).

5.1.1 Bank Substrate Size

Natural sites were dominated primarily by silt/clay substrate with lower amounts of sand, and trace amounts of other substrate size categories (Appendix D; Figures 5-1 and 5-2). Substrate size for low elevation transects at repair sites tended to be dominated by medium and small boulders with lower quantities of the other substrate categories (Figure 5-1). Repair sites' high elevation transects were also dominated by silt/clay substrate, but with much higher values of medium and small boulders, compared to natural sites (Figure 5-2). There was little difference in substrate between years.

Average substrate size varied between natural and repair sites in both 2008 and 2009 (Appendix D) as well as between design types. In 2009, the 10:1 Slope design sites tended to have more sand (33.6% along low elevation transects and 28.8% along high elevation transects) than the other design types. In 2009, the Dietl Ditch design sites had on average, more silt/clay (31.7% along low elevation transects and 48.3% along high elevation transects) than the other design types (Appendix D).

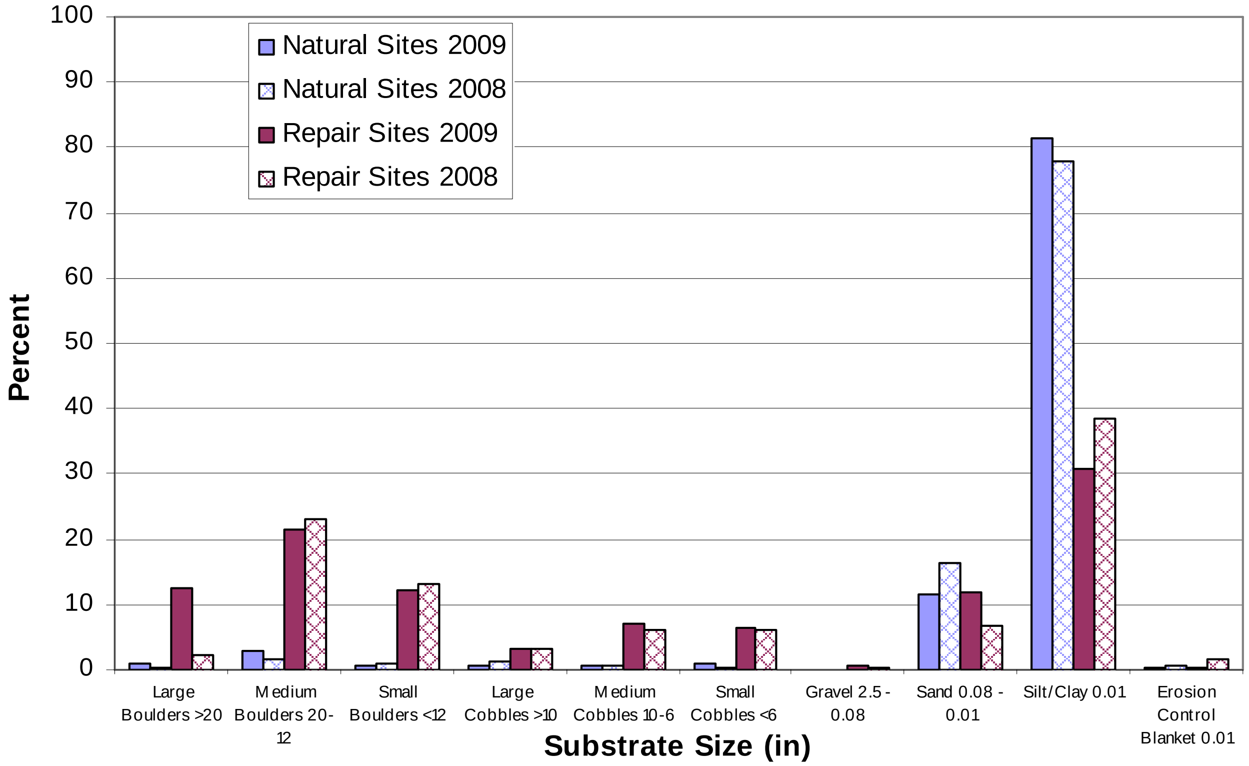

Figure 5-1. Average Percent of Bank Substrate Size (in) for Natural and Repair Sites along Low Elevation Transects. Natural Sites N=8. Repair Sites N=13.

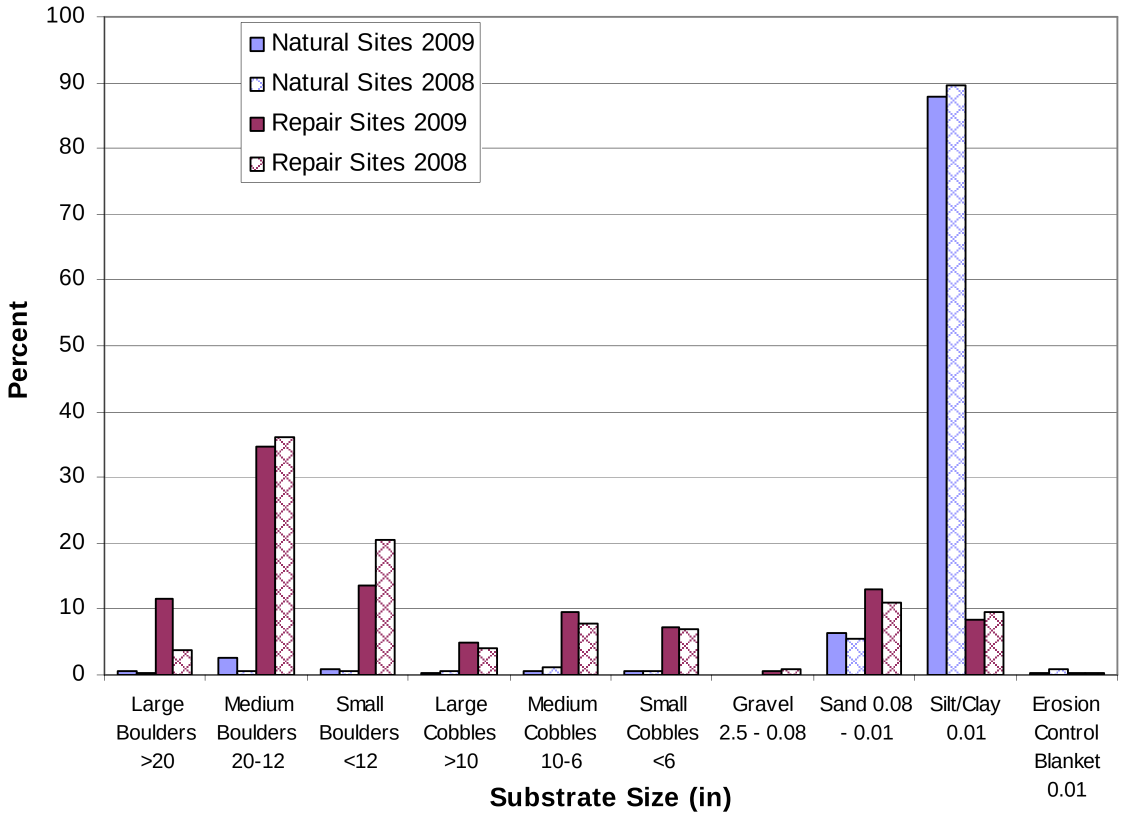

Figure 5-2. Average Percent of Bank Substrate Size (in) for Natural and Repair Sites along High Elevation Transects. Natural Sites N=8. Repair Sites N=13.

5.1.2 Aquatic Vegetation

Aquatic vegetation average percent cover was greater at the natural sites than the repair sites for the low and high elevation transects, but the only difference greater than one standard error from the mean (1-SE) is in 2008 (Figures 5-3 and 5-4). Aquatic vegetation was approximately the same for the high elevation transects in 2008 and 2009 (Table 5-1; Figure 5-4). At the natural sites, aquatic vegetation was represented more by woody vegetation than perennial herbaceous vegetation. At the repair sites, woody aquatic vegetation was more prominent at the high elevation transects while perennial herb vegetation cover was higher at the low elevation transects.

At and below low elevation transects in 2009, aquatic vegetation average percent cover ranged from 0% (Bench repair design) to 71% (10:1 Slope repair design) (Figure 5-5). At the high elevation transects in 2009, aquatic vegetation ranged from 44% (No Bench repair design) to 60% (Bench and Dietl Ditch repair designs) (Table 5-2; Figure 5-6). At three of the design type (10:1 Slope (high elevation transect), Bench, and No Bench), woody aquatic vegetation cover was greater than perennial herbaceous aquatic vegetation. At the Dietl Ditches, and the low elevation transects of the 10:1 slope design sites, vegetation cover of perennial herbaceous aquatic vegetation was higher relative to the other design types.

Table 5-1. Average Percent of Bank-line Coverage for Select Habitat Features.

Habitat Feature	Site Type[1]	2008 Low Elevation Transect	2008 High Elevation Transect	2009 Low Elevation Transect	2009 High Elevation Transect
Instream Woody Material	Natural Sites	75.4% (SE 6.6)	76.7% (SE 6.6)	55.8% (SE 8.1)	56.7% (SE 7.6)
	Repair Sites	44.4% (SE 9.8)	73.6% (SE 4.1)	42.8% (SE 8.6)	81.5% (SE 3.3)
Aquatic Vegetation	Natural Sites	41.7% (SE 7.8)	50.3% (SE 2.6)	57.1% (SE 12.5)	53.2% (SE 2.5)
	Repair Sites	34.4% (SE 10.3)	40.6% (SE 5.2)	44.8% (SE 11.1)	53.7% (SE 2.4)
Overhanging Shade	Natural Sites	63.8% (SE 9.0)	44.0% (SE 5.9)	70.8% (SE 5.7)	47.0% (SE 3.5)
	Repair Sites	1.8% (SE 1.0)	13.1% (SE 4.2)	9.5% (SE 7.3)	32.8% (SE 5.3)

[1] Natural Sites, n=8; Repair Sites, n=13.

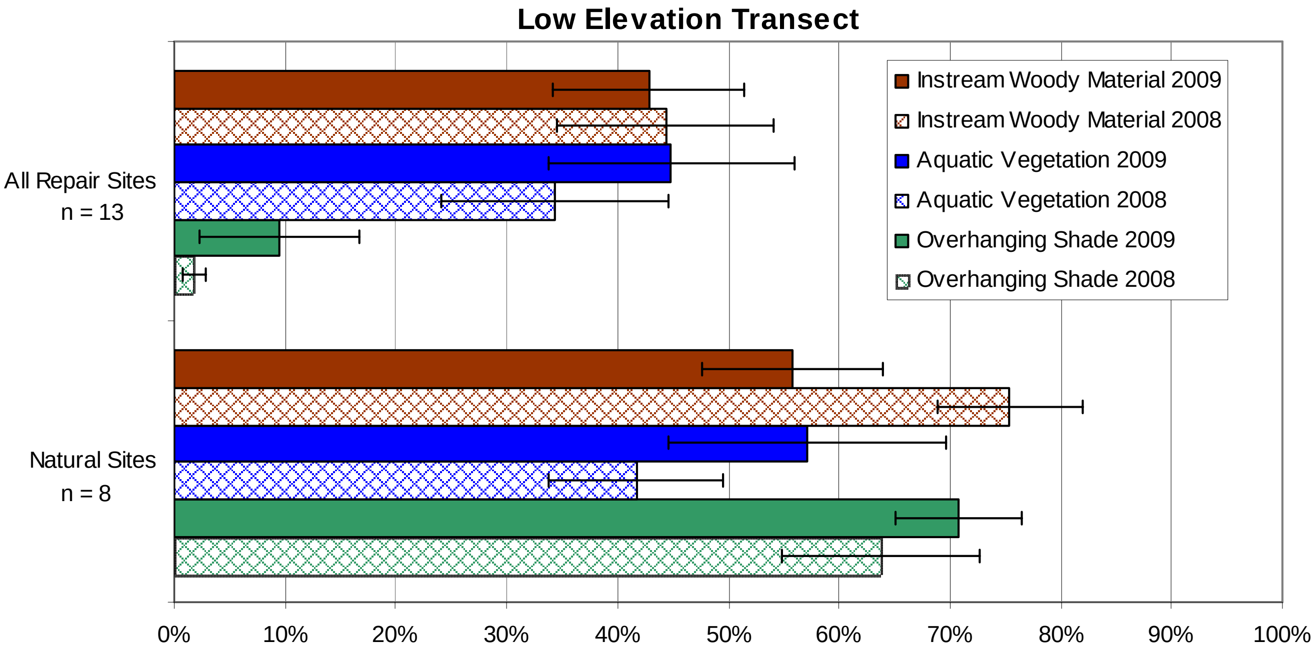

Figure 5-3. Average Percent of IWM Bank-line Coverage, Aquatic Vegetation, and Overhanging Shade for Low Elevation Transects. Natural Sites N=8. Repair Sites N=13. Error Bars Represent 1 Standard Error.

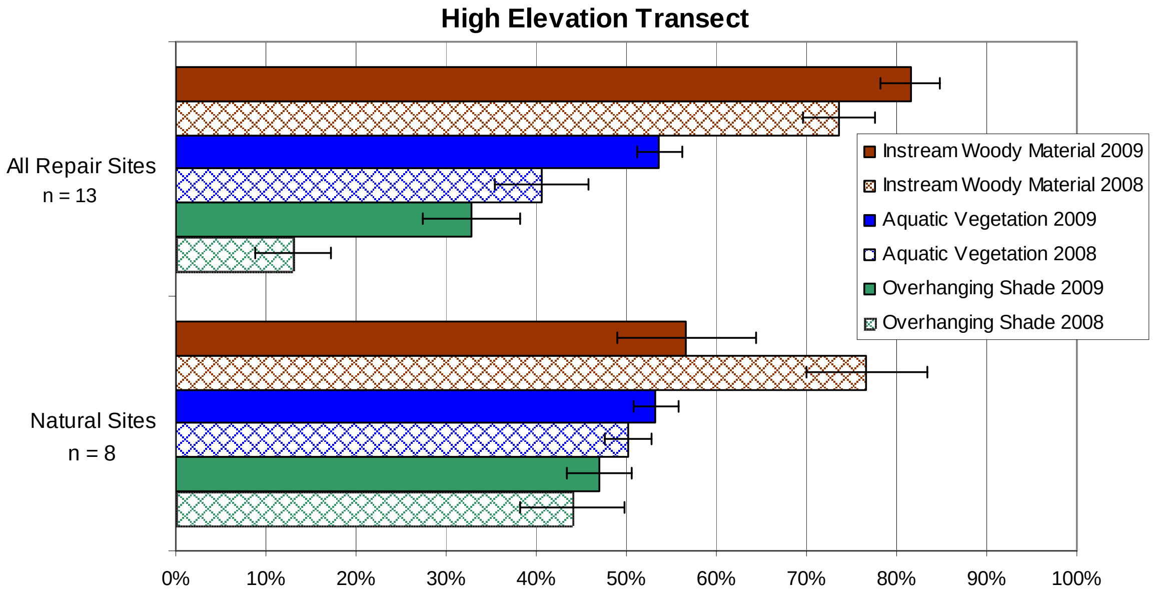

Figure 5-4. Average Percent of IWM Bank-line coverage, Aquatic Vegetation, and Overhanging Shade for High Elevation Transect. Natural Sites N=8. Repair Sites N=13. Error Bars Represent 1 Standard Error.

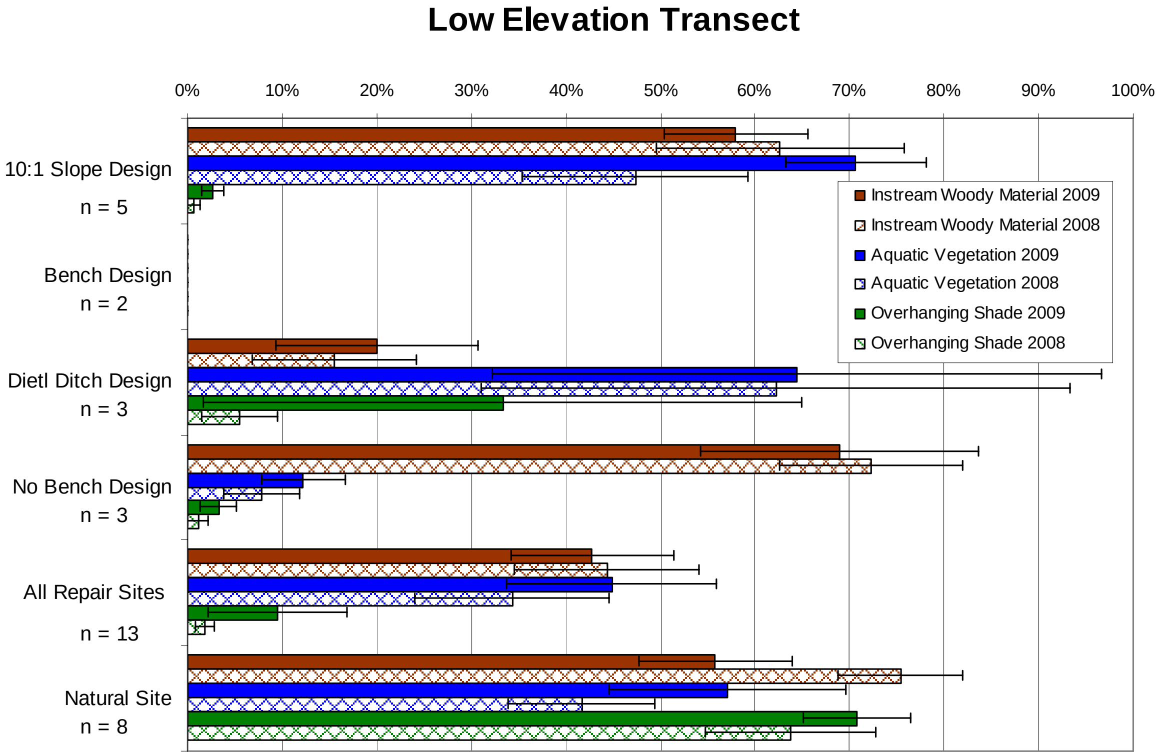

Figure 5-5. Average Percent Bank-line Coverage of Instream Woody Material, Aquatic Vegetation, and Overhanging Shade by Repair Design for Low Elevation Transects. Error Bars Represent 1 Standard Error. Measurements for the Bench Design Were Zero.

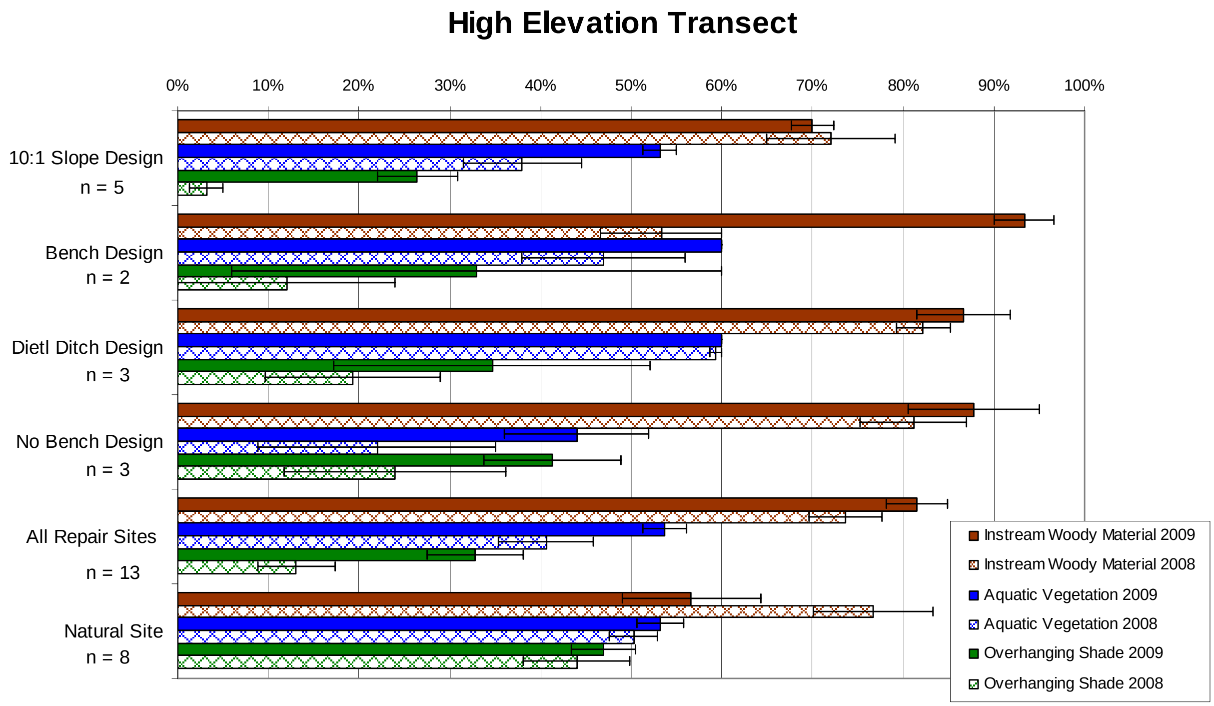

Figure 5-6. Average Percent Bank-line Coverage of Instream Woody Material, Aquatic Vegetation, and Overhanging Shade by Repair Design for High Elevation Transects. Error Bars Represent 1 Standard Error.

Table 5-2. Average Percent Bank-line Coverage of Aquatic Vegetation by Repair Design.

Repair Design	**2008**		**2009**	
	Low Elevation Transect	**High Elevation Transect**	**Low Elevation Transect**	**High Elevation Transect**
10:1 Slope Design (n=5)	47.3% (SE 11.9)	38.0% (SE 6.5)	70.7% (SE 7.4)	53.2% (SE 1.9)
Bench Design (n=2)	0.0% (SE 0.0)	47.0% (SE 9.0)	0.0% (SE 0.0)	60.0% (SE 0.0)
Dietl Ditch Design (n=3)	62.2% (SE 31.1)	59.3% (SE 0.6)	64.4% (SE 32.3)	60.0% (SE 0.0)
No Bench Design (n=3)	7.8% (SE 4.0)	22.0% (SE 13.1)	12.2% (SE 4.4)	44.0% (SE 8.0)
Natural Site (n=8)	41.7% (SE 7.8)	50.2% (SE 2.6)	57.1% (SE 12.5)	53.2% (SE 2.5)

5.1.3 Overhanging Shade

In 2008 and 2009, overhanging shade coverage was greater at the natural sites than at the repair sites for both transects (Table 5-1; Figures 5-3 and 5-4). The majority of the overhanging shade at repair sites was a result of plantings throughout the riparian restoration sites (30% of bank-line coverage for high elevation transects in 2009), and only a small percentage was from trees that were present prior to construction (5% of bank-line coverage for high elevation transects).

Overhanging shade increased in both natural and repair sites between years, but the increases between 2008 and 2009 were much greater at the repair sites.

At the low elevation transects, overhanging shade coverage in 2009 varied across levee repair design. It was lowest at the No Bench repair design sites (0%), and the greatest at the Dietl Ditches (33%) (Table 5-3; Figure 5-5). At or below the high elevation transects, overhanging shade coverage in 2009 varied with levee repair design ranging from 26% (10:1 Slope repair design) to 41% (No Bench repair design) (Table 5-3; Figure 5-6). For all levee repair design types, overhanging shade cover resulted more from restoration plantings than from pre-existing vegetation.

Table 5-3. Average Percent Bank-line Coverage of Overhanging Shade by Repair Design.

Repair Design	2008		2009	
	Low Elevation Transect	High Elevation Transect	Low Elevation Transect	High Elevation Transect
10:1 Slope Design (n=5)	0.7% (SE 0.7)	3.2% (SE 1.8)	2.7% (SE 1.2)	26.4% (SE 4.4)
Bench Design (n=2)	0.0% (SE 0.0)	12.0% (SE 12.0)	0.0% (SE 0.0)	33.0% (SE 27.0)
Dietl Ditch Design (n=3)	5.6% (SE 4.0)	19.3% (SE 9.7)	33.3% (SE 31.7)	34.7% (SE 17.5)
No Bench Design (n=3)	1.1% (SE 1.1)	24.0% (SE 12.2)	3.3% (SE 1.9)	41.3% (SE 7.5)
Natural Site (n=8)	63.8% (SE 9.0)	44.0% (SE 5.9)	70.8% (SE 5.7)	47.0% (SE 3.5)

5.1.4 Photo-documentation

Representative photographs showing comparisons of sites between 2008 and 2009 are presented in Appendix B. Photographs were taken during habitat feature monitoring fieldwork.

5.1.5 Implications for Levee Design

Numerous fish habitat features are developing at the repair sites; this is evident after collecting only 2 years of monitoring data. The more gradual slopes that were created at many of these repair sites provide shallow water habitat available for fish. For these new repair sites, aquatic vegetation coverage is moderate, and there is early establishment of overhanging shade habitat. To determine whether the repair sites are approximating natural sites, an increasing trend in average coverage of fish habitat features that indicates a trajectory toward natural site coverage values would be expected and was observed between 2008 and 2009. The Year-1 (2008) monitoring results established the baseline that will be used to evaluate any habitat feature trends in subsequent years.

Substrate category values were fairly similar across the 2 monitoring years, varying substantially between natural and repair sites. Over time, the repair sites that are subject to depositional events will likely become more similar to the natural sites while those that are subject to scour will likely become less similar.

Bank-line percent values for aquatic vegetation increased from 2008 to 2009 for both natural and repair sites (Table 5-1; Figures 5-3, 5-4). Values of aquatic vegetation were higher for natural sites at low elevation transect, but approximately the same for high elevation transects (Table 5-1). Aquatic vegetation values at repair sites should continue to increase over the next few years as the vegetation continues to establish and grow up until it reaches its carrying capacity, which does not appear to have occurred as of the 2009 growing season.

As expected, natural sites exhibit more overhanging shade than repair sites. However, overhanging shades is substantially increasing at the repair sites from 2008 to 2009 (Table 5-1; Figures 5-3, 5-4). The shade values at the repair sites should continue to increase over the next 20 or more years as the planted trees continue to grow and establish. Shade values varied across the different levee designs, but are currently heavily influenced by the presence of pre-existing trees and the age of the restoration site. As the riparian plantings grow over time, shade patterns across the different levee designs will become more evident. Nonetheless, in general, it appears that the sites that included a floodplain like the 10:1 and bench designs are more likely to develop more shade in the future due to greater access to shallow groundwater during the summer growing season and greater exposure to natural processes including winter and spring flooding which promotes natural regeneration of riparian habitat. Shade values in general increased from 2008 to 2009 and patterns across levee designs were similar in 2008 and 2009.

While habitat features presumed to be favorable to fish are developing, whether fish are using such features is evaluated in the following sections.

5.2 Results of IWM Monitoring

We noted potential problems in the SAM % of bankline IWM measurement; we observed that the measurement could be high (indicating large amounts of wood), yet the wood is located where it might not be supportive of fish (for example, IWM is present on the bank, but it is so high on the bank that it would be infrequently inundated). In an attempt to quantify IWM measurement differences, IWM was measured in various ways (see Section 4.3). Then, to evaluate how instream wood measures relate to fish use, we compared model results based on electrofishing-based IWM measures collected during April 2010 electrofishing at the individual electrofishing points (i.e., either data from the points or summaries/averages of these data), with transect-based IWM measures.

These analyses helped to evaluate a potential effect due to spatial scale (i.e., are there different habitat and fish relationships at the smaller scale vs. the larger scale?), and also to evaluate models fit to the different measures of IWM (i.e., transect-based vs. electrofishing-based at the larger spatial scale).

5.2.1 IWM % of Bankline Measure

At and below the low elevation transects, during both 2008 and 2009, natural sites had a greater average bank-line percent cover of instream woody material than repair sites (Table 5-1; Figure

5-3). At and below the high elevation transects, in 2008, natural sites had a slightly higher percent of instream wood than repair sites. In contrast, in 2009, natural sites at the higher elevation transects had less coverage of instream woody material compared to the repair sites (Figure 5-4). In 2009, the majority of the instream woody material found at repair sites was a result of placement during repair construction (54%), but naturally recruited wood was also found in abundance at the repair sites (32%). This was also true in 2008. Woody material was not placed at repair sites located downstream of RM 20; therefore, all woody material encountered downstream of RM 20 was present from natural processes.

At and below the low elevation transects, average bank-line percent cover of instream woody material differed greatly among the 4 levee repair designs, with woody material bank line coverage ranging from 0 to 72% in 2008 and 0 to 70% in 2009 for the Bench and No Bench repair designs (Table 5-4; Figure 5-5). For high elevation transects, the bank-line cover of instream woody material differed moderately in 2008 and 2009 (Table 5-4; Figure 5-6). The Bench repair design in 2009 had the highest bank-line cover (93%) for the high elevation transects, resulting entirely from recruited woody material; and the lowest bank-line percent cover value (0%) for the low elevation transect. These sites are located in the tidal zone and tend to have a large amount of drift wood deposited on top of the benches and the relatively steep banks below the benches are not conducive to deposition of woody material. The differences in wood recruitment on the benches as compared to below them is also influenced by the buoyancy of the wood which gets deposited at the highest tides and during high flow events and remains as the water recedes. Deposited drift wood is often less complex than wood that is recruited from large multi-branched trees that anchor themselves to the bed and banks of the river and as a result likely don't provide the same habitat values. There was substantial instream wood recruitment in 2009 for all the repair designs ranging from 88% (No Bench repair design) to 93% (Bench repair design) for high elevation transects. Instream wood cover was relatively consistent between years with some repair design and transect locations showing increases but others showing decreases.

Table 5-4. Average Percent Bank-line Coverage of Instream Woody Material by Repair Design.

Repair Design	2008		2009	
	Low Elevation Transect	High Elevation Transect	Low Elevation Transect	High Elevation Transect
10:1 Slope Design (n=5)	62.7% (SE 13.1)	72.0% (SE 7.0)	58.0% (SE 7.6)	70.0% (SE 2.3)
Bench Design (n=2)	0.0% (SE 0.0)	53.3% (SE 6.7)	0.0% (SE 0.0)	93.3% (SE 3.3)
Dietl Ditch Design (n=3)	15.6% (SE 8.7)	82.2% (SE 2.9)	20.0% (SE 10.7)	86.7% (SE 5.1)
No Bench Design (n=3)	72.2% (SE 9.7)	81.1% (SE 5.9)	68.9% (SE 14.7)	87.8% (SE 7.3)
Natural Site (n=8)	75.4% (SE 6.6)	76.7% (SE 6.6)	55.8% (SE 8.1)	56.7% (SE 7.6)

5.2.2 IWM Transect-based Measures

Approximately the same number of pieces of instream woody material (IWM) per 100 feet of bank-line, were documented at natural and repair sites in 2009. However, the number of pieces between 2008 and 2009 changed considerably; the natural sites lost half of their pieces (36 in 2008 to 18 in 2009) and the repair sites gained a moderate number (12 in 2008 to 18 in 2009) (Figure 5-7). Natural sites had a slightly larger average diameter and total area of IWM, per 100 feet of bank-line, than the repair sites; in 2009, the average IWM diameter of natural sites is greater than that of repair sites, by more than their standard error (SE). In 2008, the average IWM diameter of natural sites is also greater than that of the repair sites, but the difference is within their SE ranges (Table 5-5; Figures 5-8 and 5-9). A similar result was documented for average total IWM area; differences in 2008 were greater than 1 SE but were not for 2009.

Table 5-5. Average Number, Size, and Area of Pieces of Instream Woody Material below the High Elevation Transect by Site Type.

Site Type	2008			2009		
	Number of Pieces per 100 feet of Bank-line	Average Size in Diameter (in)	Total Area (ft^2) per 100 feet of Bank-line	Number of Pieces per 100 feet of Bank-line	Average Size in Diameter (in)	Total Area (ft^2) per 100 feet of Bank-line
Natural Sites (n=8)	36 (SE 10.9)	7.7 (SE 1.4)	953 (SE 416.5)	18 (SE 6.3)	9.1 (SE 0.7)	395 (SE 88.3)
Repair Sites (n=13)[1]	12 (SE 2.3)	6.2 (SE 0.6)	432 (SE 116.7)	18 (SE 3.5)	7.4 (SE 0.4)	357 (SE 60.3)
10:1 Slope Design (n=5)	11 (SE 2.2)	5.3 (SE 0.9)	594 (SE 288.4)	13 (SE 2.5)	7.2 (SE 0.9)	411 (SE 122.7)
Bench Design (n=2)	11 (SE 1.3)	6.2 (SE 0.5)	99 (SE 13.3)	33 (SE 7.1)	6.6 (SE 0.6)	89 (SE 45.6)
Dietl Ditch Design (n=3)	15 (SE 10.5)	7.2 (SE 2.1)	365 (SE 102.0)	12 (SE 8.6)	8.5 (SE 0.4)	308 (SE 37.5)
No Bench Design (n=3)	12 (SE 1.2)	6.8 (SE 1.2)	450 (SE 72.2)	22 (SE 8.7)	7.0 (SE 0.8)	494 (SE 73.8)

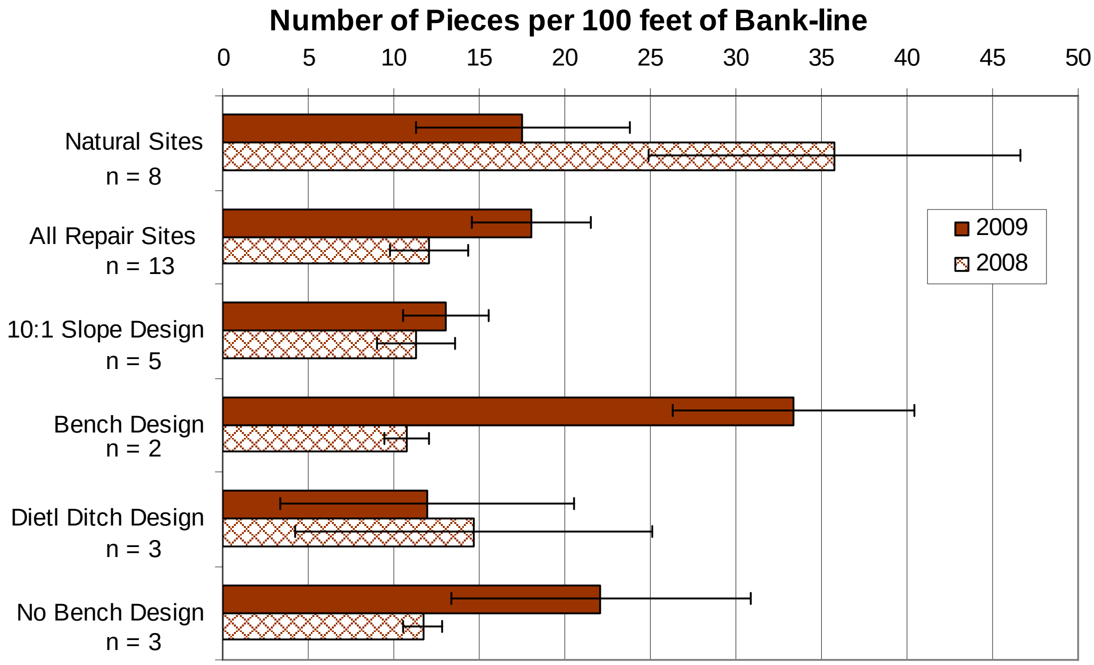

Figure 5-7. Average Number of Pieces of Instream Woody Material by Site Type.

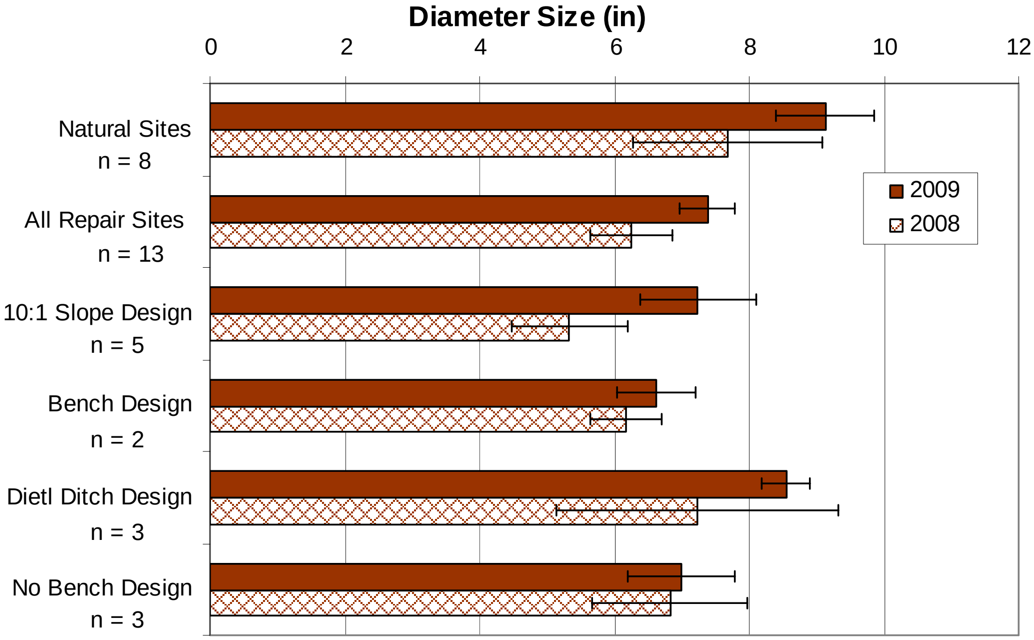

Figure 5-8. Average Diameter of Instream Woody Material by Site Type.

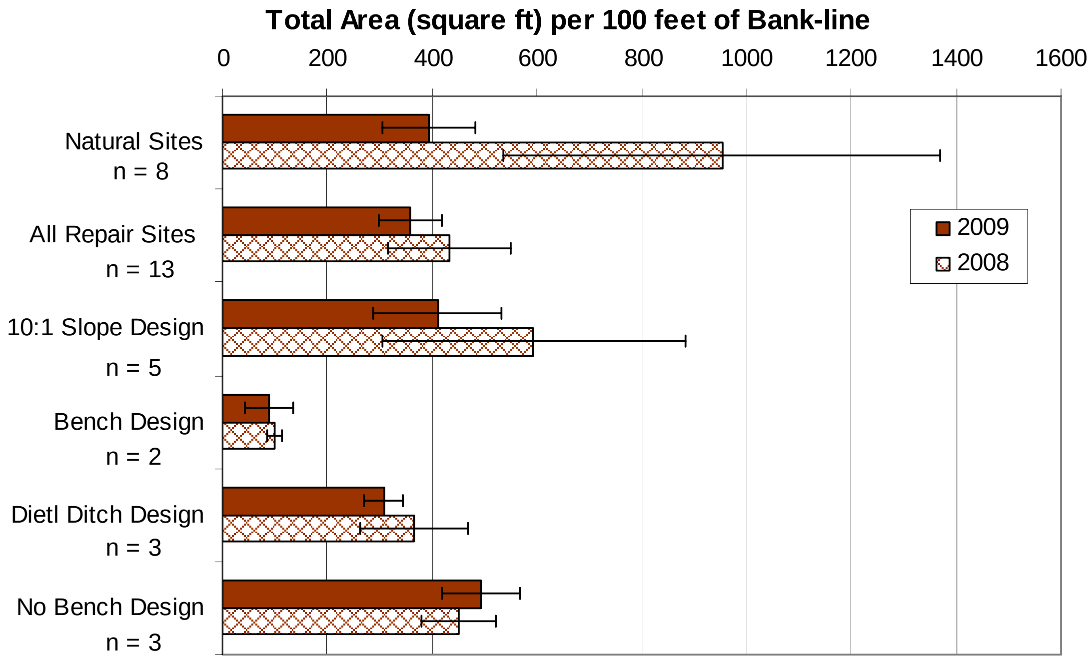

Figure 5-9. Average Total Area of Instream Woody Material by Site Type.

5.2.3 Electrofishing-based IWM and Instream Structure

Observations of IWM were recorded as IWM density, IWM size, and IWM in and out of water during the electrofishing surveys. In addition, data for submerged vegetation was collected during these surveys. Summaries of these measures were used to characterize IWM and instream structure for the site, and these variables were: average LWM density, IWM diversity, dominant IWM size, and submerged vegetation (see Section 4.5.1.1 for details on wood measures). Submerged vegetation was characterized for the site as the fraction of points that contained >10% submerged vegetation. No clear relationships between these variables with levee repair design type are evident graphically (Figures 5-10, 5-11, 5-12, 5-13).

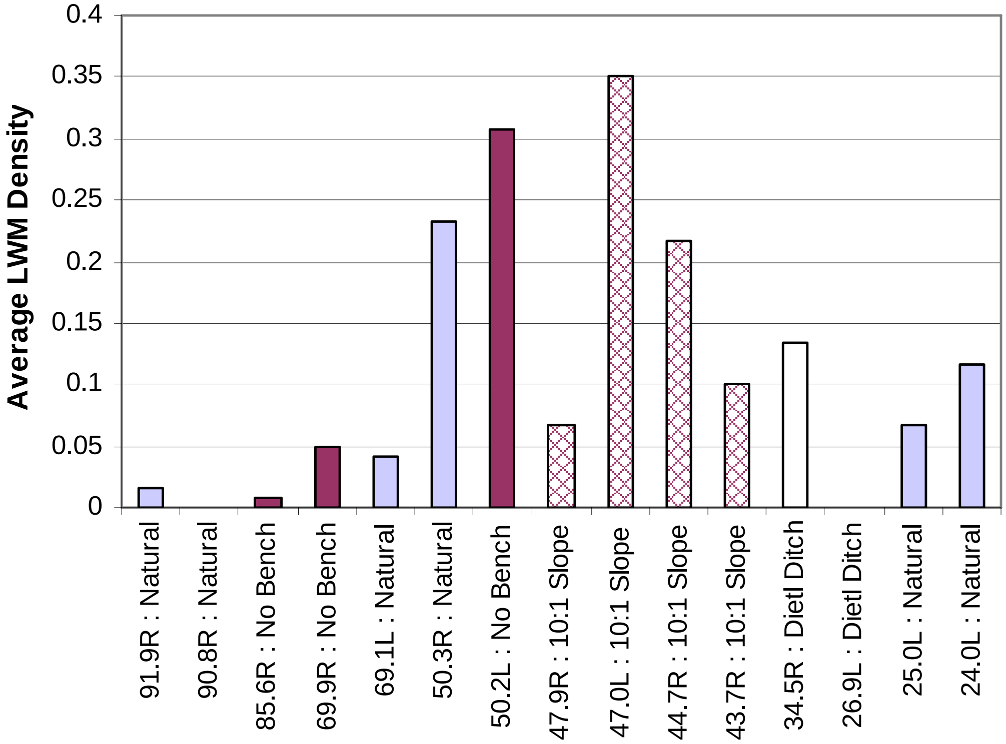

Figure 5-10. Average LWM Density, Average of Electrofishing-based IWM Measure, 2010.

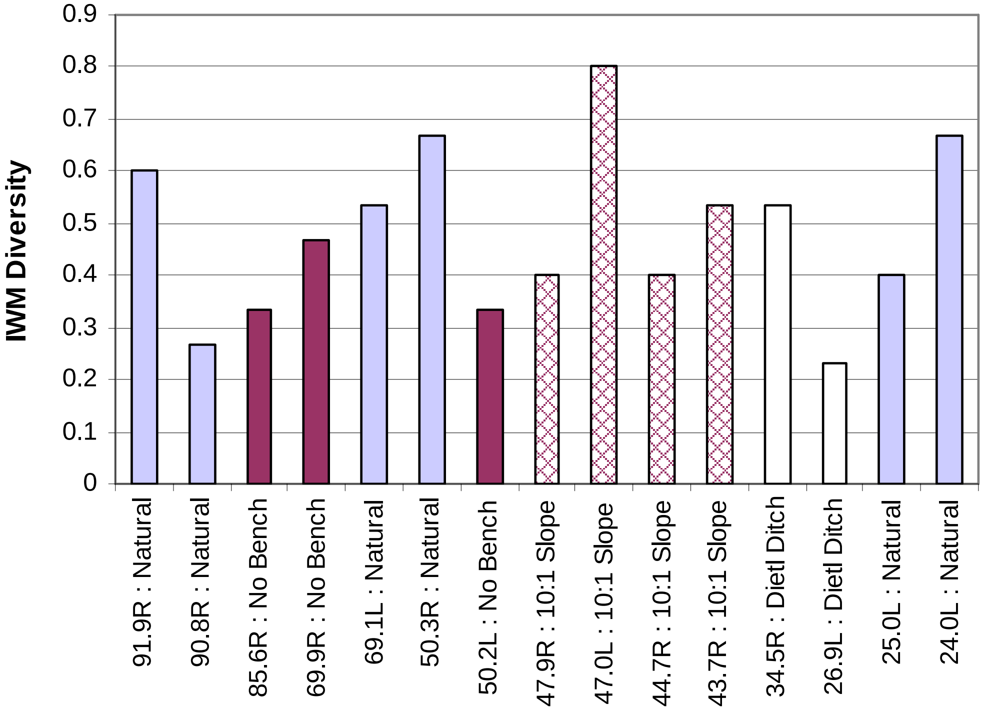

Figure 5-11. IWM Diversity, Summary of Electrofishing-based IWM Measures, 2010.

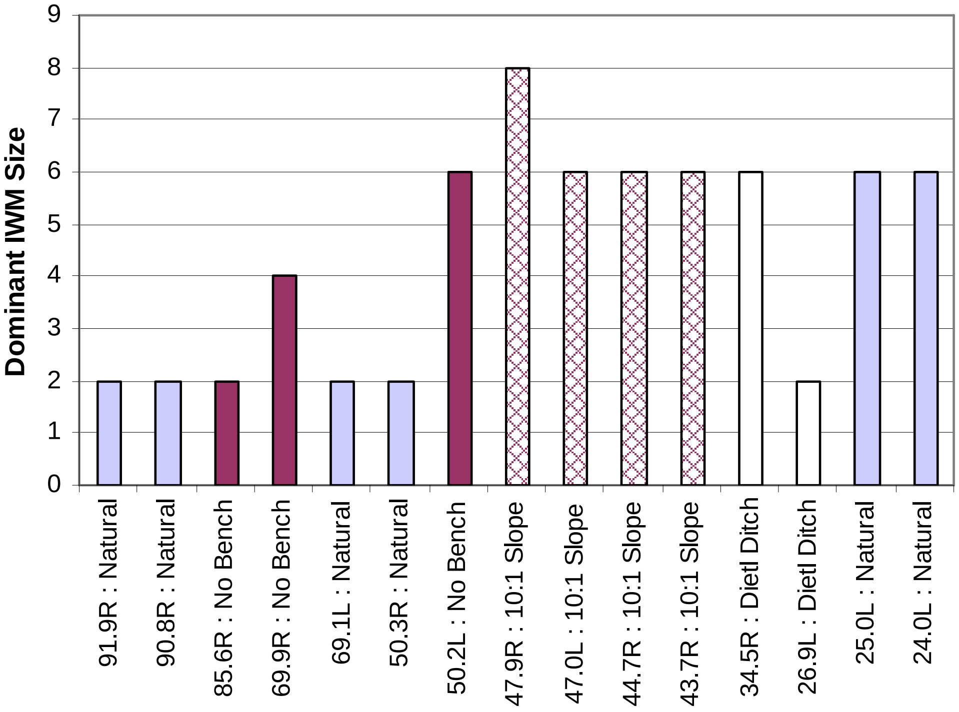

Figure 5-12. Dominant IWM Size, Summary of Electrofishing-based IWM Measure, 2010.

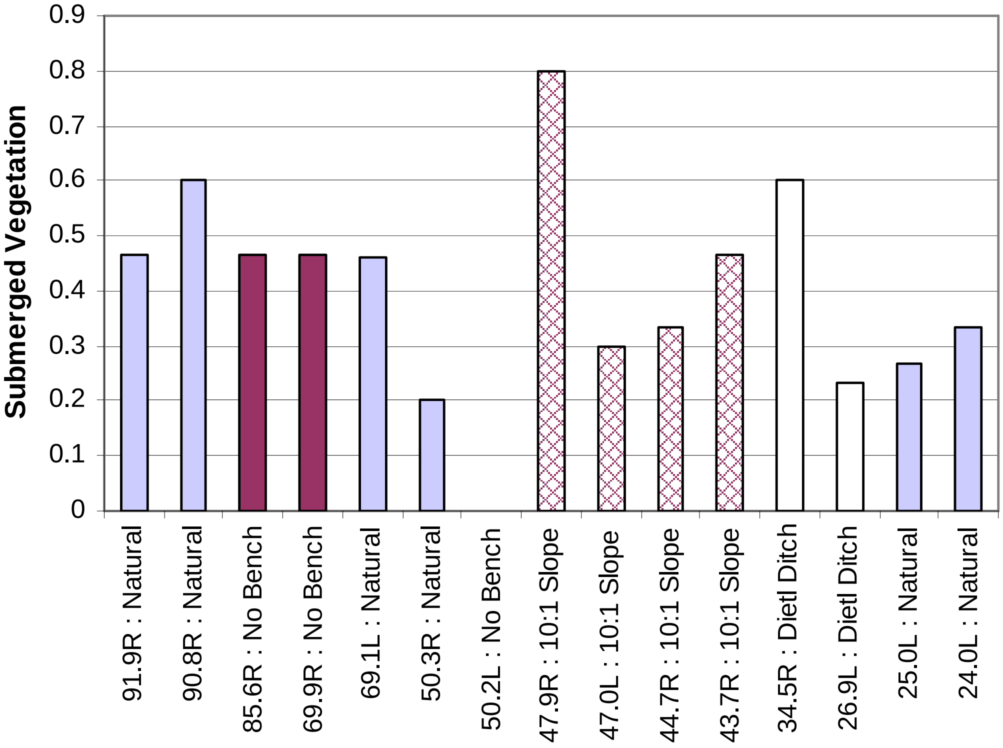

Figure 5-13. Submerged Vegetation, Summary of Electrofishing-based Habitat Measure, 2010.

5.2.3.1 Fish Use (April 2010 Electrofishing) Related to IWM Measurements at Different Spatial Scales

The modeling analyses of the April 2010 electrofishing data used:

1) Electrofishing-based measurements (i.e., IWM density, IWM size, and IWM in/out),
2) summaries/averages of electrofishing-based measurements to characterize the site (i.e., Average LWM density, Dominant IWM size, and IWM diversity, as previously defined), and
3) SAM and additional IWM variables characterizing the site (i.e., % IWM of bankline, jam area per ft, number of pieces of IWM per ft, and IWM diameter).

We found that models based on averages of electrofishing-based IWM measurements (i.e., used to characterize the site, or site scale) fit the data better than those fit directly to the electrofishing-based measures (i.e., at the electrofishing points, or point scale) (Table 5-6; Appendix E). This could perhaps indicate a stronger relationship to wood variables at the site scale than at the point scale for larger Chinook salmon juveniles (i.e., Chinook salmon juveniles in April are substantially larger than in March for instance, see Section 5.4.1) and bass predators. This result is consistent with the idea that larger fish would be more frequently utilizing habitat at a larger scale than electrofishing points. This may or may not be the case for Chinook salmon fry or smaller juveniles; it was not possible to evaluate this based on our analyses; however, because IWM point data were only collected during the April electrofishing effort and could not be applied to other electrofishing surveys when fry were captured.

Table 5-6. Point Scale and Site Scale IWM Measurement Analysis Summary using April 2010 Electrofishing Data. AIC Is a Measure of Model Fit Analogous to a Residual Sum of Squares in Linear Regression; when Comparing Models Fit to the Same Dataset, a lower Score Indicates a Better Model Fit.

Species/Life Stage	IWM Variable	AIC Statistic	Significant Relationships $p<0.05$	Not significant Relationships ($p>0.10$)
Chinook salmon juveniles	Electrofishing-based (point scale)	228.0	Positively related to IWM size IWM size: in/out interaction term	In/out of water
	Electrofishing-based (site scale)	223.6	Negatively related to Dominant size	
	Transect-based (site scale)	227.3	Positively related to Jam area	
Bass predators	Electrofishing-based (point scale)	185.7		Density In/out of water
	Electrofishing-based (site scale)	178.0	Negatively related to IWM diversity Positively related to Dominant IWM size	
	Transect-based (site scale)	178.5	Positively related to %IWM	Jam area

Models using electrofishing-based IWM measures at the site scale (i.e., Average LWM density, Dominant IWM size, and IWM diversity) appeared to fit the data better than those using transect-based IWM measures, based on AIC values. However, for bass predators, the model fit to electrofishing-based IWM measures at the site scale appeared to be only slightly better than the model fit to transect-based IWM measures (Table 5-6); for Chinook salmon juveniles, the model fit to electrofishing-based IWM measures at the site scale was substantially better than the one fit to transect-based IWM measures.

5.2.3.2 Fish use (2009 and 2010) related to Transect-based vs. Electrofishing-based IWM Variables at the Site Scale

The site scale IWM analyses include both years of electrofishing data and all other IWM sampling efforts (not just April 2010), and provide greater insight into the differences between the transect-based vs. the electrofishing-based IWM measures. Models fit to summaries of electrofishing-based data generally fit better than those fit to transect-based IWM measures, most notably for Chinook salmon juveniles, and somewhat less strongly for Chinook salmon fry and bass predators (Table 5-7; Appendix E). This was the case even though the electrofishing-based IWM measures collected in April 2010 were applied to catch data from different months and years; potentially, the fit could be even better if electrofishing-based IWM measures had been collected during each sampling effort rather than only in April 2010. Even so, the fit was sometimes substantially better for the model fit to electrofishing-based IWM measures summarized at the site scale, particularly in March for Chinook salmon juveniles (AIC 175.2 versus 179.2) and April for bass predators (AIC 323.4 versus 331.1). Note that the difference in AIC was not dramatic in the two instances where the model fit the transect-based IWM measures better (difference of 0.6 and 2.1).

Table 5-7. Summary of IWM Site Scale Analyses. AIC Is a Measure of Model Fit Analogous to a Residual Sum of Squares in Linear Regression; when Comparing Models Fit to the Same Dataset, a Lower Score Indicates a Better Model Fit. Results Indicate that the Model Fit to Data from 2010 Was Better Most of the Time.

Species	Month	AIC by analysis:		Better Fit for Electrofishing-based IWM Measures?
		Electrofishing-based IWM Measures	Transect-based IWM Measures	
Chinook salmon fry	January	257.8	259.4	Yes
	March	502.9	500.8	No
Chinook salmon juveniles	March	175.2	179.2	Yes
	April	352.2	354.2	Yes
Bass predators	January	102.7	102.1	No
	March	174.7	175.7	Yes
	April	323.4	331.1	Yes

These analyses support the use of summaries/averages of electrofishing-based IWM data (site scale) in the electrofishing analyses. Given that the electrofishing-based measurements were collected at the locations where fish were actually sampled, it is perhaps not surprising that these measurements would be more strongly related to fish presence than those collected at transects on the bank line, which may or may not be in the water when fish sampling occurred. For the transect-based IWM measures, we used the variables from the low elevation transects, because these are more frequently inundated during sampling and would have a greater chance of having sufficient depth to be used by fish. The electrofishing points during the April 2010 sampling were even farther into the channel (and away from the bank) than the SAM transects, and are probably more representative of fish habitat than data collected at the SAM transects even in other months of sampling (i.e., January, March). Therefore, these analyses support the use of summaries/averages of electrofishing-based IWM measurements in the electrofishing analyses.

5.2.4 Implications for Levee Design

Models based on summaries/averages of electrofishing-based IWM measures (site scale) fit the data better than those fit directly to the electrofishing-based IWM measures (point scale), perhaps indicating a stronger relationship to wood variables at the site scale than at the point scale for larger Chinook salmon juveniles (i.e., Chinook salmon juveniles in April are substantially larger than in March for instance, see Section 5.3.1) and bass predators. The comparison of models fit to different IWM variables at the site scale was conducted using both years of electrofishing data and all other IWM sampling efforts (not just April 2010); again, models fit to summaries of the electrofishing-based data generally fit better than those fit to the transect-based IWM measures. The implications of these findings are that summaries of electrofishing-based wood measures are better representative of fish habitat/fish use than the transect-based measures.

5.3 Results of Electrofishing

The fish count data from electrofishing (summarized as presence or absence) were used in the 3-step modeling approach to discern differences in fish use due to design type, and to identify statistically significant relationships with habitat features (see Section 4.4; Appendix F). Because electrofishing was not conducted downstream of RM 20, there were no "Bench" design types evaluated (all Benches are downstream of RM 20); however, since Bench and 10:1 design types are similar (all are bench-type designs) we used the term "Bench/10:1" in our analysis. Output from both the generalized linear models (GLM) and GLMM models consisted of 1) coefficients and standard errors for each main effect and interaction term that were included in the final models and 2) results from likelihood ratio tests evaluating the significance of these terms.

The models indicated associations between presence of species/life stages [Chinook salmon fry (total length (TL) ≤ 62 mm, fork length (FL) ≤ 55 mm), juvenile Chinook salmon (TL > 62 mm, FL > 55 mm) and bass predators (largemouth and smallmouth bass TL > 115 mm)] and design type and habitat features, as well as *a priori* identified interactions, over monthly sampling periods and for all sampling periods combined. These outputs indicated whether coefficients (design type, habitat features, interaction terms) were statistically significant ($p < 0.05$**)** and whether the associations between the coefficients and species/life stages presence were positive or negative. We interpreted those results to determine the "best" designs and habitats for fish; we assumed that "best" designs and habitats are where fish occurred most frequently. Conversely we assumed that the "worst" designs and habitats were where fish were least likely to occur. Best and worst design types were significantly better or worse, respectively, than at least one other design type. It should be carefully noted however that, because repair sites are relatively young, fish response may change in subsequent years as the sites evolve.

5.3.1 Electrofishing Data and Observations

The data obtained from electrofishing efforts included species counts, fish length, water quality, and depth measurements at each electrofishing point (Appendix C). Electrofishing surveys in 2010 were conducted between Jan 30 – Feb 1 (identified as January in the analyses), March 5 – March 10, and April 15 – April 17; in 2009, surveys were conducted between Jan 13 – Jan 15, Feb 27 – March 3 (identified as March in the analyses), and April 28 – April 30. Substantially more Chinook salmon were captured (621) than steelhead (9). Too few steelhead were captured in 2009 and 2010 to allow for meaningful analysis. (However, the telemetry data (Section 5.5) provide meaningful information about steelhead use of the study area.) Numerous other native and non-native species were captured during electrofishing (Table 5-8).

Table 5-8. Species and Mean Total Length of Fish Captured during 2009 and 2010 Electrofishing Surveys.

Common Name	Scientific Name	2009 Count	2009 Mean Total Length	2010 Count	2010 Mean Total Length
Native Species					
Chinook Salmon Fry	*Oncorhynchus tshawytscha*	122	42	362	45
Chinook Salmon Juveniles	*Oncorhynchus tshawytscha*	36	86	102	77
Delta Smelt	*Hypomesus transpacificus*	n/a	n/a	2	76
Hitch	*Lavinia exilicauda*	3	274	5	250
Pacific Lamprey (ammocoete)	*Lampetra tridentata*	1336	n/a	811	n/a
Sacramento Blackfish	*Orthodon microlepidotus*	0	n/a	15	426
Sacramento Pikeminnow	*Ptychocheilus grandis*	25	155	52	177
Sacramento Splittail	*Pogonichthys macrolepidotus*	1	290	22	341
Sacramento Sucker	*Catostomus occidentalis*	33	170	11	266
Steelhead/Rainbow	*Oncorhynchus mykiss*	6	200	9	227
Tule Perch	*Hysterocarpus traski*	310	113	376	112
Non-Native Species					
Bigscale Logperch	*Percina macrolepida*	1	85	0	n/a
Black Bullhead	*Ameiurus melas*	0	n/a	1	169
Black Crappie	*Pomoxis nigromaculatus*	1	174	1	166
Bluegill Sunfish	*Lepomis macrochirus*	14	92	75	70
Brown Bullhead	*Ameiurus nebulosus*	5	83	0	n/a
Carp	*Cyprinus carpio*	11	485	12	488
Channel Catfish	*Ictalurus punctatus*	2	200	9	306
Golden Shiner	*Notemigonus crysoleucas*	5	77	13	52
Goldfish	*Carassius auratus*	9	233	5	176
Green Sunfish	*Lepomis cyanellus*	5	106	19	92
Largemouth Bass	*Micropterus salmoides*	25	241	55	123
Inland Silverside	*Menidia beryllina*	96	74	160	61
Mosquitofish	*Gambusia affinis*	2	34	3	30
Pumpkinseed Sunfish	*Lepomis gibbosus*	16	121	0	n/a
Redear sunfish	*Lepomis microlophus*	n/a	n/a	15	159
Smallmouth Bass	*Micropterus dolomieu*	74	182	82	168
Spotted Bass	*Micropterus punctulatus*	0	245	1	n/a
Striped Bass	*Morone saxatilis*	4	260	10	236
Threadfin Shad	*Dorosoma petenense*	1	103	1	84
Warmouth	*Lepomis gulosus*	1	118	14	63
White Catfish	*Ameiurus catus*	10	195	38	224
Yellow Bullhead	*Ameiurus natalis*	2	58	0	n/a

The following analyses explores the association between fish presence and a suite of habitat and environmental variables, and tested hypotheses that the presence or absence of Chinook salmon fry, juvenile Chinook salmon and bass predators varied by levee design type.

5.3.2 Chinook Salmon Fry

The process for evaluating the objectives for Chinook salmon fry involved fitting the model to the data and interpreting the raw output; due to the large volume of results, model output required summarization prior to interpretation. We use an example to describe this process below. Full model output is presented in Appendix F, and an intermediate summarization of model output is presented in tables in the text and with greater detail in Appendix G. For Chinook salmon fry, we selected the combined GLMM analysis, because sample sizes were relatively similar between months and it is unlikely that fry habitat utilization changes between late January and March. Combined analyses include different months, depending on species and life stage, and only include data where there was sufficient fish catch to warrant analysis. For Chinook salmon fry, combined analysis included fish data from January and March; there was a total of only 2 fry captured in April of 2009 and 2010. Therefore, we selected the more powerful combined GLMM analysis, with proper accounting for the random effect with the GLMM.

The coefficients from predictive equations that were the final GLMM models for Step 1 of the combined analysis for Chinook salmon fry are presented in Table 5-9; only fixed effects coefficients are presented, as there is no explicit coefficient for the random effect. In the case of the first three rows of the table, where the Natural design type was the reference category, the final predictive equation was:

$$\begin{gathered} Logit(p) = \beta_0 + \beta_1 Month_{Jan} + \beta_2 regionKK + \beta_3 regionKL + \beta_4 design.typeNB + \ldots \\ \beta_5 design.typeBT + \beta_6 design.typeDD \ , \end{gathered}$$

where *p* is the probability of fish presence and *Logit(p)* is the transformation defined by *ln(p)-ln(1-p)*; coefficients are identified by β_x; *Month*, *regionXX, and design.typeXX* are dummy variables (coded as 0 or 1, = 1 if the variable is design type *XX*); *KK* = Ko-Ket, *KL* = Knight's Landing, *NB* = No Bench, *BT* = Bench/10:1, and *DD* = Dietl Ditch. For a categorical variable with more than two categories (i.e., region or design type), say *k* categories, then there would be *k*-1 dummy variables. For example, with design type, there are 4 possible categories (Natural, No Bench, Bench/10:1, and Dietl Ditch); therefore, there are three dummy variables related to design type. Based on this combined GLMM analysis, coefficients for design types (β_4, β_5, and β_6 from the equation above) indicate the relative magnitude of differences between the reference category and all other design types (Table 5-9). For example, the difference between Natural and No Bench design types is large compared to all other differences (see "Coefficient" and "z^2 value" columns of Table 5-9). The "z^2 value" is based on Wald tests for the coefficient and is approximately distributed as a chi-square statistic. This statistic provides a direct measure of "Deviance Explained" by the specified variable, when all other variables in the model are included. Thus, if one variable has a z^2 statistic three times that of another, the former explains three times the variation in the dependent variable as does the latter. In addition, the difference between the Natural and No Bench design types is statistically significant (p=0.006). In comparison, the difference between Bench/10:1 slope and No Bench sites is not as great, and also not significant (p=0.093). When the Bench/10:1 slope design type is the reference category, the positive coefficients for Dietl Ditch and Natural design types show that these design types could be slightly better; however, the values of these coefficients are relatively small in comparison to others, and the non-significance of these coefficients indicate that they are not statistically different from the Bench/10:1 slope design type.

Table 5-9. Comparison of Design Types, Resulting from GLMM Model Fit to Chinook Salmon Fry, Combined Analysis, Sacramento River, CA. The Dependent Variable Was the Presence (1) or Absence (0) of Chinook Salmon Fry at a Sampled Electrofishing Point. Data Were from 3 Sampling Efforts (March 2009, January 2010, and March 2010) at 15 Sites, with up to 15 Points per Site, Resulting in a Total of 615 Electrofishing Points. Note that the Effect of Design Type Was Inconclusive Based on a Likelihood Ratio Test (p=0.0675, X2=7.142, df=3).

Reference Category	Design Type	Coefficient	SE	95% CI's		z^2 Value	Pr(>|z|)
Natural	No bench	-1.083	0.393	-1.853	-0.313	7.601	0.006
	Bench/10:1	-0.442	0.377	-1.181	0.298	1.369	0.242
	Dietl Ditch	-0.101	0.466	-1.014	0.811	0.047	0.828
Dietl Ditch	Natural	0.101	0.466	-0.811	1.014	0.047	0.828
	No bench	-0.982	0.609	-2.176	0.212	2.599	0.107
	Bench/10:1	-0.341	0.599	-1.515	0.834	0.323	0.570
Bench/10:1	Dietl Ditch	0.340	0.599	-0.834	1.515	0.323	0.570
	Natural	0.442	0.377	-0.298	1.181	1.369	0.242
	No bench	-0.642	0.382	-1.391	0.108	2.816	0.093

The coefficients from the predictive equation that was the final GLMM model for Step 2 of the combined analysis for Chinook salmon fry are presented in Table 5-10. The final predictive equation is:

$$Logit(p) = \beta_0 + \beta_1 Month_{Jan} + \beta_2 regionKK + \beta_3 regionKL + \beta_4 Year2010 + \beta_5 depth + \beta_6 Sub.veg + \ldots$$

$$\beta_7 IWMdiversity + \beta_8 Boulder.cobble + \beta_9 regionKK : Year2010 + \beta_{10} regionKL : Year2010 + \ldots$$
$$\beta_{11} depth : IWMdiversity,$$

where coefficients are identified by β_x; *Month*, *regionKK and regionKL (KK = Ko-Ket, KL = Knights Landing)*, and *Year*2010 are dummy variables (coded as 0 or 1, 1 if the variable is *XX*); and *depth*, *Sub.veg* (submerged vegetation), *IWM diversity*, *Boulder.cobble* (% boulder/cobble) are all quantitative variables as previously defined.

The results from Step 2 of the combined GLMM analysis indicated that there were relatively strong relationships with depth (X^2=18.497, p<0.0001), and the depth x IWM diversity interaction (X^2=3.877, p=0.049), and inconclusive relationships with submerged vegetation (X^2=2.786, p=0.095) and % boulder/cobble (X^2=2.749, p=0.097) (Table 5-10). The strength of the relationships with depth and the depth x IWM diversity terms is evident from the relatively high values of X^2, and the low p-values resulting from the likelihood ratio tests. In addition, the 95% CI for the depth coefficient is far from zero, indicating a strong negative relationship.

The positive coefficient for the interaction term depth x IWM diversity indicates that the overall positive relationship with IWM diversity becomes even stronger at greater depths. Overall, there is a negative effect due to depth. However, as IWM diversity increases, the effect of depth becomes less negative.

Table 5-10. Significant Habitat Variables Based on GLMM Model Fit to Electrofishing Data for Chinook Salmon Fry, Combined Analysis, Sacramento River, CA. The Dependent Variable Was the Presence (1) or Absence (0) of Chinook Salmon Fry at a Sampled Electrofishing Point. Data Were from 3 Sampling Efforts (March 2009, January 2010, and March 2010) at 15 Sites, with up to 15 Points per Site, Resulting in a Total of 615 Electrofishing Points. Depth Is in Meters; Submerged Vegetation, IWM Diversity (See Section 4.5.1.1 for Detail), and % Boulder/Cobble Are All Ratios between 0 and 1.

Habitat Variable	Estimate	SE	95% CI		X^2	Pr(>X^2)
Depth	-0.591	0.140	-0.866	-0.317	18.497	<0.0001
Submerged vegetation	1.416	0.830	-0.210	3.042	2.786	0.095
IWM diversity	0.050	1.320	-2.538	2.637	0.001	0.970
% Boulder/cobble	-0.856	0.488	-1.812	0.100	2.749	0.097
Depth x IWM diversity	1.572	0.781	0.041	3.103	3.877	0.049

* Note that where there is a main effect and an interaction, we show results for the main effects based on a model fit only with the main effects. In this Table, we show the main effects of Depth and IWM diversity, while including effects of submerged vegetation and % boulder/cobble.

Raw model output from Appendix F was then summarized into tables such as Tables 5-9 and 5-10. The model output from the examples described above corresponds to the final column of these tables. After this process was conducted for each of the analyses (i.e., for Chinook salmon fry, January, March, and combined analyses for GLM and GLMM), the summary tables were formed (see Appendix G for detailed intermediate summary tables): these summary tables (Tables 5-9 and 5-10) allow more straightforward interpretation of model results.

Chinook salmon fry were captured at all levee design types and throughout the sampling area; in general more Chinook salmon fry were captured at Natural sites (Figure 5-14). Based on the coefficients obtained from the statistical modeling, the best designs were the Bench/10:1 and Natural levee types; the No Bench type was the worst design (Tables 5-9 and 5-11; Appendix F and G). The No Bench design type consistently had the largest negative coefficient of any design type (Table 5-9; Appendix F). Natural sites were consistently best, though they were only consistently better than the No Bench type (Table 5-11; Appendix F).

Chinook salmon fry were most strongly associated with aquatic vegetation, and were negatively associated with depth (Table 5-12). The negative association with depth is consistent with other research that has shown Chinook salmon fry occur in shallow waters and move to deeper depths as they age (Williams 2006b).

Substrate was also frequently found to be important; overall, Chinook salmon fry presence was higher where there was less cobble/boulder substrate (Table 5-12; Appendix G). However, once differences in design type were incorporated in the statistical models, the relationship between fry presence and cobble/boulder changed. This change in sign was due to confounding between substrate and design type, because the repair sites frequently have a much higher proportion of cobble/boulder substrate than the naturalized sites. However, when controlling for design type, there was a greater chance of presence with increasing % of cobble/boulder substrate.

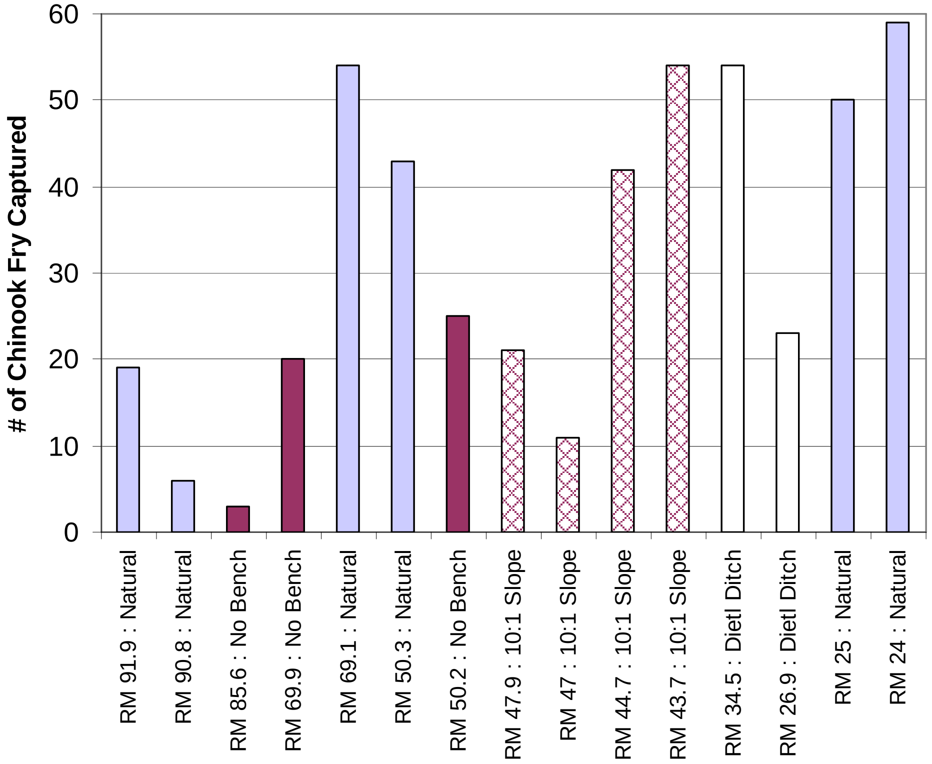

Figure 5-14. River Mile, Design Type, and Number of Chinook Salmon Fry Captured During 2009 and 2010 Electrofishing Surveys. Refer to Appendix D, Table D-4 for Raw Catch Data by Site and Date.

Table 5-11. Chinook Salmon Fry Design Type Differences Summary. Refer to Appendix F for Corresponding Raw Model Output.

	January GLM	**January GLMM**	**March GLM**	**March GLMM**	**Combined GLM**	**Combined GLMM**
Better	Natural	Natural	Bench/10:1 Natural Dietl Ditch	Bench/10:1 Natural	Natural Dietl Ditch Bench/10:1	Natural Bench/10:1
Worse	Bench/10:1 No Bench	Bench/10:1 No Bench	No Bench	No Bench	No Bench	No Bench

Table 5-12. Chinook Salmon Fry Relations with Habitat Variables, (+) Indicates a Positive Relationship, (-) a Negative Relationship. Refer to Appendix F for Corresponding Raw Model Output.

Sig/NS	January GLM	Jan GLMM	March GLM	March GLMM	Combined GLM	Combined GLMM
Significant (p<0.05)	Submerged vegetation (+) %boulder/cobble (-) Depth (-) Depth x IWM diversity (+)	Submerged vegetation (+) %boulder/cobble (-) Depth (-) Depth x IWM diversity (+)	Submerged vegetation (+) %boulder/cobble (-) Bank slope (-) LWM density (+) Depth (-) Depth x IWM diversity (+)	Bank slope (-) Depth (-)	Submerged vegetation (+) %boulder/cobble (-) Depth (-) IWM diversity (-) Depth x IWM diversity (+)	Depth (-) Depth x IWM diversity (+)
Inconclusive (0.10<p<0.05)						Submerged vegetation (+) %boulder/cobble (-) Depth (-)
Not significant (p>0.10)	IWM diversity (-)	IWM diversity (-)	IWM diversity (-)	IWM diversity (-) LWM density (+)		IWM diversity (-)

5.3.3 Chinook Salmon Juveniles

We chose to emphasize model output from the GLMM model of the April analysis (includes fish data from 2009 and 2010), because catch of juvenile Chinook salmon was dominated by the April sampling efforts (i.e., 75% of juvenile Chinook salmon captures were in April). These results are presented in Tables 5-13 and 5-14. Summaries and interpretations later in this section do include the March and combined analyses for Chinook salmon juveniles (based on March and April fish data from 2009 and 2010).

The largest difference between design types was between the Dietl Ditch and Bench/10:1 slope design types, with Dietl Ditch being the best design type and Bench/10:1 slope being the worst (Table 5-13). The coefficient for Dietl Ditch was the largest positive coefficient with respect to Bench/10:1 slope (i.e., 2.214 compared to 0.967 for the next highest, No Bench), and was the only design type comparison that yielded a significant result (p=0.019). The No Bench design type also had a relatively large coefficient, though the difference with Bench/10:1 slope sites was inconclusive (p=0.081). The difference between Dietl Ditch and Natural sites yielded the 2nd highest variation of all the comparisons (z^2 = 3.456 as compared to 5.471 for Dietl Ditch vs. Bench/10:1 slope), though the result was inconclusive (p=0.063).

Table 5-13. Comparison of Design Types, Resulting from GLMM Model Fit to Chinook Salmon Juveniles, April Analysis, Sacramento River, CA. The Dependent Variable Was the Presence (1) or Absence (0) of Chinook Salmon Fry at a Sampled Electrofishing Point. Data Were from 4 Sampling Efforts (March and April, 2009 and 2010) at 15 Sites, with up to 15 Points per Site, Resulting in a Total of 810 Electrofishing Points. Note that the Effect of Design Type Was Not Significant Based on a Likelihood Ratio Test (p=0.1216, X2=5.802, df=3).

Reference Category	Design Type	Coefficient	SE	95% CI's		z^2 Value	Pr(>|z|)
Natural	No bench	0.176	0.515	-0.834	1.186	0.116	0.733
	Bench/10:1	-0.791	0.557	-1.883	0.300	2.019	0.155
	Dietl Ditch	1.423	0.765	-0.077	2.923	3.456	0.063
Dietl Ditch	Natural	-1.423	0.765	-2.923	0.077	3.456	0.063
	No bench	-1.247	0.923	-3.055	0.562	1.825	0.177
	Bench/10:1	-2.214	0.946	-4.069	-0.359	5.471	0.019
Bench/10:1	Dietl Ditch	2.214	0.946	0.359	4.069	5.471	0.019
	Natural	0.791	0.557	-0.300	1.883	2.019	0.155
	No bench	0.967	0.555	-0.120	2.054	3.042	0.081

The two most influential habitat variables were dominant IWM size (X^2=14.356, p=0.0002) and submerged vegetation (X^2 = 8.729, p=0.0031) (Table 5-14; Appendix F). The effect due to the interaction depth x average LWM density was also relatively strong (X^2=4.176, p=0.0410). The overall effect due to average LWM density was positive, and the interaction indicates that the effect becomes stronger with increasing depth. The overall effect due to depth is negative, but becomes less negative with increasing LWM density.

Table 5-14. Significant Habitat Variables Based on GLMM Model Fit to Electrofishing Data for Chinook Salmon Juveniles, April Analysis, Sacramento River, CA. The Dependent Variable Was the Presence (1) or Absence (0) of Chinook Salmon Fry at a Sampled Electrofishing Point. Data Were from 4 Sampling Efforts (March and April, 2009 and 2010) at 15 Sites, with up to 15 Points per Site, Resulting in a Total of 810 Electrofishing Points. Depth Is in Meters; Dominant IWM Size Is in Inches; Shade, Submerged Vegetation, Average LWM Density (See Section 4.5.1.1 for Detail), and % Boulder/Cobble Are All Ratios between 0 and 1.

Habitat Variable	Estimate	SE	95% CI		X^2	Pr(>X^2)
Shade	-1.298	0.532	-2.341	-0.254	6.220	0.0126
Depth	-0.297	0.206	-1.443	0.149	2.160	0.1416
Submerged vegetation	3.884	1.301	1.335	6.433	8.729	0.0031
Dominant IWM size	-0.577	0.134	-0.839	-0.315	14.356	0.0002
Average LWM density	3.155	2.275	1.387	0.165	1.847	0.1742
Depth x average LWM density	4.161	2.072	0.100	8.222	4.176	0.0410

* Note that where there is a main effect and an interaction, we show results for the main effects based on a model fit only with the main effects. In this Table, we show the main effects of Depth and average LWM density, while including effects of shade, submerged vegetation, and dominant IWM size.

Similar to Chinook salmon fry, Chinook salmon juveniles were captured at all design types and throughout the sampling area, but no specific design type appears to be consistently associated with greater numbers of Chinook salmon juveniles (Figure 5-15). There were differences among design types, but the differences were inconsistent from one month to the next. Based on results from the statistical modeling, the Bench/10:1 design type was the best for juveniles in March, but was the worst in April (Table 5-15; Appendix G). Conversely, the Dietl Ditch design was the worst in March and the best in April (Table 5-15; Appendix G).

One explanation for these results is that the difference in design type use between months reflects a shift in habitat utilization from March to April as fish become larger (Table 5-16). Chinook salmon juveniles tend to move towards faster, deeper water as they grow (Moyle 2002). Temperature increases, making fish more active, from March to April could also be a factor.

The shift in habitat utilization, with increasing fish size, also appears to be supported by results regarding relationships with habitat features. Abundance of Chinook salmon juveniles appear to be related to a largely different suite of habitat variables, depending on month. When juveniles are smaller (i.e., March), they tend to be associated with shallower depths, lower bank slopes, and higher IWM size (Table 5-17; Appendix G). However, as they grow larger, they appear to be more strongly associated with aquatic vegetation and deeper habitat with higher LWM density. The significant positive relationship with aquatic vegetation in April suggests that as fish get larger they may require different types of cover. The one consistent relationship was with shallower depths in general; April model results indicated a significant positive interaction between depth and LWM density (Appendix G), suggesting that greater depths were being utilized with increasing LWM density. In addition, bank slope was not significant in April, in contrast to the significant negative relationship identified for March.

The results for Chinook salmon juveniles in March contrasted with those for Chinook salmon fry, whose presence had a positive relationship with aquatic vegetation. This contrast may indicate utilization of shallow nearshore areas for Chinook salmon fry, where submerged vegetation was more likely to be found.

The relationship between fish presence and IWM does not appear to be as strong overall for Chinook salmon juveniles as it does for fry, as the effect drops out when including the design type in the combined analysis for juveniles (Appendix G). This may be related to the lack of variation in wood conditions (wood is fairly homogenous in size and quantity and is relatively small in the study area) for most of the design types.

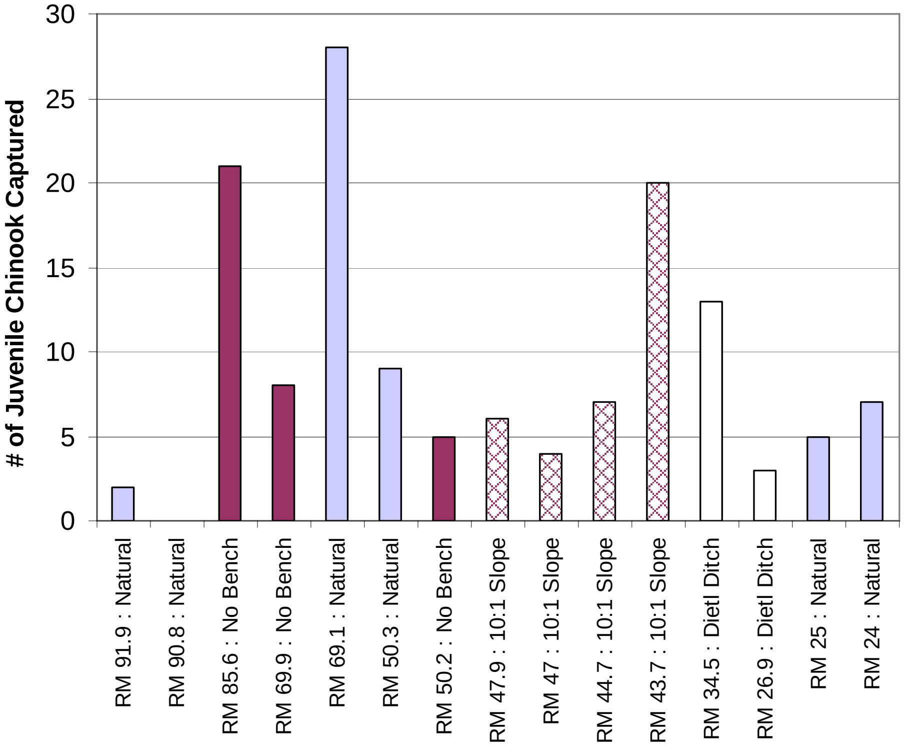

Figure 5-15. River Mile, Design Type, and Number of Chinook Salmon Juveniles Captured during 2009 and 2010 Electrofishing Surveys. Refer to Appendix D, Table D-4 for Raw Catch Data by Site and Date.

Table 5-15. Chinook Salmon Juvenile Design Type Differences Summary. Refer to Appendix F for Corresponding Raw Model Output.

	March GLM	March GLMM	April GLM	April GLMM	Combined GLM	Combined GLMM
Better	Bench/10:1	Bench/10:1	Dietl Ditch	Dietl Ditch	No differences	No differences
Worse	Natural No Bench Dietl Ditch	No Bench Dietl Ditch	Bench/10:1	Bench/10:1		

Table 5-16. Chinook Salmon and Bass Predator Mean Total Lengths (mm) by Month. Bass Predators Included Largemouth Bass, Smallmouth Bass, and Spotted Bass >115 mm TL.

Species	Year	Month	Sample Size	Mean	Min	Max
Chinook Salmon fry	2009	March	122	42.3	35	62
	2010	January	209	41.2	31	57
		March	151	51.5	32	62
		April	2	37.0	36	38
Chinook Salmon juvenile	2009	March	2	70.5	70	71
		April	34	86.9	65	99
	2010	March	35	67.0	63	98
		April	67	82.7	64	98
Bass predators	2009	January	7	149.7	133	172
		March	16	204.2	126	430
		April	42	286.0	120	435
	2010	January	20	215.3	121	411
		March	8	208.9	153	276
		April	43	215.1	133	399

5.3.4 Bass Predators

For bass predators, we chose to emphasize model output from the GLMM model of the April analysis, because habitat use based on abundance from electrofishing surveys was greatest during April; catch of bass predators was much greater for April sampling efforts as compared to other months (Table 5-16). The pertinent model output is presented in Tables 5-18 and 5-19. Summaries and interpretations later in this section do however include the additional March and combined analyses (consisting of 5 sampling efforts: March and April of 2009, and January, March, and April of 2010).

Design type differences were greatest between Dietl Ditch and Natural sites, with Dietl Ditch being the best and Natural being the worst (Table 5-18). The coefficient for Dietl Ditch was the largest (2.267) when compared to Natural, and this comparison also has the largest z^2 value (8.685) and lowest p-value (p=0.003). However, comparisons between Dietl Ditch and sites other than Natural sites did not yield significant results. Although the differences are not as great, Bench/10:1 (p=0.034) and No Bench sites (p=0.093; inconclusive) are also better than Natural sites for bass predators.

Table 5-17. Chinook Salmon Juvenile Relationships with Habitat Variables. Refer to Appendix F for corresponding Raw Model Output.

Sig/NS	March GLM	March GLMM	April GLM	April GLMM	Combined GLM	Combined GLMM
Significant (p<0.05)	Depth (-) Bank slope (-) IWM size (+) IWM size x LWM density (-)	Depth (-) Bank slope (-) IWM size (+)	Depth (-) LWM density (+) Depth x LWM density (+) IWM size (-) Shade (-) Submerged vegetation (+)	Depth (-) LWM density (+) Depth x LWM density (+) IWM size (-) Shade (-) Submerged vegetation (+)	Submerged vegetation (+) Bank slope (-) Depth (-) Depth x LWM density (+)	Depth (-)
Inconclusive (0.10<p<0.05)		IWM size x LWM density (-)			IWM size (-)	
Not significant (p>0.10)	LWM density (+)	LWM density (+)				Submerged vegetation (+) Bank slope (-) IWM size (-) LWM density (-) Depth x LWM density (+)

Table 5-18. Comparison of Design Types, Resulting from GLMM Model Fit to Bass Predators, April Analysis, Sacramento River, CA. The Dependent Variable Was the Presence (1) or Absence (0) of Bass Predators at a Sampled Electrofishing Point. Data Were from 5 Sampling Efforts at 15 Sites, with up to 15 Points per Site, Resulting in a Total of 1015 Electrofishing Points. Note That the Effect of Design Type Was Significant Based on a Likelihood Ratio Test (p=0.0460, X2=8.001, df=3).

Reference Category	Design Type	Coefficient	SE	95% CI's		z^2 Value	Pr(>|z|)
Natural	No bench	1.187	0.707	-0.199	2.573	2.816	0.093
	Bench/10:1	1.414	0.665	0.110	2.718	4.516	0.034
	Dietl Ditch	2.267	0.769	0.759	3.775	8.685	0.003
Dietl Ditch	Natural	-2.267	0.770	-3.776	-0.759	8.685	0.003
	No bench	-1.080	0.798	-2.645	0.484	1.831	0.176
	Bench/10:1	-0.853	0.761	-2.345	0.639	1.257	0.262
Bench/10:1	Dietl Ditch	0.853	0.761	-0.639	2.345	1.257	0.262
	Natural	-1.414	0.665	-2.718	-0.110	4.516	0.034
	No bench	-0.227	0.698	-1.596	1.142	0.106	0.745

Based on the April GLMM analyses, strong positive relationships were indicated for several habitat variables: aquatic vegetation (X^2=11.087, p=0.001), bank slope (X^2=9.960, p=0.002), % boulder/cobble (X^2=7.116, p=0.008), and the depth x IWM diversity interaction (X^2=10.004, p=0.002) (Table 5-19). In addition, there was one other significant interaction term, dominant IWM size x average LWM density. The effect of average LWM density is positive and increases with increasing IWM size. The main effect of IWM size is negative, though the effect becomes less negative with increasing LWM density. Overall, the effect of depth was positive (though relatively small); with increasing IWM diversity, the effect becomes greater. The main effect of IWM diversity is negative, though becomes less negative with increasing depth.

Table 5-19. Significant Habitat Variables Based on GLMM Model Fit to Electrofishing Data For Bass Predators, April Analysis, Sacramento River, CA. The Dependent Variable Was the Presence (1) or Absence (0) of Bass Predators at a Sampled Electrofishing Point. Data Were from 5 Sampling Efforts at 15 Sites, with up to 15 Points per Site, Resulting in a Total of 1015 Electrofishing Points. Depth Is in Meters; Dominant IWM Size Is in Inches; Bank Slope Is the Ratio of Change in Width to Change in Height; Aquatic Vegetation, Average LWM Density (See Section 4.5.1.1 for Detail), and % Boulder/Cobble Are All Ratios between 0 and 1.

Habitat Variable	Estimate	SE	95% CI		X^2	Pr(>X^2)
Depth	0.091	0.190	-0.281	0.464	0.228	0.633
IWM diversity	-1.563	1.490	-4.484	1.358	1.093	0.296
Bank slope	0.298	0.096	0.110	0.486	9.960	0.002
%Boulder/cobble	1.700	0.676	0.375	3.024	7.116	0.008
Dominant IWM size	-0.064	0.117	-0.294	0.166	0.293	0.588
Aquatic vegetation	1.930	0.575	0.804	3.056	11.087	0.001
Average LWM density	0.893	1.957	-2.943	4.730	0.206	0.650

Habitat Variable	Estimate	SE	95% CI		X^2	Pr($>X^2$)
Dominant IWM size x Average LWM density	3.638	1.755	0.198	7.078	4.765	0.029
Depth x IWM diversity	4.201	1.430	1.398	7.004	10.004	0.002

* Note that where there is a main effect and an interaction, we show results for the main effects based on a model fit only with the main effects. In this Table, we show the main effects of Depth, IWM diversity, dominant IWM size, and average LWM density, while including effects of bank slope, % boulder/cobble, and aquatic vegetation.

Bass predators were captured at all design types and throughout the study area (Figure 5-16) and there was substantial temporal overlap between captured bass predators and Chinook salmon (Table 5-16). Dietl Ditch and No Bench design types were generally best for the bass predator complex, depending on month; the Natural sites were consistently the worst (Table 5-20). For January and March, design types were frequently indistinguishable, perhaps due to small sample sizes (relatively few bass predators were captured during these months in comparison to April) (Table 5-16). The low number of captures during January and March may reflect less favorable temperature conditions compared to April, which is typical for many non-native species in the delta (Feyrer and Healey 2003). However, as temperatures became warmer in April, catch greatly increased, and bass predators were found to be consistently associated with both Dietl Ditch and No Bench design types.

Statistical models using the "combined" analyses for bass predators indicated that the Dietl Ditch was the best design type and Natural was always among the worst for bass predators (Table 5-20); however, the Dietl Ditch design was not significantly different from either No Bench or Bench/10:1 design types in the combined analysis until we included habitat variables in the model (Appendix G). In other words, the Dietl Ditch design was not statistically different from either No Bench or Bench/10:1 overall (although it was definitely better than Natural, and better than all the other design types in April).

In contrast to both Chinook salmon fry and juveniles, bass predators had a significant positive relationship with bank slope, indicating a strong association with steeper banks (Table 5-21). Bass predators, like Chinook salmon fry, were also positively associated with the depth:IWM diversity interaction, indicating a similar relationship with IWM diversity at greater depths. There was a negative relationship with shade, which was also found for Chinook salmon juveniles in April (Table 5-21); however, the relationship for Chinook salmon juveniles is not as strong as it is for bass predators.

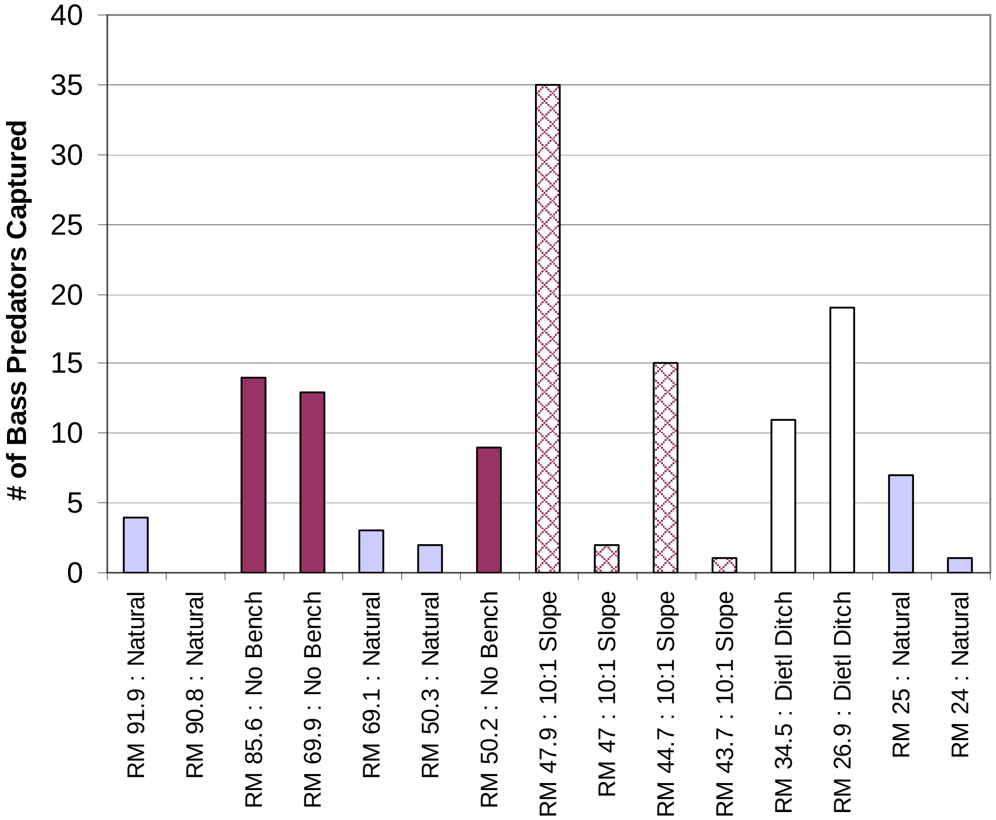

Figure 5-16. River Mile, Design Type, and Number of Bass Predators Captured during 2009 and 2010 Electrofishing Surveys. Refer to Appendix D, Table D-4 for Raw Catch Data by Site and Date.

5.3.5 Delta Smelt

Data indicate that current delta smelt abundance is the lowest it has been in recorded history (i.e., since 1967) (Mac Nally et al. 2010, Thomson et al. 2010, CDFG [date unknown]). During electrofishing surveys in 2010 two delta smelt were captured and released alive; one at river mile 34.5 and one at river mile 50.3. In addition, a female adult delta smelt was captured by CDFG at the Knights Landing outmigrant trap at RM 88.5 (Robert Vincik, CDFG, 24 May 2010). Detection of delta smelt at these unexpectedly high reaches of the Sacramento River increases concerns about bass predators and highlights the importance of understanding predator/habitat relationships.

Table 5-20. Bass Predators Design Type Differences Summary. Refer to Appendix F for Corresponding Raw Model Output.

	Jan. GLM	Jan. GLMM	March GLM	March GLMM	April GLM	April GLMM	Combined GLM	Combined GLMM
Better	No Bench	No differences	No Bench Bench/10:1	No Bench Bench/10:1	Dietl Ditch	Dietl Ditch	Dietl Ditch Bench/10:1 No Bench	Dietl Ditch No Bench Bench/10:1
Worse	Bench/10:1		Natural	Natural	Natural	Natural	Natural	Natural

Table 5-21. Bass Predator Relationships with Habitat Variables. Refer to Appendix F for Corresponding Raw Model Output.

Sig/NS	January GLM	January GLMM	March GLM	March GLMM	April GLM	April GLMM	Combined GLM	Combined GLMM
Significant ($p<0.05$)	Shade (-) IWM size x LWM density (-)	Shade (-) IWM size x LWM density (-)	Shade (-) Bank slope (+) Aquatic vegetation (-) IWM diversity (-)	Shade (-) Bank slope (+) Aquatic vegetation (-) IWM diversity (-)	Bank slope (+) %boulder/cobble (+) Aquatic vegetation (+) IWM size (-) IWM size x LWM density (+) Depth x IWM diversity (+)	Bank slope (+) %boulder/cobble (+) Aquatic vegetation (+) IWM size (-) IWM size x LWM density (+) Depth x IWM diversity (+)	Bank slope (+) Shade (-) IWM diversity (-) Depth x IWM diversity (+)	Shade (-) Depth x IWM diversity (+)
Inconclusive ($0.10<p<0.05$)			Depth x IWM diversity (-)	Depth x IWM diversity (-)				Bank slope (+)
Not significant ($p>0.10$)	IWM size (+) LWM density (-)	IWM size (+) LWM density (-)	Depth (-)	Depth (-)	LWM density (+) Depth (+) IWM diversity (+)	LWM density (+) Depth (+) IWM diversity (+)	Depth (-)	Depth (-)

5.3.6 Implications for Levee Design

There is no simple answer to the question, "Which levee designs and habitat features are "best" for each species and life stage being considered?" Assessment of levee types and habitat features is complicated by relationships between space (regions and river miles), time (e.g., fish grow and adapt to different habitats), and ecological and physical interactions. Nevertheless, as depicted in Table 5-22, there are certain levee types and habitat features which consistently rank as the best or worst for each species and life stage. These conclusions are of course based on the current state of the habitat at the repair sites; these sites will evolve and change with time, and their habitat value to fish will probably also change. Additionally, as described below, certain levee types and habitat features may increase co-occurrence of predatory bass and juvenile Chinook salmon. Future research should assess whether this increased co-occurrence results in increased predation of Chinook salmon by predatory bass. However, when comparing the benefits and costs of different levee types, minimizing potential use by predatory bass should be a consideration, irrespective of potential increases in predation that may be associated with certain levee types.

Bench 10:1 design types were not beneficial for Chinook salmon juveniles as currently built, however, relationships with habitat variables suggest that they could be if there is high enough LWM density at greater depths. With these modifications, Bench 10:1 (and Natural) design types will generally have benefits to Chinook salmon and not predatory bass. Conversely, Dietl Ditch levee types are generally preferable to both Chinook salmon juveniles and predatory bass. Furthermore, there are strong indications that steeper banks are preferable to predatory bass. Overall, existing information indicates that levee designs should focus on shallower depths and more gentle slopes, with Natural and Bench 10:1 levee types emerging as the best.

Table 5-22. Summary Interpretation of the Design Type and Habitat Features GLMs Based on Electrofishing Data.

Species/Life Stage	"Best" Design Types	"Worst" Design Types	Habitat Features[1] Positive Significant	Habitat Features[1] Negative Significant
Chinook Salmon Fry (Jan, Mar)	Bench/10:1 Natural	No Bench	Submerged Vegetation Depth x IWM Diversity	% Boulder / Cobble Depth IWM Diversity
Chinook Salmon Juveniles (Apr)	Dietl Ditch	Bench/10:1	Submerged Vegetation LWM Density Depth x LWM Density	Depth IWM size Shade

Species/Life Stage	"Best" Design Types	"Worst" Design Types	Habitat Features[1] Positive Significant	Habitat Features[1] Negative Significant
Bass Predators (Apr)	Dietl Ditch	Natural	Bank Slope % Boulder / Cobble Aquatic vegetation IWM size x LWM density Depth x IWM Diversity	IWM size

[1] Habitat features that are connected with an "x" indicate interaction terms.

5.4 Results of Telemetry

In 2010, the majority (i.e., 51%, ranging from 12% – 72% depending on release site) of released steelhead were detected at least once by one of the 20 functional telemetry receivers placed at our study sites (Table 5-23). For juvenile Chinook salmon, the overall detection rate was 73%, with a range of 31% - 90% depending on release site.

The telemetry dataset from 2009 and 2010 was used to evaluate residency patterns and duration with respect to specific sites, spatial and temporal variables, design types, and site specific habitat features. Mean residency times for both Chinook salmon and steelhead smolts appeared to be higher at the sites downstream of RM 15 (Figures 5-17, 5-18). It should be noted however that the subsequent GLM analyses break the data into stay vs. go and residency duration components; the mean is not necessarily a good measure of either component, and also does not account for spatial, temporal, and habitat variables that may be affecting residency.

Table 5-23. Summary of Detection Efficiency for Steelhead and Chinook Salmon Juveniles Released by H. T. Harvey & Associates or Other Groups within the California Fish Tracking Consortium into the Mainstem Sacramento River, CA, in 2010.

Location	Month(s) of Release	RM	Species	Number Released	Number Detected	Proportion Detected
Battle Creek Weir	Dec 2009	282	Chinook	120	40	0.33
Butte City Boat Ramp	Dec 2009 Jan 2010	169	Chinook	102	32	0.31
Elkhorn Landing	Jan 2010 Feb 2010	69	Chinook	497	479	0.96
Elverta Road	Jan 2010	83	Chinook	100	85	0.85
Irvine Finch Boat Ramp	Dec 2009 Jan 2010	200	Chinook	102	41	0.40
Jelly Ramp	Dec 2009 Jan 2010	258	Chinook	102	51	0.50
Knights Landing	Jan 2010	100	Chinook	100	90	0.90

Location	Month(s) of Release	RM	Species	Number Released	Number Detected	Proportion Detected
Butte City Boat Ramp	Dec 2009 Jan 2010	169	Steelhead	100	16	0.16
Elkhorn Landing	Jan 2010 Feb 2010 March 2010	100	Steelhead	519	376	0.72
Irvine Finch Boat Ramp	Dec 2009 Jan 2010	200	Steelhead	100	17	0.17
Jelly Ramp	Dec 2009 Jan 2010	258	Steelhead	100	12	0.12

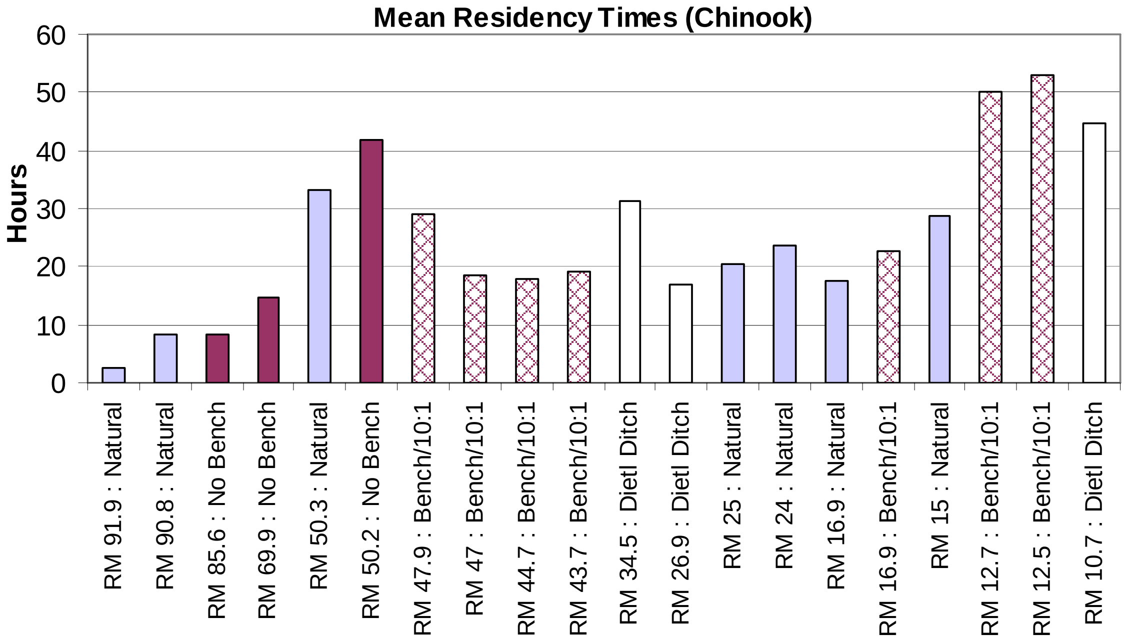

Figure 5-17. Design Type, River Miles and Mean Residency Time of Chinook Salmon Smolts based upon 2009 and 2010 Telemetry Data.

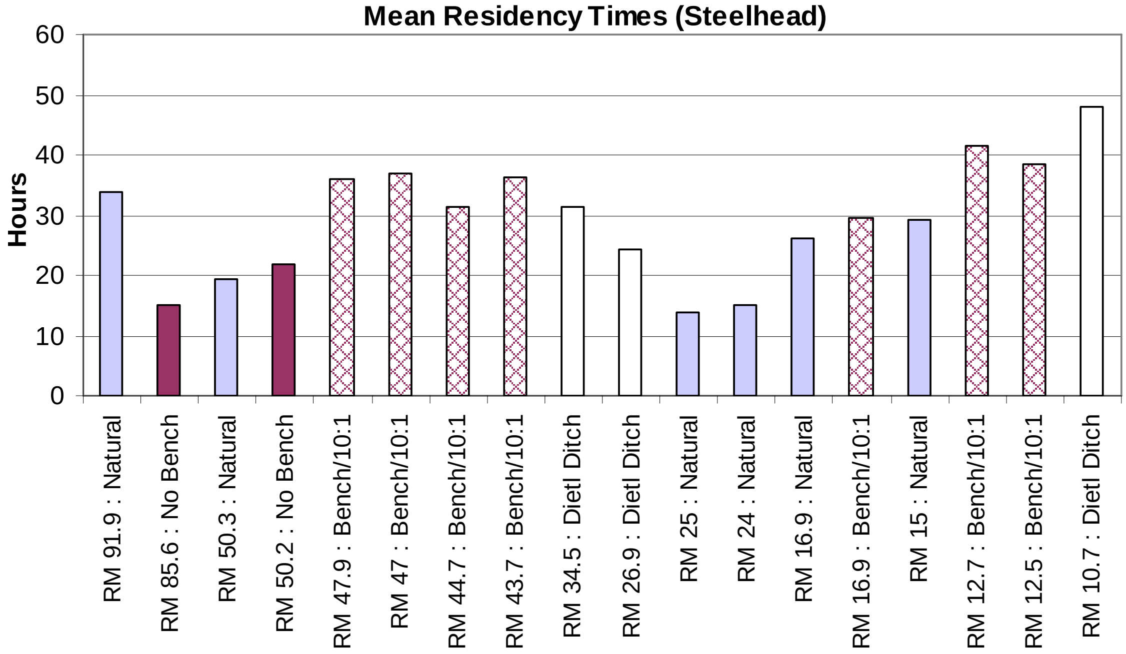

Figure 5-18. Design Type, River Miles and Mean Residency Time of Steelhead Smolts based upon 2009 and 2010 Telemetry Data.

5.4.1 Residency Using GLM Analyses for Chinook salmon

Residency was evaluated based on two criteria: residency duration and whether a fish stays or leaves. Residency duration was expressed as the number of hours a fish stays at a site, whereas "stay vs. go" was a binary variable based on the length of time spent at a site. If more than one hour was spent at a site, then it was assumed that the fish stayed. We selected this 1-hour threshold based on extremely low numbers of detections after 1 h. Based on graphical analysis, we observed two distinct behaviors: 1) rapid migration through the site (going or leaving), and 2) staying at the site for an hour or more (staying). Histograms were used to evaluate distributions of residence times less than 24 h based on data from 2009 and 2010 (Figure 5-19). The purpose of this analysis was to discern a break in the pattern that would suggest a transition between moving and holding behavior. In the 2009 analyses, before sufficient data were available to support any other threshold, the threshold for staying vs. going was selected arbitrarily to be 12 hours.

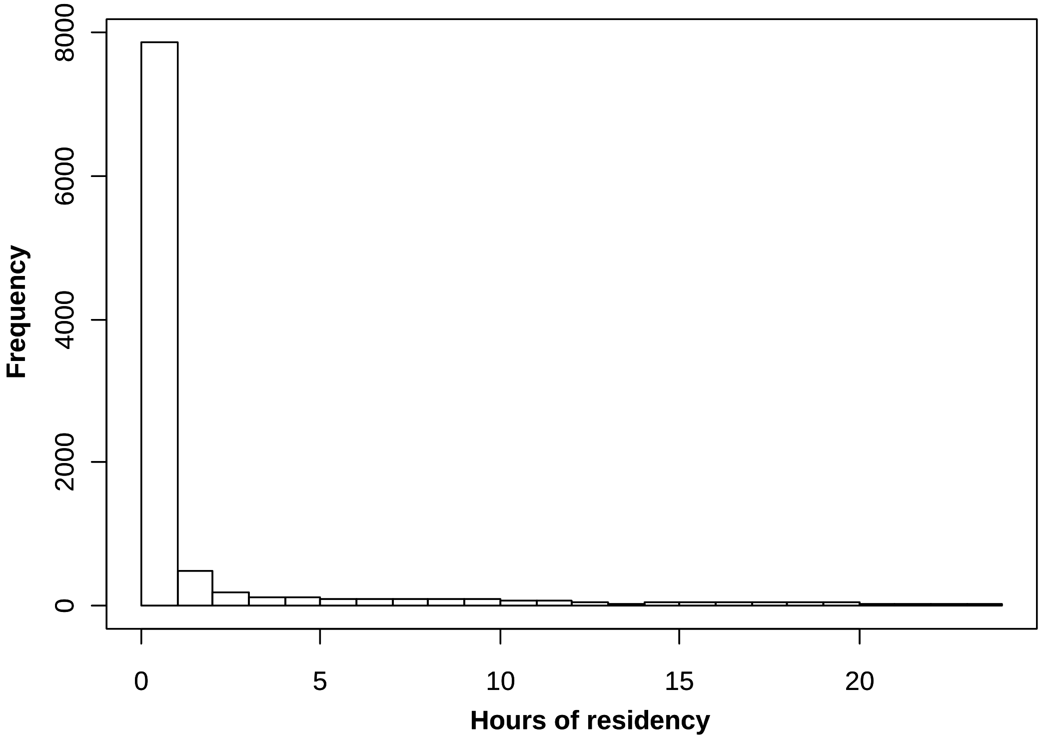

Figure 5-19. Frequency of Chinook salmon Residency Times based on 2009 and 2010 Telemetry Data.

5.4.1.1 Residency Criteria in Relation to Design Type

Marine survival of Chinook salmon is positively related to fish size during seaward migration (Unwin 1997, Duffy 2009) and fish may feed and grow while "residing" at levee sites. Furthermore, certain levee design types may provide increased refuge from predators. However, Chinook salmon growth and refuge from predators have not been evaluated at the levees so we can only hypothesize that increased residency and "staying" are beneficial to juvenile Chinook salmon. Based on this hypothesis, we interpreted the "best" levee types as having the longest residency duration and strongest relationship with fish staying and the "worst" levee types, the shortest residency duration and strongest relationship with fish leaving.

We selected the analysis based on all 4 regions for presenting detailed model output, because it was of particularly great interest to discern differences in relationships between residency and habitat variables for the entire study area between RM 10 and RM 95. In addition, the magnitude of the differences for coefficients between the upper 3 regions and the lowermost region downstream of RM 20 can be examined. The complete raw model output is provided in Appendix H.

Design type in general appeared to be more strongly related to influencing a fish to stay in comparison to residency duration, though it was strongly related to both processes. With respect to staying vs. going, Natural sites are substantially worse than any other design type (z^2 from 37.271 to 325.406, $p<0.0001$ for all comparisons). In contrast, Dietl Ditch is by far the best design type for influencing a fish to stay (z^2 from 60.280 to 325.406, $p<0.0001$ for all comparisons). The coefficients for residency duration indicate that Natural sites are substantially better than Bench/10:1 slope (z^2=17.481, p<0.0001) and Dietl Ditch (z^2=14.432, p=0.0001); the No Bench design is better than Natural, though the difference is not as great (z^2=4.052) (Table 5-24).

Table 5-24. Comparison of Design Types, Resulting from GLM Model Fit to Chinook Salmon Telemetry Data From 2009/2010, All 4 Regions, Sacramento River, CA.

Ref. Category	Design Type	Coef.	SE	95% CI		z^2 Value	Pr(>|z|)
Residency Duration							
Natural	No bench	0.475	0.236	0.013	0.937	4.052	0.0441
	Bench/ 10:1	-0.577	0.138	-0.848	-0.307	17.481	<0.0001
	Dietl Ditch	-0.628	0.165	-0.952	-0.304	14.432	0.0001
Dietl Ditch	Natural	0.628	0.165	0.304	0.952	14.440	0.0001
	No bench	1.103	0.236	0.641	1.565	21.902	<0.0001
	Bench/ 10:1	0.051	0.133	-0.211	0.312	0.145	0.7033
Bench/ 10:1	Dietl Ditch	-0.051	0.133	-0.312	0.211	0.145	0.7035
	Natural	0.577	0.138	0.307	0.848	17.481	<0.0001
	No bench	1.053	0.218	0.626	1.480	23.310	<0.0001
Stay vs. Go							
Natural	No bench	0.610	0.100	0.414	0.806	37.271	<0.0001
	Bench/ 10:1	0.772	0.061	0.653	0.890	162.461	<0.0001
	Dietl Ditch	1.405	0.078	1.252	1.557	325.406	<0.0001
Dietl Ditch	Natural	-1.405	0.078	-1.557	-1.252	325.406	<0.0001
	No bench	-0.795	0.102	-0.996	-0.594	60.280	<0.0001
	Bench/ 10:1	-0.633	0.068	-0.766	-0.501	87.572	<0.0001
Bench/ 10:1	Dietl Ditch	0.633	0.068	0.501	0.766	87.572	<0.0001
	Natural	-0.772	0.061	-0.890	-0.653	162.461	<0.0001
	No bench	-0.162	0.092	-0.341	0.018	3.105	0.0780

Based on residency duration, the No Bench design type tended to be the best for Chinook salmon juveniles regardless of whether the analysis included all 4 regions or only the upper 3 regions (Table 5-25, Appendices H, I, and J). The Bench/10:1 slope and Dietl Ditch design types tended to be the worst with respect to residency duration for both analyses. Based on the analysis of all 4 regions, Dietl Ditch was however the best in terms of influencing whether a fish stayed, indicating that overall it is somewhat neutral with respect to both residency criteria. When including data from all regions, natural sites were the worst design type with respect to influencing a fish to stay.

Table 5-25. Chinook Salmon Residence Time Analysis Summary for Evaluating Design Type Differences, Based on GLM Analyses (Step 1 Results), 2009/2010.

Regions Grouped	Residency Duration	Stay vs. Go
Knights Landing Garcia Bend Ko-Ket Rio Vista	No Bench – best Bench/10:1, Dietl Ditch – worst	Dietl Ditch – best Natural – worst
Knights Landing Garcia Bend Ko-Ket	No Bench – best Dietl Ditch, Bench/10:1 – worst	No differences

5.4.1.2 Residence Criteria in Relation to Habitat Features

Based on the detailed model output from the analysis of all 4 regions (Table 5-26), there were strong positive relationships between residency and larger substrate overall (p=0.0002 for residency duration and p=0.0256 for stay vs. go), and between the probability of staying and IWM diameter in the lowermost region (z^2=64.333, p<0.0001). Bank slope and jam area had a strong negative influence on the decision to stay (p<0.0001 for both variables), with an even larger negative effect due to jam area in the lowermost region (-0.106 as coefficient for jam area in the lowermost region, compared to -0.067 for the upper 3 regions).

Table 5-26. Significant Habitat Variables Based on GLM Model Fit to Telemetry Data for Larger Tagged Chinook Salmon Juveniles, Sacramento River, CA. The dependent Variable Is Residence Time in Hours. IWM Diameter Is in Inches; Jam Area Is in sq ft/ Lineal ft of Bankline; Bank Slope Is the Ratio of Change in Width to Change in Height; Average LWM Density (See Section 4.5.1.1 for Detail) and % Boulder/Cobble Are Ratios between 0 and 1. RV = Rio Vista Region.

Variable	Coefficient	SE	95% CI		z^2 Value	Pr(>|z|)
Residency Duration						
%boulder/ cobble	0.744	0.199	0.354	1.134	13.965	0.0002
Stay vs. Go						
Bank slope	-0.055	0.012	-0.079	-0.030	19.237	<0.0001
%boulder/ cobble	0.229	0.103	0.028	0.431	4.982	0.0256
IWM diameter	-0.109	0.020	-0.148	-0.069	28.794	<0.0001
regionRV x IWM diameter	0.214	0.027	0.162	0.267	64.433	<0.0001
Jam area	-0.067	0.012	-0.090	-0.045	33.966	<0.0001
regionRV x Jam area	-0.039	0.016	-0.071	-0.008	5.890	0.0152

There were major differences in the relationships between residency and habitat features when comparing the analysis based on all 4 regions with the analysis based on the upper 3 regions.

Overall, there was a positive relationship with %boulder/cobble and a negative relationship with bank slope based on all 4 regions, but the reverse relationships with these variables based on the upper 3 regions (Table 5-27). There were significant positive relationships with IWM variables for both analyses, though IWM diameter was important in the analysis based on all 4 regions as opposed to LWM density in the analysis based on the upper 3 regions.

Table 5-27. Chinook Salmon Residence Time Analysis Summary Evaluating Relationships with Habitat Features (Based on Step 2 Modeling). Habitat Features in Italics Indicate Where There Is a Difference in the Relationship between the Upper Three Regions and the Lowest Region (+ Indicates Positive Relationship; - Indicates Negative Relationship).

Regions Grouped	Residency Duration	Stay vs. Go
Analysis of Data from All 4 Regions		
Knights Landing Garcia Bend Ko-Ket	% Boulder/Cobble (+)	Bank slope (-) %Boulder/cobble (+) *IWM diameter (-)* *Jam area (-)*
Rio Vista		Bank slope (-) %Boulder/cobble (+) *IWM diameter (+)* *Jam area (-, <Upper)*
Analysis of Data from Upper 3 Regions Only		
Knights Landing Garcia Bend Ko-Ket	IWM diversity (-) LWM density (+)	Bank slope (+) %Boulder/cobble (-) LWM density (+)

5.4.2 Residency Using GLM Analyses for Steelhead

In both years, the likelihood of steelhead staying versus leaving (the "stay vs. go" criterion) appeared to be most strongly related to habitat features; residency duration was not strongly related to habitat and did not usually differ by design type (Table 5-29). There were few habitat variables identified as significant for steelhead residency duration, in contrast to staying vs. leaving. This pattern with respect to residency duration is not surprising, given the typically rapid movement of these large hatchery juveniles through the study area.

5.4.2.1 Residency Criteria in Relation to Design Type

Similar to our interpretation for Chinook salmon residency, for steelhead we interpreted "best" as having the longest residency duration and strongest relationship with fish staying, and "worst" the shortest residency duration and strongest relationship with fish leaving. Based on the analysis of data from all 4 regions, the coefficients for design type show no differences in relation to residency duration (Table 5-28). In contrast, there are substantial significant differences between the best design type, Dietl Ditch, and all the other design types with respect to influencing the decision to stay, with the strongest differences with Natural (z^2=53.363, p<0.0001) and No Bench (z^2=34.082, p<0.0001) design types. The Bench/10:1 slope design is intermediate between Dietl Ditch (p=0.0006) and the two worst design types, Natural (p<0.0001) and No Bench (p=0.0001).

Table 5-28. Comparison of Design Types, Resulting from GLM Model Fit to Steelhead Telemetry Data from 2009/2010, All 4 Regions, Sacramento River, CA.

Reference Category	Design Type	Coefficient	SE	95% CI's		z^2 Value	Pr(>|z|)
Residency duration							
Natural	No bench	0.179	0.342	-0.492	0.850	0.272	0.6016
	Bench/10:1	0.081	0.163	-0.238	0.401	0.248	0.6185
	Dietl Ditch	-0.172	0.210	-0.584	0.241	0.666	0.4145
Dietl Ditch	Natural	0.172	0.210	-0.241	0.584	0.172	0.8160
	No bench	0.350	0.346	-0.328	1.029	0.097	1.0130
	Bench/10:1	0.253	0.187	-0.114	0.619	0.031	1.3520
Bench/10:1	Dietl Ditch	-0.253	0.187	-0.619	0.114	0.031	-1.3510
	Natural	-0.081	0.163	-0.401	0.238	0.382	-0.4980
	No bench	0.098	0.331	-0.550	0.746	0.589	0.2960
Stay vs. Go							
Natural	No bench	-0.142	0.145	-0.426	0.142	0.960	0.3271
	Bench/10:1	0.413	0.078	0.260	0.565	28.260	<0.0001
	Dietl Ditch	0.739	0.101	0.541	0.937	53.363	<0.0001
Dietl Ditch	Natural	-0.739	0.101	-0.937	-0.541	53.363	<0.0001
	No bench	-0.881	0.151	-1.176	-0.585	34.082	<0.0001
	Bench/10:1	-0.326	0.095	-0.512	-0.141	11.896	0.0006
Bench/10:1	Dietl Ditch	0.326	0.095	0.141	0.512	11.896	0.0006
	Natural	-0.413	0.078	-0.565	-0.260	28.260	<0.0001
	No bench	-0.555	0.140	-0.830	-0.279	15.603	0.0001

Based primarily on the residency criteria of stay vs. go, the Natural and No Bench design type tended to be the worst for steelhead (Table 5-29, Appendices I and J). The Dietl Ditch design tended to be best in terms of influencing a fish to stay. Design type did not appear to affect residency duration when considering all 4 regions, though Bench/10:1 appeared to be best when analyzing the upper 3 regions. Natural was also the worst design type when considering residency duration in the upper 3 regions.

Table 5-29. Steelhead Residence Time Analysis Summary for Evaluating Design Type Differences, based on GLM Analyses (Step 1 Results), 2009/2010.

Regions Grouped	Residency Duration	Stay vs. Go
Knights Landing Garcia Bend Ko-Ket Rio Vista	No differences	Dietl Ditch – best Natural, No Bench – worst
Knights Landing Garcia Bend Ko-Ket	Bench/10:1 – best Dietl Ditch, Natural – worst	Dietl Ditch – best Natural, Bench/10:1, No Bench – worst

5.4.2.2 Residency Criteria in Relation to Habitat Features

The strongest relationships with habitat variables based on the analysis of all 4 regions was for bank slope (negative, $z^2=13.816$, $p=0.0002$) and the regionRV x IWM diameter interaction (positive, $z^2=17.372$, $p<0.0001$), based on the residency criteria of stay vs. go (Table 5-30). No significant relationships with habitat variables were detected for residency duration. In contrast, the relationship between residency (stay vs. go) and IWM diameter was negative (coefficient of -0.053) in the upper 3 regions. The relationship with %boulder/cobble was also strong and positive ($z^2=8.851$, $p=0.0029$).

Table 5-30. Significant Habitat Variables based on GLM Model Fit to Telemetry Data for Steelhead Juveniles, Sacramento River, CA. The Dependent Variable Is Residence Time in Hours. IWM Diameter Is in Inches; Jam Area Is in sq ft/ Lineal ft of Bankline; Bank Slope Is the Ratio of Change in Width to Change in Height; % Boulder/Cobble Is a Ratio between 0 and 1. RV = Rio Vista Region.

Variable	Coefficient	SE	95% CI		z^2 Value	Pr(>|z|)
Residency duration						
None	N/A	N/A	N/A	N/A	N/A	N/A
Stay vs. Go						
Bank slope	-0.065	0.018	-0.100	-0.031	13.816	0.0002
%boulder/cobble	0.261	0.088	0.089	0.434	8.851	0.0029
IWM diameter	-0.053	0.027	-0.106	0.001	3.756	0.0527
regionRV x IWM diameter	0.141	0.034	0.075	0.207	17.372	<0.0001
Jam area	-0.026	0.018	-0.060	0.009	2.123	0.1450
regionRV x Jam area	-0.047	0.024	-0.093	-0.001	3.940	0.0471

Relationships between residency and habitat features (stay vs. go) were consistently negatively related to bank slope and positively related to %Boulder/cobble when all 4 regions were analyzed (Table 5-29). Negative relationships with IWM variables were indicated for the upper 3 regions based on the residency criteria of stay vs. go, based on either analysis. However, there was a positive relationship between residency (stay vs. go) and IWM diameter for the lowermost region, and a positive relationship between residency duration and IWM diversity based on the analysis of the upper 3 regions (Table 5-31).

Table 5-31. Steelhead Habitat Relationships based on Step 2. Habitat Features in Italics Indicate Where There Is a Difference in the Relationship between the Upper Three Regions and the Lowest Region (+ Indicates Positive Relationship; - Indicates Negative Relationship).

Region	Residency Duration	Stay vs. Go
Analysis based on Data from All 4 Regions		
Knights Landing Garcia Bend Ko-Ket	NA	Bank slope (-) %Boulder/Cobble (+) *IWM diameter (-)** Jam area (-)**
Rio Vista	NA	Bank slope (-) %Boulder/Cobble (+) *IWM diameter (+)* Jam area (-, <Upper)
Analysis of Data based on Upper 3 Regions Only		
Knights Landing Garcia Bend Ko-Ket	%Boulder/Cobble (+) IWM diversity (+)	Bank slope (-) LWM density (-)

* Inconclusive (0.05<p<0.10).
**Not significant (p>0.10).

At sites upstream of RM 20 (i.e., the upper 3 regions), it appears that steelhead residency was most frequently associated with lower slopes, larger substrate, and IWM (Table 5-31; Appendix J). When including design type, none of the habitat variables were significant; this suggests that design type is seriously confounded with the habitat variables that are influential for steelhead residency (Appendix J). In other words, design type appears to be related to both residency and the significant habitat variables, complicating interpretation of the relationship between residency and habitat variables in Step 3. The relationship between residency and lower slopes and larger substrate may suggest use of shallower main channel nearshore habitats associated with the repair design types.

At sites downstream of RM 20 (i.e., in the Rio Vista region), there were differences in the relationships with IWM diameter and jam area. As for sites upstream of RM 20 (i.e., upper 3 regions), residency was associated with larger substrate and reduced bank slope (note that these interactions were not specifically explored, but that relationships with these variables were assumed to be the same between the upper 3 regions and the lowest region a priori). It appears that wood is not as important for residency upstream of RM 20 as they are downstream of RM 20. Overall, there is a greater probability of staying at sites downstream of RM 20 than upstream of RM 20 (Appendix H); however, at sites downstream of RM 20, it appears that the habitat features associated with the design types are not as influential to residency (Appendix J). Due to the much wider river channel in this tidally influenced area, this is perhaps not surprising. The likelihood of a fish keying in on relatively small bankline features when faced with such a great extent of area seems somewhat unlikely.

There were conflicting associations with IWM measures, though these variables frequently show up as significant. Residency duration is associated with few habitat variables, although in general there are positive associations with IWM measures. In contrast, whether a fish stays appears to be negatively influenced by most IWM measures. These conflicting relationships could potentially be due to decreased detection efficiency in areas with greater densities of IWM.

5.4.3 Implications for Levee Design

Telemetry results were based on larger tagged juvenile Chinook salmon and steelhead, larger than any captured by electrofishing. Tagged Chinook salmon and steelhead smolts were more likely to stay at sites in the Lower Sacramento River and Delta compared to sites upstream of RM 20, based on acoustic telemetry; we assume this was likely a response to increasing tidal influence. As noted above, these larger tagged juveniles/smolts are not consistently associated with any specific levee design types or habitat features. This suggests that use of the levee structures by larger juveniles/smolts is minimal.

5.5 Water Quality

There was seasonal variation in water quality, with increasing water temperatures from January through April. The mean water temperature was 55.6°F (13.1°C (6.7°C – 23.3°C)) at the Knights Landing trap (RM 88.5) and 55.2°F (12.9°C (9.3°C – 17.6°C)) at electrofishing sites during the survey period. Salinity remained low at all sites (≤ 0.1 ppt). Water clarity had a mean depth of 1.9 ft (.1 ft – 6.1 ft) at the Knights Landing trap and 1.3 ft (0 ft – 5.8 ft) at electrofishing sites (Appendix C).

6 EVALUATING THE METHODOLOGY AND MEETING THE STUDY OBJECTIVES

6.1 Evaluating the Methodology

Our reflections on the methodology focus on:

- Measurement of IWM
- Interpretation of the GLMs and GLMMs
- Potentially confounding factors

We evaluated many measurements and descriptors of IWM. Electrofishing-based IWM measurements summarized at the site scale appear to be better predictors of fish presence than transect-based IWM measurements (see Section 5.2.4). Accurately characterizing IWM in a way that is meaningful for fish is a task that will probably require further refinement in the future. However, by any measure, much of the IWM at repair sites appears to be placed too high. It may score well based on the SAM, but if much of it is not inundated for a long enough time, then its value decreases.

The GLMs and GLMMs were successful in identifying the "best" levee repair design types and features within those types, however, the results of the 3-step approach must be interpreted carefully. The Step 3 results using the telemetry data were of limited value because there was a great deal of confounding between the habitat variables; this was not the case for electrofishing. For the telemetry data, Step 3 results allowed us to determine that the very habitat features that look to be important in explaining differences in fish behavior are the same features that are confounded with (that is, associated with) design type. The reason for doing a Step 3 is not to identify which design types are better for fish or which habitat features are better for fish. Rather, the principal objective in Step 3 is to see which habitat features are contributing to the differences in design type observed in the Step 1 analysis, and to see whether design type is contributing to the differences observed with respect to the habitat features identified in Step 2.

A major finding of these analyses is that results differ considerably comparing upstream of RM 20 to downstream of RM 20 (Tables 5-19 and 5-20). Some design types (for example, the Bench repair type) are only at the lower end of the river. Some of the differences among habitat features are due primarily to their specific locations on the Sacramento River, which dictated the site designs that could be utilized. For example, Bench design type sites tended to have lower IWM at lower elevation transects because they are located downstream of RM 20, where IWM was not installed due to concerns about creating habitat for predators of delta smelt. The bench designs also tended to have steep slopes immediately below the benches where the low elevation transects are located. These steep slopes are not conducive to IWM recruitment. However, the benches themselves, where the higher transects are located, are excellent locations for IWM recruitment, which resulted in high IWM values despite the fact that no IWM was installed at these sites. Sites downstream of RM 32 including those downstream of RM 20, are influenced more by the tides than by season, and as a result are inundated more frequently and thus have more opportunities to recruit wood. Therefore, there is at least one recognized complicating factor that needs to be considered in future designs.

A secondary finding was that fish residency was often related to tagged fish release location and date. For Chinook salmon, both residency duration and the likelihood of staying at a site were affected by release location, release date, and date of arrival at a site, based on the analysis of data from all 4 regions (Appendices I and J). Generally, fish released within or near the study area had greater residency duration and a higher likelihood of staying. Chinook salmon juveniles arriving later in the season tended to have a greater likelihood for staying and greater associated residency duration. In addition, the likelihood for staying was also associated with flow, with less chance for staying at higher flows. There was also a regional effect, where it was most likely for fish to stay in the lowest region, Rio Vista. Whether a fish arrived at a site during the day versus night did not appear to influence residency duration or the likelihood of staying based on either analysis.

For steelhead, significant relationships were observed between residency duration or whether a fish stays and release location, release date, region, and date of arrival at a site, based on the analysis of data from all 4 regions. Both duration and the likelihood of staying were typically greater when the release location was within the study area (Appendices I and J). The later the release date and arrival date at a site, the less likely the fish was to stay; and the later the arrival date, the less time it spent at the site. The regional effect was not as clear as that of Chinook salmon juveniles. Residency duration appeared to be greater in the upper 3 regions, yet the likelihood of staying was greater in the lowest region, Rio Vista. The relationship with flow was also not clear, with conflicting results for whether a fish stays and residency duration.

6.2 Meeting the Study Objectives

The overall objectives of this study were to:

1) identify habitat features of levee repair sites that promote native fish use, so that repair sites can maximize value for fish, and
2) determine if fish use is similar between naturalized sites and levee repair sites.

The sampling and analytical methods were generally successful in allowing us to meet the study objectives. Given the data collected so far, we can state the following:

Use of the levee repair sites by juvenile steelhead and larger juvenile Chinook salmon is minimal. Based on analysis of the telemetry data, the juvenile steelhead and larger juvenile Chinook salmon (93-218 mm total length, mean 162 mm) are not strongly associated with specific levee design types or habitat features. Many of these fish were likely smolts outmigrating to the sea. Furthermore, juvenile steelhead were rarely captured during electrofishing (a total of 15 captures in 2009 and 2010, ranging from 159 to 270 mm TL with mean of 216 mm), and large juvenile Chinook salmon were not captured during electrofishing surveys (juvenile Chinook salmon in electrofishing surveys ranged from 31-100 mm TL with mean of 53 mm). Inconsistent association between the juvenile steelhead and larger juvenile Chinook salmon and the levee types/habitat features, combined with the fact that these juveniles were rarely captured at the levees, indicates that use of the levees by juvenile steelhead and larger juvenile Chinook salmon is minimal.

Smaller or younger Chinook salmon (≤100 mm total length) were strongly associated with the Bench, 10:1 and Dietl Ditch levee repair design types, based on electrofishing. However, the Dietl Ditch repair type was also strongly associated with bass predators, raising concerns about increased Chinook salmon predation at the Dietl Ditch design types. Similarly, steep banks appear to be beneficial to both juvenile Chinook salmon and predatory bass.

Shallower depths and submerged vegetation appeared important for both Chinook salmon fry and juveniles. Earlier in the season (January/March), predation pressure may be much less as temperatures are less favorable for bass, and fewer bass predators appear to be present, based on electrofishing. The implications for this may be that we can try to maximize the habitat features that are most beneficial to Chinook salmon fry and juveniles during all months, while considering as part of the design what can be done to reduce conditions favorable for bass predators in April (under typically lower flow conditions).

Therefore, based on the existing data, the most beneficial levee repair type for fry and juvenile Chinook salmon is the Bench and 10:1 slope design type. However, the number of levees sampled in this study was low and the three year sampling effort likely does not reflect the temporal variation that occurs at these sites. Therefore, future research to increase our knowledge of levee and habitat use by juvenile salmonids and their predators should include increasing electrofishing surveys at more sites within fewer regions (to better distinguish between repair types), and should include repair sites that are not based on using the SAM (standard, rip-rap levees) as an additional control. Future monitoring, especially using telemetry (active and passive) as the technology advances, should generally focus on smaller Chinook salmon (e.g., <100 mm), which appear to have a stronger association with the levees than steelhead or larger Chinook salmon, and their predators.

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APPENDIX A.

Design Types Engineering Drawings

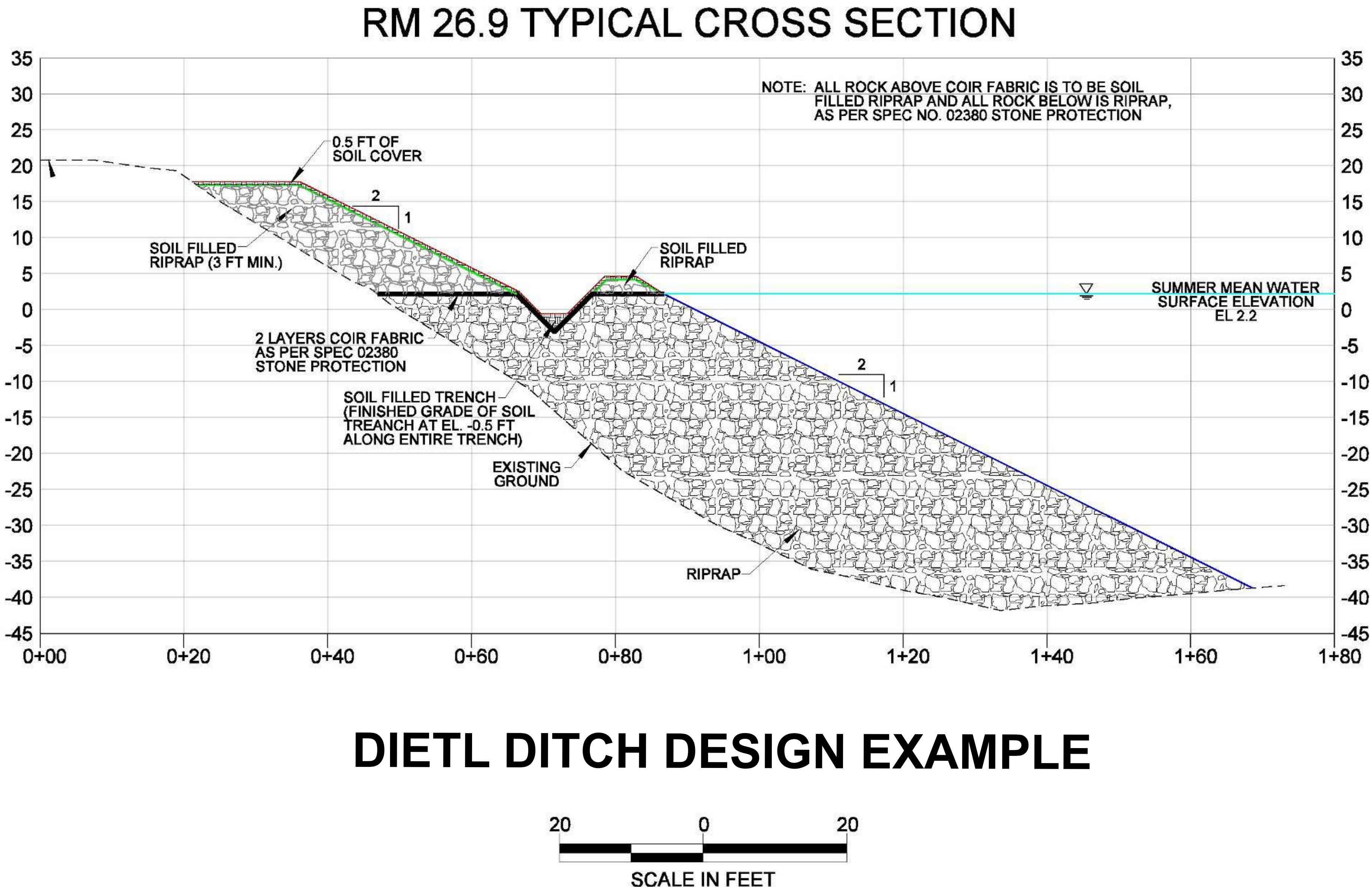
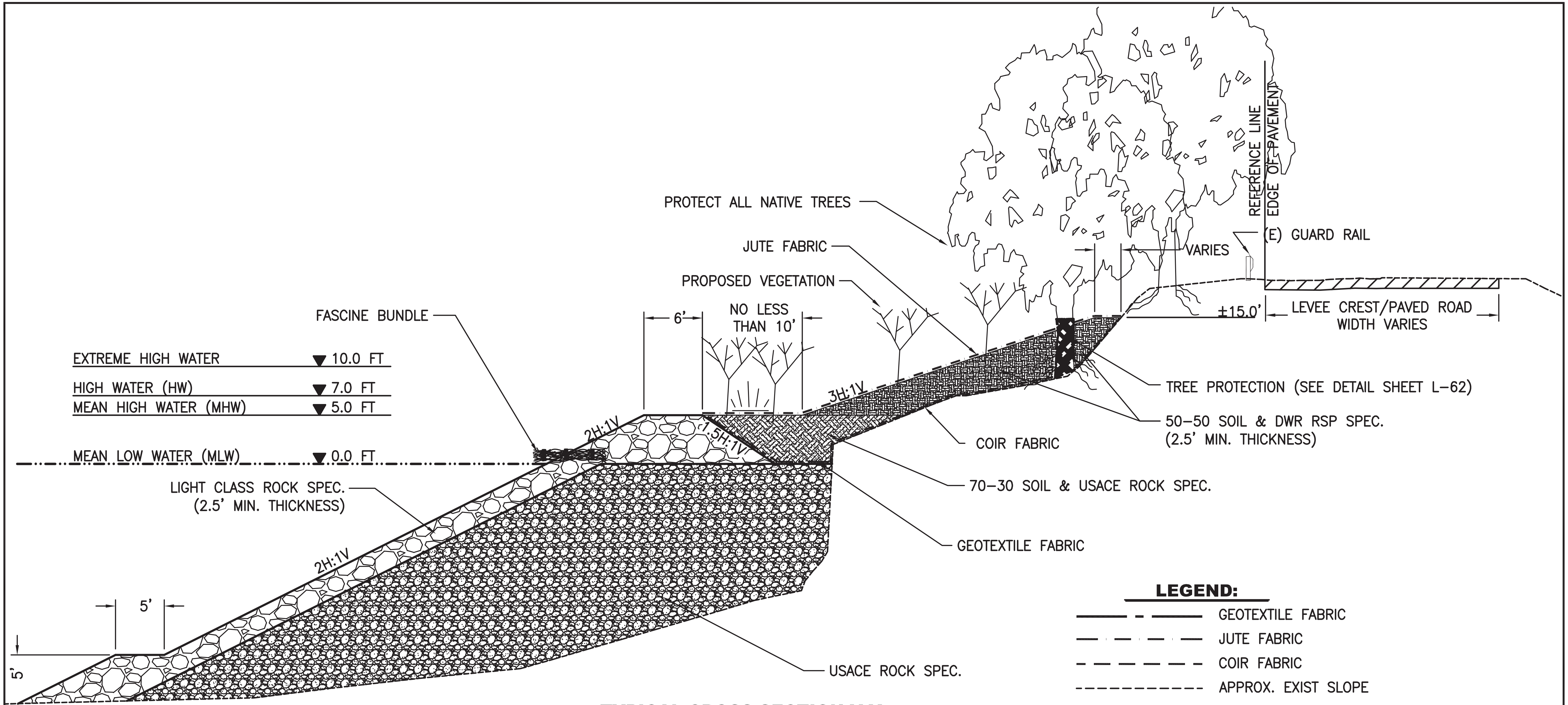


Figure 7. Typical Design Cross Section at Sacramento River Mile 26.9L



TYPICAL CROSS SECTION Y-Y

*SITES 3-8 1"=10'

LEGEND:

——— - ———	GEOTEXTILE FABRIC
— · — · — · —	JUTE FABRIC
— — — — — —	COIR FABRIC
- - - - - - - - - - -	APPROX. EXIST SLOPE
— · · — · · — · ·	MEAN LOW WATERLINE
▩	USACE SPEC.
▨	70-30 SOIL & USACE ROCK SPEC.
▦	50-50 SOIL & DWR RSP SPEC.
⬡	LIGHT CLASS ROCK SPEC.

USACE ROCK SPEC

STONE WEIGHT POUNDS	CUMULATIVE % FINER BY WEIGHT
400	100
250	70-100
100	50-80
30	32-58
5	2-20
1	0-10
LESS THAN 1/2" MAX. DIMENSION	

NOTE: 5% OF THE MATERIAL CAN WEIGH MORE THAN 400 POUNDS. HOWEVER NO PIECE SHALL WEIGH MORE THAN 500 POUNDS

DWR RSP SPEC

WEIGHT (LB.)	% SMALLER BY WEIGHT MIN	MAX
400	.	100
300	85	100
70	15	50
15	0	5

LIGHT CLASS ROCK

ROCK WEIGHT	% LARGER THAN
1/4 TON	0-5
200 LB.	50-100
25 LB.	95-100

BENCH DESIGN EXAMPLE

REV.	DATE	BY	DESCRIPTION	APPROVED	DATE

DESIGNED BY: GILBERT LABRIE
DRAWN BY: Y. HER/J MEDINA
REVIEWED BY: GILBERT LABRIE
SUBMITTED BY:
PROJECT MANAGER
DATE: 12/22/06

DCC
ENGINEERING
CO.,INC.
Tel (916)776-2277 Fax (916)776-2282
P.O. BOX 929, WALNUT GROVE, CA 95690

Architecture
Civil Engineering
Land Use Planning
Feasibility Studies
Environmental Permitting
Program/Construction Management

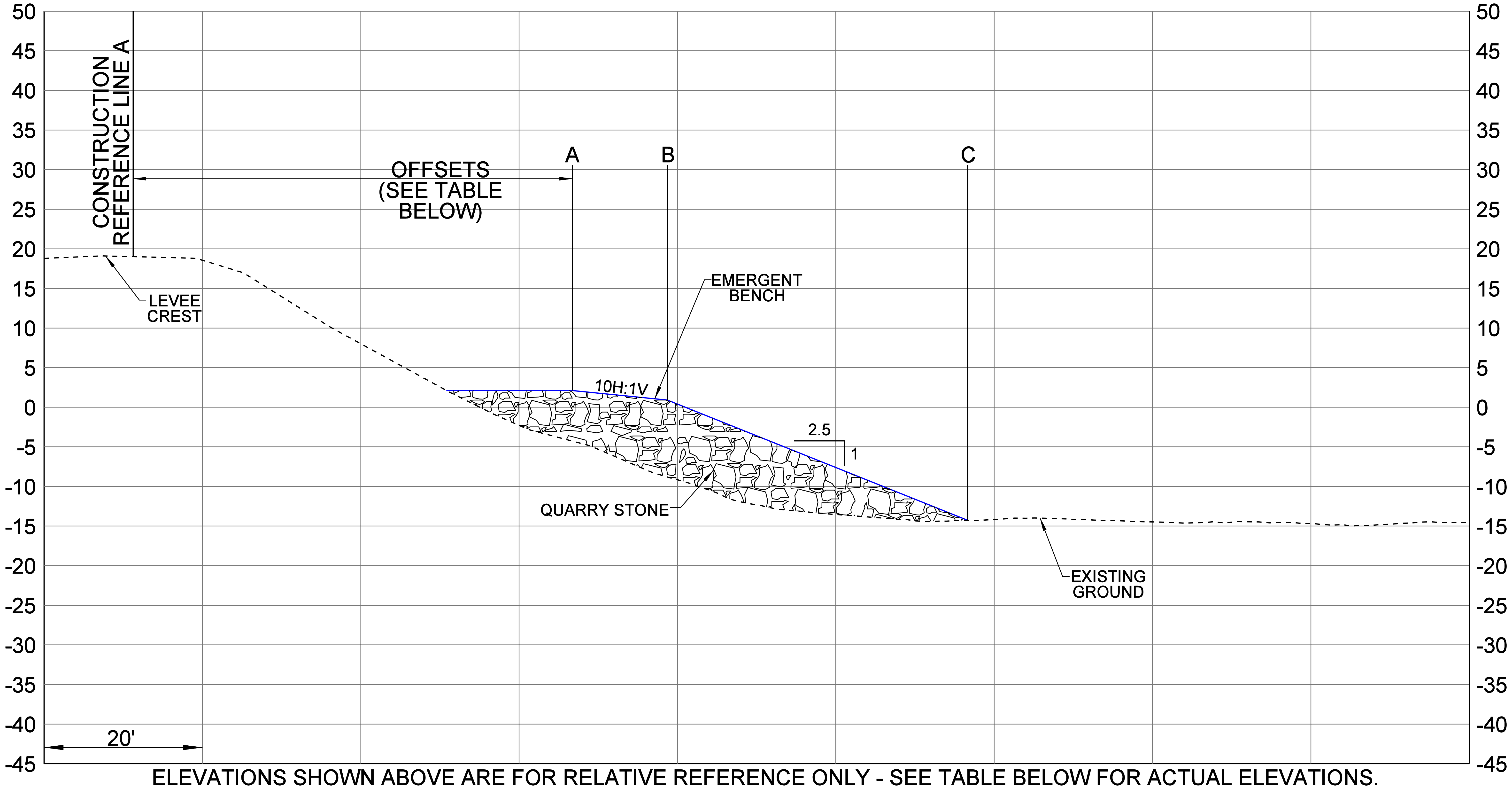
APPROVED BY:
REG. NO.:
EXP. DATE:
DATE:

BRANNAN-ANDRUS LEVEE
MAINTENANCE DISTRICT
PL 84-99 REPAIR SITES

TYPICAL CROSS SECTION
Y-Y

7002.95
SHEET REFERENCE NUMBER:
C-26
24 OF 52

A C-3 C-5 SAC RM 16.9L REFERENCE CROSS SECTION FOR OFFSET/ELEVATION DATA



ELEVATIONS SHOWN ABOVE ARE FOR RELATIVE REFERENCE ONLY - SEE TABLE BELOW FOR ACTUAL ELEVATIONS.

SAC RM 16.9L TABLE OF OFFSET/ELEVATION DATA

STATION ALONG CONSTRUCTION REFERENCE LINE A	ANGLE FROM REFERENCE LINE	A TOP OF EMERGENT BENCH 10:1 SLOPE		B TOP OF LOWER 2.5:1 SLOPE		C TOE OF LOWER 2.5:1 SLOPE	
	DEGREES	OFFSET FT	ELEVATION FT	OFFSET FT	ELEVATION FT	OFFSET FT	ELEVATION FT
0+49						64.5	-13.2
0+92		40.6	2.1			84.0	-13.6
1+29		50.1	2.1	62.1	0.9	98.6	-13.7
1+70		50.1	2.1	62.1	0.9	98.8	-13.8
2+20		50.1	2.1	62.1	0.9	97.0	-13.1
2+62		50.1	2.1	62.1	0.9	98.0	-13.5
3+02		40.1	2.1			82.6	-13.3
3+50						60.6	-12.2

NOTES:
1. ALL CROSS SECTION OFFSETS ARE MEASURED PERPENDICULAR TO THE CONSTRUCTION REFERENCE LINE UNLESS OTHERWISE NOTED IN ABOVE TABLE.
2. ELEVATIONS GIVEN ARE FOR FINISHED QUARRY STONE SURFACES.
3. BLANK ENTRY INDICATES THAT THE SPECIFIED "BREAKLINE" FEATURE IS NON-EXISTENT AT THE GIVEN REFERENCE LINE STATIONING.

10:1 DESIGN EXAMPLE

THOMAS WEST SMITH
No. 20,525
Exp. 09/30/07
CIVIL

US Army Corps
of Engineers
Sacramento District

Symbol | Description | Date | Approved

Designed by: A.B. Alvarado
Dwn by: ABA
Ckd by: HHP
Reviewed by: R.T. Smith
Submitted by: Thomas W. Smith
Date: 12/15/06
Rev.
Design file no: 50-04-6253
Spec No. 1573
File name: C1ci08gn.dgn
Plot date: 12/13/06
Plot scale: 1:10

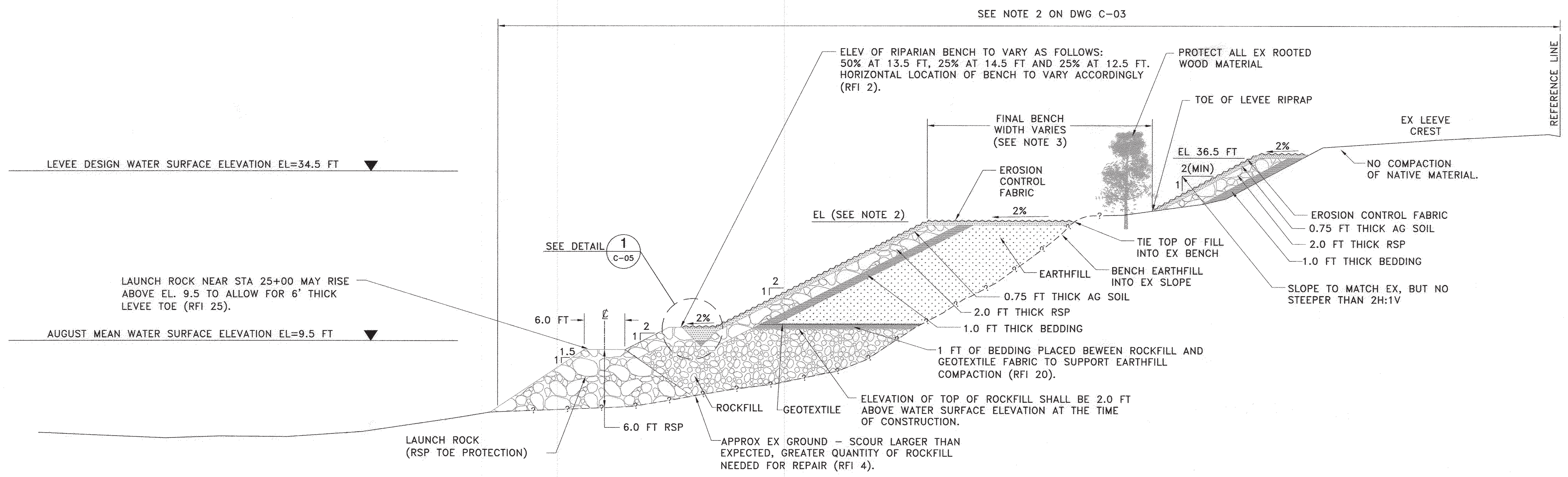
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA

AYRES ASSOCIATES
ENGINEERS
SCIENTISTS
SURVEYORS
Fort Collins, CO
Denver, CO
Sacramento, CA

SACRAMENTO RIVER BANK PROTECTION PROJECT
SACRAMENTO RIVER AND STEAMBOAT SLOUGH
EMERGENCY EROSION CONTROL SITES
RIVERMILE (SAC RM) 16.9L,
(SB RM) 19.0R, 19.4R AND 22.7R,
PHASE I

REFERENCE CROSS SECTION
SAC RM 16.9L

Sheet reference number:
C-5
Sheet 8 of 20



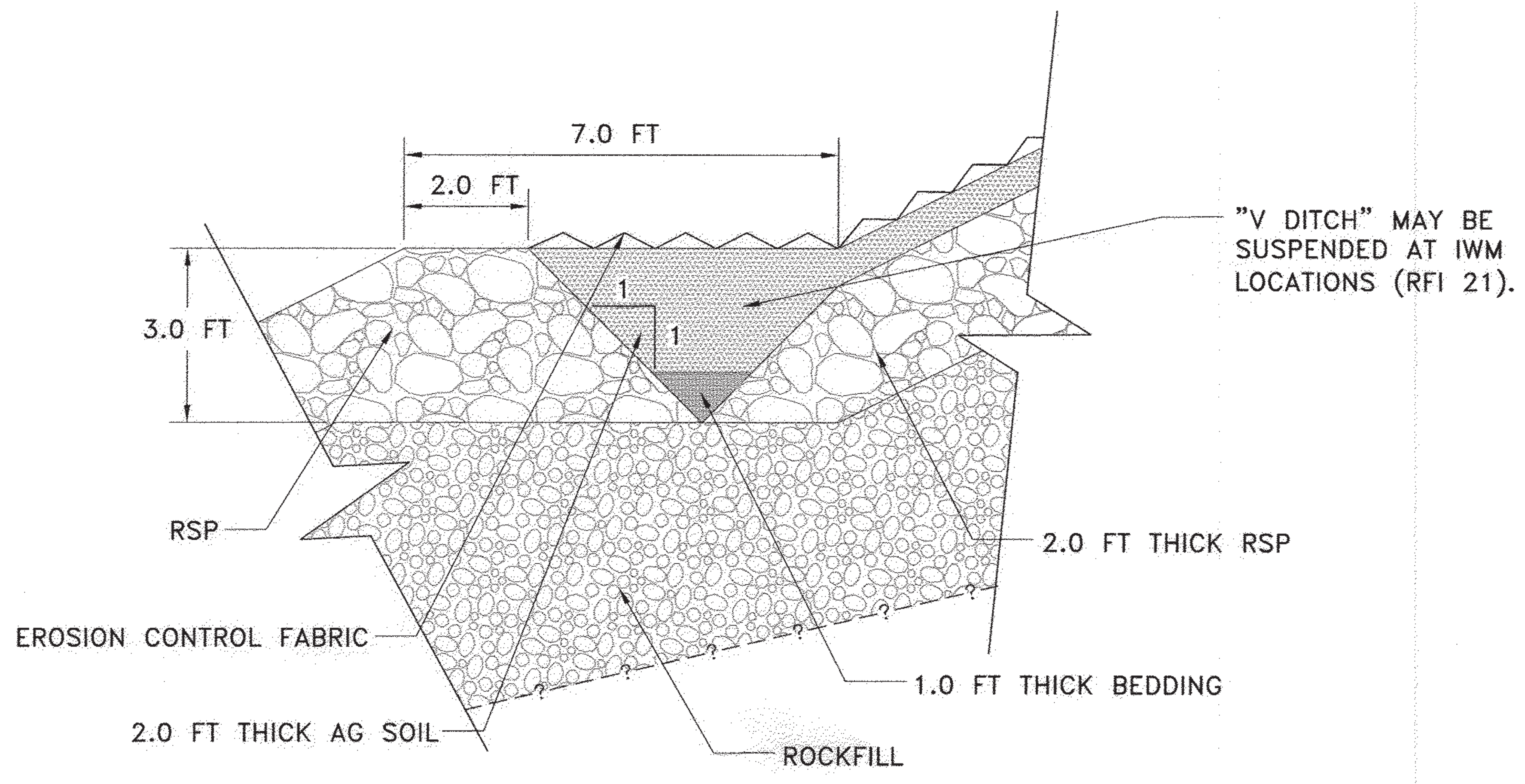
TYPICAL CROSS SECTION

NTS
(SEE NOTE 1)

NOTES:

1. SEE LANDSCAPE DRAWINGS FOR PLANTING AND WOODY DEBRIS.
2. TIE TOP OF FILL INTO EX BENCH
3. FINAL BENCH WIDTH VARIES AS FOLLOW:
   STA 11+68 – STA 20+11 (16–32 FT)
   STA 20+11 – STA 21+07 (32–50 FT)
   STA 21+07 – STA 25+58 (36–50 FT)

   SEE LAYOUT PLAN FOR TRANSITIONING BENCH WIDTH
4. NO AG FILL SHALL BE PLACED WITHIN 20.0 FEET OF ELDERBERRY SHRUBS OR WITHIN THE DRIPLINE OF EXISTING TREES TO REMAIN.



DETAIL 1 C-05

NTS

NO BENCH DESIGN EXAMPLE

ROBERT KENT GREEN
No. 29218
Exp. 3-31-09
CIVIL

		AS-BUILT		
REV	DATE	DESCRIPTION	SUB.	APPD

DESIGNED S. PUNYAMURTHULA
DRAWN S. GODINEZ
CHECKED M. FORREST
REG. NO. CE-27855
APPROVAL RECOMMENDED R. GREEN
REG. NO. CE-29218
APPROVAL BY S. SALAH-MARS
REG. NO. CE-50445

URS

REVIEWED DION ABELLON
REG. NO. CE-62497
DATE 06/05/06
APPROVAL RECOMMENDED RONALD LEE
REG. NO. CE-30612
APPROVED PROJECT MANAGER DONALD KUROSAKA
REG. NO. CE-29366

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
DIVISION OF ENGINEERING
FLOOD MANAGEMENT

STATE EMERGENCY EROSION REPAIR PROJECT
EMERGENCY LEVEE EROSION REPAIR – PHASE II
SACRAMENTO-MILE 69.9R & 56.8R

SACRAMENTO RIVER-MILE 69.9, RIGHT BANK
TYPICAL REPAIR SECTION AND DETAILS

SPEC NO. 06-18
DRAWING NO. C-05
REV. AB
SHEET NO. 008

Courtney_Lyerly Sep 28, 2008 - 11:58am
G:\DWR\DREAMS - 4600004456\TO 02 Em Levee Repairs\06 DELIVERABLES\2005 Critical Sites\DELIVERABLES\2005-As-Built Contract DrawingsC-05 AI.dwg

APPENDIX B.

2008 and 2009 Photographs of Habitat Features

Site 10.7L, Photo-point 4. Repair site with Dietl ditch design. Note the large abundance of aquatic vegetation within the Dietl ditch. Photo taken September 2008.

Site 10.7L, Photo-point 4. Repair site with Dietl ditch design. Note the large abundance of aquatic vegetation within the Dietl ditch. Photo taken October 2009.

Site 12.5L, Photo-point 2. Repair site with bench design. Photo taken August 2008.

Site 12.5L, Photo-point 2. Repair site with bench design. Photo taken September 2009.

Site 12.7L, Photo-point 2. Repair site with bench design. Note the early development of overhanging shade from the willow plantings adjacent to the channel. Photo taken August 2008.

Site 12.7L, Photo-point 2. Repair site with bench design. Note the continued development of overhanging shade from the willow plantings adjacent to the channel. Photo taken September 2009.

Site 15.0R, Photo-point 4. Natural site.   Photo taken September 2008.

Site 15.0R, Photo-point 4. Natural site.   Photo taken October 2009.

Site 16.9L, Photo-point 1. Repair site with 10:1 slope design. Photo taken August 2008.

Site 16.9L, Photo-point 1. Repair site with 10:1 slope design. Photo taken October 2009.

Site 16.9R, Photo-point 2. Natural site. Note the abundance of aquatic vegetation within the main channel. Photo taken September 2008.

Site 16.9R, Photo-point 2. Natural site. Note the abundance of aquatic vegetation within the main channel. Photo taken October 2009.

Site 24.0L, Photo-point 4. Natural site. Note the large amount of overhanging shade. Photo taken August 2008.

Site 24.0L, Photo-point 4. Natural site. Note the large amount of overhanging shade. Photo taken October 2009.

Site 25.0L, Photo-point 2. Natural site. Note that the majority of the instream woody material is submerged. Photo taken August 2008.

Site 25.0L, Photo-point 2. Natural site. Note that the majority of the instream woody material is submerged. Photo taken October 2009.

Site 26.9L, Photo-point 1. Repair site with Dietl ditch design. Standing on the bank side of the ditch, facing north. Note the large abundance of aquatic vegetation within the Dietl ditch. Photo taken August 2008.

Site 26.9L, Photo-point 1. Repair site with Dietl ditch design. Standing on the bank side of the ditch, facing north. Note the large abundance of aquatic vegetation within the Dietl ditch. Photo taken September 2009.

Site 34.5R, Photo-point 2. Repair site with Dietl ditch design. Standing on island, facing south. Photo taken August 2008.

Site 34.5R, Photo-point 2. Repair site with Dietl ditch design. Standing on island, facing south. Photo taken September 2009.

Site 43.7R, Photo-point 4. Repair site with 10:1 slope design. Note that a large portion of the installed instream woody material is above the water level. Photo taken August 2008.

Site 43.7R, Photo-point 4. Repair site with 10:1 slope design. Note that a large portion of the installed instream woody material is above the water level. Also note the rapid development of woody riparian vegetation. Photo taken August 2009.

Site 44.7R, Photo-point 4. Repair site with 10:1 slope design. Note that a large portion of the installed instream woody material is above the water level. Photo taken August 2008.

Site 44.7R, Photo-point 4. Repair site with 10:1 slope design. Note that a large portion of the installed instream woody material is above the water level. Also note the continued development of the riparian plantings. Photo taken August 2009.

Site 47.0L, Photo-point 2. Repair site with 10:1 slope design. Photo taken August 2008.

Site 47.0L, Photo-point 2. Repair site with 10:1 slope design. Photo taken August 2009.

Site 47.9R, Photo-point 1. Repair site with 10:1 slope design. Photo taken August 2008.

Site 47.9R, Photo-point 1. Repair site with 10:1 slope design. Photo taken August 2009.

Site 50.2L, Photo-point 1. Repair site with a no bench design. Photo taken August 2008.

Site 50.2L, Photo-point 1. Repair site with a no bench design. Photo taken October 2009.

Site 50.3R, Photo-point 2. Natural site. Photo taken August 2008.

Site 50.3R, Photo-point 2. Natural site. Photo taken October 2009.

Site 69.1L, Photo-point 1. Natural site. Photo taken August 2008.

Site 69.1L, Photo-point 1. Natural site. Photo taken October 2009.

Site 69.9R, Photo-point 1. Repair site with a no bench design. Photo taken August 2008.

Site 69.9R, Photo-point 1. Repair site with a no bench design. Note the rapid development of riparian vegetation. Photo taken August 2009.

Site 85.6R, Photo-point 1. Repair site with a no bench design. Photo taken August 2008.

Site 85.6R, Photo-point 1. Repair site with a no bench design. Photo taken September 2009.

Site 90.8R, Photo-point 1. Natural site. Photo taken August 2008.

Site 90.8R, Photo-point 1. Natural site. Photo taken October 2009.

Site 91.9R, Photo-point 1. Natural site. Photo taken August 2008.

Site 91.9R, Photo-point 1. Natural site. Photo taken October 2009.

APPENDIX C.

Knights Landing Trapping and Water Quality Data

The out-migrant trap at Knight’s Landing was operated by CA Department of Fish and Game. A total of 19,461 juvenile Chinook salmon were captured between Oct. 12, 2009 and June 28, 2010. Peak captures occurred during late-January and mid-April; corresponding with peak river flows. Based on the trap data, it appears that electrofishing surveys occurred during times when juvenile Chinook salmon were relatively abundant in the river (Figure C-2). Juvenile Chinook salmon lengths ranged from 27 mm to 180 mm fork length (Table C-1).

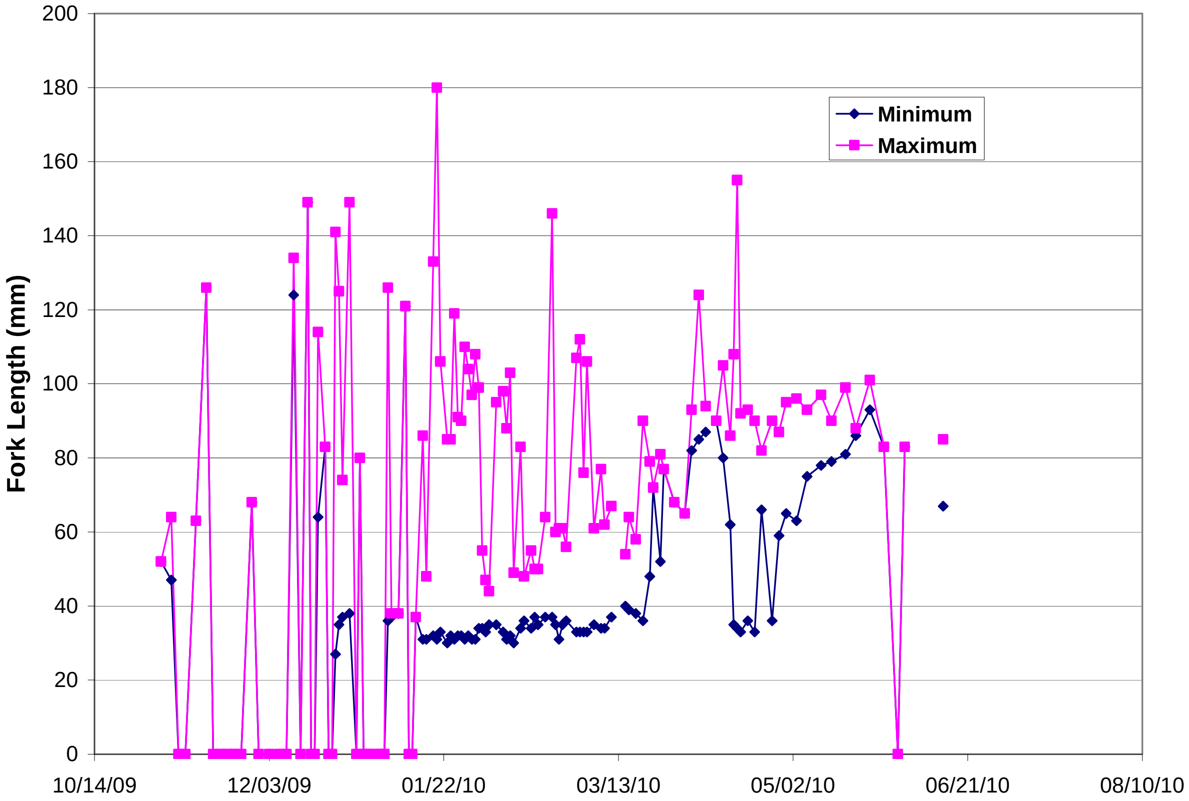


Figure C-1. Fork Length of Juvenile Chinook Salmon Trapped in Knights Landing Screw Trap.

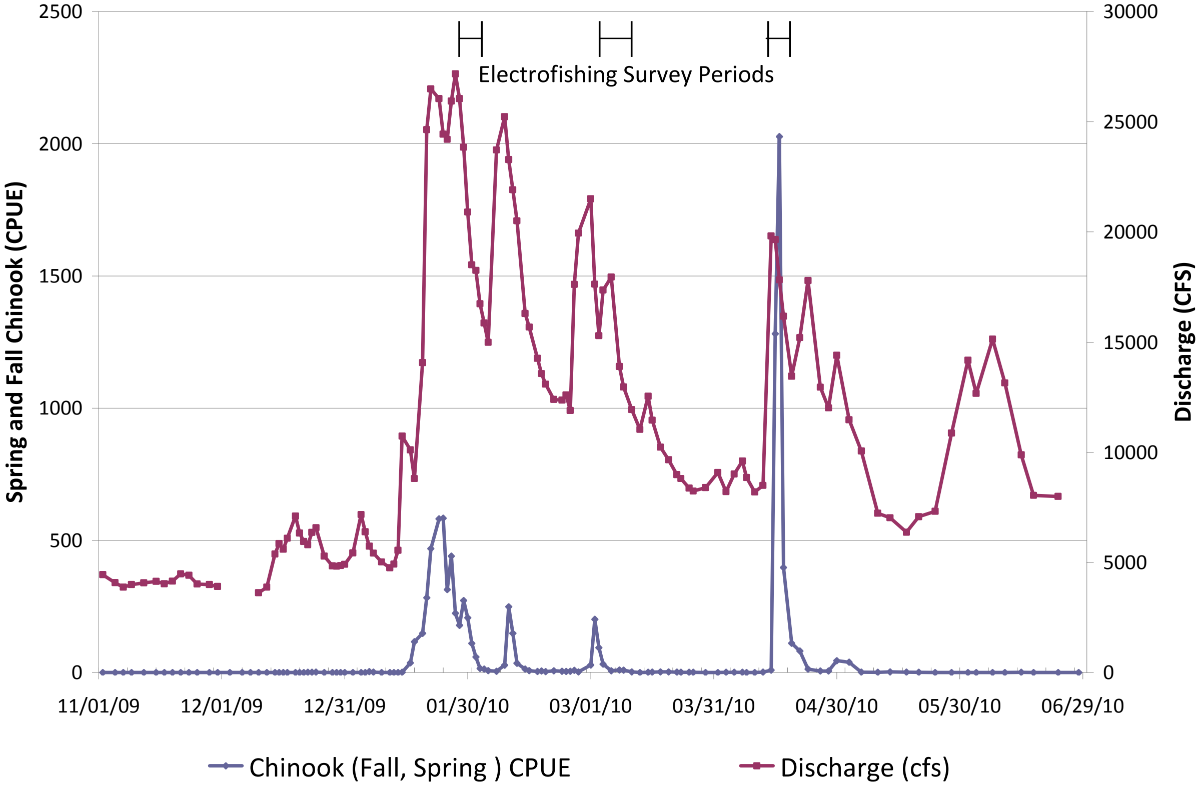


Figure C-2. Electrofishing Periods Coincided with Periods when Fish Were Relatively Abundant in the River.

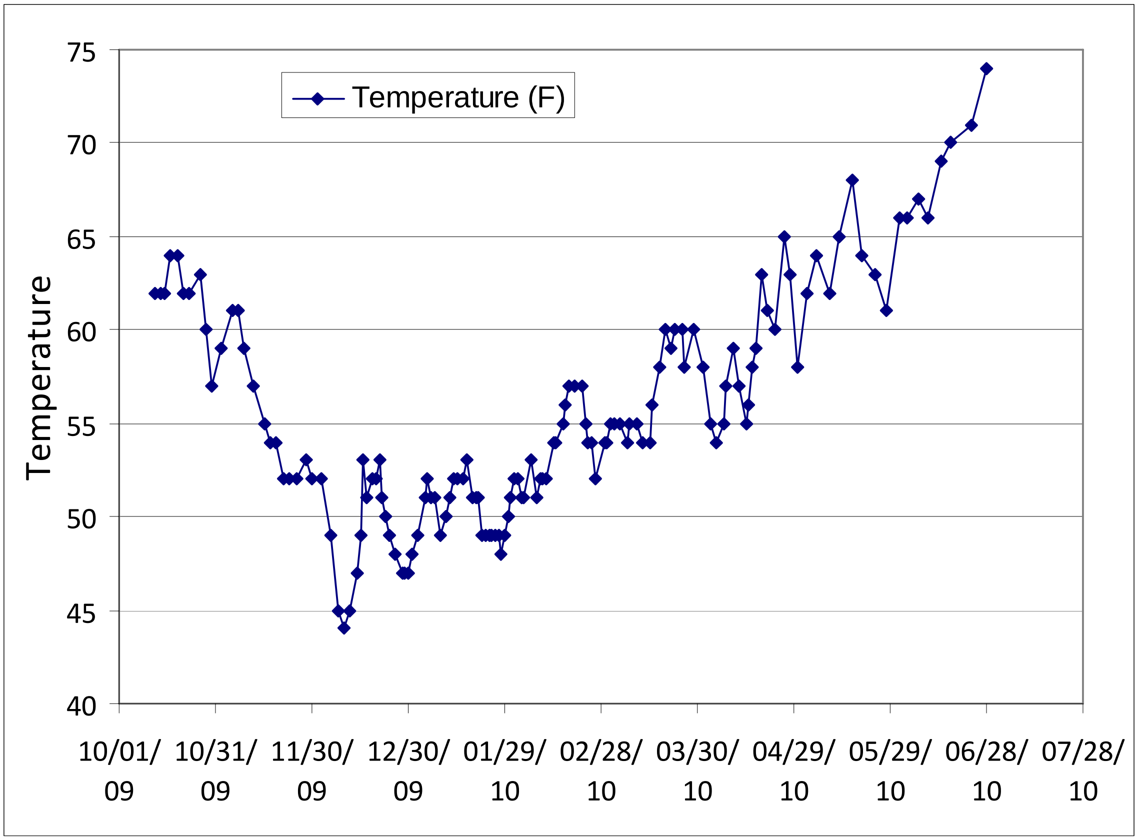


Figure C-3. Water Temperature Data Collected at the Knights Landing Screw Trap.

Table C-1. Water Quality Data Collected during Electrofishing Surveys and Out-migrant Trapping by DFG At Knights Landing.

Method	Date	Site ID	Reach	Levee Type	Conductivity (microS)	Salinity (ppt)	Temp (C)	Water Clarity (m)	Water Velocity (cm/sec)
Efishing	1/13/2009	44.7R	1b	Repair			9.3		
Efishing	1/13/2009	47.0L	1b	Repair			9.4		
Efishing	1/14/2009	47.9R	1b	Repair	220.5	0.1	9.6	1.1	0.02
Efishing	1/15/2009	43.7R	1b	Repair	179.6	0.1	10.2	1.44	0.00
Efishing	1/15/2009	50.3R	1b	Natural	154.5	0.1	10.0	1.1	0.00
Efishing	2/27/2009	47.0L	1b	Repair			13.0		
Efishing	2/27/2009	47.9R	1b	Repair			12.9		
Efishing	2/27/2009	50.2L	1b	Repair			12.8		
Efishing	2/27/2009	50.3R	1b	Natural			12.8		
Efishing	2/28/2009	69.1L	1b	Natural			13.0		
Efishing	2/28/2009	69.9R	1b	Repair			13.0		
Efishing	2/28/2009	85.6R	2	Repair			12.3		
Efishing	2/28/2009	90.8R	2	Natural			12.0		
Efishing	2/28/2009	91.9R	2	Natural			12.0		
Efishing	3/3/2009	24.0L	1b	Natural			12.8		

Method	Date	Site ID	Reach	Levee Type	Conductivity (microS)	Salinity (ppt)	Temp (C)	Water Clarity (m)	Water Velocity (cm/sec)
Efishing	3/3/2009	25.0L	1b	Natural			12.9		
Efishing	3/3/2009	26.9L	1b	Repair			13.3		
Efishing	3/3/2009	34.5R	1b	Repair			13.3		
Efishing	3/3/2009	43.7R	1b	Repair			13.1		
Efishing	3/3/2009	44.7R	1b	Repair			12.9		
Efishing	4/28/2009	43.7R	1b	Repair	99.5	0.1	16.9	0.5	0.00
Efishing	4/28/2009	44.7R	1b	Repair	99.5	0.1	16.9	0.8	0.00
Efishing	4/28/2009	47.0L	1b	Repair	105.3	0.1	16.9	0.7	0.17
Efishing	4/28/2009	47.9R	1b	Repair	98.7	0.1	16.7	1.1	
Efishing	4/28/2009	50.2L	1b	Repair	99.5	0.1	16.6	0.9	
Efishing	4/28/2009	50.3R	1b	Natural	99.8	0.1	16.3	1.2	
Efishing	4/29/2009	69.1L	1b	Natural	101.2	0.1	16.6	0.9	0.47
Efishing	4/29/2009	69.9R	1b	Repair	128.3	0.1	17.1	0.8	0.09
Efishing	4/29/2009	85.6R	2	Repair	142.5	0.1	17.6	0.9	0.09
Efishing	4/29/2009	90.8R	2	Natural	126.9	0.1	17.1	0.8	0.35
Efishing	4/29/2009	91.9R	2	Natural	128.1	0.1	16.8	0.8	0.41
Efishing	4/30/2009	24.0L	1b	Natural	115.3	0.1	16.7	0.8	0.15
Efishing	4/30/2009	25.0L	1b	Natural	116	0.1	16.6	1.2	0.06
Efishing	4/30/2009	26.9L	1b	Repair	114.2	0.1	16.4	1.1	0.15
Efishing	4/30/2009	34.5R	1b	Repair	109.3	0.1	16.0	1.1	0.02
Efishing	1/30/2010	43.7R	1b	Repair	0.1	0.0	9.8	20	0.22
Efishing	1/30/2010	44.7R	1b	Repair	0.1	0.0		20	0.45
Efishing	1/30/2010	47.0L	1b	Repair	0.1	0.0	9.6	15	1.00
Efishing	1/30/2010	47.9R	1b	Repair	0.1	0.0	9.6	15	0.30
Efishing	1/30/2010	50.2L	1b	Repair	0.1	0.0	9.6	20	0.00
Efishing	1/30/2010	50.3R	1b	Natural	0.1	0.0	9.7	0.0	0.00
Efishing	1/31/2010	24.0L	1b	Natural			10.1	15	0.06
Efishing	1/31/2010	25.0L	1b	Natural			10.3	20	0.16
Efishing	1/31/2010	26.9L	1b	Repair	0.0	0.0	10.1	15	1.60
Efishing	1/31/2010	34.5R	1b	Repair			10.2	15	0.55
Efishing	2/1/2010	69.1L	1b	Natural			10.6	25	0.38
Efishing	2/1/2010	69.9R	1b	Repair	0.1	0.0	10.7	20	0.10
Efishing	2/1/2010	85.6R	2	Repair	0.1	0.0	10.9	0.0	1.50
Efishing	2/1/2010	90.8R	2	Natural	0.1	0.0	10.8	0.0	
Efishing	2/1/2010	91.9R	2	Natural	0.1	0.0	10.8	30	1.10
Efishing	3/5/2010	69.1L	1b	Natural			11.8	30	1.05
Efishing	3/5/2010	69.9R	1b	Repair			11.8	35	0.84
Efishing	3/6/2010	85.6R	2	Repair			10.8	20	1.11
Efishing	3/6/2010	90.8R	2	Natural			10.5	20	1.08
Efishing	3/6/2010	91.9R	2	Natural			10.6	25	1.44
Efishing	3/7/2010	43.7R	1b	Repair			11.5	20	0.17

Method	Date	Site ID	Reach	Levee Type	Conductivity (microS)	Salinity (ppt)	Temp (C)	Water Clarity (m)	Water Velocity (cm/sec)
Efishing	3/7/2010	44.7R	1b	Repair			11.6	20	0.72
Efishing	3/7/2010	47.0L	1b	Repair			11.9	20	0.72
Efishing	3/9/2010	47.9R	1b	Repair			12.7	40	0.43
Efishing	3/9/2010	50.2L	1b	Repair			12.7	50	0.49
Efishing	3/9/2010	50.3R	1b	Natural			12.7	60	0.34
Efishing	3/10/2010	24.0L	1b	Natural			12.8	50	0.13
Efishing	3/10/2010	25.0L	1b	Natural			12.7	70	0.30
Efishing	3/10/2010	26.9L	1b	Repair			12.8	70	0.50
Efishing	3/10/2010	34.5R	1b	Repair			12.8	60	0.82
Efishing	4/15/2010	69.1L	1b	Natural			13.2	15	
Efishing	4/15/2010	69.9R	1b	Repair			13.1	8	
Efishing	4/15/2010	85.6R	2	Repair			13.1	9	
Efishing	4/15/2010	90.8R	2	Natural			13.2	0.0	
Efishing	4/15/2010	91.9R	2	Natural			13.4	8	
Efishing	4/16/2010	43.7R	1b	Repair			13.5	9	0.15
Efishing	4/16/2010	44.7R	1b	Repair			13.6	9	1.10
Efishing	4/16/2010	47.0L	1b	Repair			14.1	10	0.54
Efishing	4/16/2010	47.9R	1b	Repair				10	0.79
Efishing	4/16/2010	50.2L	1b	Repair			14.6	11	0.92
Efishing	4/16/2010	50.3R	1b	Natural			14.1	9.5	0.61
Efishing	4/17/2010	24.0L	1b	Natural			15.1	10	0.10
Efishing	4/17/2010	25.0L	1b	Natural			14.9	10	0.40
Efishing	4/17/2010	26.9L	1b	Repair				11	1.66
Efishing	4/17/2010	34.5R	1b	Repair				11	0.44
Trapping	10/12/09	KL					16.7	6.1	
Trapping	10/14/09	KL					16.7	3.2	
Trapping	10/15/09	KL					16.7	2.4	
Trapping	10/17/09	KL					17.8	2.7	
Trapping	10/19/09	KL					17.8	3.8	
Trapping	10/21/09	KL					16.7	2.4	
Trapping	10/23/09	KL					16.7	2.4	
Trapping	10/26/09	KL					17.2	1.9	
Trapping	10/28/09	KL					15.6	3.0	
Trapping	10/30/09	KL					13.9	3.6	
Trapping	11/02/09	KL					15.0	3.4	
Trapping	11/05/09	KL					16.1	3.3	
Trapping	11/07/09	KL					16.1	3.0	
Trapping	11/09/09	KL					15.0	3.3	
Trapping	11/12/09	KL					13.9	3.3	
Trapping	11/15/09	KL					12.8	2.9	
Trapping	11/17/09	KL					12.2	2.9	

Method	Date	Site ID	Reach	Levee Type	Conductivity (microS)	Salinity (ppt)	Temp (C)	Water Clarity (m)	Water Velocity (cm/sec)
Trapping	11/19/09	KL					12.2	3.0	
Trapping	11/21/09	KL					11.1	2.9	
Trapping	11/23/09	KL					11.1	2.6	
Trapping	11/25/09	KL					11.1	2.8	
Trapping	11/28/09	KL					11.7	2.6	
Trapping	11/30/09	KL					11.1	2.8	
Trapping	12/03/09	KL					11.1	2.6	
Trapping	12/06/09	KL					9.4	2.7	
Trapping	12/08/09	KL					7.2	3.1	
Trapping	12/10/09	KL					6.7	3.6	
Trapping	12/12/09	KL					7.2	3.7	
Trapping	12/14/09	KL					8.3	1.5	
Trapping	12/15/09	KL					9.4	1.4	
Trapping	12/16/09	KL					11.7	1.5	
Trapping	12/17/09	KL					10.6	1.3	
Trapping	12/19/09	KL					11.1	1.5	
Trapping	12/20/09	KL					11.1	1.7	
Trapping	12/21/09	KL					11.7	1.6	
Trapping	12/22/09	KL					10.6	1.5	
Trapping	12/23/09	KL					10.0	1.7	
Trapping	12/24/09	KL					9.4	1.2	
Trapping	12/26/09	KL					8.9	1.7	
Trapping	12/28/09	KL					8.3	2.5	
Trapping	12/29/09	KL					8.3	2.9	
Trapping	12/30/09	KL					8.3	2.4	
Trapping	12/31/09	KL					8.9	2.6	
Trapping	01/02/10	KL					9.4	2.5	
Trapping	01/04/10	KL					10.6	2.3	
Trapping	01/05/10	KL					11.1	1.5	
Trapping	01/06/10	KL					10.6	2.8	
Trapping	01/07/10	KL					10.6	1.9	
Trapping	01/09/10	KL					9.4	2.9	
Trapping	01/11/10	KL					10.0	3.0	
Trapping	01/12/10	KL					10.6	2.6	
Trapping	01/13/10	KL					11.1	3.2	
Trapping	01/14/10	KL					11.1	2.1	
Trapping	01/16/10	KL					11.1	0.9	
Trapping	01/17/10	KL					11.7	0.8	
Trapping	01/19/10	KL					10.6	0.9	
Trapping	01/20/10	KL					10.6	0.4	
Trapping	01/21/10	KL					10.6	0.0	

Method	**Date**	**Site ID**	**Reach**	**Levee Type**	**Conductivity (microS)**	**Salinity (ppt)**	**Temp (C)**	**Water Clarity (m)**	**Water Velocity (cm/sec)**
Trapping	01/22/10	KL					9.4	0.2	
Trapping	01/23/10	KL					9.4	0.3	
Trapping	01/24/10	KL					9.4	0.5	
Trapping	01/25/10	KL					9.4	0.5	
Trapping	01/26/10	KL					9.4	0.7	
Trapping	01/27/10	KL					9.4	0.4	
Trapping	01/28/10	KL					8.9	0.4	
Trapping	01/29/10	KL					9.4	0.5	
Trapping	01/30/10	KL					10.0	0.7	
Trapping	01/31/10	KL					10.6	0.7	
Trapping	02/01/10	KL					11.1	0.8	
Trapping	02/02/10	KL					11.1	0.9	
Trapping	02/03/10	KL					10.6	0.9	
Trapping	02/04/10	KL					10.6	1.0	
Trapping	02/06/10	KL					11.7	0.9	
Trapping	02/08/10	KL					10.6	0.4	
Trapping	02/09/10	KL					11.1	0.6	
Trapping	02/10/10	KL					11.1	0.7	
Trapping	02/11/10	KL					11.1	0.7	
Trapping	02/13/10	KL					12.2	0.9	
Trapping	02/14/10	KL					12.2	0.9	
Trapping	02/16/10	KL					12.8	0.9	
Trapping	02/17/10	KL					13.3	1.2	
Trapping	02/18/10	KL					13.9	1.2	
Trapping	02/20/10	KL					13.9	1.1	
Trapping	02/22/10	KL					13.9	1.4	
Trapping	02/23/10	KL					12.8	1.4	
Trapping	02/24/10	KL					12.2	1.3	
Trapping	02/25/10	KL					12.2	1.0	
Trapping	02/26/10	KL					11.1	0.6	
Trapping	03/01/10	KL					12.2	0.4	
Trapping	03/02/10	KL					12.2	0.5	
Trapping	03/03/10	KL					12.8	0.8	
Trapping	03/04/10	KL					12.8	0.7	
Trapping	03/06/10	KL					12.8	0.6	
Trapping	03/08/10	KL					12.2	1.4	
Trapping	03/09/10	KL					12.8	1.7	
Trapping	03/11/10	KL					12.8	1.9	
Trapping	03/13/10	KL					12.2	2.0	
Trapping	03/15/10	KL					12.2	2.0	
Trapping	03/16/10	KL					13.3	1.6	

Method	Date	Site ID	Reach	Levee Type	Conductivity (microS)	Salinity (ppt)	Temp (C)	Water Clarity (m)	Water Velocity (cm/sec)
Trapping	03/18/10	KL					14.4	2.0	
Trapping	03/20/10	KL					15.6	2.3	
Trapping	03/22/10	KL					15.0	2.5	
Trapping	03/23/10	KL					15.6	2.6	
Trapping	03/25/10	KL					15.6	2.9	
Trapping	03/26/10	KL					14.4	3.0	
Trapping	03/29/10	KL					15.6	3.9	
Trapping	04/01/10	KL					14.4	3.3	
Trapping	04/03/10	KL					12.8	2.4	
Trapping	04/05/10	KL					12.2	3.0	
Trapping	04/07/10	KL					12.8	1.4	
Trapping	04/08/10	KL					13.9	2.4	
Trapping	04/10/10	KL					15.0	3.0	
Trapping	04/12/10	KL					13.9	3.0	
Trapping	04/14/10	KL					12.8	0.1	
Trapping	04/15/10	KL					13.3	0.2	
Trapping	04/16/10	KL					14.4	0.6	
Trapping	04/17/10	KL					15.0	0.6	
Trapping	04/19/10	KL					17.2	1.0	
Trapping	04/21/10	KL					16.1	1.2	
Trapping	04/23/10	KL					15.6	1.0	
Trapping	04/26/10	KL					18.3	1.6	
Trapping	04/28/10	KL					17.2	1.5	
Trapping	04/30/10	KL					14.4	0.5	
Trapping	05/03/10	KL					16.7	1.5	
Trapping	05/06/10	KL					17.8	1.4	
Trapping	05/10/10	KL					16.7	2.7	
Trapping	05/13/10	KL					18.3	1.9	
Trapping	05/17/10	KL					20.0	2.3	
Trapping	05/20/10	KL					17.8	2.0	
Trapping	05/24/10	KL					17.2	2.6	
Trapping	05/28/10	KL					16.1	1.6	
Trapping	06/01/10	KL					18.9	1.8	
Trapping	06/03/10	KL					18.9	2.0	
Trapping	06/07/10	KL					19.4	2.7	
Trapping	06/10/10	KL					18.9	2.1	
Trapping	06/14/10	KL					20.6	2.1	
Trapping	06/17/10	KL					21.1	1.8	
Trapping	06/23/10	KL					21.7	3.3	
Trapping	06/28/10	KL					23.3	2.2	

APPENDIX D.

Habitat Features Measurements

Table D-1. Select Habitat Feature Values for Monitoring Sites.

Site	Repair or Natural	Repair Design	Water Surface Elevation (ft)		Wetted Areas (ft^2)		Study Segment Shoreline Length	Bank Slope		Floodplain Inundation Ratio
			Summer/ Fall	Winter/ Spring	Summer/ Fall	Winter/ Spring		Summer/ Fall	Winter/ Spring	
10.7L	Repair	Dietl Ditch	0	5.0	443940	446960	302	2.0:1	2.0:1	1.00
12.5L	Repair	Bench	0	5.0	221888	243848	183	2.0:1	2.0:1	1.02
12.7L	Repair	Bench	0	5.0	784080	793800	648	2.0:1	2.0:1	1.00
15.0R	Natural	Natural	1.0	5.0	119700	182250	450	3.4:1	3.4:1	1.01
16.9R	Natural	Natural	2.0	5.0	119250	121500	450	3.0:1	3.0:1	1.02
16.9L	Repair	10:1 Slope	2.0	5.0	106875	120375	167	2.5:1	2.0:1	1.02
24.0L	Natural	Natural	2.8	4.5	93000	96000	600	2.0:1	1.7:1	1.03
25.0L	Natural	Natural	2.8	5.0	112500	115200	600	4.0:1	1.8:1	1.03
26.9L	Repair	Dietl Ditch	2.9	4.8	75208	76330	449	2.0:1	2.0:1	1.04
34.5R	Repair	Dietl Ditch	2.7	3.9	129413	130645	493	2.0:1	2.0:1	1.07
43.7R	Repair	10:1 Slope	4.1	6.0	205725	212055	633	2.0:1	2.0:1	1.07
44.7R	Repair	10:1 Slope	4.3	6.2	164000	167280	656	3.0:1	2.0:1	1.10
47.0L	Repair	10:1 Slope	4.6	6.7	143060	152390	622	2.0:1	2.0:1	1.06
47.9R	Repair	10:1 Slope	4.8	6.6	256230	261158	657	10.0:1	8.0:1	1.06
50.2L	Repair	No Bench	5.3	9.8	212175	222938	615	2.5:1	2.0:1	1.28
50.3R	Natural	Natural	5.3	9.8	156375	162000162000	450	4.8:0	4.8:1	1.25
69.1L	Natural	Natural	8.1	11.9	179700	177901779000	600	3.8:0	3.8:1	1.75
69.9R	Repair	No Bench	8.1	11.9	212333	228526	701	1.5:1	2.2:1	1.07
85.6R	Repair	No Bench	14.8	22.3	74280	82018	619	2.0:1	2.0:1	1.28
90.8R	Natural	Natural	16.9	24.6	69000	78600	600	1.5:1	1.8:1	1.37
91.9R	Natural	Natural	17.3	25.1	68100	81000	600	1.8:1	2.8:1	1.48

Assumptions: Natural bank slopes taken from Hec-Ras UNET model on Sacramento River System developed by PBS&J. Wetted Areas calculated from the centerline of the river to the seasonal shoreline elevation. Values for Wetted Areas were estimated using the UNET model to determine center of the levee distance and multiplied by the site length. Floodplain Inundation Ration was calculated by dividing the total wetted surface area at 2-year flood (calulated using UNET model) by the reach average wetted surface area during winter/spring.

Table D-2. Average Percent of Bank Substrate Size across Monitoring Sites.

Site Type	Class	Diameter Size (in)	Diameter Size (cm)	2008		2009	
				Low Elevation Transect	High Elevation Transect	Low Elevation Transect	High Elevation Transect
Natural Sites (n=8)	Large Boulders	>20	>50.8	0.3	0.4	0.6	0.9
	Medium Boulders	20 - 12	50.8 – 30.5	0.6	1.8	2.6	2.9
	Small Boulders	<12	<30.5	0.6	1.0	0.9	0.8
	Large Cobbles	>10	>25.4	0.6	1.3	0.4	0.6
	Medium Cobbles	10 - 6	25.4 – 15.2	1.3	0.6	0.5	0.6
	Small Cobbles	<6	<15.2	0.6	0.4	0.6	1.0
	Gravel	2.5 - 0.08	6.3 – 0.2	0.0	0.0	0.0	0.0
	Sand	0.08 - 0.01	0.2 – 0.03	5.6	16.3	6.3	11.6
	Silt/Clay	0.01	0.03	89.6	77.9	87.8	81.4
	Erosion Control Blanket	0.01	0.03	0.8	0.5	0.4	0.3
Repair Sites (n=13)	Large Boulders	>20	>50.8	3.7	2.4	11.5	12.5
	Medium Boulders	20 - 12	50.8 – 30.5	36.2	23.0	34.8	21.5
	Small Boulders	<12	<30.5	20.6	13.2	13.5	12.2
	Large Cobbles	>10	>25.4	4.2	3.2	4.8	3.2
	Medium Cobbles	10 - 6	25.4 – 15.2	7.8	6.1	9.5	7.0
	Small Cobbles	<6	<15.2	6.9	6.2	7.3	6.5
	Gravel	2.5 - 0.08	6.3 – 0.2	0.8	0.4	0.5	0.6
	Sand	0.08 - 0.01	0.2 – 0.03	10.8	6.8	12.9	11.8
	Silt/Clay	0.01	0.03	9.5	38.3	8.5	30.6
	Erosion Control Blanket	0.01	0.03	0.2	1.6	0.2	0.2

Table D-3. Average Percent of Bank Substrate Size across Monitoring Sites in 2008 and 2009.

Site Type	Class	Size (in)	2008		2009	
			Low Elevation Transect	High Elevation Transect	Low Elevation Transect	High Elevation Transect
Natural Sites (n=8)	Large Boulders	>20	0.3	0.4	0.6	0.9
	Medium Boulders	20 - 12	0.6	1.8	2.6	2.9
	Small Boulders	<12	0.6	1.0	0.9	0.8
	Large Cobbles	>10	0.6	1.3	0.4	0.6
	Medium Cobbles	10 - 6	1.3	0.6	0.5	0.6
	Small Cobbles	<6	0.6	0.4	0.6	1.0
	Gravel	2.5 - 0.08	0.0	0.0	0.0	0.0
	Sand	0.08 - 0.01	5.6	16.3	6.3	11.6
	Silt/Clay	0.01	89.6	77.9	87.8	81.4
	Erosion Control Blanket	0.01	0.8	0.5	0.4	0.3
Repair Sites (n=13)	Large Boulders	>20	3.7	2.4	11.5	12.5
	Medium Boulders	20 - 12	36.2	23.0	34.8	21.5
	Small Boulders	<12	20.6	13.2	13.5	12.2
	Large Cobbles	>10	4.2	3.2	4.8	3.2
	Medium Cobbles	10 - 6	7.8	6.1	9.5	7.0
	Small Cobbles	<6	6.9	6.2	7.3	6.5
	Gravel	2.5 - 0.08	0.8	0.4	0.5	0.6
	Sand	0.08 - 0.01	10.8	6.8	12.9	11.8
	Silt/Clay	0.01	9.5	38.3	8.5	30.6
	Erosion Control Blanket	0.01	0.2	1.6	0.2	0.2

Table D-4. Electrofishing catch results from 2009 and 2010

Date	Site	Number of Chinook Juveniles	Number of Chinook Fry	Number of Bass Predators
2/27/2009	47.0L	0	3	0
	47.9R	0	0	3
	50.2L	0	0	1
	50.3R	0	0	0
2/28/2009	69.1L	0	24	0
	69.9R	0	5	2
	85.6R	0	0	1
	90.8R	0	4	0
	91.9R	0	4	0
3/3/2009	24.0L	1	16	0
	25.0L	1	19	4
	26.9L	0	9	2
	34.5R	0	11	0
	43.7R	0	10	0
	44.7R	0	17	3
4/28/2009	43.7R	1	0	1
	44.7R	1	0	3
	47.0L	0	0	0
	47.9R	1	0	17
	50.2L	2	0	2
	50.3R	1	0	0
4/29/2009	69.1L	1	0	1
	69.9R	2	0	2
	85.6R	16	0	2
	90.8R	0	0	0
	91.9R	2	0	2
4/30/2009	24.0L	0	0	0
	25.0L	0	0	1
	26.9L	0	0	7
	34.5R	7	0	4
1/30/2010	43.7R	0	12	0
	44.7R	0	10	0
	47.0L	0	1	0
	47.9R	0	12	2
	50.2L	0	7	0
	50.3R	0	23	1
1/31/2010	24.0L	0	38	0
	25.0L	0	26	1
	26.9L	0	8	0
	34.5R	0	30	2
2/1/2010	69.1L	0	18	2
	69.9R	0	10	7
	85.6R	0	2	5
	90.8R	0	2	0
	91.9R	0	10	0

Date	Site	Number of Chinook Juveniles	Number of Chinook Fry	Number of Bass Predators
3/5/2010	69.1L	1	12	0
	69.9R	0	5	1
3/6/2010	85.6R	0	1	3
	90.8R	0	0	0
	91.9R	0	5	0
3/7/2010	43.7R	14	32	0
	44.7R	5	15	2
	47.0L	2	7	1
3/9/2010	47.9R	2	9	0
	50.2L	2	18	0
	50.3R	2	20	0
3/10/2010	24.0L	4	5	0
	25.0L	2	5	0
	26.9L	0	5	1
	34.5R	1	12	0
4/15/2010	69.1L	26	0	0
	69.9R	6	0	1
	85.6R	5	0	3
	90.8R	0	0	0
	91.9R	0	0	2
4/16/2010	43.7R	5	0	0
	44.7R	1	0	3
	47.0L	2	0	1
	47.9R	3	0	10
	50.2L	1	0	6
	50.3R	6	0	1
4/17/2010	24.0L	2	0	1
	25.0L	2	0	1
	26.9L	3	1	9
	34.5R	5	1	5

APPENDIX E.

Electrofishing GLM and GLMM Raw Output IWM vs. SAM

Appendix E. Electrofishing GLM and GLMM raw output for IWM comparisons

Comparison of scale (April 2010 analyses)
(Includes models fit to Electrofishing-based data (point-scale), Electrofishing-based data (site-scale), and Transect-based data (site-scale)).

Only GLMM results from Step 2 (Habitat) presented.

WORKSHEET LABELS ("spp_Step")
Example: "ckj_GLMM2" means Chinook salmon juvenile results from step 2 of the by-month analyses.

Species	
ckj	Chinook salmon juveniles
bp	Bass predators

Step	
2	Habitat variables

[Note that only step 2 results were saved, as this was the focus of the IWM analyses]

VARIABLES

Category	**Variables**	**Efish**	**Telem/ Upper3**	**Telem/ All4**	**As named in "Summary of Output Appendix"**	**Description**
Spatial/ Temporal	region	X	X			As defined in text, "KL" = Knights Landing, "GB" = Garcia Bend, "KK" = Ko-Ket
	Year	X				Year of electrofishing sampling effort
Design Type	rep_design	X	X	X		Design type
IWM	iwm_dia_in			X	IWM diameter	Additional IWM measure at site-level
	jam_area_ft2_pft			X	Jam area	Additional IWM measure at site-level
	diverse.meas	X	X		IWM diversity	summary measure based on IWM data collected at electrofishing points in April 2010
	avg.LWM.density	X	X		LWM density	average measure based on IWM data collected at electrofishing points in April 2010
	Dom.size.IWM	X	X		IWM size	summary measure (Dominant size) based on IWM data collected at electrofishing points in April 2010
	EV_Apr	X	X		Submerged vegetation	summary measure based on presence of submerged vegatation (presence defined as >10%) collected at electrofishing points in April 2010
	depth	X			Depth	depth measured at the stern for each electrofishing point

Chinook salmon juvenile, GLMM

Electrofishing-based (point-scale)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.9523	0.74046	-2.637	0.00837	**
regionKK	-0.06581	0.62111	-0.106	0.91562	
regionKL	-1.46149	0.8268	-1.768	0.07712	.
IWMsize_num	0.21039	0.12101	1.739	0.0821	.
IWM.inout3b.>50% above surface	0.86063	0.74053	1.162	0.24516	
IWMsize_num:IWM.inout3b.>50% above surface	-0.2979	0.14087	-2.115	0.03446	*

Likelihood ratio tests:	LogLik	Df	Chisq	Pr(>Chisq)
Complete	-107	7		
IWMsize_num:IWM.inout	-109.25	6	4.5088	0.03372
region	-108.71	5	3.4164	0.1812

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.60131	0.77544

Number of obs: 218, groups: Site, 15

AIC=228

Electrofishing-based (site-scale)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.97711	0.24323	-4.017	5.89E-05	***
regionKK	-0.03157	0.42202	-0.075	0.94036	
regionKL	-2.05269	0.65549	-3.132	0.00174	**
Dom.size.IWM	-0.2795	0.10074	-2.775	0.00553	**

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.076535	0.27665

Number of obs: 218, groups: Site, 15

AIC=223.6

Transect-based (site-scale)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.973	0.7159	-1.359	0.1741	
regionKK	0.3915	0.5624	0.696	0.4863	
regionKL	-1.654	0.7673	-2.155	0.0311	*
iwm_sum	-3.2806	1.7665	-1.857	0.0633	.
jam_area_ft2_pft	0.4886	0.2441	2.002	0.0453	*

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.29475	0.5429

Number of obs: 218, groups: Site, 15

AIC = 227.3

Bass Predators, GLMM

Electrofishing-based (point-scale)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.79645	0.76342	-2.353	0.0186	*
regionKK	0.19409	0.73162	0.265	0.7908	
regionKL	-0.54713	0.88516	-0.618	0.5365	
IWMdens_num	0.469	1.69178	0.277	0.7816	
IWM.inout3b.>50% above surface	0.02664	0.7256	0.037	0.9707	
IWMdens_num:IWM.inout3b.>50% above surface	-4.55295	3.19147	-1.427	0.1537	

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)	
Complete model	-85.869	7			185.738
IWMdens_num:IWM.inout	-87.067	6	2.3959	0.1217	
IWMdens_num	-87.487	5	0.8392	0.3596	compared to model above
IWM.inout	-88.01	4	1.0456	0.3065	compared to model above

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.79153	0.88968

Number of obs: 218, groups: Site, 15

AIC=185.7

Electrofishing-based (site-scale)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.975	0.2554	-7.732	1.06E-14	***
diverse.meas	-3.6016	1.7754	-2.029	0.0425	*
Dom.size.IWM	0.2924	0.1164	2.512	0.012	*

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.19815	0.44514

Number of obs: 218, groups: Site, 15

AIC = 178

Transect-based (site-scale)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.8888	1.005	-3.87	0.000109	***
iwm_sum	5.0631	2.0261	2.499	0.012456	*
jam_area_ft2_pft	-0.3681	0.2835	-1.298	0.194216	

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.45186	0.6722

Number of obs: 218, groups: Site, 15

AIC = 178.5

Site-scale analyses only

Note that all of these analyses were by month analyses with only IWM variables summarized at the site-scale
(whether the method was transect-based or electrofishing-based).

WORKSHEET LABELS ("spp_Step")

Example: "ckf_2" means Chinook salmon fry results from step 2 of the by-month analyses.

Species	
ckf	Chinook salmon fry
ckj	Chinook salmon juveniles
bp	Bass predators

Step	
2	Habitat variables (2A = GLM, 2B = GLMM)

[Note that only step 2 results were saved, as this was the focus of the IWM analyses]

VARIABLES

Category	Variable	Efish	Telem/ Upper3	Telem/ All4	As named in "Summary of Output Appendix"	Description
Spatial/ Temporal	region	X	X			As defined in text, "KL" = Knights Landing, "GB" = Garcia Bend, "KK" = Ko-Ket
	Year	X				Year of electrofishing sampling effort
Design Type	rep_design	X	X	X		Design type
IWM	iwm_dia_in			X	IWM diameter	Additional IWM measure at site-level
	jam_area_ft2_pft			X	Jam area	Additional IWM measure at site-level
	diverse.meas	X	X		IWM diversity	summary measure based on IWM data collected at electrofishing points in April 2010
	avg.LWM.density	X	X		LWM density	average measure based on IWM data collected at electrofishing points in April 2010
	Dom.size.IWM	X	X		IWM size	summary measure (Dominant size) based on IWM data collected at electrofishing points in April 2010
	EV_Apr	X	X		Submerged vegetation	summary measure based on presence of submerged vegatation (presence defined as >10%) collected at electrofishing points in April 2010
	depth	X			Depth	depth measured at the stern for each electrofishing point

Chinook salmon fry, Step 2 (ckf_2)

2A (GLM)

Transect-based

March	Estimate	Std. Error	t value	Pr(>|t|)	AIC	
(Intercept)	-1.4254	0.3533	-4.035	0.0001		
regionKK	0.7449	0.38741	1.923	0.0552		
regionKL	-0.5842	0.48323	-1.209	0.2274		
Yearb.2010	0.8446	0.29792	2.835	0.0048		
jam_area_ft2_pft	0.1442	0.05232	2.757	0.0061		
regionKK:Yearb.2010	-1.5682	0.50851	-3.084	0.0022		
regionKL:Yearb.2010	-1.2896	0.68263	-1.889	0.0596	504.1	506.6

Electrofishing-based

March	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.7366	0.2169	-3.395	0.0008
regionKK	0.3749	0.3544	1.058	0.2908
regionKL	-0.7257	0.4738	-1.532	0.1263
Yearb.2010	0.6673	0.2856	2.337	0.0199
diverse.meas	1.7584	0.7666	2.294	0.0223
regionKK:Yearb.2010	-1.2896	0.4976	-2.592	0.0099
regionKL:Yearb.2010	-0.9697	0.671	-1.445	0.1492

January	Estimate	Std. Error	t value	Pr(>|t|)		
(Intercept)	-0.05366	0.19145	-0.2803	0.7796		
regionKK	1.17199	0.38415	3.0509	0.0026		
regionKL	-1.45504	0.44047	-3.3034	0.0011		
iwm_dia_in	0.15542	0.09077	1.7122	0.0884	257.4	255.8

January	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.4227	0.3411	1.239	0.2167
regionKK	1.0717	0.4078	2.628	0.0093
regionKL	-1.5721	0.6197	-2.537	0.0120
Avg.LWM.density	-2.3975	1.8752	-1.279	0.2025
Dom.size.IWM	0.127	0.1367	0.929	0.3540
Avg.LWM.density:Dom.size.IWM	-1.7484	0.9553	-1.83	0.0687

2B (GLMM)

Transect-based

March	Estimate	Std. Error	z value	Pr(>|z|)			
(Intercept)	-1.58062	0.47339	-3.339	0.0008	***		
regionKK	0.83041	0.50493	1.645	0.1000			
regionKL	-0.61001	0.59585	-1.024	0.3059			
Yearb.2010	0.93903	0.31396	2.991	0.0028	**		
jam_area_ft2_pft	0.16024	0.07157	2.239	0.0252	*		
regionKK:Yearb.2010	-1.66757	0.5231	-3.188	0.0014	**		
regionKL:Yearb.2010	-1.33413	0.70168	-1.901	0.0573		500.8	502.9

Electrofishing-based

March	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.8018	0.275	-2.916	0.0036
regionKK	0.4305	0.4542	0.948	0.3432
regionKL	-0.7778	0.5821	-1.336	0.1815
Yearb.2010	0.7157	0.2914	2.456	0.0141
diverse.meas	1.8982	1.1002	1.725	0.0845
regionKK:Yearb.2010	-1.3492	0.5019	-2.688	0.0072
regionKL:Yearb.2010	-1.0045	0.6858	-1.465	0.1430

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.20705	0.45502

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-242.38	8		
jam_area_ft2_pft	-244.84	7	4.9199	0.0266

January	Estimate	Std. Error	z value	Pr(>|z|)			
(Intercept)	-0.05365	0.19145	-0.28	0.7793			
regionKK	1.17198	0.38411	3.051	0.0023	**		
regionKL	-1.45505	0.44052	-3.303	0.0010	***		
iwm_dia_in	0.1554	0.09075	1.712	0.0868		259.4	257.8

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	6.10E-12	2.47E-06

Number of obs: 205, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-124.71	5		
iwm_dia_in	-126.14	4	2.8707	0.0902

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.20123	0.44858

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-243.45	8		
diverse.meas	-244.84	7	2.7739	0.0958

January	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	0.4227	0.3411	1.239	0.2153
regionKK	1.0717	0.4077	2.628	0.0086
regionKL	-1.5721	0.6199	-2.536	0.0112
Avg.LWM.density	-2.3975	1.8751	-1.279	0.2010
Dom.size.IWM	0.127	0.1367	0.929	0.3529
Avg.LWM.density:Dom.size.IWM	-1.7483	0.9553	-1.83	0.0672

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	7.92E-11	8.90E-06

Number of obs: 205, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-121.9	7		
Avg.LWM.density:Dom.size.IWM	-123.61	6	3.415	0.0646

Chinook salmon juvenile, Step 2 (cjk_2)

2A (GLM)

Transect-based

April	Estimate	Std. Error	t value	Pr(>|t|)	AIC	
(Intercept)	-2.1333	0.35973	-5.9304	0.0000		
regionKK	0.626	0.62413	1.003	0.3165		
regionKL	0.5372	0.56505	0.9508	0.3423		
Yearb.2010	0.9459	0.4479	2.112	0.0353		
iwm_dia_in	0.163	0.09137	1.7844	0.0751		
regionKK:Yearb.2010	-0.7787	0.73204	-1.0637	0.2881		
regionKL:Yearb.2010	-1.9068	0.80033	-2.3825	0.0177	358.8	355.35

March	Estimate	Std. Error	t value	Pr(>|t|)		
(Intercept)	-5.908	1.21671	-4.856	0.0000		
Yearb.2010	3.8814	1.48854	2.607	0.0095		
jam_area_ft2_pft	-0.0322	0.17791	-0.181	0.8565		
iwm_dia_in	-0.9019	0.31506	-2.863	0.0044		
jam_area_ft2_pft:iwm_dia_in	0.2642	0.09593	2.755	0.0061	183.9	178.75

Electrofishing-based

April	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.17386	0.35286	-6.16063	0.0000
regionKK	0.22816	0.59478	0.3836	0.7015
regionKL	-0.04691	0.60414	-0.07765	0.9381
Yearb.2010	1.20011	0.41306	2.90544	0.0039
Dom.size.IWM	-0.20043	0.07657	-2.61778	0.0092
regionKK:Yearb.2010	-0.29132	0.70555	-0.41289	0.6799
regionKL:Yearb.2010	-1.79279	0.80058	-2.23936	0.0257

March	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-6.6694	0.998	-6.683	0.0000
Yearb.2010	2.7275	0.7449	3.661	0.0003
diverse.meas	3.1736	1.395	2.275	0.0234
Dom.size.IWM	0.3888	0.1185	3.282	0.0011

2B (GLMM)

Transect-based

April	Estimate	Std. Error	z value	Pr(>|z|)			
(Intercept)	-2.2444	0.4317	-5.199	0.0000	***		
regionKK	0.3794	0.7762	0.489	0.6250			
regionKL	0.3215	0.737	0.436	0.6626			
Yearb.2010	0.9727	0.4744	2.051	0.0403	*		
iwm_dia_in	0.1387	0.1241	1.118	0.2637			
regionKK:Yearb.2010	-0.5711	0.7918	-0.721	0.4707			
regionKL:Yearb.2010	-1.7863	0.8245	-2.167	0.0303		354.2	352.2

Electrofishing-based

April	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.2517	0.416	-5.413	0.0000
regionKK	0.1222	0.7077	0.173	0.8629
regionKL	-0.2371	0.7793	-0.304	0.7609
Yearb.2010	1.2034	0.422	2.852	0.0044
Dom.size.IWM	-0.2196	0.1167	-1.881	0.0600
regionKK:Yearb.2010	-0.2039	0.7206	-0.283	0.7772
regionKL:Yearb.2010	-1.7675	0.8218	-2.151	0.0315

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.38934	0.62397

Number of obs: 400, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-169.11	8		
iwm_dia_in	-169.7	7	1.176	0.2782

March	Estimate	Std. Error	z value	Pr(>|z|)			
(Intercept)	-5.99479	1.47453	-4.066	0.0000	***		
Yearb.2010	3.88027	1.72475	2.25	0.0245	*		
jam_area_ft2_pft	-0.08193	0.28213	-0.29	0.7715			
iwm_dia_in	-0.80088	0.40617	-1.972	0.0486	*		
jam_area_ft2_pft:iwm_dia_in	0.2359	0.13208	1.786	0.0741		179.2	175.2

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.9696	0.98468

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-83.615	6		
jam_area_ft2_pft:iwm_dia_in	-86.877	5	6.5238	0.01064

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept	0.32243	0.56783

Number of obs: 400, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-168.09	8		
Dom.size.IWM	-169.7	7	3.2102	0.0732

March	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-5.3565	0.8168	-6.558	0.0000
Yearb.2010	2.8008	0.777	3.605	0.0003
diverse.meas	3.769	2.2155	1.701	0.0889
Dom.size.IWM	0.4644	0.18	2.58	0.0099

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept	0.61919	0.78689

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-82.598	5		
Dom.size.IWM	-86.143	4	7.0909	0.0077
diverse.meas	-84.056	4	2.9161	0.0877

Bass predators, Step 2 (bp_2)

2A (GLM)

Transect-based

April	Estimate	Std. Error	t value	Pr(>|t|)	AIC	
(Intercept)	-2.4767	0.54605	-4.536	0.0000		
iwm_sum	1.9764	0.91083	2.17	0.0306		
jam_area_ft2_pft	-0.1502	0.09268	-1.62	0.1060		
iwm_dia_in	0.1359	0.07047	1.929	0.0545	355.5	332.6

March	Estimate	Std. Error	t value	Pr(>|t|)		
(Intercept)	-2.8731	0.3614	-7.9499	0.0000		
Yearb.2010	-0.1634	0.5403	-0.3024	0.7625		
iwm_dia_in	-0.2671	0.1145	-2.3317	0.0202	179.3	173.8

January	Estimate	Std. Error	t value	Pr(>|t|)		
(Intercept)	-1.095	0.7668	-1.429	0.1547		
iwm_sum	-2.622	1.3452	-1.949	0.0527	102.3	101.7

Electrofishing-based

April	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.8485	0.16241	-11.381	0.0000
diverse.meas	-4.3058	1.17963	-3.65	0.0003
Dom.size.IWM	0.2846	0.07105	4.006	0.0001

March	Estimate	SE	t value	Pr(>|t|)
(Intercept)	-2.6814	0.3205	-8.367	0.0000
Yearb.2010	-0.9495	0.4516	-2.102	0.0362
diverse.meas	-6.0448	2.0422	-2.96	0.0033
Dom.size.IWM	0.1898	0.1056	1.798	0.0730

January	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.2721	0.6995	-1.819	0.0705
Avg.LWM.density	-13.0518	8.1975	-1.592	0.1129
Dom.size.IWM	0.5613	0.2898	1.937	0.0542
Avg.LWM.density:Dom.size.IWM	-6.171	3.4606	-1.783	0.0761

2B (GLMM)

Transect-based

January	Estimate	SE	z value	Pr(>|z|)		
(Intercept)	-1.254	1.137	-1.103	0.2700		
iwm_sum	-2.917	1.918	-1.521	0.1280	102.1	102.7

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.73121	0.85511

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-48.054	3		
iwm_sum	-49.244	2	2.3808	0.1228

March	Estimate	Std. Error	z value	Pr(>|z|)		
(Intercept)	-3.3813	0.5147	-6.57	0.0000 ***		
Yearb.2010	-0.1828	0.5934	-0.308	0.7581		
iwm_dia_in	-0.3439	0.1722	-1.997	0.0459	175.7	174.7

Electrofishing-based

January	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.505	0.8451	-1.781	0.0749
Avg.LWM.density	-12.5052	9.2376	-1.354	0.1758
Dom.size.IWM	0.5961	0.3588	1.662	0.0966
Avg.LWM.density:Dom.size.IWM	-6.2899	3.9695	-1.584	0.1131

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.47681	0.69051

Number of obs: 205, groups: Site, 15

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-46.329	5		
Avg.LWM.density:Dom.size.IWM	-48.374	4	4.0893	0.0432

March	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.8581	0.3863	-7.399	0.0000
Yearb.2010	-0.9548	0.4642	-2.057	0.0397
diverse.meas	-6.4181	2.6235	-2.446	0.0144
Dom.size.IWM	0.209	0.1432	1.459	0.1445

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	1.3082	1.1438

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-83.852	4		
iwm_dia_in	-85.922	3	4.139	0.0419

April	Estimate	Std. Error	z value	Pr(>|z|)			
(Intercept)	-2.681594	1.034733	-2.592	0.0096	**		
iwm_sum	1.093891	1.506332	0.726	0.4677			
jam_area_ft2_pft	-0.028325	0.124471	-0.228	0.8200			
iwm_dia_in	-0.006723	0.089739	-0.075	0.9403		331.1	323.4

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	1.0686	1.0337

Number of obs: 400, groups: Site, 15

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-160.54	5		
iwm_dia_in	-160.54	4	0.0052	0.9428
jam_area_pft	-160.56	4	0.05	0.8230
iwm_sum	-160.79	4	0.4958	0.4814

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.36541	0.60449

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-82.335	5		
Dom.size.IWM	-83.405	4	2.1384	0.1437
diverse.meas	-85.61	4	6.5491	0.0105

April	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.9901	0.2586	-7.695	0.0000
diverse.meas	-4.0641	1.8036	-2.253	0.0242
Dom.size.IWM	0.2434	0.1225	1.986	0.0470

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.56513	0.75175

Number of obs: 400, groups: Site, 15

Likelihood ratio tests:	LogLike	df	Chisq	Pr(>Chisq)
Complete	-157.69	4		
Dom.size.IWM	-159.4	3	3.4295	0.0640
diverse.meas	-159.92	3	4.4656	0.0346

AIC summary

Species	Month	Measurement method	AIC of best model	IWM variables in final model:
Chinook salmon fry	Jan (2009)	Transect-based	259.4	iwm_dia_in (+)**
Chinook salmon fry	Jan (2009)	Electrofishing-based	257.8	Avg.LWM.density (-) Dom.size.IWM (+) Avg.LWM.density:Dom.size.IWM (-)**
Bass predators	Jan (2009)	Transect-based	102.1	iwm_sum (-)*
Bass predators	Jan (2009)	Electrofishing-based	102.7	Avg.LWM.density (-) Dom.size.IWM (+) Avg.LWM.density:Dom.size.IWM (-)
Chinook salmon fry	Mar	Transect-based	500.8	jam_area_pft (+)
		Electrofishing-based	502.9	diverse.meas (+)**
Chinook salmon juveniles	Mar	Transect-based	179.2	jam_area_pft (-) iwm_dia_in (-) jam_area_pft:iwm_dia_in (+)
		Electrofishing-based	175.2	diverse.meas (+)** Dom.size.IWM (+)
Bass predators	Mar	Transect-based	175.7	iwm_dia_in (-)
Bass predators	Mar	Electrofishing-based	174.7	diverse.meas (-) Dom.size.IWM (+)**
Chinook salmon juveniles	April	Transect-based	354.2	iwm_dia_in (+)*
Chinook salmon juveniles	April	Electrofishing-based	352.2	Dom.size.IWM (-)**
Bass predators	April	Transect-based	331.1	iwm_sum (+)* jam_area_pft (-)* iwm_dia_in (+)*
Bass predators	April	Electrofishing-based	323.4	diverse.meas (-) Dom.size.IWM (+)**

Note: Data for Transect-based IWM variables was available for correspondence to 2009 and 2010 fish data, based on summer 2008 and summer 2009 habitat surveys.
*P>0.10 after including random effect.
**0.05<P<0.10 after including random effect.

APPENDIX F.

Electrofishing GLM and GLMM Raw Output

Appendix F. Electrofishing GLM and GLMM raw output

WORKSHEET LABELS ("spp_Analysis_Step")

Example: "bp_com_1" means bass predators, combined analyses, step 1

Species	
ckf	Chinook salmon fry
ckj	Chinook salmon juveniles
bp	Bass predators

Step	
1	Design Type (1A = GLM, 1B = GLMM)
2	Habitat variables (2A = GLM, 2B = GLMM)
3	Design type and habitat variables (3A = GLM, 3B = GLMM)

Analysis	
com	combined analysis
(month)	by month, mar = March, apr = April

VARIABLES

Category	Variable	Efish	Telem/ Upper3	Telem/ All4	As named in "Summary of Output Appendix"	Description
Spatial/Temporal	release		X	X		Release location for Chinook (both analyses) and for steelhead (All4 analysis only)
	release2		X			Release location for steelhead (Upper3), combining a few categories: "SacElkLanding" = Elk River ramp, within the study area; "a.Other" = release locations above the study area
	mn.flow		X	X		Average daily flow from USGS gaging station on the first day of detection at a site
	region	X	X			As defined in text, "KL" = Knights Landing, "GB" = Garcia Bend, "KK" = Ko-Ket
	region2			X		"Upper" = Upper 3 regions; "RV" = Rio Vista (lowest region)
	fod_num		X	X		First date of detection at a site, numeric
	dr_num		X	X		Release date, numeric
	daynight		X	X		Day or night at first time of detection at a site, based on sunrise/sunset times
	Year	X				Year of electrofishing sampling effort
	Effort	X				Month of capture
Design Type	rep_design	X	X	X		Design type
Habitat	shade_sum	X	X	X	Shade	% shade at low elevation (summer) transect
	bslope_sum	X	X	X	Bank slope	Bank slope at low elevation (summer) transect
	BC_sum	X	X	X	%Boulder/Cobble	% Boulder/cobble at low elevation (summer) transect
	aq_sum	X	X	X	Aquatic vegetation	% Aquatic vegetation at low elevation (summer) transect
	iwm_dia_in			X	IWM diameter	Additional IWM measure at site-level
	jam_area_pft			X	Jam area	Additional IWM measure at site-level
	diversemeas	X	X		IWM diversity	summary measure based on IWM data collected at electrofishing points in April 2010
	avgLWMdensity	X	X		LWM density	average measure based on IWM data collected at electrofishing points in April 2010
	domsizeIWM	X	X		IWM size	summary measure (Dominant size) based on IWM data collected at electrofishing points in April 2010
	EV_Apr	X	X		Submerged vegetation	summary measure based on presence of submerged vegatation (presence defined as >10%) collected at electrofishing points in April 2010
	depth	X			Depth	depth measured at the stern for each electrofishing point

Bass predators, January analysis, Step 1 (bp_jan_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.2771	0.7202	-4.5505	<0.0001
rep_designDietl Ditch	0.8792	1.0314	0.8524	0.3950
rep_designNatural	0.3196	0.8840	0.3616	0.7181
rep_designno bench	1.4053	0.8431	1.6669	0.0971

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
rep_design	98.16	4	4.0157	0.2598

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.9575	0.5127	-5.7683	<0.0001
rep_designa.Ten.one.slope	-0.3196	0.8840	-0.3616	0.7181
rep_designDietl Ditch	0.5596	0.8990	0.6225	0.5343
rep_designno bench	1.0857	0.6746	1.6094	0.1091

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.3979	0.7384	-3.2474	0.0014
rep_designa.Natural	-0.5596	0.8990	-0.6225	0.5343
rep_designa.Ten.one.slope	-0.8792	1.0314	-0.8524	0.3950
rep_designno bench	0.5261	0.8588	0.6126	0.5408

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.5936	0.8948	-4.0160	0.0001	***
rep_designDietl Ditch	0.9105	1.3326	0.6830	0.4940	
rep_designNatural	0.3795	1.1036	0.3440	0.7310	
rep_designno bench	1.4490	1.1188	1.2950	0.1950	

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-48.25	5		
rep_design	-49.24	2	1.9848	0.5756

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.6419	0.8012

Number of obs: 205, groups: Site, 15

Bass predators, March analysis, Step 1 (bp_mar_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.9222	0.3858	-4.9823	<0.0001
rep_designDietl Ditch	-0.5066	0.6932	-0.7308	0.4653
rep_designNatural	-1.4387	0.6174	-2.3302	0.0203
rep_designno bench	0.1418	0.5150	0.2753	0.7832
Yearb.2010	-0.9297	0.4495	-2.0685	0.0392

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	169.76	5		
Year	174.32	4	4.5578	0.0328
rep_design	178.63	2	8.8678	0.0311

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.3609	0.5255	-6.3960	<0.0001
rep_designa.Ten.one.slope	1.4387	0.6173	2.3300	0.0203
rep_designDietl Ditch	0.9321	0.7834	1.1900	0.2348
rep_designno bench	1.5804	0.6316	2.5020	0.0127
Yearb.2010	-0.9297	0.4495	-2.0690	0.0392

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.4288	0.6160	-3.9431	0.0001
rep_designa.Natural	-0.9321	0.7834	-1.1898	0.2348
rep_designa.Ten.one.slope	0.5066	0.6932	0.7308	0.4653
rep_designno bench	0.6484	0.7058	0.9186	0.3588
Yearb.2010	-0.9297	0.4495	-2.0685	0.0392

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.2229	0.6356	-3.4970	0.0005	***
Yearb.2010	-0.9550	0.4672	-2.0440	0.0410	*
rep_designDietl Ditch	-0.4786	1.1183	-0.4280	0.6687	
rep_designNatural	-1.6806	0.9526	-1.7640	0.0777	.
rep_designno bench	0.2764	0.9088	0.3040	0.7610	

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-83.43	6		
rep_design	-85.92	3	4.9773	0.1735
Year	-85.75	5	4.6275	0.0315

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.8696	0.9325

Number of obs: 410, groups: Site, 15

Bass predators, April analysis, Step 1 (bp_apr_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.7590	0.3437	-8.0270	<0.0001
rep_designa.Ten.one.slope	1.5590	0.4125	3.7790	0.0002
rep_designDietl Ditch	2.0650	0.4542	4.5480	<0.0001
rep_designno bench	1.0670	0.4502	2.3700	0.0183

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	327.81	4		
rep_design	355.03	1	27.2261	<0.0001

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.6931	0.2970	-2.3340	0.0201
rep_designa.Natural	-2.0655	0.4542	-4.5470	<0.0001
rep_designa.Ten.one.slope	-0.5068	0.3745	-1.3530	0.1767
rep_designno bench	-0.9985	0.4157	-2.4020	0.0168

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.2000	0.2281	-5.2600	<0.0001
rep_designDietl Ditch	0.5068	0.3745	1.3530	0.1767
rep_designNatural	-1.5586	0.4125	-3.7790	0.0002
rep_designno bench	-0.4917	0.3696	-1.3300	0.1841

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.5562	0.4637	-3.3560	0.0008	***
rep_designDietl Ditch	0.8534	0.7612	1.1210	0.2623	
rep_designNatural	-1.4139	0.6653	-2.1250	0.0336	*
rep_designno bench	-0.2269	0.6984	-0.3250	0.7452	

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-156.84	5		
rep_design	-160.84	2	8.0014	0.0460

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.5507	0.7421

Number of obs: 400, groups: Site, 15

Bass predators, combined analysis, Step 1 (bp_com_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.5812	0.2631	-9.8090	<0.0001
Effortjan	-0.9794	0.3118	-3.1410	0.0017
Effortmar	-1.1279	0.2535	-4.4490	<0.0001
rep_designa.Ten.one.slope	1.2645	0.3088	4.0940	<0.0001
rep_designDietl Ditch	1.5599	0.3455	4.5150	<0.0001
rep_designno bench	1.1980	0.3233	3.7060	0.0002

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	610.67	6		
rep_design	640.00	3	29.3273	<0.0001
Effort	636.13	4	25.4585	<0.0001

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.3167	0.2023	-6.5075	<0.0001
Effortjan	-0.9794	0.3118	-3.1409	0.0017
Effortmar	-1.1279	0.2535	-4.4493	<0.0001
rep_designDietl Ditch	0.2954	0.3008	0.9820	0.3264
rep_designNatural	-1.2645	0.3089	-4.0940	<0.0001
rep_designno bench	-0.0665	0.2750	-0.2417	0.8091

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.3832	0.2227	-6.2114	<0.0001
Effortjan	-0.9794	0.3118	-3.1409	0.0017
Effortmar	-1.1279	0.2535	-4.4493	<0.0001
rep_designa.Ten.one.slope	0.0665	0.2750	0.2417	0.8091
rep_designDietl Ditch	0.3619	0.3157	1.1462	0.2520
rep_designNatural	-1.1980	0.3233	-3.7057	0.0002

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.8337	0.4038	-7.0180	<0.0001	***
Effortjan	-1.0106	0.4848	-2.0850	0.0371	*
Effortmar	-1.1629	0.4376	-2.6580	0.0079	**
rep_designa.Ten.one.slope	1.0792	0.4993	2.1620	0.0307	*
rep_designDietl Ditch	1.5347	0.5848	2.6240	0.0087	**
rep_designno bench	1.3983	0.5141	2.7200	0.0065	**

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-293.27	7		
rep_design	-298.27	4	9.9983	0.0186
Effort	-297.24	5	7.9348	0.0189

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.7492	0.8656

Number of obs: 1015, groups: Effort:Site, 45

Bass predators, January analysis, Step 2 (bp_jan_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.5795	0.6729	-0.8613	0.3901
shade_sum	-2.9630	1.2529	-2.3649	0.0190
dom.size.IWM	0.4660	0.2848	1.6359	0.1034
avg.LWM.density	-10.1176	7.4768	-1.3532	0.1775
dom.size.IWM:avg.LWM.density	-8.0368	3.3908	-2.3702	0.0187

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	86.26	5		
dom.size.IWM:avg.LWM.density	95.15	4	8.8912	0.0029
shade_sum	93.70	4	7.4439	0.0064

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.5796	0.6731	-0.8610	0.3892	
shade_sum	-2.9630	1.2531	-2.3650	0.0181	*
dom.size.IWM	0.4659	0.2849	1.6360	0.1019	
avg.LWM.density	-10.1171	7.4781	-1.3530	0.1761	
dom.size.IWM:avg.LWM.density	-8.0367	3.3906	-2.3700	0.0178	*

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-43.13	6		
dom.size.IWM:avg.LWM.density	-47.21	5	8.1533	0.0043
shade_sum	-46.33	5	6.4009	0.0114

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	2.02E-14	1.42E-07

Number of obs: 205, groups: Site, 15

Bass predators, March analysis, Step 2 (bp_mar_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.0208	0.4592	-4.4003	<0.0001
regionKK	2.6977	1.1068	2.4374	0.0152
regionKL	-0.0081	0.7486	-0.0108	0.9914
Yearb.2010	-0.0027	0.5661	-0.0047	0.9962
shade_sum	-4.5586	1.7160	-2.6566	0.0082
depth	-0.5919	0.4552	-1.3002	0.1943
diverse.meas	-6.1548	3.0080	-2.0461	0.0414
bslope_sum	0.2674	0.1208	2.2136	0.0274
aq_sum	-3.1669	1.2466	-2.5404	0.0115
depth:diverse.meas	-5.8524	3.0627	-1.9108	0.0567

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	148.62	10		
depth:diverse.meas	152.36	9	3.7445	0.0530
aq_sum	156.03	9	7.4142	0.0065
bslope_sum	153.47	9	4.8519	0.0276
shade_sum	160.23	9	11.6081	0.0007
Year	148.62	9	0.0000	0.9962
region	155.62	8	7.0057	0.0301

2B (GLM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.0208	0.4593	-4.4000	<0.0001	***
regionKK	2.6976	1.1071	2.4370	0.0148	*
regionKL	-0.0080	0.7487	-0.0110	0.9914	
Yearb.2010	-0.0027	0.5662	-0.0050	0.9962	
shade_sum	-4.5586	1.7162	-2.6560	0.0079	**
depth	-0.5919	0.4553	-1.3000	0.1936	
diverse.meas	-6.1547	3.0083	-2.0460	0.0408	*
bslope_sum	0.2674	0.1209	2.2120	0.0270	*
aq_sum	-3.1669	1.2466	-2.5400	0.0111	*
depth:diverse.meas	-5.8525	3.0621	-1.9110	0.0560	.

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-74.31	11		
depth:diverse.meas	-76.18	10	3.7445	0.0530
aq_sum	-78.01	10	7.3994	0.0065
bslope_sum	-76.67	10	4.7128	0.0299
shade_sum	-79.76	10	10.8930	0.0010
Year	-80.23	9	11.8350	0.0027
region	-80.58	8	12.5520	0.0057

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 410, groups: Site, 15

Bass predators, April analysis, Step 2 (bp_apr_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.8841	0.6858	-5.6638	<0.0001
depth	0.0905	0.1966	0.4604	0.6455
diverse.meas	1.7450	1.9511	0.8944	0.3717
bslope_sum	0.2982	0.0959	3.1102	0.0020
BC_sum	1.6997	0.6754	2.5165	0.0123
dom.size.IWM	-0.4643	0.2025	-2.2928	0.0224
aq_sum	1.9298	0.5744	3.3595	0.0009
avg.LWM.density	0.0273	2.4790	0.0110	0.9912
dom.size.IWM:avg.LWM.density	3.6378	1.7553	2.0725	0.0389
depth:diverse.meas	4.2013	1.4302	2.9376	0.0035

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	291.77	10		
depth:diverse.meas	301.78	9	10.0039	0.0016
dom.size.IWM:avg.LWM.density	296.54	9	4.7648	0.0290
aq_sum	303.69	9	11.9181	0.0006
BC_sum	298.89	9	7.1155	0.0076
bslope_sum	301.75	9	9.9830	0.0016

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.8841	0.6860	-5.6620	<0.0001	***
depth	0.0905	0.1966	0.4600	0.6453	
diverse.meas	1.7450	1.9511	0.8940	0.3711	
bslope_sum	0.2982	0.0959	3.1110	0.0019	**
BC_sum	1.6997	0.6756	2.5160	0.0119	*
dom.size.IWM	-0.4643	0.2025	-2.2930	0.0219	*
aq_sum	1.9298	0.5746	3.3590	0.0008	***
avg.LWM.density	0.0273	2.4787	0.0110	0.9912	
dom.size.IWM:avg.LWM.density	3.6378	1.7551	2.0730	0.0382	*
depth:diverse.meas	4.2009	1.4299	2.9380	0.0033	**

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-145.89	11		
depth:diverse.meas	-150.89	10	10.0040	0.0016
dom.size.IWM:avg.LWM.density	-148.27	10	4.7648	0.0291
aq_sum	-151.43	10	11.0870	0.0009
BC_sum	-149.44	10	7.1155	0.0076
bslope_sum	-150.87	10	9.9600	0.0016

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 400, groups: Site, 15

Bass predators, combined analysis, Step 2 (bp_com_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.4072	0.1753	-8.0278	<0.0001
Effortjan	-1.0237	0.3188	-3.2114	0.0014
Effortmar	-1.1429	0.2597	-4.4015	<0.0001
shade_sum	-1.2108	0.3734	-3.2421	0.0012
depth	-0.0025	0.1297	-0.0192	0.9847
diverse.meas	-2.5777	1.0018	-2.5731	0.0102
bslope_sum	0.1490	0.0377	3.9506	0.0001
depth:diverse.meas	2.1415	0.9151	2.3401	0.0195

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	582.73	8		
depth:diverse.meas	588.49	7	5.7601	0.0164
bslope_sum	597.17	7	14.4410	0.0001
shade_sum	594.55	7	11.8240	0.0006
Effort	607.90	6	25.1719	<0.0001

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.4633	0.2921	-5.0100	<0.0001	***
Effortjan	-1.0480	0.4485	-2.3370	0.0195	*
Effortmar	-1.2047	0.4002	-3.0110	0.0026	**
shade_sum	-1.4886	0.4886	-3.0470	0.0023	**
depth	-0.0690	0.1535	-0.4490	0.6531	
diverse.meas	-2.3275	1.3696	-1.6990	0.0892	.
bslope_sum	0.1349	0.0690	1.9550	0.0506	.
depth:diverse.meas	2.1389	1.0778	1.9840	0.0472	*

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-286.01	9		
depth:diverse.meas	-288.12	8	4.2037	0.0403
bslope_sum	-287.77	8	3.5083	0.0611
shade_sum	-291.13	8	10.2260	0.0014
Effort	-291.00	7	9.9689	0.0068

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.5065	0.7117

Number of obs: 1015, groups: Effort:Site, 45

Bass predators, January analysis, Step 3 (bp_jan_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.6329	1.1221	-2.3463	0.0200
rep_designDietl Ditch	2.3963	1.4809	1.6182	0.1072
rep_designNatural	0.8509	1.1892	0.7155	0.4751
rep_designno bench	2.6967	1.2381	2.1781	0.0306
dom.size.IWM	0.9765	0.4256	2.2944	0.0228
avg.LWM.density	-13.3307	9.8237	-1.3570	0.1763
dom.size.IWM:avg.LWM.density	-8.6337	4.4395	-1.9448	0.0532

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	85.11	7		
dom.size.IWM:avg.LWM.density	93.65	6	8.5381	0.0035
rep_design	93.70	4	8.5899	0.0353

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.7820	0.9814	-1.8158	0.0709
rep_designa.no bench	1.8459	0.8183	2.2559	0.0252
rep_designa.Ten.one.slope	-0.8509	1.1891	-0.7155	0.4751
rep_designDietl Ditch	1.5455	1.1702	1.3207	0.1881
dom.size.IWM	0.9765	0.4256	2.2945	0.0228
avg.LWM.density	-13.3307	9.8237	-1.3570	0.1763
dom.size.IWM:avg.LWM.density	-8.6337	4.4394	-1.9448	0.0532

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.2365	1.5536	-0.1523	0.8791
rep_designa.Natural	-1.5455	1.1703	-1.3205	0.1882
rep_designa.no bench	0.3004	1.1613	0.2586	0.7962
rep_designa.Ten.one.slope	-2.3963	1.4812	-1.6179	0.1073
dom.size.IWM	0.9765	0.4256	2.2945	0.0228
avg.LWM.density	-13.3307	9.8237	-1.3570	0.1763
dom.size.IWM:avg.LWM.density	-8.6337	4.4394	-1.9448	0.0532

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.7822	0.9818	-1.8150	0.0695	.
rep_designa.Ten.one.slope	-0.8508	1.1891	-0.7160	0.4743	
rep_designDietl Ditch	1.5453	1.1705	1.3200	0.1868	
rep_designno bench	1.8459	0.8184	2.2550	0.0241	*
dom.size.IWM	0.9764	0.4255	2.2950	0.0217	*
avg.LWM.density	-13.3286	9.8241	-1.3570	0.1749	
dom.size.IWM:avg.LWM.density	-8.6328	4.4387	-1.9450	0.0518	.

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-42.56	8		
dom.size.IWM:avg.LWM.density	-46.82	7	8.5192	0.0035
rep_design	-46.33	5	7.5469	0.0564

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	4.35E-12	2.08E-06

Number of obs: 205, groups: Site, 15

Bass predators, March analysis, Step 3 (bp_mar_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.1434	1.4657	-0.7801	0.4358
rep_designa.Ten.one.slope	-0.8726	1.5142	-0.5762	0.5648
rep_designDietl Ditch	-1.2952	1.3972	-0.9270	0.3545
rep_designno bench	-1.2580	1.5392	-0.8173	0.4142
Yearb.2010	-0.6388	0.4827	-1.3233	0.1865
shade_sum	-4.1038	2.7023	-1.5186	0.1296
diverse.meas	-6.0639	2.4711	-2.4539	0.0146

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	158.44	7		
diverse.meas	166.35	6	7.9099	0.0049
shade_sum	162.15	6	3.7083	0.0541
Year	160.23	6	1.7961	0.1802
rep_design	159.89	4	1.4563	0.6924

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.0160	0.4091	-4.9280	<0.0001	***
Yearb.2010	-0.6388	0.4828	-1.3230	0.1858	
rep_designDietl Ditch	-0.4227	0.7755	-0.5450	0.5857	
rep_designNatural	0.8726	1.5146	0.5760	0.5646	
rep_designno bench	-0.3854	0.5455	-0.7070	0.4799	
shade_sum	-4.1038	2.7029	-1.5180	0.1289	
diverse.meas	-6.0641	2.4712	-2.4540	0.0141	*

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-79.22	8		
diverse.meas	-82.33	7	6.2261	0.0126
shade_sum	-80.94	7	3.4331	0.0639
rep_design	-79.88	5	1.3315	0.7217
Year	-80.12	7	1.7961	0.1802

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	1.47E-14	1.21E-07

Number of obs: 410, groups: Site, 15

Bass predators, April analysis, Step 3 (bp_apr_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.9146	0.4759	-6.1244	<0.0001
rep_designa.Ten.one.slope	0.6159	0.6305	0.9768	0.3293
rep_designDietl Ditch	2.3570	0.5967	3.9499	0.0001
rep_designno bench	1.1663	0.6084	1.9171	0.0560
depth	-0.1260	0.2080	-0.6055	0.5452
diverse.meas	1.6859	1.8898	0.8921	0.3729
bslope_sum	0.4635	0.1123	4.1272	0.0000
dom.size.IWM	-0.3402	0.1870	-1.8196	0.0696
avg.LWM.density	-0.7082	2.5233	-0.2807	0.7791
dom.size.IWM:avg.LWM.density	3.3997	1.7682	1.9227	0.0553
depth:diverse.meas	3.8310	1.4834	2.5826	0.0102

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.7482	0.4898	-3.5691	0.0004
rep_designa.Ten.one.slope	-0.5505	0.5800	-0.9490	0.3432
rep_designDietl Ditch	1.1906	0.4743	2.5102	0.0125
rep_designNatural	-1.1663	0.6084	-1.9171	0.0560
depth	-0.1260	0.2080	-0.6055	0.5452
diverse.meas	1.6859	1.8898	0.8921	0.3729
bslope_sum	0.4635	0.1123	4.1272	<0.0001
dom.size.IWM	-0.3402	0.1870	-1.8196	0.0696
avg.LWM.density	-0.7082	2.5233	-0.2807	0.7791
dom.size.IWM:avg.LWM.density	3.3997	1.7682	1.9227	0.0553
depth:diverse.meas	3.8310	1.4834	2.5826	0.0102

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	286.58	11		
depth:diverse.meas	294.19	10	7.6105	0.0058
dom.size.IWM:avg.LWM.density	290.77	10	4.1892	0.0407
bslope_sum	306.15	10	19.5757	<0.0001
rep_design	305.82	8	19.2442	0.0002

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.5576	0.3842	-1.4512	0.1475
rep_designa.no bench	-1.1906	0.4743	-2.5102	0.0125
rep_designa.Ten.one.slope	-1.7411	0.6025	-2.8896	0.0041
rep_designNatural	-2.3570	0.5968	-3.9496	0.0001
depth	-0.1260	0.2080	-0.6055	0.5452
diverse.meas	1.6859	1.8898	0.8921	0.3729
bslope_sum	0.4635	0.1123	4.1272	<0.0001
dom.size.IWM	-0.3402	0.1870	-1.8196	0.0696
avg.LWM.density	-0.7082	2.5233	-0.2807	0.7791
dom.size.IWM:avg.LWM.density	3.3997	1.7682	1.9227	0.0553
depth:diverse.meas	3.8310	1.4834	2.5826	0.0102

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.2987	0.5025	-4.5740	<0.0001	***
rep_designDietl Ditch	1.7411	0.6026	2.8890	0.0039	**
rep_designNatural	-0.6159	0.6306	-0.9770	0.3288	
rep_designno bench	0.5505	0.5801	0.9490	0.3427	
depth	-0.1260	0.2080	-0.6050	0.5449	
diverse.meas	1.6860	1.8898	0.8920	0.3723	
bslope_sum	0.4635	0.1123	4.1280	0.0000	***
dom.size.IWM	-0.3402	0.1870	-1.8200	0.0688	.
avg.LWM.density	-0.7083	2.5229	-0.2810	0.7789	
dom.size.IWM:avg.LWM.density	3.3998	1.7680	1.9230	0.0545	.
depth:diverse.meas	3.8308	1.4832	2.5830	0.0098	**

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-143.29	12		
depth:diverse.meas	-147.09	11	7.6105	0.0058
dom.size.IWM:avg.LWM.density	-145.38	11	4.1892	0.0407
bslope_sum	-151.84	11	17.0940	<0.0001
rep_design	-152.27	9	17.9560	0.0004

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 400, groups: Site, 15

Bass predators, combined analysis, Step 3 (bp_com_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.7832	0.4719	-3.7787	0.0002
Effortjan	-1.0087	0.3213	-3.1393	0.0017
Effortmar	-1.1519	0.2613	-4.4086	<0.0001
rep_designa.Ten.one.slope	-0.0391	0.5188	-0.0754	0.9399
rep_designDietl Ditch	1.1775	0.4595	2.5628	0.0105
rep_designno bench	0.4775	0.5438	0.8781	0.3801
shade_sum	-1.0310	0.5858	-1.7599	0.0787
depth	-0.0991	0.1379	-0.7184	0.4727
diverse.meas	-1.7280	1.0951	-1.5779	0.1149
bslope_sum	0.2241	0.0533	4.2065	<0.0001
depth:diverse.meas	1.7148	0.9630	1.7807	0.0753

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	571.74	11		
depth:diverse.meas	574.99	10	3.2514	0.0714
bslope_sum	590.36	10	18.6262	<0.0001
shade_sum	575.04	10	3.3019	0.0692
rep_design	582.73	8	10.9910	0.0118
Effort	596.71	9	24.9683	<0.0001

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.6056	0.3106	-1.9500	0.0515
Effortjan	-1.0087	0.3213	-3.1393	0.0017
Effortmar	-1.1519	0.2613	-4.4086	<0.0001
rep_designa.no bench	-0.7000	0.3569	-1.9612	0.0501
rep_designa.Ten.one.slope	-1.2167	0.4326	-2.8122	0.0050
rep_designNatural	-1.1775	0.4595	-2.5627	0.0105
shade_sum	-1.0310	0.5858	-1.7599	0.0787
depth	-0.0991	0.1379	-0.7184	0.4727
diverse.meas	-1.7280	1.0951	-1.5779	0.1149
bslope_sum	0.2241	0.0533	4.2065	<0.0001
depth:diverse.meas	1.7148	0.9630	1.7807	0.0753

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.3057	0.2619	-4.9850	<0.0001
Effortjan	-1.0087	0.3213	-3.1393	0.0017
Effortmar	-1.1519	0.2613	-4.4086	<0.0001
rep_designa.Ten.one.slope	-0.5166	0.3973	-1.3003	0.1938
rep_designDietl Ditch	0.7000	0.3569	1.9612	0.0501
rep_designNatural	-0.4775	0.5438	-0.8781	0.3801
shade_sum	-1.0310	0.5858	-1.7599	0.0787
depth	-0.0991	0.1379	-0.7184	0.4727
diverse.meas	-1.7280	1.0951	-1.5779	0.1149
bslope_sum	0.2241	0.0533	4.2065	<0.0001
depth:diverse.meas	1.7148	0.9630	1.7807	0.0753

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.6706	0.5951	-2.8070	0.0050	**
Effortjan	-1.0239	0.4241	-2.4140	0.0158	*
Effortmar	-1.1493	0.3693	-3.1120	0.0019	**
rep_designa.Ten.one.slope	-0.3086	0.6519	-0.4730	0.6360	
rep_designDietl Ditch	1.0530	0.6169	1.7070	0.0878	.
rep_designno bench	0.4306	0.6851	0.6280	0.5297	
shade_sum	-1.4103	0.6906	-2.0420	0.0412	*
depth	-0.1150	0.1537	-0.7480	0.4543	
diverse.meas	-1.2768	1.4467	-0.8820	0.3775	
bslope_sum	0.2282	0.0814	2.8020	0.0051	**
depth:diverse.meas	1.8203	1.0766	1.6910	0.0909	.

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-283.37	12		
depth:diverse.meas	-284.88	11	3.0186	0.0823
depth	-285.43	10	4.1202	0.1274
diverse.meas	-285.51	10	4.2799	0.1177
bslope_sum	-287.01	11	7.2730	0.0070
shade_sum	-285.59	11	4.4309	0.0353
rep_design	-286.01	9	5.2859	0.1520
Effort	-288.64	10	10.5460	0.0051

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.3651	0.6042

Number of obs: 1015, groups: Effort:Site, 45

Chinook salmon fry, January, Step 1 (ckf_jan_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.3302	0.2734	-1.2081	0.2284
regionKK	0.5316	0.5963	0.8915	0.3737
regionKL	-1.8285	0.5054	-3.6180	0.0004
rep_designDietl Ditch	0.8973	0.8078	1.1107	0.2680
rep_designNatural	1.0026	0.4621	2.1696	0.0312
rep_designno bench	-0.0113	0.4434	-0.0255	0.9797

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete model	246.03	6		
rep_design	252.44	3	6.4076	0.0934
region	268.85	4	22.8145	<0.0001

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.3302	0.2734	-1.2080	0.2270	
regionKK	0.5316	0.5962	0.8920	0.3726	
regionKL	-1.8286	0.5054	-3.6180	0.0003	***
rep_designDietl Ditch	0.8973	0.8077	1.1110	0.2666	
rep_designNatural	1.0026	0.4621	2.1700	0.0300	*
rep_designno bench	-0.0113	0.4434	-0.0260	0.9797	

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-123.02	7		
rep_design	-126.14	4	6.2510	0.1000
region	-130.91	5	15.7980	0.0004

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 205, groups: Site, 15

Chinook salmon fry, March, Step 1 (ckf_mar_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.4242	0.2563	-1.6547	0.0988
regionKK	0.1612	0.4534	0.3555	0.7224
regionKL	-0.8157	0.5054	-1.6139	0.1073
Yearb.2010	0.7105	0.2914	2.4383	0.0152
rep_designDietl Ditch	-0.1009	0.5198	-0.1940	0.8463
rep_designNatural	-0.0613	0.3268	-0.1877	0.8512
rep_designno bench	-1.1482	0.3629	-3.1640	0.0017
regionKK:Yearb.2010	-1.3555	0.4984	-2.7195	0.0068
regionKL:Yearb.2010	-1.0085	0.6772	-1.4893	0.1372

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.5250	0.5051	-1.0394	0.2992
regionKK	0.1612	0.4534	0.3555	0.7224
regionKL	-0.8157	0.5054	-1.6139	0.1073
Yearb.2010	0.7105	0.2914	2.4383	0.0152
rep_designa.no bench	-1.0473	0.5505	-1.9026	0.0578
rep_designa.Ten.one.slope	0.1009	0.5198	0.1940	0.8463
rep_designNatural	0.0395	0.4043	0.0977	0.9222
regionKK:Yearb.2010	-1.3555	0.4984	-2.7195	0.0068
regionKL:Yearb.2010	-1.0085	0.6772	-1.4893	0.1372

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	485.02	9		
region:Year	493.23	7	8.2088	0.0165
rep_design	497.97	6	12.9510	0.0047

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.4465	0.3103	-1.4390	0.1502
regionKK	0.1444	0.5601	0.2580	0.7965
regionKL	-0.8781	0.5838	-1.5040	0.1326
Yearb.2010	0.7334	0.2943	2.4920	0.0127 *
rep_designDietl Ditch	-0.0918	0.6821	-0.1350	0.8930
rep_designNatural	-0.0388	0.4318	-0.0900	0.9284
rep_designno bench	-1.1707	0.4581	-2.5550	0.0106 *
regionKK:Yearb.2010	-1.3759	0.5012	-2.7450	0.0061 **
regionKL:Yearb.2010	-1.0218	0.6853	-1.4910	0.1359

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.5383	0.6491	-0.8290	0.4070
regionKK	0.1444	0.5601	0.2580	0.7965
regionKL	-0.8781	0.5838	-1.5040	0.1326
Yearb.2010	0.7334	0.2943	2.4920	0.0127 *
rep_designa.Ten.one.slope	0.0918	0.6821	0.1340	0.8930
rep_designNatural	0.0530	0.5281	0.1000	0.9201
rep_designno bench	-1.0789	0.7071	-1.5260	0.1271
regionKK:Yearb.2010	-1.3759	0.5012	-2.7450	0.0061 **
regionKL:Yearb.2010	-1.0217	0.6852	-1.4910	0.1360

Likelihood ratio tests:	LogLik	df	Chisq	Pr(>Chisq)
Complete	-241.38	10		
region:Year	-245.51	8	8.2475	0.0162
rep_design	-244.84	7	6.9108	0.0748

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.1134	0.3368

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-1.6172	0.4169	-3.8790	0.0001 ***
regionKK	0.1444	0.5601	0.2580	0.7965
regionKL	-0.8781	0.5838	-1.5040	0.1326
Yearb.2010	0.7334	0.2943	2.4920	0.0127 *
rep_design3a.Ten.one.slope	1.1707	0.4581	2.5550	0.0106 *
rep_design3Dietl Ditch	1.0789	0.7071	1.5260	0.1271
rep_design3Natural	1.1319	0.4703	2.4070	0.0161 *
regionKK:Yearb.2010	-1.3759	0.5012	-2.7450	0.0060 **
regionKL:Yearb.2010	-1.0218	0.6853	-1.4910	0.1359

Chinook salmon fry, combined analysis, Step 1 (ckf_com_1)

1A (No interactions, GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.2908	0.2007	1.4489	0.1479
Effortmar	-0.6665	0.1831	-3.6393	0.0003
regionKK	-0.2365	0.3041	-0.7777	0.4370
regionKL	-1.5358	0.3024	-5.0781	<0.0001
rep_designDietl Ditch	0.2513	0.4142	0.6068	0.5442
rep_designNatural	0.3103	0.2644	1.1738	0.2409
rep_designno bench	-0.7207	0.2779	-2.5933	0.0097

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.1244	0.3855	-0.3227	0.7470
Effortjan	0.6665	0.1831	3.6393	0.0003
regionKK	-0.2365	0.3041	-0.7777	0.4370
regionKL	-1.5358	0.3024	-5.0781	<0.0001
rep_designa.no bench	-0.9721	0.4299	-2.2609	0.0241
rep_designa.Ten.one.slope	-0.2513	0.4142	-0.6068	0.5442
rep_designNatural	0.0590	0.3189	0.1850	0.8533

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	758.53	7		
rep_design	772.81	4	14.2835	0.0025
region	790.67	5	32.1456	<0.0001
Effort	771.89	6	13.3593	0.0003

1B (No interactions, GLMM)

	Estimate	SE	z value	Pr(>|z|)	
(Intercept)	-0.0435	0.3145	-0.1380	0.8901	
Effortjan	0.6928	0.2492	2.7800	0.0054	**
regionKK	-0.1713	0.4420	-0.3880	0.6984	
regionKL	-1.6413	0.4023	-4.0800	<0.0001	***
rep_designa.no bench	-1.0829	0.3928	-2.7570	0.0058	**
rep_designa.Ten.one.slope	-0.4415	0.3773	-1.1700	0.2420	
rep_designDietl Ditch	-0.1012	0.4656	-0.2170	0.8279	

	Estimate	SE	z value	Pr(>|z|)	
(Intercept)	-0.1446	0.5618	-0.2570	0.7969	
Effortjan	0.6927	0.2492	2.7800	0.0054	**
regionKK	-0.1713	0.4419	-0.3880	0.6983	
regionKL	-1.6413	0.4023	-4.0800	<0.0001	***
rep_designa.Natural	0.1011	0.4656	0.2170	0.8281	
rep_designa.no bench	-0.9818	0.6092	-1.6120	0.1070	
rep_designa.Ten.one.slope	-0.3405	0.5993	-0.5680	0.5699	

Likelihood ratio tests:	logLik	df	Chisq	Pr(>Chisq)
Complete	-375.70	8		
rep_design	-379.27	5	7.1424	0.0675
region	-383.92	6	16.4370	0.0003
Effort	-379.16	7	6.9117	0.0086

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.1985	0.4455

Number of obs: 615, groups: Effort:Site, 30

	Estimate	SE	z value	Pr(>|z|)
(Intercept)	-0.4849	0.2532	-1.9150	0.0555
Effortjan	0.6927	0.2492	2.7800	0.0054
regionKK	-0.1713	0.4419	-0.3880	0.6984
regionKL	-1.6413	0.4023	-4.0800	<0.0001
rep_designDietl Ditch	0.3404	0.5993	0.5680	0.5701
rep_designNatural	0.4415	0.3773	1.1700	0.2420
rep_designno bench	-0.6415	0.3823	-1.6780	0.0933

1C, (With interactions, GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.9488	0.3945	-2.4049	0.0165
Effortmar	0.5747	0.3629	1.5836	0.1138
regionKK	0.4136	0.4379	0.9446	0.3453
regionKL	-0.7250	0.5012	-1.4466	0.1485
Yearb.2010	0.6186	0.2845	2.1743	0.0301
rep_designDietl Ditch	1.9749	0.6467	3.0536	0.0024
rep_designNatural	1.3903	0.4184	3.3231	0.0009
rep_designno bench	0.0054	0.4407	0.0122	0.9903
regionKK:Yearb.2010	-0.9596	0.4624	-2.0752	0.0384
regionKL:Yearb.2010	-1.2118	0.5982	-2.0256	0.0432
Effortmar:rep_designDietl Ditch	-2.5292	0.6857	-3.6886	0.0002
Effortmar:rep_designNatural	-1.6236	0.4717	-3.4416	0.0006
Effortmar:rep_designno bench	-1.1468	0.5671	-2.0222	0.0436

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.3741	0.2532	-1.4772	0.1401
Effortjan	-0.5747	0.3629	-1.5836	0.1138
regionKK	0.4136	0.4379	0.9445	0.3453
regionKL	-0.7250	0.5012	-1.4466	0.1485
Yearb.2010	0.6186	0.2845	2.1743	0.0301
rep_designDietl Ditch	-0.5543	0.4749	-1.1672	0.2436
rep_designNatural	-0.2332	0.3111	-0.7496	0.4538
rep_designno bench	-1.1415	0.3610	-3.1622	0.0016
regionKK:Yearb.2010	-0.9596	0.4624	-2.0752	0.0384
regionKL:Yearb.2010	-1.2118	0.5982	-2.0256	0.0432
Effortjan:rep_designDietl Ditch	2.5292	0.6857	3.6884	0.0002
Effortjan:rep_designNatural	1.6236	0.4717	3.4416	0.0006
Effortjan:rep_designno bench	1.1468	0.5671	2.0222	0.0436

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	737.37	13		
Effort:rep_design	756.01	10	18.6423	0.0003
region:Year	743.84	11	6.4736	0.0393
rep_design	770.44	7	33.0698	<0.0001

With Natural as the reference design

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.4415	0.3897	1.1329	0.2577
Effortmar	-1.0488	0.3234	-3.2433	0.0012
regionKK	0.4136	0.4379	0.9445	0.3453
regionKL	-0.7250	0.5012	-1.4466	0.1485
Yearb.2010	0.6186	0.2845	2.1743	0.0301
rep_designa.Ten.one.slope	-1.3903	0.4184	-3.3232	0.0009
rep_designDietl Ditch	0.5845	0.5707	1.0243	0.3061
rep_designno bench	-1.3850	0.4485	-3.0878	0.0021
regionKK:Yearb.2010	-0.9596	0.4624	-2.0752	0.0384
regionKL:Yearb.2010	-1.2118	0.5982	-2.0256	0.0432
Effortmar:rep_designa.Ten.one.slope	1.6236	0.4717	3.4417	0.0006
Effortmar:rep_designDietl Ditch	-0.9056	0.6449	-1.4041	0.1608
Effortmar:rep_designno bench	0.4767	0.5473	0.8711	0.3841

With natural as the reference design

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.6073	0.2972	-2.0432	0.0415
Effortjan	1.0488	0.3234	3.2433	0.0012
regionKK	0.4136	0.4379	0.9445	0.3453
regionKL	-0.7250	0.5012	-1.4466	0.1485
Yearb.2010	0.6186	0.2845	2.1743	0.0301
rep_designa.Ten.one.slope	0.2332	0.3111	0.7496	0.4538
rep_designDietl Ditch	-0.3211	0.3793	-0.8464	0.3977
rep_designno bench	-0.9082	0.3642	-2.4938	0.0129
regionKK:Yearb.2010	-0.9596	0.4624	-2.0752	0.0384
regionKL:Yearb.2010	-1.2118	0.5982	-2.0256	0.0432
Effortjan:rep_designa.Ten.one.slope	-1.6236	0.4717	-3.4417	0.0006
Effortjan:rep_designDietl Ditch	0.9056	0.6449	1.4041	0.1608
Effortjan:rep_designno bench	-0.4767	0.5473	-0.8711	0.3841

1D (With interactions, GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.0254	0.4305	-2.3820	0.0172	*
Effortmar	0.6181	0.4324	1.4290	0.1529	
regionKK	0.5654	0.5094	1.1100	0.2671	
regionKL	-0.7770	0.5615	-1.3840	0.1664	
Yearb.2010	0.6628	0.2887	2.2960	0.0217	*
rep_designDietl Ditch	1.9593	0.7444	2.6320	0.0085	**
rep_designNatural	1.4190	0.4821	2.9440	0.0032	**
rep_designno bench	0.0412	0.5127	0.0800	0.9360	
regionKK:Yearb.2010	-1.0746	0.4735	-2.2700	0.0232	*
regionKL:Yearb.2010	-1.1689	0.6233	-1.8750	0.0608	.
Effortmar:rep_designDietl Ditch	-2.6240	0.7988	-3.2850	0.0010	**
Effortmar:rep_designNatural	-1.6743	0.5609	-2.9850	0.0028	**
Effortmar:rep_designno bench	-1.2109	0.6767	-1.7890	0.0735	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.5768	0.4102	-3.8440	0.0001	***
Effortjan	0.5926	0.5421	1.0930	0.2743	
regionKK	0.5653	0.5094	1.1100	0.2671	
regionKL	-0.7770	0.5614	-1.3840	0.1664	
Yearb.2010	0.6628	0.2887	2.2960	0.0217	*
rep_designa.Ten.one.slope	1.1695	0.4486	2.6070	0.0091	**
rep_designDietl Ditch	0.5049	0.6371	0.7920	0.4281	
rep_designNatural	0.9142	0.4476	2.0420	0.0411	*
regionKK:Yearb.2010	-1.0746	0.4735	-2.2700	0.0232	*
regionKL:Yearb.2010	-1.1689	0.6233	-1.8750	0.0607	.
Effortjan:rep_designa.Ten.one.slope	-1.2107	0.6767	-1.7890	0.0736	.
Effortjan:rep_designDietl Ditch	1.4132	0.8627	1.6380	0.1014	
Effortjan:rep_designNatural	0.4636	0.6440	0.7200	0.4716	

Likelihood ratio tests:	logLik	df	Chisq	Pr(>Chisq)
Complete	-367.41	14		
Effort:rep_design	-373.52	11	12.2110	0.0067
region:Year	-370.79	12	6.7496	0.0342
rep_design	-376.80	8	18.7680	0.0046

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.3936	0.4316	0.9120	0.3618	
Effortmar	-1.0562	0.3760	-2.8090	0.0050	**
regionKK	0.5654	0.5094	1.1100	0.2670	
regionKL	-0.7770	0.5614	-1.3840	0.1664	
Yearb.2010	0.6628	0.2887	2.2960	0.0217	*
rep_designa.no bench	-1.3778	0.5128	-2.6870	0.0072	**
rep_designa.Ten.one.slope	-1.4190	0.4821	-2.9430	0.0033	**
rep_designDietl Ditch	0.5402	0.6488	0.8330	0.4051	
regionKK:Yearb.2010	-1.0745	0.4735	-2.2690	0.0232	*
regionKL:Yearb.2010	-1.1689	0.6233	-1.8750	0.0607	.
Effortmar:rep_designa.no bench	0.4636	0.6440	0.7200	0.4716	
Effortmar:rep_designa.Ten.one.slope	1.6743	0.5609	2.9850	0.0028	**
Effortmar:rep_designDietl Ditch	-0.9497	0.7519	-1.2630	0.2066	

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.6626	0.3538	-1.8730	0.0611	.
Effortjan	1.0562	0.3760	2.8090	0.0050	**
regionKK	0.5654	0.5094	1.1100	0.2671	
regionKL	-0.7770	0.5614	-1.3840	0.1664	
Yearb.2010	0.6628	0.2887	2.2960	0.0217	*
rep_designa.no bench	-0.9142	0.4476	-2.0420	0.0411	*
rep_designa.Ten.one.slope	0.2553	0.3980	0.6410	0.5213	
rep_designDietl Ditch	-0.4094	0.4870	-0.8410	0.4006	
regionKK:Yearb.2010	-1.0746	0.4735	-2.2700	0.0232	*
regionKL:Yearb.2010	-1.1689	0.6233	-1.8750	0.0608	.
Effortjan:rep_designa.no bench	-0.4636	0.6440	-0.7200	0.4716	
Effortjan:rep_designa.Ten.one.slope	-1.6743	0.5609	-2.9850	0.0028	**
Effortjan:rep_designDietl Ditch	0.9496	0.7519	1.2630	0.2066	

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.1044	0.3231

Number of obs: 615, groups: Effort:Site, 30

Chinook salmon fry, January, Step 2 (ckf_jan_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.4885	0.4763	-1.0260	0.3063
regionKK	0.9626	0.4460	2.1580	0.0321
regionKL	-1.2958	0.5500	-2.3560	0.0194
depth	-0.6519	0.2370	-2.7510	0.0065
EV_Apr	3.3192	0.9974	3.3280	0.0010
diverse.meas	-1.7063	1.5597	-1.0940	0.2753
BC_sum	-1.7314	0.6442	-2.6880	0.0078
depth:diverse.meas	4.2844	1.1980	3.5760	0.0004

No warnings; trust t-tests

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	229.20	8		
depth:diverse.meas	245.22	7	16.0203	0.0001
BC_sum	236.68	7	7.4826	0.0062
EV_Apr	241.53	7	12.3249	0.0004
region	243.70	6	14.4981	0.0007

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.4884	0.4762	-1.0260	0.3050	
regionKK	0.9626	0.4460	2.1580	0.0309	*
regionKL	-1.2958	0.5500	-2.3560	0.0185	*
depth	-0.6519	0.2370	-2.7510	0.0059	**
EV_Apr	3.3192	0.9973	3.3280	0.0009	***
diverse.meas	-1.7063	1.5597	-1.0940	0.2740	
BC_sum	-1.7314	0.6442	-2.6880	0.0072	**
depth:diverse.meas	4.2842	1.1978	3.5770	0.0003	***

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-114.60	9		
depth:diverse.meas	-122.60	8	16.0020	0.0001
BC_sum	-118.34	8	7.4826	0.0062
EV_Apr	-120.76	8	12.3220	0.0004
region	-121.57	7	13.9360	0.0009

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 205, groups: Site, 15

Chinook salmon fry, March, Step 2 (ckf_mar_2)

2A (GLM)

Without random effect term:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.6236	0.6004	-2.7042	0.0071
regionKK	-0.1652	0.4054	-0.4076	0.6838
regionKL	-0.6272	0.5948	-1.0544	0.2923
Yearb.2010	0.4795	0.3034	1.5805	0.1148
depth	-0.6516	0.1713	-3.8045	0.0002
EV_Apr	2.8813	1.0772	2.6749	0.0078
diverse.meas	-1.8336	1.3181	-1.3912	0.1650
bslope_sum	-0.2041	0.0718	-2.8408	0.0047
BC_sum	-1.2254	0.4537	-2.7009	0.0072
avg.LWM.density	4.6100	2.1137	2.1811	0.0298
regionKK:Yearb.2010	-1.1677	0.5176	-2.2560	0.0246
regionKL:Yearb.2010	-0.6465	0.6881	-0.9396	0.3480
depth:diverse.meas	2.1572	0.9181	2.3497	0.0193

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	467.89	13		
depth:diverse.meas	473.70	12	5.8181	0.0159
region:Year	473.17	11	5.2844	0.0712
avg.LWM.density	472.72	12	4.8388	0.0278
BC_sum	475.25	12	7.3664	0.0066
bslope_sum	476.43	12	8.5464	0.0035
EV_Apr	475.1191	12	7.2331	0.0072

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.5748	0.6601	-2.3860	0.0170	*
regionKK	-0.1430	0.4364	-0.3280	0.7431	
regionKL	-0.6074	0.6301	-0.9640	0.3350	
Yearb.2010	0.4819	0.3049	1.5800	0.1141	
depth	-0.6648	0.1768	-3.7610	0.0002	***
EV_Apr	2.7137	1.1789	2.3020	0.0213	*
diverse.meas	-1.6198	1.4503	-1.1170	0.2640	
bslope_sum	-0.1987	0.0794	-2.5040	0.0123	*
BC_sum	-1.1279	0.4977	-2.2660	0.0234	*
avg.LWM.density	4.1924	2.3296	1.8000	0.0719	.
regionKK:Yearb.2010	-1.1832	0.5187	-2.2810	0.0225	*
regionKL:Yearb.2010	-0.6655	0.6907	-0.9640	0.3353	
depth:diverse.meas	1.97525	0.96379	2.049	0.040418	*

Likelihood ratio tests:	LogLik	Df	Chisq	Pr(>Chisq)
Complete	-233.83	14		
depth:diverse.meas	-235.34	13	3.0246	0.0820
region:Year	-236.52	12	5.3705	0.0682
avg.LWM.density	-234.90	13	2.1360	0.1439
BC_sum	-235.33	13	2.9994	0.0833
bslope_sum	-236.03	13	4.3982	0.0360
EV_Apr	-235.58	13	3.4950	0.0616

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.0419	0.2047

Number of obs: 410, groups: Site, 15

Updated on 7 Sept 2010.

Chinook salmon fry, combined analysis, Step 2 (ckf_com_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.4932	0.9253	2.6947	0.0072
Effortmar	-0.6229	0.2149	-2.8989	0.0039
regionKK	-0.0292	0.3823	-0.0764	0.9391
regionKL	-0.6445	0.5120	-1.2589	0.2086
Yearb.2010	0.2229	0.2836	0.7861	0.4321
depth	-1.2509	0.3553	-3.5203	0.0005
EV_Apr	1.1691	0.5229	2.2361	0.0257
diverse.meas	-3.2937	1.4603	-2.2555	0.0245
BC_sum	-0.8456	0.3132	-2.7003	0.0071
regionKK:Yearb.2010	-0.1510	0.4371	-0.3454	0.7299
regionKL:Yearb.2010	-0.5413	0.5790	-0.9349	0.3502
depth:diverse.meas	1.6520	0.6160	2.6819	0.0075

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	740.51	12		
depth:diverse.meas	748.10	11	7.5817	0.0059
region:Year	741.38	10	0.8635	0.6494
BC_sum	747.85	11	7.3313	0.0068
EV_Apr	745.62	11	5.1112	0.0238
Effort	749.05	11	8.5313	0.0035

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	2.5849	1.2792	2.0210	0.0433	*
Effortmar	-0.7101	0.3150	-2.2540	0.0242	*
regionKK	0.5304	0.5302	1.0000	0.3172	
regionKL	-0.4450	0.6803	-0.6540	0.5131	
Yearb.2010	0.3578	0.3006	1.1900	0.2339	
depth	-1.3854	0.4373	-3.1680	0.0015	**
EV_Apr	1.4162	0.8297	1.7070	0.0879	.
diverse.meas	-3.2172	2.0204	-1.5920	0.1113	
BC_sum	-0.8558	0.4878	-1.7540	0.0794	.
regionKK:Yearb.2010	-0.7043	0.4810	-1.4640	0.1431	
regionKL:Yearb.2010	-0.6446	0.6445	-1.0000	0.3173	
depth:diverse.meas	1.5722	0.7810	2.0130	0.0441	*

Likelihood ratio tests:	LogLik	Df	Chisq	Pr(>Chisq)
Complete	-363.66	13		
depth:diverse.meas	-365.60	12	3.8766	0.0490
depth	-374.85	11	22.3740	<0.0001
diverse.meas	-365.60	11	3.8780	0.1438
BC_sum	-365.04	12	2.7494	0.0973
EV_Apr	-365.05	12	2.7862	0.0951
region:Year	-364.85	11	2.3787	0.3044
Effort	-366.07	12	4.8119	0.0283

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.3604	0.6003

Number of obs: 615, groups: Effort:Site, 30

Chinook salmon fry, January, Step 3 (ckf_jan_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.0343	0.6063	-3.3553	0.0010
regionKK	-0.5813	0.8039	-0.7231	0.4705
regionKL	-1.4399	0.6071	-2.3717	0.0187
rep_designDietl Ditch	2.6315	1.1193	2.3511	0.0197
rep_designNatural	2.2304	0.6837	3.2622	0.0013
rep_designno bench	0.1076	0.5471	0.1967	0.8442
depth	-0.9703	0.2906	-3.3394	0.0010
EV_Apr	3.3783	1.0671	3.1660	0.0018
diverse.meas	-0.5394	1.3656	-0.3950	0.6933
depth:diverse.meas	3.2789	1.1869	2.7625	0.0063

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.1961	0.5866	0.3343	0.7385
regionKK	-0.5813	0.8040	-0.7230	0.4705
regionKL	-1.4399	0.6071	-2.3718	0.0187
rep_designa.Ten.one.slope	-2.2304	0.6837	-3.2621	0.0013
rep_designDietl Ditch	0.4011	0.8140	0.4927	0.6228
rep_designno bench	-2.1228	0.7020	-3.0239	0.0028
depth	-0.9703	0.2906	-3.3395	0.0010
EV_Apr	3.3783	1.0672	3.1656	0.0018
diverse.meas	-0.5394	1.3656	-0.3950	0.6933
depth:diverse.meas	3.2789	1.1870	2.7622	0.0063

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	223.40	10		
depth:diverse.meas	232.45	9	9.0484	0.0026
EV_Apr	234.30	9	10.8970	0.0010
rep_design	236.68	7	13.2845	0.0041
region	229.54	8	6.1390	0.0464

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-2.0343	0.6063	-3.3550	0.0008 ***
regionKK	-0.5813	0.8039	-0.7230	0.4696
regionKL	-1.4399	0.6071	-2.3720	0.0177 *
rep_designDietl Ditch	2.6315	1.1193	2.3510	0.0187 *
rep_designNatural	2.2304	0.6837	3.2620	0.0011 **
rep_designno bench	0.1076	0.5471	0.1970	0.8440
depth	-0.9703	0.2906	-3.3390	0.0008 ***
EV_Apr	3.3783	1.0671	3.1660	0.0015 **
diverse.meas	-0.5394	1.3656	-0.3950	0.6929
depth:diverse.meas	3.2786	1.1869	2.7620	0.0057 **

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 205, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-111.70	11		
depth:diverse.meas	-116.22	10	9.0484	0.0026
EV_Apr	-117.15	10	10.8970	0.0010
rep_design	-118.34	8	13.2840	0.0041
region	-114.77	9	6.1390	0.0464

Chinook salmon fry, March, Step 3 (ckf_mar_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.2987	0.6933	-3.3150	0.0010
regionKK	-0.9711	0.5255	-1.8480	0.0654
regionKL	-0.6470	0.5935	-1.0900	0.2763
Yearb.2010	0.6880	0.3215	2.1400	0.0330
rep_designDietl Ditch	1.2337	0.6546	1.8850	0.0602
rep_designNatural	2.2228	0.7541	2.9470	0.0034
rep_designno bench	-2.9389	0.6410	-4.5850	<0.0001
depth	-0.7380	0.1940	-3.8040	0.0002
bslope_sum	-0.3957	0.0966	-4.0960	0.0001
BC_sum	3.3497	1.0724	3.1230	0.0019
regionKK:Yearb.2010	-1.7501	0.5412	-3.2340	0.0013
regionKL:Yearb.2010	-0.9521	0.6994	-1.3610	0.1742

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	449.11	12		
region:Year	460.08	10	10.9686	0.0042
BC_sum	459.75	11	10.6359	0.0011
bslope_sum	468.45	11	19.3438	<0.0001
depth	466.06	11	16.9530	<0.0001
rep_design	477.77	9	28.6614	<0.0001

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.2987	0.6931	-3.3160	0.0009	***
regionKK	-0.9711	0.5255	-1.8480	0.0646	.
regionKL	-0.6470	0.5935	-1.0900	0.2757	
Yearb.2010	0.6881	0.3215	2.1400	0.0324	*
rep_designDietl Ditch	1.2337	0.6546	1.8850	0.0595	.
rep_designNatural	2.2228	0.7539	2.9480	0.0032	**
rep_designno bench	-2.9389	0.6406	-4.5880	<0.0001	***
depth	-0.7380	0.1940	-3.8030	0.0001	***
bslope_sum	-0.3957	0.0966	-4.0960	<0.0001	***
BC_sum	3.3496	1.0719	3.1250	0.0018	**
regionKK:Yearb.2010	-1.7501	0.5413	-3.2330	0.0012	**
regionKL:Yearb.2010	-0.9521	0.6995	-1.3610	0.1735	

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-224.56	13		
BC_sum	-229.87	12	10.6360	0.0011
bslope_sum	-232.75	12	16.3820	0.0001
depth	-233.03	12	16.9530	<0.0001
rep_design	-236.11	10	23.1130	<0.0001
region:Year	-230.04	11	10.9690	0.0042

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	5.7E-12	2.4E-06

Number of obs: 410, groups: Site, 15

Chinook salmon fry, combined analysis, Step 3 (ckf_com_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.8472	0.9924	3.8766	0.0001
Effortmar	-1.4386	0.3501	-4.1094	0.0000
regionKK	-0.3384	0.4843	-0.6988	0.4849
regionKL	0.1180	0.5317	0.2220	0.8244
Yearb.2010	0.4276	0.2940	1.4544	0.1464
rep_designa.Ten.one.slope	-1.8901	0.4619	-4.0925	<0.0001
rep_designDietl Ditch	1.3118	0.6140	2.1364	0.0331
rep_designno bench	-2.2427	0.5148	-4.3560	0.0000
depth	-1.4716	0.3778	-3.8952	0.0001
diverse.meas	-2.8461	1.4289	-1.9917	0.0469
regionKK:Yearb.2010	-1.0022	0.4767	-2.1024	0.0359
regionKL:Yearb.2010	-1.0251	0.6069	-1.6890	0.0917
Effortmar:rep_designa.Ten.one.slope	1.9024	0.4917	3.8689	0.0001
Effortmar:rep_designDietlDitch	-0.7076	0.6738	-1.0502	0.2941
Effortmar:rep_designno bench	1.1926	0.5740	2.0778	0.0382
depth:diverse.meas	1.5651	0.6450	2.4265	0.0155

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.4209	0.8779	2.7575	0.0060
Effortjan	-0.4638	0.3723	-1.2458	0.2133
regionKK	-0.3384	0.4843	-0.6988	0.4849
regionKL	0.1180	0.5317	0.2220	0.8244
Yearb.2010	0.4276	0.2940	1.4543	0.1464
rep_designDietl Ditch	0.5919	0.5555	1.0655	0.2871
rep_designNatural	-0.0122	0.3338	-0.0367	0.9708
rep_designno bench	-1.0623	0.3736	-2.8437	0.0046
depth	-1.4716	0.3776	-3.8968	0.0001
diverse.meas	-2.8461	1.4287	-1.9921	0.0468
regionKK:Yearb.2010	-1.0022	0.4767	-2.1024	0.0359
regionKL:Yearb.2010	-1.0251	0.6069	-1.6890	0.0917
Effortjan:rep_designDietl Ditch	2.6100	0.7141	3.6549	0.0003
Effortjan:rep_designNatural	1.9024	0.4917	3.8693	0.0001
Effortjan:rep_designno bench	0.7098	0.5810	1.2217	0.2223
depth:diverse.meas	1.5652	0.6449	2.4269	0.0155

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	707.24	16		
depth:diverse.meas	713.45	15	6.2115	0.0127
Effort:rep_design	728.91	13	21.6746	0.0001
region:Year	712.96	14	5.7208	0.0572
rep_design	750.40	10	43.1589	<0.0001

3B (GLMM)

	Estimate	td. Error z	value	Pr(>|z|)
(Intercept)	1.6414	0.9421	1.7420	0.0815 .
Effortmar	-0.2514	0.5419	-0.4640	0.6427
regionKK	-0.2904	0.5529	-0.5250	0.5995
regionKL	0.0734	0.5899	0.1240	0.9010
Yearb.2010	0.4554	0.2989	1.5240	0.1276
rep_designa.Ten.one.slope	0.3438	0.5308	0.6480	0.5172
rep_designDietl Ditch	3.6263	0.8643	4.1960	<0.0001 ***
rep_designNatural	2.3191	0.5756	4.0290	0.0001 ***
depth	-1.4911	0.4071	-3.6620	0.0003 ***
diverse.meas	-2.8743	1.6192	-1.7750	0.0759 .
regionKK:Yearb.2010	-1.0936	0.4879	-2.2410	0.0250 *
regionKL:Yearb.2010	-0.9894	0.6323	-1.5650	0.1176
Effortmar:rep_designa.Ten.one.slope	0.7293	0.6795	1.0730	0.2831
Effortmar:rep_designDietl Ditch	-1.9580	0.8880	-2.2050	0.0275 *
Effortmar:rep_designNatural	-1.2197	0.6604	-1.8470	0.0648 .
depth:diverse.meas	1.5281	0.7078	2.1590	0.0309 *

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.3900	0.9687	1.4350	0.1513
Effortjan	0.2514	0.5418	0.4640	0.6427
regionKK	-0.2903	0.5529	-0.5250	0.5995
regionKL	0.0734	0.5899	0.1240	0.9010
Yearb.2010	0.4554	0.2989	1.5240	0.1276
rep_designa.Ten.one.slope	1.0731	0.4571	2.3480	0.0189 *
rep_designDietl Ditch	1.6682	0.6872	2.4270	0.0152 *
rep_designNatural	1.0993	0.4724	2.3270	0.0200 *
depth	-1.4911	0.4071	-3.6620	0.0003 ***
diverse.meas	-2.8743	1.6192	-1.7750	0.0759 .
regionKK:Yearb.2010	-1.0936	0.4879	-2.2410	0.0250 *
regionKL:Yearb.2010	-0.9894	0.6323	-1.5650	0.1176
Effortjan:rep_designa.Ten.one.slope	-0.7293	0.6795	-1.0730	0.2831
Effortjan:rep_designDietl Ditch	1.9580	0.8880	2.2050	0.0275 *
Effortjan:rep_designNatural	1.2197	0.6604	1.8470	0.0648 .
depth:diverse.meas	1.5281	0.7078	2.1590	0.0309 *

Likelihood ratio tests:	logLik	Df	Chisq	Pr(>Chisq)
Complete	-352.64	17		
depth:diverse.meas	-354.94	16	4.5950	0.0321
Effort:rep_design	-359.70	14	14.1170	0.0028
region:Year	-355.62	15	5.9536	0.0510
rep_design	-365.89	11	26.4980	0.0002

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	3.9604	1.0885	3.6380	0.0003 ***
Effortmar	-1.4711	0.3987	-3.6890	0.0002 ***
regionKK	-0.2903	0.5529	-0.5250	0.5995
regionKL	0.0734	0.5899	0.1240	0.9010
Yearb.2010	0.4554	0.2989	1.5240	0.1276
rep_designa.Ten.one.slope	-1.9753	0.5212	-3.7900	0.0002 ***
rep_designDietl Ditch	1.3072	0.6900	1.8940	0.0582 .
rep_designno bench	-2.3190	0.5756	-4.0290	0.0001 ***
depth	-1.4911	0.4071	-3.6620	0.0003 ***
diverse.meas	-2.8743	1.6192	-1.7750	0.0759 .
regionKK:Yearb.2010	-1.0936	0.4879	-2.2410	0.0250 *
regionKL:Yearb.2010	-0.9894	0.6323	-1.5650	0.1176
Effortmar:rep_designa.Ten.one.slope	1.9490	0.5734	3.3990	0.0007 ***
Effortmar:rep_designDietl Ditch	-0.7384	0.7740	-0.9540	0.3401
Effortmar:rep_designno bench	1.2197	0.6604	1.8470	0.0648 .
depth:diverse.meas	1.5281	0.7078	2.1590	0.0309 *

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	2.4893	1.0267	2.4250	0.0153 *
Effortjan	1.4711	0.3987	3.6890	0.0002 ***
regionKK	-0.2903	0.5529	-0.5250	0.5995
regionKL	0.0733	0.5899	0.1240	0.9011
Yearb.2010	0.4554	0.2989	1.5240	0.1276
rep_designa.no bench	-1.0993	0.4724	-2.3270	0.0200 *
rep_designa.Ten.one.slope	-0.0262	0.4140	-0.0630	0.9495
rep_designDietl Ditch	0.5689	0.5421	1.0490	0.2940
depth	-1.4911	0.4071	-3.6630	0.0003 ***
diverse.meas	-2.8743	1.6192	-1.7750	0.0759 .
regionKK:Yearb.2010	-1.0936	0.4879	-2.2410	0.0250 *
regionKL:Yearb.2010	-0.9893	0.6323	-1.5650	0.1177
Effortjan:rep_designa.no bench	-1.2197	0.6604	-1.8470	0.0648 .
Effortjan:rep_designa.Ten.one.slope	-1.9490	0.5734	-3.3990	0.0007 ***
Effortjan:rep_designDietl Ditch	0.7383	0.7740	0.9540	0.3401
depth:diverse.meas	1.5281	0.7078	2.1590	0.0309 *

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.0972	0.3117

Number of obs: 615, groups: Effort:Site, 30

Chinook salmon juveniles, March analysis, Step 1 (ckj_mar_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.7020	0.7346	-5.0400	<0.0001
Yearb.2010	2.7090	0.7439	3.6420	0.0003
rep_designDietl Ditch	-2.3990	1.0563	-2.2710	0.0237
rep_designNatural	-1.0540	0.4309	-2.4460	0.0149
rep_designno bench	-2.1320	0.7779	-2.7400	0.0064

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.7560	0.7611	-6.2490	<0.0001
Yearb.2010	2.7090	0.7439	3.6420	0.0003
rep_designa.Ten.one.slope	1.0540	0.4309	2.4460	0.0149
rep_designDietl Ditch	-1.3450	1.0646	-1.2630	0.2073
rep_designno bench	-1.0780	0.7891	-1.3660	0.1728

Note: effects due to region not estimable.

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	173.28	5		
rep_design	189.66	2	16.3774	0.0009
Year	199.24	4	25.9630	<0.0001

1B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.9598	0.8737	-4.5320	<0.0001	***
Yearb.2010	2.7989	0.7792	3.5920	0.0003	***
rep_designDietl Ditch	-2.4865	1.3488	-1.8430	0.0653	.
rep_designNatural	-1.1275	0.7002	-1.6100	0.1073	
rep_designno bench	-2.2479	1.0513	-2.1380	0.0325	*

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.0874	0.8700	-5.8480	<0.0001	***
Yearb.2010	2.7989	0.7792	3.5920	0.0003	***
rep_designa.Ten.one.slope	1.1275	0.7002	1.6100	0.1073	
rep_designDietl Ditch	-1.3590	1.3367	-1.0170	0.3093	
rep_designno bench	-1.1204	1.0356	-1.0820	0.2793	

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.6465	0.8041

Number of obs: 410, groups: Site, 15

Likelihood ratio tests:	LogLik	df	Chisq	Pr(Chisq)
Complete	-84.21	6		
rep_design	-87.50	3	6.5822	0.0865
Year	-97.49	5	26.5740	<0.0001

Chinook salmon juveniles, April analysis, Step 1 (ckj_apr_1)

1A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.7698	0.4279	-6.4723	<0.0001
regionKK	-1.0059	0.8206	-1.2258	0.2210
regionKL	0.2091	0.5896	0.3547	0.7230
Yearb.2010	1.2502	0.4148	3.0140	0.0027
rep_designDietl Ditch	2.2276	0.7579	2.9394	0.0035
rep_designNatural	0.7954	0.4367	1.8216	0.0693
rep_designno bench	0.8757	0.4190	2.0900	0.0373
regionKK:Yearb.2010	-0.4549	0.7240	-0.6283	0.5302
regionKL:Yearb.2010	-1.8396	0.8009	-2.2969	0.0222

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.9743	0.4499	-4.3880	<0.0001
regionKK	-1.0059	0.8206	-1.2258	0.2210
regionKL	0.2091	0.5896	0.3547	0.7230
Yearb.2010	1.2502	0.4148	3.0140	0.0027
rep_designa.Ten.one.slope	-0.7955	0.4367	-1.8216	0.0693
rep_designDietl Ditch	1.4322	0.6195	2.3118	0.0213
rep_designno bench	0.0802	0.3905	0.2054	0.8374
regionKK:Yearb.2010	-0.4549	0.7240	-0.6283	0.5302
regionKL:Yearb.2010	-1.8396	0.8009	-2.2969	0.0222

Likelihood ratio tests:	Deviance	df	LRT	Pr(>Chisq)
Complete	331.87	9		
region:Year	337.30	7	5.4282	0.0663
rep_design	343.19	6	11.3241	0.0101

1B (GLMM)

	Estimate S	td. Error z	value	Pr(>|z|)	
(Intercept)	-2.8105	0.4849	-5.7970	<0.0001	***
regionKK	-1.0441	0.9252	-1.1290	0.2591	
regionKL	0.0719	0.6861	0.1050	0.9166	
Yearb.2010	1.2272	0.4199	2.9230	0.0035	**
rep_designDietl Ditch	2.2139	0.9465	2.3390	0.0193	*
rep_designNatural	0.7913	0.5569	1.4210	0.1554	
rep_designno bench	0.9672	0.5546	1.7440	0.0812	.
regionKK:Yearb.2010	-0.3976	0.7345	-0.5410	0.5883	
regionKL:Yearb.2010	-1.7938	0.8170	-2.1950	0.0281	*

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.0192	0.5214	-3.8730	0.0001	***
regionKK	-1.0442	0.9252	-1.1290	0.2590	
regionKL	0.0718	0.6861	0.1050	0.9166	
Yearb.2010	1.2272	0.4199	2.9230	0.0035	**
rep_designa.Ten.one.slope	-0.7913	0.5569	-1.4210	0.1554	
rep_designDietl Ditch	1.4226	0.7653	1.8590	0.0630	.
rep_designno bench	0.1759	0.5155	0.3410	0.7329	
regionKK:Yearb.2010	-0.3976	0.7345	-0.5410	0.5883	
regionKL:Yearb.2010	-1.7938	0.8170	-2.1950	0.0281	*

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.8432	0.5018	-3.6730	0.0002	***
regionKK	-1.0441	0.9252	-1.1290	0.2591	
regionKL	0.0719	0.6861	0.1050	0.9166	
Yearb.2010	1.2272	0.4199	2.9230	0.0035	**
rep_designa.Ten.one.slope	-0.9672	0.5546	-1.7440	0.0812	.
rep_designDietl Ditch	1.2466	0.9227	1.3510	0.1767	
rep_designNatural	-0.1759	0.5155	-0.3410	0.7329	
regionKK:Yearb.2010	-0.3976	0.7345	-0.5410	0.5883	
regionKL:Yearb.2010	-1.7938	0.8170	-2.1950	0.0281	*

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.1861	0.4314

Number of obs: 400, groups: Site, 15

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.5966	0.9260	-0.6440	0.5194	
regionKK	-1.0441	0.9252	-1.1290	0.2591	
regionKL	0.0718	0.6861	0.1050	0.9166	
Yearb.2010	1.2272	0.4199	2.9220	0.0035	**
rep_designa.Natural	-1.4226	0.7653	-1.8590	0.0630	.
rep_designa.Ten.one.slope	-2.2139	0.9465	-2.3390	0.0193	*
rep_designno bench	-1.2467	0.9227	-1.3510	0.1767	
regionKK:Yearb.2010	-0.3976	0.7345	-0.5410	0.5883	
regionKL:Yearb.2010	-1.7937	0.8170	-2.1950	0.0281	*

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-164.90	10		
region:Year	-167.40	8	5.0027	0.0820
rep_design	-167.80	7	5.8023	0.1216

Chinook salmon juveniles, combined analysis, Step 1 (ckj_com_1)

Step 1A (Without interactions, GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.6692	0.3773	-7.0738	<0.0001
Effortmar	-0.9597	0.2390	-4.0157	0.0001
regionKK	0.4780	0.6277	0.7614	0.4466
regionKL	0.5480	0.5728	0.9567	0.3390
Yearb.2010	1.8271	0.3799	4.8096	0.0000
rep_designDietl Ditch	0.1817	0.5517	0.3294	0.7419
rep_designNatural	-0.0348	0.3466	-0.1005	0.9200
rep_designno bench	0.0428	0.3363	0.1273	0.8987
regionKK:Yearb.2010	-0.9437	0.6050	-1.5600	0.1192
regionKL:Yearb.2010	-2.3877	0.7687	-3.1063	0.0020

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	528.18	10		
region:Year	538.62	8	10.4390	0.0054
rep_design	528.49	7	0.3046	0.9592
Effort	545.43	9	17.2508	<0.0001

Step 1B (Without interactions, GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.8261	0.5310	-7.2050	<0.0001	***
Effortb.apr	1.1505	0.4061	2.8330	0.0046	**
regionKK	0.6291	0.8514	0.7390	0.4600	
regionKL	0.1778	0.7925	0.2240	0.8225	
Yearb.2010	1.8308	0.3920	4.6710	<0.0001	***
rep_designDietl Ditch	-0.3523	0.9591	-0.3670	0.7134	
rep_designNatural	-0.2026	0.5963	-0.3400	0.7340	
rep_designno bench	-0.0435	0.6042	-0.0720	0.9427	
regionKK:Yearb.2010	-0.8402	0.6265	-1.3410	0.1799	
regionKL:Yearb.2010	-2.3742	0.8120	-2.9240	0.0035	**

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-261.97	11		
region:Year	-267.04	9	10.1400	0.0063
rep_design	-262.12	8	0.3092	0.9583
Effort	-270.75	10	17.5670	<0.0001

1C (With interactions, GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.8598	0.4367	-6.5483	<0.0001
Effortmar	-1.2022	0.8421	-1.4277	0.1538
regionKK	0.2929	0.6588	0.4446	0.6567
regionKL	0.3898	0.5823	0.6694	0.5034
Yearb.2010	1.3713	0.4195	3.2692	0.0011
rep_designDietl Ditch	1.1130	0.6124	1.8175	0.0695
rep_designNatural	0.4805	0.4344	1.1061	0.2690
rep_designno bench	0.8835	0.4200	2.1038	0.0357
regionKK:Yearb.2010	-0.7236	0.6366	-1.1367	0.2560
regionKL:Yearb.2010	-2.2237	0.7830	-2.8401	0.0046
Effortmar:rep_designDietl Ditch	-3.1343	1.1565	-2.7101	0.0069
Effortmar:rep_designNatural	-1.0551	0.5858	-1.8011	0.0721
Effortmar:rep_designno bench	-2.7097	0.8849	-3.0622	0.0023
Effortmar:Yearb.2010	1.7285	0.8049	2.1476	0.0321

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.0620	0.7811	-5.2003	<0.0001
Effortapr	1.2022	0.8420	1.4279	0.1537
regionKK	0.2929	0.6588	0.4446	0.6567
regionKL	0.3898	0.5823	0.6694	0.5034
Yearb.2010	3.0999	0.7761	3.9940	0.0001
rep_designDietl Ditch	-2.0213	1.1373	-1.7772	0.0759
rep_designNatural	-0.5746	0.4737	-1.2130	0.2255
rep_designno bench	-1.8262	0.7835	-2.3309	0.0200
regionKK:Yearb.2010	-0.7236	0.6366	-1.1367	0.2560
regionKL:Yearb.2010	-2.2237	0.7830	-2.8400	0.0046
Effortapr:rep_designDietl Ditch	3.1343	1.1563	2.7107	0.0069
Effortapr:rep_designNatural	1.0551	0.5858	1.8011	0.0721
Effortapr:rep_designno bench	2.7097	0.8847	3.0628	0.0023
Effortapr:Yearb.2010	-1.7285	0.8049	-2.1475	0.0321

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	502.18	14		
Effort:Year	508.35	13	6.1712	0.0130
Effort:rep_design	520.63	11	18.4459	0.0004
region:Year	510.56	12	8.3753	0.0152
rep_design	520.86	8	18.6757	0.0047

1D (With interactions, GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.2109	0.8723	-4.8270	<0.0001	***
Effortb.apr	1.2549	0.9743	1.2880	0.1977	
regionKK	0.4929	0.7922	0.6220	0.5338	
regionKL	0.0710	0.7401	0.0960	0.9236	
Yearb.2010	3.1363	0.8144	3.8510	0.0001	***
rep_designDietl Ditch	-2.2063	1.3692	-1.6110	0.1071	
rep_designNatural	-0.6379	0.6820	-0.9350	0.3496	
rep_designno bench	-1.8590	0.9609	-1.9350	0.0530	.
regionKK:Yearb.2010	-0.7830	0.6502	-1.2040	0.2285	
regionKL:Yearb.2010	-2.1295	0.8204	-2.5960	0.0094	**
Effortb.apr:Yearb.2010	-1.7588	0.8372	-2.1010	0.0357	*
Effortb.apr:rep_designDietl Ditch	3.1408	1.4233	2.2070	0.0273	*
Effortb.apr:rep_designNatural	1.0623	0.8325	1.2760	0.2019	
Effortb.apr:rep_designno bench	2.9127	1.1499	2.5330	0.0113	*

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.9560	0.5372	-5.5030	<0.0001	***
Effortmar	-1.2549	0.9743	-1.2880	0.1977	
regionKK	0.4929	0.7922	0.6220	0.5338	
regionKL	0.0710	0.7401	0.0960	0.9236	
Yearb.2010	1.3775	0.4242	3.2470	0.0012	**
rep_designDietl Ditch	0.9345	0.9146	1.0220	0.3069	
rep_designNatural	0.4244	0.6230	0.6810	0.4957	
rep_designno bench	1.0537	0.6471	1.6280	0.1035	
regionKK:Yearb.2010	-0.7830	0.6502	-1.2040	0.2285	
regionKL:Yearb.2010	-2.1295	0.8204	-2.5960	0.0094	**
Effortmar:Yearb.2010	1.7588	0.8372	2.1010	0.0357	*
Effortmar:rep_designDietl Ditch	-3.1408	1.4233	-2.2070	0.0273	*
Effortmar:rep_designNatural	-1.0624	0.8325	-1.2760	0.2019	
Effortmar:rep_designno bench	-2.9130	1.1500	-2.5330	0.0113	*

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-247.34	15		
Effort:rep_design	-252.04	12	9.4108	0.0243
Effort:Year	-250.43	14	6.1738	0.0130
region:Year	-250.98	13	7.2884	0.0261

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.3555	0.5962

Number of obs: 810, groups: Effort:Site, 30

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-6.0700	1.1565	-5.2490	<0.0001	***
Effortb.apr	4.1675	1.2356	3.3730	0.0007	***
regionKK	0.4930	0.7922	0.6220	0.5338	
regionKL	0.0710	0.7401	0.0960	0.9236	
Yearb.2010	3.1363	0.8144	3.8510	0.0001	***
rep_designa.Ten.one.slope	1.8590	0.9609	1.9350	0.0530	.
rep_designDietl Ditch	-0.3473	1.5537	-0.2240	0.8231	
rep_designNatural	1.2211	1.0029	1.2180	0.2234	
regionKK:Yearb.2010	-0.7831	0.6502	-1.2040	0.2285	
regionKL:Yearb.2010	-2.1294	0.8204	-2.5960	0.0094	**
Effortb.apr:Yearb.2010	-1.7588	0.8372	-2.1010	0.0357	*
Effortb.apr:rep_designa.Ten.one.slope	-2.9126	1.1499	-2.5330	0.0113	*
Effortb.apr:rep_designDietl Ditch	0.2281	1.6160	0.1410	0.8878	
Effortb.apr:rep_designNatural	-1.8503	1.1246	-1.6450	0.0999	.

Chinook salmon juveniles, March analysis, Step 2 (ckj_mar_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-5.5691	0.9236	-6.0300	<0.0001
Yearb.2010	2.6274	0.7543	3.4830	0.0005
depth	-0.6669	0.2844	-2.3450	0.0195
bslope_sum	-0.3494	0.1491	-2.3430	0.0196
dom.size.IWM	0.9877	0.4032	2.4500	0.0147
avg.LWM.density	4.2606	3.2292	1.3190	0.1878
dom.size.IWM:avg.LWM.densit	-4.2663	2.2297	-1.9130	0.0564

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	153.64	7		
dom.size.IWM:avg.LWM.densit	158.19	6	4.5497	0.0329
bslope_sum	160.32	6	6.6773	0.0098
depth	160.46	6	6.8152	0.0090
Year	175.65	6	22.0122	<0.0001

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.5829	0.9344	-5.9750	<0.0001	***
Yearb.2010	2.6369	0.7619	3.4610	0.0005	***
depth	-0.6725	0.2934	-2.2920	0.0219	*
bslope_sum	-0.3411	0.1551	-2.2000	0.0278	*
dom.size.IWM	0.9653	0.4078	2.3670	0.0179	*
avg.LWM.density	4.1834	3.3030	1.2670	0.2053	
dom.size.IWM:avg.LWM.densit	-4.1538	2.2726	-1.8280	0.0676	.

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-76.79	8		
dom.size.IWM:avg.LWM.densit	-78.61	7	3.6465	0.0562
bslope_sum	-78.86	7	4.1514	0.0416
depth	-79.90	7	6.2365	0.0125
Year	-87.80	7	22.0220	<0.0001

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.0512	0.2262

Number of obs: 410, groups: Site, 15

Chinook salmon juveniles, April analysis, Step 2 (ckj_apr_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.3168	0.9230	-4.6770	<0.0001
regionKK	0.7389	0.6416	1.1517	0.2502
regionKL	-0.3677	0.6500	-0.5656	0.5720
Yearb.2010	1.2124	0.4215	2.8764	0.0042
shade_sum	-1.2978	0.5322	-2.4387	0.0152
depth	-0.7816	0.3328	-2.3483	0.0194
EV_Apr	3.8837	1.3002	2.9870	0.0030
dom.size.IWM	-0.5771	0.1337	-4.3165	<0.0001
avg.LWM.density	6.8946	2.9492	2.3378	0.0199
regionKK:Yearb.2010	-0.2540	0.7572	-0.3355	0.7374
regionKL:Yearb.2010	-1.0392	0.8680	-1.1973	0.2319
depth:avg.LWM.density	4.1616	2.0722	2.0083	0.0453

No warnings; t-tests ok

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	318.12	12		
depth:avg.LWM.density	322.29	11	4.1764	0.0410
region:Year	319.58	10	1.4610	0.4817
dom.size.IWM	338.63	11	20.5150	<0.0001
EV_Apr	327.62	11	9.5033	0.0021
shade_sum	324.34	11	6.2268	0.0126

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.3168	0.9232	-4.6760	<0.0001	***
regionKK	0.7389	0.6417	1.1510	0.2495	
regionKL	-0.3677	0.6501	-0.5660	0.5717	
Yearb.2010	1.2124	0.4216	2.8760	0.0040	**
shade_sum	-1.2978	0.5323	-2.4380	0.0148	*
depth	-0.7816	0.3328	-2.3480	0.0189	*
EV_Apr	3.8837	1.3006	2.9860	0.0028	**
dom.size.IWM	-0.5771	0.1337	-4.3160	<0.0001	***
avg.LWM.density	6.8945	2.9502	2.3370	0.0194	*
regionKK:Yearb.2010	-0.2540	0.7573	-0.3350	0.7373	
regionKL:Yearb.2010	-1.0392	0.8681	-1.1970	0.2313	
depth:avg.LWM.density	4.1614	2.0719	2.0080	0.0446	*

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-159.06	13		
depth:avg.LWM.density	-161.15	12	4.1764	0.0410
depth	-162.23	11	6.3367	0.0421
avg.LWM.density	-162.07	11	6.0231	0.0492
region:Year	-159.79	11	1.4610	0.4817
dom.size.IWM	-166.24	12	14.3560	0.0002
EV_Apr	-163.42	12	8.7286	0.0031
shade_sum	-162.17	12	6.2204	0.0126

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0	0

Number of obs: 400, groups: Site, 15

Chinook salmon juveniles, combined analysis, Step 2 (ckj_com_2)

2A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.1348	0.8128	-5.0869	<0.0001
Effortmar	-2.3455	0.7601	-3.0856	0.0021
regionKK	0.6665	0.5628	1.1843	0.2366
regionKL	0.1078	0.6307	0.1709	0.8643
Yearb.2010	1.3498	0.4119	3.2768	0.0011
depth	-1.0081	0.3053	-3.3024	0.0010
EV_Apr	2.9735	1.1069	2.6863	0.0074
bslope_sum	-0.1527	0.0677	-2.2577	0.0242
dom.size.IWM	-0.1568	0.0908	-1.7270	0.0846
avg.LWM.density	4.5229	2.5960	1.7422	0.0819
regionKK:Yearb.2010	-1.1265	0.6218	-1.8115	0.0704
regionKL:Yearb.2010	-1.3117	0.8338	-1.5732	0.1161
Effortmar:Yearb.2010	1.7801	0.8063	2.2078	0.0275
depth:avg.LWM.density	4.2583	1.9121	2.2270	0.0262

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	501.29	14		
depth:avg.LWM.density	506.40	13	5.1102	0.0238
dom.size.IWM	504.21	13	2.9182	0.0876
bslope_sum	506.70	13	5.4052	0.0201
EV_Apr	508.64	13	7.3466	0.0067
depth	514.10	13	12.8054	0.0003

2B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.2183	0.9417	-1.2940	0.1957	
Effortmar	-2.5036	0.8347	-2.9990	0.0027	**
regionKK	0.5548	0.6960	0.7970	0.4254	
regionKL	-0.0779	0.8301	-0.0940	0.9253	
Yearb.2010	1.3458	0.4224	3.1860	0.0014	**
depth	-0.7575	0.3215	-2.3560	0.0185	*
EV_Apr	1.9867	1.5570	1.2760	0.2020	
bslope_sum	-0.1424	0.1001	-1.4220	0.1549	
dom.size.IWM	-0.0749	0.1328	-0.5640	0.5727	
avg.LWM.density	-2.6493	3.6778	-0.7200	0.4713	
regionKK:Yearb.2010	-1.1009	0.6488	-1.6970	0.0898	.
regionKL:Yearb.2010	-1.4962	0.8662	-1.7270	0.0841	.
Effortmar:Yearb.2010	1.8363	0.8442	2.1750	0.0296	*
depth:avg.LWM.density	2.3361	2.1828	1.0700	0.2845	

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-247.19	15		
depth:avg.LWM.density	-247.71	14	1.0275	0.3107
dom.size.IWM	-247.34	14	0.2894	0.5906
bslope_sum	-248.13	14	1.8722	0.1712
EV_Apr	-247.90	14	1.4083	0.2353
Effort:Year	-250.53	14	6.6674	0.0098
region:Year	-249.62	13	4.8608	0.0880

Random effects:

Groups	Name	Variance	Std.Dev.
Effort:Site	(Intercept)	0.3947	0.6282

Number of obs: 810, groups: Effort:Site, 30

Chinook salmon juveniles, March analysis, Step 3 (ckj_mar_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.5988	1.0083	-4.5611	<0.0001
Yearb.2010	2.7322	0.7613	3.5889	0.0004
rep_designDietl Ditch	-2.0629	1.1234	-1.8363	0.0671
rep_designNatural	-0.7835	0.5956	-1.3155	0.1891
rep_designno bench	-1.4011	0.8754	-1.6006	0.1103
depth	-0.5230	0.3368	-1.5530	0.1212
bslope_sum	-0.4172	0.1509	-2.7656	0.0059
dom.size.IWM	0.8704	0.4091	2.1275	0.0340
avg.LWM.density	2.8773	3.3321	0.8635	0.3884
dom.size.IWM:avg.LWM.density	-4.3116	2.2715	-1.8982	0.0584

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-5.3823	0.9570	-5.6242	<0.0001
Yearb.2010	2.7322	0.7613	3.5889	0.0004
rep_designa.Ten.one.slope	0.7835	0.5956	1.3155	0.1891
rep_designDietl Ditch	-1.2794	1.1763	-1.0876	0.2774
rep_designno bench	-0.6176	0.9264	-0.6667	0.5053
depth	-0.5230	0.3368	-1.5530	0.1212
bslope_sum	-0.4172	0.1509	-2.7656	0.0059
dom.size.IWM	0.8704	0.4091	2.1275	0.0340
avg.LWM.density	2.8773	3.3321	0.8635	0.3884
dom.size.IWM:avg.LWM.density	-4.3116	2.2715	-1.8982	0.0584

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	146.93	10		
dom.size.IWM:avg.LWM.density	151.38	9	4.4546	0.0348
bslope_sum	156.40	9	9.4672	0.0021
depth	149.87	9	2.9449	0.0861
rep_design	153.64	7	6.7137	0.0816
Year	170.24	9	23.3137	<0.0001

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-5.9999	1.1138	-5.3871	<0.0001
Yearb.2010	2.7322	0.7613	3.5889	0.0004
rep_designa.Ten.one.slope	1.4011	0.8754	1.6007	0.1102
rep_designDietl Ditch	-0.6617	1.3119	-0.5044	0.6143
rep_designNatural	0.6176	0.9264	0.6667	0.5053
depth	-0.5230	0.3368	-1.5530	0.1212
bslope_sum	-0.4172	0.1509	-2.7656	0.0059
dom.size.IWM	0.8704	0.4091	2.1275	0.0340
avg.LWM.density	2.8773	3.3321	0.8635	0.3884
dom.size.IWM:avg.LWM.density	-4.3116	2.2715	-1.8982	0.0584

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.5987	1.0083	-4.5610	<0.0001	***
Yearb.2010	2.7322	0.7616	3.5880	0.0003	***
rep_designDietl Ditch	-2.0629	1.1236	-1.8360	0.0664	.
rep_designNatural	-0.7835	0.5957	-1.3150	0.1884	
rep_designno bench	-1.4011	0.8755	-1.6000	0.1095	
depth	-0.5230	0.3368	-1.5530	0.1204	
bslope_sum	-0.4172	0.1509	-2.7640	0.0057	**
dom.size.IWM	0.8704	0.4090	2.1280	0.0333	*
avg.LWM.density	2.8773	3.3323	0.8630	0.3879	
dom.size.IWM:avg.LWM.density	-4.3117	2.2711	-1.8980	0.0576	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.3823	0.9570	-5.6240	<0.0001	***
Yearb.2010	2.7322	0.7616	3.5880	0.0003	***
rep_designa.Ten.one.slope	0.7835	0.5957	1.3150	0.1884	
rep_designDietl Ditch	-1.2793	1.1765	-1.0870	0.2769	
rep_designno bench	-0.6176	0.9265	-0.6670	0.5051	
depth	-0.5230	0.3368	-1.5530	0.1204	
bslope_sum	-0.4172	0.1509	-2.7640	0.0057	**
dom.size.IWM	0.8704	0.4090	2.1280	0.0333	*
avg.LWM.density	2.8773	3.3323	0.8630	0.3879	
dom.size.IWM:avg.LWM.density	-4.3117	2.2711	-1.8980	0.0576	.

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-73.46	11		
dom.size.IWM:avg.LWM.density	-75.69	10	4.4546	0.0348
bslope_sum	-77.65	10	8.3606	0.0038
depth	-74.94	10	2.9449	0.0862
rep_design	-76.79	8	6.6403	0.0843
Year	-85.12	10	23.3140	<0.0001

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	6.53E-14	2.56E-07

Number of obs: 410, groups: Site, 15

Chinook salmon juveniles, April analysis, Step 3 (ckj_apr_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.1860	0.6917	-6.0516	<0.0001
regionKK	-1.1099	0.8110	-1.3686	0.1719
regionKL	-0.0757	0.6068	-0.1248	0.9008
Yearb.2010	1.2109	0.4222	2.8679	0.0044
rep_designDietl Ditch	3.0637	0.8281	3.6997	0.0002
rep_designNatural	1.2534	0.4695	2.6697	0.0079
rep_designno bench	1.5318	0.4860	3.1517	0.0017
depth	-0.5441	0.2308	-2.3577	0.0189
EV_Apr	2.1822	0.8742	2.4962	0.0130
regionKK:Yearb.2010	-0.6990	0.7408	-0.9435	0.3460
regionKL:Yearb.2010	-1.2072	0.8441	-1.4302	0.1535

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.6541	0.5143	-5.1608	<0.0001
regionKK	-1.1099	0.8110	-1.3686	0.1719
regionKL	-0.0757	0.6068	-0.1248	0.9008
Yearb.2010	1.2109	0.4222	2.8679	0.0044
rep_designa.Ten.one.slope	-1.5318	0.4861	-3.1516	0.0018
rep_designDietl Ditch	1.5318	0.7859	1.9492	0.0520
rep_designNatural	-0.2784	0.3954	-0.7041	0.4818
depth	-0.5441	0.2308	-2.3577	0.0189
EV_Apr	2.1822	0.8742	2.4963	0.0130
regionKK:Yearb.2010	-0.6990	0.7408	-0.9435	0.3460
regionKL:Yearb.2010	-1.2072	0.8441	-1.4302	0.1535

No warnings.

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	321.89	11		
region:Year	324.36	9	2.4772	0.2898
EV_Apr	328.30	10	6.4104	0.0113
depth	327.87	10	5.9860	0.0144
rep_design	341.18	8	19.2945	0.0002

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.1860	0.6918	-6.0510	<0.0001	***
regionKK	-1.1099	0.8111	-1.3680	0.1712	
regionKL	-0.0757	0.6069	-0.1250	0.9007	
Yearb.2010	1.2109	0.4223	2.8670	0.0041	**
rep_designDietl Ditch	3.0637	0.8284	3.6990	0.0002	***
rep_designNatural	1.2534	0.4696	2.6690	0.0076	**
rep_designno bench	1.5318	0.4861	3.1510	0.0016	**
depth	-0.5441	0.2308	-2.3580	0.0184	*
EV_Apr	2.1822	0.8744	2.4960	0.0126	*
regionKK:Yearb.2010	-0.6990	0.7409	-0.9430	0.3455	
regionKL:Yearb.2010	-1.2072	0.8442	-1.4300	0.1527	

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.9325	0.5728	-5.1190	<0.0001	***
regionKK	-1.1099	0.8111	-1.3680	0.1712	
regionKL	-0.0757	0.6069	-0.1250	0.9007	
Yearb.2010	1.2109	0.4223	2.8670	0.0041	**
rep_designa.Ten.one.slope	-1.2534	0.4696	-2.6690	0.0076	**
rep_designDietl Ditch	1.8102	0.6878	2.6320	0.0085	**
rep_designno bench	0.2784	0.3954	0.7040	0.4814	
depth	-0.5441	0.2308	-2.3580	0.0184	*
EV_Apr	2.1822	0.8744	2.4960	0.0126	*
regionKK:Yearb.2010	-0.6990	0.7409	-0.9430	0.3455	
regionKL:Yearb.2010	-1.2072	0.8442	-1.4300	0.1527	

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.6541	0.5144	-5.1600	<0.0001	***
regionKK	-1.1099	0.8111	-1.3680	0.1712	
regionKL	-0.0757	0.6069	-0.1250	0.9007	
Yearb.2010	1.2109	0.4223	2.8670	0.0041	**
rep_designa.Ten.one.slope	-1.5318	0.4861	-3.1510	0.0016	**
rep_designDietl Ditch	1.5318	0.7860	1.9490	0.0513	.
rep_designNatural	-0.2784	0.3954	-0.7040	0.4814	
depth	-0.5441	0.2308	-2.3580	0.0184	*
EV_Apr	2.1822	0.8744	2.4960	0.0126	*
regionKK:Yearb.2010	-0.6990	0.7409	-0.9430	0.3455	
regionKL:Yearb.2010	-1.2074	0.8442	-1.4300	0.1527	

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.1223	0.8751	-1.2830	0.1996	
regionKK	-1.1099	0.8111	-1.3680	0.1712	
regionKL	-0.0757	0.6069	-0.1250	0.9007	
Yearb.2010	1.2109	0.4223	2.8670	0.0041	**
rep_designa.Natural	-1.8102	0.6878	-2.6320	0.0085	**
rep_designa.Ten.one.slope	-3.0637	0.8284	-3.6990	0.0002	***
rep_designno bench	-1.5318	0.7860	-1.9490	0.0513	.
depth	-0.5441	0.2308	-2.3580	0.0184	*
EV_Apr	2.1823	0.8744	2.4960	0.0126	*
regionKK:Yearb.2010	-0.6990	0.7409	-0.9430	0.3455	
regionKL:Yearb.2010	-1.2073	0.8442	-1.4300	0.1527	

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	7.94E-10	2.82E-05

Number of obs: 400, groups: Site, 15

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-160.94	12		
region:Year	-162.18	10	2.4772	0.2898
EV_Apr	-163.36	11	4.8356	0.0279
depth	-163.64	11	5.4028	0.0201
rep_design	-166.86	9	11.8330	0.0080

Chinook salmon juveniles, combined analysis, Step 3 (ckj_com_3)

3A (GLM)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.9684	0.6241	-6.3586	<0.0001
Effortmar	-0.9744	0.8514	-1.1444	0.2528
regionKK	-0.0438	0.6572	-0.0667	0.9468
regionKL	0.0111	0.6208	0.0178	0.9858
Yearb.2010	1.3214	0.4268	3.0963	0.0020
rep_designDietl Ditch	1.8331	0.6853	2.6748	0.0076
rep_designNatural	0.8176	0.4517	1.8101	0.0707
rep_designno bench	1.1976	0.4610	2.5981	0.0095
depth	-0.5854	0.1904	-3.0752	0.0022
EV_Apr	1.8981	0.8338	2.2765	0.0231
bslope_sum	-0.1388	0.0710	-1.9546	0.0510
regionKK:Yearb.2010	-0.9057	0.6422	-1.4104	0.1588
regionKL:Yearb.2010	-1.5579	0.8187	-1.9029	0.0574
Effortmar:Yearb.2010	1.5900	0.8116	1.9591	0.0505
Effortmar:rep_designDietl Ditch	-3.2600	1.1666	-2.7944	0.0053
Effortmar:rep_designNatural	-1.0431	0.5938	-1.7567	0.0794
Effortmar:rep_designno bench	-2.7648	0.8960	-3.0856	0.0021

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.3095	0.8920	-3.7102	0.0002
Effortapr	0.9744	0.8514	1.1445	0.2528
regionKK	-0.0438	0.6572	-0.0667	0.9468
regionKL	0.0111	0.6208	0.0178	0.9858
Yearb.2010	2.9114	0.7808	3.7286	0.0002
rep_designDietl Ditch	-1.4269	1.1674	-1.2223	0.2220
rep_designNatural	-0.2255	0.4945	-0.4560	0.6485
rep_designno bench	-1.5672	0.8089	-1.9373	0.0531
depth	-0.5854	0.1902	-3.0773	0.0022
EV_Apr	1.8981	0.8338	2.2765	0.0231
bslope_sum	-0.1388	0.0709	-1.9564	0.0508
regionKK:Yearb.2010	-0.9057	0.6422	-1.4103	0.1588
regionKL:Yearb.2010	-1.5579	0.8187	-1.9029	0.0574
Effortapr:Yearb.2010	-1.5900	0.8116	-1.9591	0.0505
Effortapr:rep_designDietl Ditch	3.2600	1.1664	2.7950	0.0053
Effortapr:rep_designNatural	1.0431	0.5938	1.7567	0.0794
Effortapr:rep_designno bench	2.7648	0.8959	3.0862	0.0021

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-3.5350	0.8977	-3.9379	0.0001
Effortapr	2.0175	0.8192	2.4627	0.0140
regionKK	-0.0438	0.6572	-0.0667	0.9468
regionKL	0.0111	0.6208	0.0178	0.9858
Yearb.2010	2.9114	0.7808	3.7286	0.0002
rep_designa.Ten.one.slope	0.2255	0.4946	0.4560	0.6485
rep_designDietl Ditch	-1.2014	1.1242	-1.0687	0.2855
rep_designno bench	-1.3416	0.8299	-1.6167	0.1063
depth	-0.5854	0.1902	-3.0773	0.0022
EV_Apr	1.8981	0.8338	2.2765	0.0231
bslope_sum	-0.1388	0.0709	-1.9564	0.0508
regionKK:Yearb.2010	-0.9057	0.6422	-1.4103	0.1588
regionKL:Yearb.2010	-1.5579	0.8187	-1.9029	0.0574
Effortapr:Yearb.2010	-1.5900	0.8115	-1.9592	0.0504
Effortapr:rep_designa.Ten.one.slope	-1.0431	0.5938	-1.7567	0.0794
Effortapr:rep_designDietlDitch	2.2169	1.1550	1.9195	0.0553
Effortapr:rep_designno bench	1.7217	0.8846	1.9462	0.0520

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-4.7364	1.4339	-3.3032	0.0010
Effortapr	4.2344	1.2904	3.2816	0.0011
regionKK	-0.0438	0.6572	-0.0667	0.9468
regionKL	0.0111	0.6208	0.0178	0.9858
Yearb.2010	2.9114	0.7808	3.7285	0.0002
rep_designa.Natural	1.2014	1.1241	1.0687	0.2855
rep_designa.Ten.one.slope	1.4269	1.1672	1.2225	0.2219
rep_designno bench	-0.1403	1.3328	-0.1052	0.9162
depth	-0.5854	0.1902	-3.0773	0.0022
EV_Apr	1.8981	0.8338	2.2765	0.0231
bslope_sum	-0.1388	0.0709	-1.9564	0.0508
regionKK:Yearb.2010	-0.9057	0.6422	-1.4104	0.1588
regionKL:Yearb.2010	-1.5579	0.8187	-1.9029	0.0574
Effortapr:Yearb.2010	-1.5900	0.8114	-1.9595	0.0504
Effortapr:rep_designa.Natural	-2.2169	1.1553	-1.9190	0.0553
Effortapr:rep_designa.Ten.one.slope	-3.2600	1.1668	-2.7939	0.0053
Effortapr:rep_designno bench	-0.4952	1.3418	-0.3691	0.7122

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.5175	0.5865	-2.5875	0.0098
Effortmar	-2.0175	0.8194	-2.4622	0.0140
regionKK	-0.0438	0.6572	-0.0667	0.9468
regionKL	0.0111	0.6208	0.0178	0.9858
Yearb.2010	1.3214	0.4268	3.0963	0.0020
rep_designa.Ten.one.slope	-0.8176	0.4517	-1.8101	0.0707
rep_designDietl Ditch	1.0155	0.5560	1.8264	0.0682
rep_designno bench	0.3800	0.4116	0.9233	0.3562
depth	-0.5854	0.1902	-3.0772	0.0022
EV_Apr	1.8981	0.8338	2.2765	0.0231
bslope_sum	-0.1388	0.0709	-1.9564	0.0508
regionKK:Yearb.2010	-0.9057	0.6422	-1.4104	0.1588
regionKL:Yearb.2010	-1.5579	0.8187	-1.9029	0.0574
Effortmar:Yearb.2010	1.5900	0.8116	1.9591	0.0504
Effortmar:rep_designa.Ten.one.slope	1.0431	0.5938	1.7567	0.0794
Effortmar:rep_designDietl Ditch	-2.2169	1.1551	-1.9193	0.0553
Effortmar:rep_designno bench	-1.7217	0.8847	-1.9460	0.0520

Likelihood ratio tests:	Deviance	Df	LRT	Pr(>Chisq)
Complete	486.46	17		
Effort:rep_design	505.61	14	19.1477	0.0003
Effort:Year	491.44	16	4.9780	0.0257
region:Year	491.05	15	4.5895	0.1008
bslope_sum	490.48	16	4.0262	0.0448
EV_Apr	491.82	16	5.3619	0.0206
depth	496.86	16	10.3978	0.0013

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-1.1375	0.5393	-2.1091	0.0353
Effortmar	-3.7392	1.0725	-3.4864	0.0005
regionKK	-0.0438	0.6572	-0.0667	0.9468
regionKL	0.0111	0.6208	0.0178	0.9858
Yearb.2010	1.3214	0.4268	3.0963	0.0020
rep_designa.Ten.one.slope	-1.1976	0.4610	-2.5981	0.0095
rep_designDietl Ditch	0.6355	0.6403	0.9925	0.3213
rep_designNatural	-0.3800	0.4116	-0.9233	0.3562
depth	-0.5854	0.1902	-3.0772	0.0022
EV_Apr	1.8981	0.8338	2.2765	0.0231
bslope_sum	-0.1388	0.0709	-1.9564	0.0508
regionKK:Yearb.2010	-0.9057	0.6422	-1.4104	0.1588
regionKL:Yearb.2010	-1.5579	0.8187	-1.9029	0.0574
Effortmar:Yearb.2010	1.5900	0.8116	1.9591	0.0504
Effortmar:rep_designa.Ten.one.slope	2.7648	0.8959	3.0862	0.0021
Effortmar:rep_designDietl Ditch	-0.4952	1.3418	-0.3691	0.7122
Effortmar:rep_designNatural	1.7217	0.8846	1.9463	0.0520

3B (GLMM)

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.4869	0.9764	-3.5710	0.0004	***
Effortb.apr	1.1138	0.9268	1.2020	0.2295	
regionKK	0.1089	0.7333	0.1490	0.8819	
regionKL	-0.1360	0.7286	-0.1870	0.8519	
Yearb.2010	3.0183	0.8100	3.7260	0.0002	***
rep_designDietl Ditch	-1.5690	1.2954	-1.2110	0.2258	
rep_designNatural	-0.2722	0.6161	-0.4420	0.6586	
rep_designno bench	-1.5231	0.9103	-1.6730	0.0943	.
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6517	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8388	-1.9020	0.0572	.
Effortb.apr:Yearb.2010	-1.7035	0.8337	-2.0430	0.0410	*
Effortb.apr:rep_designDietl Ditch	3.2208	1.3136	2.4520	0.0142	*
Effortb.apr:rep_designNatural	1.0195	0.7309	1.3950	0.1631	
Effortb.apr:rep_designno bench	2.7816	1.0365	2.6840	0.0073	**

Likelihood ratio tests:	LogLike	Df	Chisq	Pr(>Chisq)
Complete	-242.20	18		
Effort:rep_design	-247.68	15	10.9590	0.0120
Effort:Year	-245.01	17	5.6254	0.0177
region:Year	-244.56	16	4.7290	0.0940
bslope_sum	-243.27	17	2.1445	0.1431
EV_Apr	-243.31	17	2.2247	0.1358
depth	-246.31	17	8.2237	0.0041

Random effects:

Groups	Name	Variance	Std.Dev.
Site	(Intercept)	0.1807	0.4251

Number of obs: 810, groups: Effort:Site, 30

Updated on 25 October 2010

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.3731	0.7024	-3.3780	0.0007	***
Effortmar	-1.1139	0.9268	-1.2020	0.2294	
regionKK	0.1089	0.7333	0.1490	0.8819	
regionKL	-0.1360	0.7285	-0.1870	0.8519	
Yearb.2010	1.3148	0.4285	3.0680	0.0022	**
rep_designDietl Ditch	1.6519	0.8448	1.9550	0.0506	.
rep_designNatural	0.7473	0.5607	1.3330	0.1826	
rep_designno bench	1.2586	0.5971	2.1080	0.0350	*
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6516	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8387	-1.9020	0.0572	.
Effortmar:Yearb.2010	1.7035	0.8337	2.0430	0.0410	*
Effortmar:rep_designDietl Ditch	-3.2208	1.3136	-2.4520	0.0142	*
Effortmar:rep_designNatural	-1.0195	0.7309	-1.3950	0.1631	
Effortmar:rep_designno bench	-2.7817	1.0365	-2.6840	0.0073	**

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.6258	0.6663	-2.4400	0.0147	*
Effortmar	-2.1333	0.8841	-2.4130	0.0158	*
regionKK	0.1089	0.7333	0.1480	0.8819	
regionKL	-0.1360	0.7285	-0.1870	0.8519	
Yearb.2010	1.3148	0.4285	3.0680	0.0022	**
rep_designa.no bench	0.5114	0.5251	0.9740	0.3301	
rep_designa.Ten.one.slope	-0.7472	0.5607	-1.3330	0.1826	
rep_designDietl Ditch	0.9046	0.7086	1.2770	0.2018	
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6516	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8387	-1.9020	0.0572	.
Effortmar:Yearb.2010	1.7035	0.8337	2.0430	0.0410	*
Effortmar:rep_designa.no bench	-1.7622	1.0161	-1.7340	0.0829	.
Effortmar:rep_designa.Ten.one.slope	1.0194	0.7309	1.3950	0.1631	
Effortmar:rep_designDietl Ditch	-2.2017	1.2957	-1.6990	0.0893	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.0100	1.1858	-4.2250	<0.0001	***
Effortb.apr	3.8956	1.1696	3.3310	0.0009	***
regionKK	0.1089	0.7333	0.1490	0.8819	
regionKL	-0.1360	0.7286	-0.1870	0.8519	
Yearb.2010	3.0183	0.8100	3.7260	0.0002	***
rep_designa.Ten.one.slope	1.5231	0.9103	1.6730	0.0943	.
rep_designDietl Ditch	-0.0459	1.4694	-0.0310	0.9751	
rep_designNatural	1.2509	0.9329	1.3410	0.1800	
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7006	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6517	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8388	-1.9020	0.0572	.
Effortb.apr:Yearb.2010	-1.7035	0.8337	-2.0430	0.0410	*
Effortb.apr:rep_designa.Ten.one.slope	-2.7817	1.0365	-2.6840	0.0073	**
Effortb.apr:rep_designDietl Ditch	0.4391	1.4963	0.2930	0.7692	
Effortb.apr:rep_designNatural	-1.7624	1.0161	-1.7340	0.0828	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.1144	0.6308	-1.7670	0.0773	.
Effortmar	-3.8956	1.1696	-3.3310	0.0009	***
regionKK	0.1089	0.7333	0.1480	0.8820	
regionKL	-0.1360	0.7285	-0.1870	0.8519	
Yearb.2010	1.3148	0.4285	3.0680	0.0022	**
rep_designa.Ten.one.slope	-1.2587	0.5971	-2.1080	0.0350	*
rep_designDietl Ditch	0.3932	0.8206	0.4790	0.6318	
rep_designNatural	-0.5114	0.5251	-0.9740	0.3301	
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1305	
regionKK:Yearb.2010	-0.9379	0.6517	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5952	0.8387	-1.9020	0.0572	.
Effortmar:Yearb.2010	1.7035	0.8337	2.0430	0.0410	*
Effortmar:rep_designa.Ten.one.slope	2.7818	1.0365	2.6840	0.0073	**
Effortmar:rep_designDietl Ditch	-0.4391	1.4963	-0.2930	0.7692	
Effortmar:rep_designNatural	1.7623	1.0161	1.7340	0.0829	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.0559	1.5611	-3.2390	0.0012	**
Effortb.apr	4.3347	1.3987	3.0990	0.0019	**
regionKK	0.1089	0.7333	0.1490	0.8819	
regionKL	-0.1360	0.7286	-0.1870	0.8519	
Yearb.2010	3.0183	0.8100	3.7260	0.0002	***
rep_designa.no bench	0.0459	1.4694	0.0310	0.9751	
rep_designa.Ten.one.slope	1.5690	1.2954	1.2110	0.2258	
rep_designNatural	1.2968	1.2274	1.0570	0.2907	
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6517	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8388	-1.9020	0.0572	.
Effortb.apr:Yearb.2010	-1.7035	0.8337	-2.0430	0.0410	*
Effortb.apr:rep_designa.no bench	-0.4391	1.4963	-0.2930	0.7692	
Effortb.apr:rep_designa.Ten.one.slope	-3.2208	1.3136	-2.4520	0.0142	*
Effortb.apr:rep_designNatural	-2.2015	1.2956	-1.6990	0.0893	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.7212	1.0037	-0.7190	0.4724	
Effortmar	-4.3347	1.3987	-3.0990	0.0019	**
regionKK	0.1089	0.7333	0.1480	0.8819	
regionKL	-0.1360	0.7285	-0.1870	0.8519	
Yearb.2010	1.3148	0.4285	3.0680	0.0022	**
rep_designa.no bench	-0.3932	0.8206	-0.4790	0.6318	
rep_designa.Ten.one.slope	-1.6519	0.8449	-1.9550	0.0506	.
rep_designNatural	-0.9046	0.7086	-1.2770	0.2017	
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6517	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8387	-1.9020	0.0572	.
Effortmar:Yearb.2010	1.7035	0.8337	2.0430	0.0410	*
Effortmar:rep_designa.no bench	0.4391	1.4963	0.2940	0.7692	
Effortmar:rep_designa.Ten.one.slope	3.2208	1.3136	2.4520	0.0142	*
Effortmar:rep_designNatural	2.2013	1.2956	1.6990	0.0893	.

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.7591	0.9798	-3.8370	0.0001	***
Effortb.apr	2.1333	0.8841	2.4130	0.0158	*
regionKK	0.1089	0.7333	0.1490	0.8819	
regionKL	-0.1360	0.7285	-0.1870	0.8519	
Yearb.2010	3.0183	0.8100	3.7260	0.0002	***
rep_designa.no bench	-1.2509	0.9329	-1.3410	0.1800	
rep_designa.Ten.one.slope	0.2722	0.6161	0.4420	0.6586	
rep_designDietl Ditch	-1.2968	1.2274	-1.0570	0.2907	
depth	-0.5385	0.1954	-2.7560	0.0059	**
EV_Apr	1.7007	1.0611	1.6030	0.1090	
bslope_sum	-0.1343	0.0888	-1.5120	0.1304	
regionKK:Yearb.2010	-0.9379	0.6517	-1.4390	0.1501	
regionKL:Yearb.2010	-1.5951	0.8387	-1.9020	0.0572	.
Effortb.apr:Yearb.2010	-1.7035	0.8337	-2.0430	0.0410	*
Effortb.apr:rep_designa.no bench	1.7623	1.0161	1.7340	0.0829	.
Effortb.apr:rep_designa.Ten.one.slope	-1.0195	0.7309	-1.3950	0.1631	
Effortb.apr:rep_designDietl Ditch	2.2012	1.2956	1.6990	0.0893	.

APPENDIX G.

Summary Tables of Electrofishing GLM and GLMM Model Output

Chinook Fry

Table G-1. Chinook Fry Design Type Differences Summary, Step 1 Results Summary Based on GLM Model Fit.

Better/Worse	By Month		Combined		
	January	March	January	March	All
Better	Natural	Bench/10:1 Natural Dietl Ditch**	Dietl Ditch Natural	Bench/10:1 Natural	Natural Dietl Ditch Bench/10:1
Indistinguishable	Dietl Ditch*			Dietl Ditch*	
Worse	Bench/10:1 No Bench	No Bench	No Bench Bench/10:1	No Bench	No Bench

* p>0.10 when compared to best and also when compared to worst
** Inconclusive p-value (0.10<p<0.05), when compared to No Bench

Table G-2. Chinook Fry Design Type Differences Summary, Step 1 Results Summary Based on GLMM Model Fit.

Better/Worse	By Month		Combined		
	January	March	January	March	All
Better	Natural	Bench/10:1 Natural	Dietl Ditch Natural	Bench/10:1 Natural	Natural Bench/10:1
Indistinguishable	Dietl Ditch*	Dietl Ditch*		Dietl Ditch*	Dietl Ditch*
Worse	Bench/10:1 No Bench	No Bench	No Bench Bench/10:1	No Bench	No Bench

* p>0.10 when compared to best and also when compared to worst

Table G-3. Chinook Fry Design Type Differences Summary, Step 3 Results Summary Based on GLM Model Fit.

Better/Worse	By Month		Combined	
	January	March	January	March
Better	Dietl Ditch Natural	Natural Dietl Ditch*	Dietl Ditch	Dietl Ditch Bench/10:1 Natural
Intermediate		Bench/10:1	Natural	
Worse	No Bench Bench/10:1	No Bench	Bench/10:1 No Bench	No Bench

* Inconclusive p-value (0.10<p<0.05), when compared to Bench/10:1

Table G-4. Chinook Fry Design Type Differences Summary, Step 3 Results Summary Based on GLMM Model Fit.

Better/Worse	By Month		Combined	
	January	March	January	March
Better	Dietl Ditch Natural	Natural Dietl Ditch*	Dietl Ditch*	Dietl Ditch Natural Bench/10:1
Intermediate		Bench/10:1	Natural	
Worse	No Bench Bench/10:1	No Bench	Bench/10:1 No Bench	No Bench

* Inconclusive p-value when comparing to the intermediate category

Chinook Juveniles

Table G-5. Chinook Juvenile Design Type Differences Summary, Step 1 Results Summary Based on GLM Model Fit.

Better/Worse	By Month		Combined		
	March	April	March	April	All
Better	Bench/10:1	Dietl Ditch*	Bench/10:1*	Dietl Ditch* No Bench	No differences
Indistinguishable			Natural	Natural	
Intermediate		No Bench Natural*			
Worse	Natural No Bench Dietl Ditch	10:1	No Bench Dietl Ditch	Bench/10:1	

* April (DD when compared to NB, Natural when compared to 10:1); Combined/March (Bench/10:1 when compared to Dietl Ditch); Combined/April (DD vs. 10:1)

Table G-6. Chinook Juvenile Design Type Differences Summary, Step 1 Results Summary Based on GLMM Model Fit.

Better/Worse	By Month		Combined		
	March	April**	March	April	All
Better	Bench/10:1*	DD	Bench/10:1*	No differences	No differences
Indistinguishable	Natural		Natural Dietl Ditch		
Intermediate		No Bench Natural			
Worse	No Bench Dietl Ditch	10:1	No Bench		

* March (10:1 vs. DD); Combined/March (10:1 vs. No Bench); Combined/April (DD vs. 10:1)

** Note also that the April By Month analysis has a complication, and can be best expressed with the following indistinguishable pairs: DD&NB, NB&Natural, Natural/10:1. Or: DD was >10:1 and Natural (Inconclusive); NB was >10:1 (Inconclusive), not distinguishable from anything else; Natural was <DD (Inconclusive), not distinguishable from anything else; 10:1 was <DD and <NB (Inconclusive), not distinguishable from Natural

Table G-7. Chinook Juvenile Design Type Differences Summary, Step 3 Results Summary Based on GLM Model Fit.

Better/Worse	By Month		Combined	
	March	April	March	April**
Better	Bench/10:1*	Dietl Ditch*	Bench/10:1	Dietl Ditch*
Indistinguishable	Natural No Bench		Natural Dietl Ditch	
Intermediate		No Bench Natural		No Bench Natural*
Worse	Dietl Ditch	Bench/10:1	No Bench	Bench/10:1

* March (10:1 vs. DD), April (DD vs. NB), Combined/April (DD vs. Natural, Natural vs. 10:1)

** Combined/April was a little more complicated than indicated, and can be expressed in the following pairs of non-distinguishables: DD&NB, NB&Natural, DD&NB&Natural were all however >10:1 (with Natural being inconclusively better)

Table G-8. Chinook Juvenile Design Type Differences Summary, Step 3 Results Summary Based on GLMM Model Fit.

Better/Worse	By Month		Combined	
	March	April	March	April
Better	Bench/10:1*	Dietl Ditch	Bench/10:1	Dietl Ditch* No Bench
Indistinguishable	Natural No Bench	No Bench Natural	Natural Dietl Ditch	Natural
Intermediate				
Worse	Dietl Ditch	Bench/10:1	No Bench	Bench/10:1

* March (10:1 vs. DD); Combined/April (DD vs. 10:1)

Bass Predators

Table G-9. Bass Predator Design Type Differences Summary, Step 1 Results Summary Based on GLM Model Fit.

Better/Worse	By Month		Combined	
	January	March	April**	All
Better	No Bench*	No Bench Bench/10:1	Dietl Ditch	Dietl Ditch Bench/10:1 No Bench
Indistinguishable	Dietl Ditch Natural	Dietl Ditch		
Intermediate			Bench/10:1 No Bench	
Worse	Bench/10:1	Natural	Natural	Natural

* January (NB vs. 10:1)

** April results can be expressed with the following indistinguishable pairs: DD&Bench/10:1, Bench/10:1&No Bench

Table G-10. Bass Predator Design Type Differences Summary, Step 1 Results Summary Based on GLMM Model Fit.

Better/Worse	By Month		Combined	
	January	March	April**	All
Better	No differences	No Bench Bench/10:1*	Dietl Ditch*	Dietl Ditch No Bench Bench/10:1
Indistinguishable		Dietl Ditch		
Intermediate			Bench/10:1 No Bench*	
Worse		Natural	Natural	Natural

* March (Bench/10:1 vs. Natural); April (DD vs. NB; NB vs. Natural)

** April can best be expressed as the following indistinguishable pairs: DD&Bench/10:1, Bench/10:1&NB

Table G-11. Bass Predator Design Type Differences Summary, Step 3 Results Summary Based on GLM Model Fit.

Better/Worse	By Month		Combined	
	January	March	April**	All
Better	No Bench	No differences	Dietl Ditch	Dietl Ditch*
Indistinguishable	Dietl Ditch			
Intermediate			No Bench* Bench/10:1	
Worse	Natural Bench/10:1		Natural	No Bench Natural Bench/10:1

* April (NB vs. Natural); Combined/All (DD vs. NB)

** April best expressed as the following indistinguishable pairs: NB&Bench/10:1, Bench/10:1&Natural

Table G-12. Bass Predator Design Type Differences Summary, Step 3 Results Summary Based on GLMM Model Fit.

Better/Worse	By Month		Combined	
	January	March	April**	All
Better	No Bench	No differences	Dietl Ditch	Dietl Ditch
Indistinguishable	Dietl Ditch			No Bench
Intermediate			No Bench* Bench/10:1	
Worse	Natural Bench/10:1		Natural	Natural Bench/10:1

* April (NB vs. Natural)

** April results can be best expressed with the following indistinguishable pairs: NB&Bench/10:1, Bench/10:1&Natural

Chinook Fry

Table G-13. Chinook Fry Relations with Habitat Variables, Step 2 Results Summary Based on GLM Model Fit.

Sig/NS	January	March	Combined
Significant (p<0.05)	Submerged vegetation (+) %boulder/cobble (-) [Depth (-)] [Depth:IWM diversity (+)]	Submerged vegetation (+) %boulder/cobble (-) Bank slope (-) LWM density (+) [Depth (-)] Depth:IWM diversity (+)	Submerged vegetation (+) %boulder/cobble (-) [Depth (-)] [IWM diversity (-)] Depth:IWM diversity (+)
Not significant (p>0.10)	[IWM diversity (-)]	[IWM diversity (-)]	

Table G-14. Chinook Fry Relations with Habitat Variables, Step 2 Results Summary Based on GLMM Model Fit.

Sig/NS	January	March	Combined
Significant (p<0.05)	Submerged vegetation (+) %boulder/cobble (-) [Depth (-)] [Depth:IWM diversity (+)]	Bank slope (-) [Depth (-)]	[Depth (-)] [Depth:IWM diversity (+)]
Inconclusive (0.05<p<0.10)		Submerged vegetation (+) %boulder/cobble (-) [Depth:IWM diversity (+)]	Submerged vegetation (+) %boulder/cobble (-)
Not significant (p>0.10)	[IWM diversity (-)]	[IWM diversity (-)] LWM density (+)	[IWM diversity (-)]

Table G-15. Chinook Fry Relations with Habitat Variables, Step 3 Results Summary Based on GLM Model Fit.

Sig/NS	January	March	Combined
Significant (p<0.05)	Submerged vegetation (+) [Depth (-)] [Depth:IWM diversity (+)]	%boulder/cobble (+) Depth (-) Bank slope (-)	[Depth (-)] [IWM diversity (-)] [Depth:IWM diversity (+)]
Not significant (p>0.10)	[IWM diversity (-)]		

Table G-16. Chinook Fry Relations with Habitat Variables, Step 3 Results Summary Based on GLMM Model Fit.

Sig/NS	January	March	Combined
Significant (p<0.05)	Submerged vegetation (+) [Depth (-)] [Depth:IWM dversity (+)]	%boulder/cobble (+) Depth (-) Bank slope (-)	[Depth (-)] [Depth:IWM diversity (+)]
Inconclusive (0.05<p<0.10)			[IWM diversity (-)]
Not significant (p>0.10)	[IWM diversity (-)]		

Chinook Juveniles

Table G-17. Chinook Juvenile Relationships With Habitat Variables, Step 2 Results Summary Based on GLM Model Fit.

Sig/NS	March	April	Combined
Significant (p<0.05)	Depth (-) Bank slope (-) [IWM size (+)] [IWM size: LWM density (-)]	[Depth (-)] [LWM density (+)] [Depth:LWM density (+)] IWM size (-) Shade (-) Submerged vegetation (+)	Submerged vegetation (+) Bank slope (-) [Depth (-)] [Depth:LWM density (+)]
Inconclusive (0.05<p<0.10)			[LWM density (+)] IWM size (-)
Not significant (p>0.10)	[LWM density (+)]		

Table G-18. Chinook Juvenile Relationships With Habitat Variables, Step 2 Results Summary Based on GLMM Model Fit.

Sig/NS	March	April	Combined
Significant (p<0.05)	Depth (-) Bank slope (-) [IWM size (+)]	[Depth (-)] [LWM density (+)] [Depth:LWM density (+)] IWM size (-) Shade (-) Submerged vegetation (+)	[Depth (-)]
Inconclusive (0.05<p<0.10)	[IWM size: LWM density (-)]		
Not significant (p>0.10)	[LWM density (+)]		Submerged vegetation (+) Bank slope (-) IWM size (-) [LWM density (-)] [Depth:LWM density (+)]

Table G-19. Chinook Juvenile Relationships with Habitat Variables, Step 3 Results Summary Based on GLM Model Fit.

Sig/NS	March	April	Combined
Significant (p<0.05)	Bank slope (-) [IWM size (+)] [IWM size: LWM density (-)]	Depth (-) Submerged vegetation (+)	Submerged vegetation (+) Bank slope (-) Depth (-)
Inconclusive (0.05<p<0.10)	Depth (-)		
Not significant (p>0.10)	[LWM density (+)]		

Table G-20. Chinook Juvenile Relationships with Habitat Variables, Step 3 Results Summary Based on GLMM Model Fit.

Sig/NS	March	April	Combined
Significant (p<0.05)	Bank slope (-) [IWM size (+)] [IWM size: LWM density (-)]	Depth (-) Submerged vegetation (+)	Depth (-)
Inconclusive (0.05<p<0.10)	Depth (-)		
Not significant (p>0.10)	[LWM density (+)]		Submerged vegetation (+) Bank slope (-)

Bass Predators

Table G-21. Bass Predator Relationships With Habitat Variables, Step 2 Results Summary Based on GLM Model Fit.

Sig/NS	January	March	April	Combined
Significant (p<0.05)	Shade (-) [IWM size: LWM density (-)]	Shade (-) Bank slope (+) Aquatic vegetation (-) [IWM diversity (-)]	Bank slope (+) %boulder/cobble (+) Aquatic vegetation (+) [IWM size (-)] [IWM size: LWM density (+)] [Depth: IWM diversity (+)]	Bank slope (+) Shade (-) [IWM diversity (-)] [Depth: IWM diversity (+)]
Inconclusive (0.05<p<0.10)		[Depth: IWM diversity (-)]		
Not significant (p>0.10)	[IWM size (+)] [LWM density (-)]	[Depth (-)]	[LWM density (+)] [Depth (+)] [IWM diversity (+)]	[Depth (-)]

Table G-22. Bass Predator Relationships With Habitat Variables, Step 2 Results Summary Based on GLMM Model Fit (Note that Only Results from the Combined Changed from GLM to GLMM).

Sig/NS	January	March	April	Combined
Significant (p<0.05)	Shade (-) [IWM size: LWM density (-)]	Shade (-) Bank slope (+) Aquatic vegetation (-) [IWM diversity (-)]	Bank slope (+) %boulder/cobble (+) Aquatic vegetation (+) [IWM size (-)] [IWM size: LWM density (+)] [Depth: IWM diversity (+)]	Shade (-) [Depth: IWM diversity (+)]
Inconclusive (0.05<p<0.10)		[Depth: IWM diversity (-)]		[IWM diversity (-)] Bank slope (+)
Not significant (p>0.10)	[IWM size (+)] [LWM density (-)]	[Depth (-)]	[LWM density (+)] [Depth (+)] [IWM diversity (+)]	[Depth (-)]

Table G-23. Bass Predator Relationships With Habitat Variables, Step 3 Results Summary Based on GLM Model Fit.

Sig/NS	January	March	April	Combined
Significant (p<0.05)	[IWM size (+)] [IWM size: LWM density (-)]	IWM diversity (-)	Bank slope (+) [IWM size: LWM density (+)] [Depth: IWM diversity (+)]	Bank slope (+)
Inconclusive (0.05<p<0.10)		Shade (-)	[IWM size (-)]	Shade (-) [Depth: IWM diversity (+)]
Not significant (p>0.10)	[LWM density (-)]		[LWM density (-)] [Depth (-)] [IWM diversity (+)]	[Depth (-)] [IWM diversity (-)]

Table G-24. Bass Predator Relationships with Habitat Variables, Step 3 Results Summary Based on GLMM Model Fit (Note that Only Results from the Combined Changed from GLM to GLMM).

Sig/NS	January	March	April	Combined
Significant (p<0.05)	[IWM size (+)] [IWM size: LWM density (-)]	IWM diversity (-)	Bank slope (+) [IWM size: LWM density (+)] [Depth: IWM diversity (+)]	Shade (-) Bank slope (+)
Inconclusive (0.05<p<0.10)		Shade (-)	[IWM size (-)]	[Depth: IWM diversity (+)]
Not significant (p>0.10)	[LWM density (-)]		[LWM density (-)] [Depth (-)] [IWM diversity (+)]	[Depth (-)] [IWM diversity (-)]

APPENDIX H.

Telemetry GLM Raw Output

Appendix H. Telemetry GLM raw output

WORKSHEET LABELS ("spp_Analysis_Step")

Example: "sh_Upper3_1" means Steelhead results from analysis of data from the Upper 3 regions only, Step 1 (spatial/temporal).

Species	
sh	Steelhead
ck	Chinook salmon

Analysis	
Upper3	analysis of data from the Upper 3 regions only
All 4	analysis of data from all 4 regions

Step	
1	Design Type (1A/1B = "gamlss", 1C = GLMM)
2	Habitat variables (2A = "gamlss", 2B = GLMM)
3	Design type and habitat variables (3A = "gamlss", 3B = GLMM)

VARIABLES

Category	Variables	Efish	Telem/Upper3	Telem/All4	As named in "Summary of Output Appendix"	Description
Spatial/Temporal	release		X	X		Release location for Chinook (both analyses) and for steelhead (All4 analysis only)
	release2		X			Release location for steelhead (Upper3), combining a few categories: "SacElkLanding" = Elk River ramp, within the study area; "a.Other" = release locations above the study area
	mn.flow		X	X		Average daily flow from USGS gaging station on the first day of detection at a site
	region	X	X			As defined in text, "KL" = Knights Landing, "GB" = Garcia Bend, "KK" = Ko-Ket
	region2			X		"Upper" = Upper 3 regions; "RV" = Rio Vista (lowest region)
	fod_num		X	X		First date of detection at a site, numeric
	dr_num		X	X		Release date, numeric
	daynight		X	X		Day or night at first time of detection at a site, based on sunrise/sunset times
	Year	X				Year of electrofishing sampling effort
	Effort	X				Month of capture
Design Type	rep_design	X	X	X		Design type
Habitat	shade_sum	X	X	X	Shade	% shade at low elevation (summer) transect
	bslope_sum	X	X	X	Bank slope	Bank slope at low elevation (summer) transect
	BC_sum	X	X	X	%Boulder/Cobble	% Boulder/cobble at low elevation (summer) transect
	aq_sum	X	X	X	Aquatic vegetation	% Aquatic vegetation at low elevation (summer) transect
	iwm_dia_in			X	IWM diameter	Additional IWM measure at site-level
	jam_area_pft			X	Jam area	Additional IWM measure at site-level
	diversemeas	X	X		IWM diversity	summary measure based on IWM data collected at electrofishing points in April 2010
	avgLWMdensity	X	X		LWM density	average measure based on IWM data collected at electrofishing points in April 2010
	domsizeIWM	X	X		IWM size	summary measure (Dominant size) based on IWM data collected at electrofishing points in April 2010
	EV_Apr	X	X		Submerged vegetation	summary measure based on presence of submerged vegatation (presence defined as >10%) collected at electrofishing points in April 2010
	depth	X			Depth	depth measured at the stern for each electrofishing point

Chinook salmon, All 4, Step 1 (ck_All4_1)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.9683	15.3047	-0.1290	0.8977	
release3abvSA	-0.6519	0.2105	-3.0970	0.0020	**
release3SAabvFe	0.2279	0.3523	0.6470	0.5176	
release3SAblwAmer	0.3748	0.1827	2.0520	0.0402	*
fod_num	0.0187	0.0054	3.4520	0.0006	***
dr_num	-0.0184	0.0058	-3.1910	0.0014	**
daynightnight	0.4231	0.1140	3.7130	0.0002	***
rep_designBench_ten_to_1	-0.5774	0.1381	-4.1810	<0.0001	***
rep_designDietl Ditch	-0.6281	0.1653	-3.7990	0.0001	***
rep_designNo Bench	0.4748	0.2358	2.0130	0.0441	*
Log(theta)	-8.2304	15.3132	-0.5370	0.5909	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	11.2974	1.1611	9.7300	< 2e-16	***
release3abvSA	-0.4153	0.1565	-2.6530	0.0080	**
release3SAabvFe	0.4559	0.1653	2.7570	0.0058	**
release3SAblwAmer	0.0568	0.1786	0.3180	0.7505	
log10(fd.flow)	-3.1387	0.2540	-12.3570	< 2e-16	***
region2RV	1.9042	0.0642	29.6630	< 2e-16	***
fod_num	0.0071	0.0034	2.0940	0.0363	*
dr_num	-0.0083	0.0034	-2.4910	0.0128	*
daynightnight	-0.3372	0.0542	-6.2260	<0.0001	***
rep_designBench_ten_to_1	0.7715	0.0605	12.7460	< 2e-16	***
rep_designDietl Ditch	1.4048	0.0779	18.0390	< 2e-16	***
rep_designNo Bench	0.6099	0.0999	6.1050	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.3684	13.1973	-0.1790	0.8576	
release3abvSA	-0.6511	0.2105	-3.0930	0.0020	**
release3SAabvFe	0.2279	0.3521	0.6470	0.5174	
release3SAblwAmer	0.3758	0.1827	2.0570	0.0397	*
fod_num	0.0187	0.0054	3.4540	0.0006	***
dr_num	-0.0183	0.0058	-3.1900	0.0014	**
daynightnight	0.4233	0.1139	3.7150	0.0002	***
rep_design20.Natural	0.6281	0.1653	3.8000	0.0001	***
rep_design2Bench_ten_to_1	0.0508	0.1333	0.3810	0.7033	
rep_design2No Bench	1.1030	0.2357	4.6800	<0.0001	***
Log(theta)	-7.9992	13.2046	-0.6060	0.5447	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.7022	1.1636	10.9160	< 2e-16	***
release3abvSA	-0.4153	0.1565	-2.6530	0.0080	**
release3SAabvFe	0.4559	0.1653	2.7570	0.0058	**
release3SAblwAmer	0.0568	0.1786	0.3180	0.7505	
log10(fd.flow)	-3.1387	0.2540	-12.3570	< 2e-16	***
region2RV	1.9042	0.0642	29.6630	< 2e-16	***
fod_num	0.0071	0.0034	2.0940	0.0363	*
dr_num	-0.0083	0.0034	-2.4910	0.0128	*
daynightnight	-0.3372	0.0542	-6.2260	<0.0001	***
rep_design20.Natural	-1.4048	0.0779	-18.0390	< 2e-16	***
rep_design2Bench_ten_to_1	-0.6333	0.0677	-9.3580	< 2e-16	***
rep_design2No Bench	-0.7949	0.1024	-7.7640	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-2.4053	13.9449	-0.1720	0.8631	
release3abvSA	-0.6513	0.2105	-3.0940	0.0020	**
release3SAabvFe	0.2293	0.3524	0.6510	0.5153	
release3SAblwAmer	0.3756	0.1827	2.0560	0.0398	*
fod_num	0.0187	0.0054	3.4520	0.0006	***
dr_num	-0.0183	0.0058	-3.1900	0.0014	**
daynightnight	0.4233	0.1140	3.7150	0.0002	***
rep_designBT0.Natural	0.5774	0.1381	4.1810	<0.0001	***
rep_designBTDietl Ditch	-0.0508	0.1333	-0.3810	0.7035	
rep_designBTNo Bench	1.0530	0.2181	4.8280	<0.0001	***
Log(theta)	-8.0886	13.9523	-0.5800	0.5621	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.0689	1.1598	10.4060	< 2e-16	***
release3abvSA	-0.4153	0.1565	-2.6530	0.0080	**
release3SAabvFe	0.4559	0.1653	2.7570	0.0058	**
release3SAblwAmer	0.0568	0.1786	0.3180	0.7505	
log10(fd.flow)	-3.1387	0.2540	-12.3570	< 2e-16	***
region2RV	1.9042	0.0642	29.6630	< 2e-16	***
fod_num	0.0071	0.0034	2.0940	0.0363	*
dr_num	-0.0083	0.0034	-2.4910	0.0128	*
daynightnight	-0.3372	0.0542	-6.2260	<0.0001	***
rep_designBT0.Natural	-0.7715	0.0605	-12.7460	< 2e-16	***
rep_designBTDietl Ditch	0.6333	0.0677	9.3580	< 2e-16	***
rep_designBTNo Bench	-0.1616	0.0917	-1.7620	0.0780	.

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.3683	14.1251	-0.0970	0.9228	
release3abvSA	-0.6515	0.2105	-3.0950	0.0020	**
release3SAabvFe	0.2297	0.3525	0.6520	0.5146	
release3SAblwAmer	0.3756	0.1827	2.0560	0.0398	*
fod_num	0.0187	0.0054	3.4540	0.0006	***
dr_num	-0.0184	0.0058	-3.1920	0.0014	**
daynightnight	0.4231	0.1140	3.7130	0.0002	***
rep_designNB0.Natural	-0.4749	0.2358	-2.0140	0.0440	*
rep_designNBBench_ten_to_1	-1.0521	0.2180	-4.8260	<0.0001	***
rep_designNBDietl Ditch	-1.1028	0.2357	-4.6790	<0.0001	***
Log(theta)	-8.1034	14.1341	-0.5730	0.5664	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	11.9073	1.1639	10.2310	< 2e-16	***
release3abvSA	-0.4153	0.1565	-2.6530	0.0080	**
release3SAabvFe	0.4559	0.1653	2.7570	0.0058	**
release3SAblwAmer	0.0568	0.1786	0.3180	0.7505	
log10(fd.flow)	-3.1387	0.2540	-12.3570	< 2e-16	***
region2RV	1.9042	0.0642	29.6630	< 2e-16	***
fod_num	0.0071	0.0034	2.0940	0.0363	*
dr_num	-0.0083	0.0034	-2.4910	0.0128	*
daynightnight	-0.3372	0.0542	-6.2260	<0.0001	***
rep_designNB0.Natural	-0.6099	0.0999	-6.1050	<0.0001	***
rep_designNBBench_ten_to_1	0.1616	0.0917	1.7620	0.0780	.
rep_designNBDietl Ditch	0.7949	0.1024	7.7640	<0.0001	***

Chinook salmon, All 4, Step 2 (ck_All4_2)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-6.5129	70.7514	-0.0920	0.9267	
release3abvSA	-0.2096	0.2963	-0.7070	0.4793	
release3SAabvFe	0.4555	0.3575	1.2740	0.2026	
release3SAblwAmer	0.5585	0.2693	2.0740	0.0381	*
fod_num	0.0125	0.0062	2.0140	0.0440	*
dr_num	-0.0126	0.0067	-1.8890	0.0589	.
daynightnight	0.3064	0.1153	2.6570	0.0079	**
year1b.2010	-3.2547	1.1267	-2.8890	0.0039	**
shade_sum	1.4065	0.2786	5.0480	<0.0001	***
BC_sum	0.7440	0.1991	3.7370	0.0002	***
fod_num:year1b.2010	0.0210	0.0081	2.5880	0.0097	**
Log(theta)	-11.7593	70.7508	-0.1660	0.8680	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	13.0498	1.2126	10.7620	< 2e-16	***
release3abvSA	-0.6781	0.1804	-3.7590	0.0002	***
release3SAabvFe	0.4361	0.1622	2.6890	0.0072	**
release3SAblwAmer	-0.1407	0.1929	-0.7300	0.4656	
log10(fd.flow)	-3.1791	0.2721	-11.6830	< 2e-16	***
region2RV	1.7251	0.0672	25.6910	< 2e-16	***
fod_num	0.0083	0.0034	2.4140	0.0158	*
dr_num	-0.0112	0.0033	-3.3790	0.0007	***
daynightnight	-0.3696	0.0547	-6.7610	<0.0001	***
year1b.2010	0.6175	0.4018	1.5370	0.1243	
shade_sum	-0.6876	0.1251	-5.4950	<0.0001	***
bslope_sum	-0.0548	0.0125	-4.3860	<0.0001	***
BC_sum	0.2293	0.1028	2.2320	0.0256	*
jam_area_pft	-0.0891	0.0074	-12.0160	< 2e-16	***
dr_num:year1b.2010	-0.0057	0.0031	-1.8670	0.0619	.

Testing interactions with region:

Component	Model term	df	X2	Pr(>X2)
Base		28		
Count	region2:iwm_dia_in	2	1.8078	0.4050
	region2:jam_area_pft	2	4.7648	0.0923
Zero	region2:iwm_dia_in	2	66.0660	<0.0001
	region2:jam_area_pft	1	5.8390	0.0157

Coefficients of main effects and interaction terms fit one at a time (significant interactions only):

Component	Term	Coefficient	SE	z value	Pr(>|z|)	
Zero	iwm_dia_in	-0.1087	0.0203	-5.3660	<0.0001	***
	region2RV:iwm_dia_in	0.2143	0.0267	8.0270	<0.0001	***
	jam_area_pft	-0.0673	0.0116	-5.8280	<0.0001	***
	region2RV:jam_area_pft	-0.0390	0.0161	-2.4270	0.0152	*

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-6.5129	70.7514	-0.0920	0.9267	
release3abvSA	-0.2096	0.2963	-0.7070	0.4793	
release3SAabvFe	0.4555	0.3575	1.2740	0.2026	
release3SAblwAmer	0.5585	0.2693	2.0740	0.0381	*
fod_num	0.0125	0.0062	2.0140	0.0440	*
dr_num	-0.0126	0.0067	-1.8890	0.0589	.
daynightnight	0.3064	0.1153	2.6570	0.0079	**
year1b.2010	-3.2547	1.1267	-2.8890	0.0039	**
shade_sum	1.4065	0.2786	5.0480	<0.0001	***
BC_sum	0.7440	0.1991	3.7370	0.0002	***
fod_num:year1b.2010	0.0210	0.0081	2.5880	0.0097	**
Log(theta)	-11.7593	70.7508	-0.1660	0.8680	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.7634	1.2178	10.4810	< 2e-16	***
release3abvSA	-0.7320	0.1817	-4.0290	0.0001	***
release3SAabvFe	0.3764	0.1635	2.3020	0.0214	*
release3SAblwAmer	-0.2354	0.1941	-1.2120	0.2254	
log10(fd.flow)	-3.1753	0.2727	-11.6450	< 2e-16	***
region2RV	1.9382	0.1089	17.7910	< 2e-16	***
fod_num	0.0082	0.0035	2.3540	0.0186	*
dr_num	-0.0108	0.0034	-3.2090	0.0013	**
daynightnight	-0.3542	0.0549	-6.4560	<0.0001	***
year1b.2010	1.1641	0.4146	2.8070	0.0050	**
shade_sum	-0.7085	0.1296	-5.4680	<0.0001	***
bslope_sum	-0.0474	0.0143	-3.3100	0.0009	***
BC_sum	0.5013	0.1134	4.4210	<0.0001	***
jam_area_pft	-0.0759	0.0118	-6.4500	<0.0001	***
iwm_dia_in	-0.1000	0.0205	-4.8750	<0.0001	***
dr_num:year1b.2010	-0.0098	0.0032	-3.1150	0.0018	**
region2RV:iwm_dia_in	0.2209	0.0268	8.2400	< 2e-16	***
region2RV:jam_area_pft	-0.0586	0.0168	-3.4940	0.0005	***

Chinook salmon, All 4, Step 3 (ck_All4_3)

Without BC:

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-0.9787	8.6517	-0.1130	0.9099	
release3abvSA	-0.3344	0.2892	-1.1560	0.2475	
release3SAabvFe	0.2994	0.3524	0.8490	0.3956	
release3SAblwAmer	0.4976	0.2631	1.8910	0.0586	.
fod_num	0.0145	0.0060	2.4150	0.0157	*
dr_num	-0.0143	0.0064	-2.2200	0.0264	*
daynightnight	0.3803	0.1142	3.3290	0.0009	***
rep_designBench_ten_to_1	-0.0658	0.2422	-0.2720	0.7859	
rep_designDietl Ditch	-0.1873	0.2416	-0.7760	0.4380	
rep_designNo Bench	1.0080	0.3066	3.2870	0.0010	**
year1b.2010	-3.3804	1.1537	-2.9300	0.0034	**
shade_sum	0.7447	0.3227	2.3080	0.0210	*
fod_num:year1b.2010	0.0232	0.0083	2.7830	0.0054	**
Log(theta)	-6.6703	8.6751	-0.7690	0.4419	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	11.9156	1.2279	9.7040	< 2e-16	***
release3abvSA	-0.7366	0.1830	-4.0250	0.0001	***
release3SAabvFe	0.3557	0.1674	2.1250	0.0336	*
release3SAblwAmer	-0.2602	0.1956	-1.3300	0.1834	
log10(fd.flow)	-3.1887	0.2754	-11.5790	< 2e-16	***
region2RV	2.4335	0.1149	21.1870	< 2e-16	***
fod_num	0.0063	0.0035	1.8000	0.0718	.
dr_num	-0.0080	0.0034	-2.3700	0.0178	*
daynightnight	-0.3634	0.0554	-6.5640	<0.0001	***
year1b.2010	1.6339	0.4224	3.8680	0.0001	***
rep_designBench_ten_to_1	0.8531	0.0900	9.4740	< 2e-16	***
rep_designDietl Ditch	1.5355	0.0885	17.3420	< 2e-16	***
rep_designNo Bench	0.9760	0.1265	7.7140	<0.0001	***
bslope_sum	0.0330	0.0152	2.1640	0.0305	*
iwm_dia_in	-0.1335	0.0230	-5.7980	<0.0001	***
jam_area_pft	-0.0515	0.0128	-4.0350	0.0001	***
dr_num:year1b.2010	-0.0138	0.0032	-4.3020	<0.0001	***
region2RV:iwm_dia_in	0.2424	0.0298	8.1240	<0.0001	***
region2RV:jam_area_pft	-0.0813	0.0185	-4.3930	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.1660	8.6512	-0.1350	0.8928	
release3abvSA	-0.3344	0.2892	-1.1570	0.2475	
release3SAabvFe	0.2994	0.3524	0.8490	0.3956	
release3SAblwAmer	0.4976	0.2631	1.8910	0.0586	.
fod_num	0.0145	0.0060	2.4150	0.0157	*
dr_num	-0.0143	0.0064	-2.2200	0.0264	*
daynightnight	0.3803	0.1142	3.3290	0.0009	***
rep_design20.Natural	0.1873	0.2416	0.7760	0.4380	
rep_design2Bench_ten_to_1	0.1216	0.1375	0.8840	0.3767	
rep_design2No Bench	1.1953	0.2393	4.9960	<0.0001	***
year1b.2010	-3.3804	1.1537	-2.9300	0.0034	**
shade_sum	0.7447	0.3227	2.3080	0.0210	*
fod_num:year1b.2010	0.0232	0.0083	2.7830	0.0054	**
Log(theta)	-6.6703	8.6742	-0.7690	0.4419	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	13.4511	1.2276	10.9570	< 2e-16	***
release3abvSA	-0.7366	0.1830	-4.0250	0.0001	***
release3SAabvFe	0.3557	0.1674	2.1250	0.0336	*
release3SAblwAmer	-0.2602	0.1956	-1.3300	0.1834	
log10(fd.flow)	-3.1887	0.2754	-11.5790	< 2e-16	***
region2RV	2.4335	0.1149	21.1870	< 2e-16	***
fod_num	0.0063	0.0035	1.8000	0.0718	.
dr_num	-0.0080	0.0034	-2.3700	0.0178	*
daynightnight	-0.3634	0.0554	-6.5640	<0.0001	***
year1b.2010	1.6339	0.4224	3.8680	0.0001	***
rep_design20.Natural	-1.5355	0.0885	-17.3420	< 2e-16	***
rep_design2Bench_ten_to_1	-0.6824	0.0835	-8.1720	<0.0001	***
rep_design2No Bench	-0.5595	0.1131	-4.9490	<0.0001	***
bslope_sum	0.0330	0.0152	2.1640	0.0305	*
iwm_dia_in	-0.1335	0.0230	-5.7980	<0.0001	***
jam_area_pft	-0.0515	0.0128	-4.0350	0.0001	***
dr_num:year1b.2010	-0.0138	0.0032	-4.3020	<0.0001	***
region2RV:iwm_dia_in	0.2424	0.0298	8.1240	<0.0001	***
region2RV:jam_area_pft	-0.0813	0.0185	-4.3930	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-1.0429	8.6307	-0.1210	0.9038	
release3abvSA	-0.3344	0.2892	-1.1560	0.2475	
release3SAabvFe	0.2994	0.3524	0.8490	0.3956	
release3SAblwAmer	0.4976	0.2631	1.8910	0.0586	.
fod_num	0.0145	0.0060	2.4150	0.0157	*
dr_num	-0.0143	0.0064	-2.2200	0.0264	*
daynightnight	0.3803	0.1142	3.3290	0.0009	***
rep_designBT0.Natural	0.0658	0.2422	0.2720	0.7859	
rep_designBTDietl Ditch	-0.1216	0.1375	-0.8840	0.3767	
rep_designBTNo Bench	1.0738	0.2188	4.9060	<0.0001	***
year1b.2010	-3.3804	1.1537	-2.9300	0.0034	**
shade_sum	0.7447	0.3227	2.3080	0.0210	*
fod_num:year1b.2010	0.0232	0.0083	2.7830	0.0054	**
Log(theta)	-6.6688	8.6550	-0.7710	0.4410	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.7687	1.2262	10.4130	< 2e-16	***
release3abvSA	-0.7366	0.1830	-4.0250	0.0001	***
release3SAabvFe	0.3557	0.1674	2.1250	0.0336	*
release3SAblwAmer	-0.2602	0.1956	-1.3300	0.1834	
log10(fd.flow)	-3.1887	0.2754	-11.5790	< 2e-16	***
region2RV	2.4335	0.1149	21.1870	< 2e-16	***
fod_num	0.0063	0.0035	1.8000	0.0718	.
dr_num	-0.0080	0.0034	-2.3700	0.0178	*
daynightnight	-0.3634	0.0554	-6.5640	<0.0001	***
year1b.2010	1.6339	0.4224	3.8680	0.0001	***
rep_designBT0.Natural	-0.8531	0.0900	-9.4740	< 2e-16	***
rep_designBTDietl Ditch	0.6824	0.0835	8.1720	<0.0001	***
rep_designBTNo Bench	0.1229	0.1025	1.1990	0.2305	
bslope_sum	0.0330	0.0152	2.1640	0.0305	*
iwm_dia_in	-0.1335	0.0230	-5.7980	<0.0001	***
jam_area_pft	-0.0515	0.0128	-4.0350	0.0001	***
dr_num:year1b.2010	-0.0138	0.0032	-4.3020	<0.0001	***
region2RV:iwm_dia_in	0.2424	0.0298	8.1240	<0.0001	***
region2RV:jam_area_pft	-0.0813	0.0185	-4.3930	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	0.0294	8.6424	0.0030	0.9973	
release3abvSA	-0.3344	0.2892	-1.1560	0.2475	
release3SAabvFe	0.2994	0.3524	0.8490	0.3956	
release3SAblwAmer	0.4976	0.2631	1.8910	0.0586	.
fod_num	0.0145	0.0060	2.4150	0.0157	*
dr_num	-0.0143	0.0064	-2.2200	0.0264	*
daynightnight	0.3803	0.1142	3.3290	0.0009	***
rep_designNB0.Natural	-1.0080	0.3066	-3.2870	0.0010	**
rep_designNBBench_ten_to_1	-1.0738	0.2188	-4.9060	<0.0001	***
rep_designNBDietl Ditch	-1.1953	0.2393	-4.9960	<0.0001	***
year1b.2010	-3.3805	1.1537	-2.9300	0.0034	**
shade_sum	0.7447	0.3227	2.3080	0.0210	*
fod_num:year1b.2010	0.0232	0.0083	2.7830	0.0054	**
Log(theta)	-6.6702	8.6724	-0.7690	0.4418	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.8916	1.2277	10.5010	< 2e-16	***
release3abvSA	-0.7366	0.1830	-4.0250	0.0001	***
release3SAabvFe	0.3557	0.1674	2.1250	0.0336	*
release3SAblwAmer	-0.2602	0.1956	-1.3300	0.1834	
log10(fd.flow)	-3.1887	0.2754	-11.5790	< 2e-16	***
region2RV	2.4335	0.1149	21.1870	< 2e-16	***
fod_num	0.0063	0.0035	1.8000	0.0718	.
dr_num	-0.0080	0.0034	-2.3700	0.0178	*
daynightnight	-0.3634	0.0554	-6.5640	<0.0001	***
year1b.2010	1.6339	0.4224	3.8680	0.0001	***
rep_designNB0.Natural	-0.9760	0.1265	-7.7140	<0.0001	***
rep_designNBBench_ten_to_1	-0.1229	0.1025	-1.1990	0.2305	
rep_designNBDietl Ditch	0.5595	0.1131	4.9490	<0.0001	***
bslope_sum	0.0330	0.0152	2.1640	0.0305	*
iwm_dia_in	-0.1335	0.0230	-5.7980	<0.0001	***
jam_area_pft	-0.0515	0.0128	-4.0350	0.0001	***
dr_num:year1b.2010	-0.0138	0.0032	-4.3020	<0.0001	***
region2RV:iwm_dia_in	0.2424	0.0298	8.1240	<0.0001	***
region2RV:jam_area_pft	-0.0813	0.0185	-4.3930	<0.0001	***

Chinook salmon, Upper 3, Step 1 (ck_Upper3_1)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-18.3425	125.3395	-0.1460	0.8837	
release3abvSA	-0.6725	0.4065	-1.6540	0.0980	.
release3SAabvFe	0.0118	1.0305	0.0110	0.9909	
release3SAblwAmer	0.4595	0.4845	0.9480	0.3429	
year1b.2010	-0.6860	0.2829	-2.4250	0.0153	*
log10(fd.flow)	2.4001	0.6976	3.4410	0.0006	***
daynightnight	0.5544	0.1735	3.1960	0.0014	**
rep_designBench_ten_to_1	-0.6591	0.1826	-3.6090	0.0003	***
rep_designDietl Ditch	-0.6277	0.2137	-2.9380	0.0033	**
rep_designNo Bench	0.6371	0.2643	2.4100	0.0159	*
Log(theta)	-15.1864	125.3029	-0.1210	0.9035	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	17.9107	1.7866	10.0250	< 2e-16	***
release3abvSA	-0.1131	0.2292	-0.4940	0.6216	
release3SAabvFe	1.3468	0.3758	3.5840	0.0003	***
release3SAblwAmer	0.1084	0.2695	0.4020	0.6875	
log10(fd.flow)	-4.5191	0.3856	-11.7190	< 2e-16	***
regionKK	0.6373	0.1317	4.8390	<0.0001	***
regionKL	-2.2417	0.3199	-7.0060	<0.0001	***
dr_num	-0.0043	0.0017	-2.5030	0.0123	*
daynightnight	-0.7441	0.0744	-9.9980	< 2e-16	***
rep_designBench_ten_to_1	0.1102	0.1025	1.0760	0.2821	
rep_designDietl Ditch	0.0020	0.1198	0.0170	0.9866	
rep_designNo Bench	0.1829	0.1248	1.4660	0.1426	

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-19.1588	137.9901	-0.1390	0.8896	
release3abvSA	-0.6725	0.4065	-1.6550	0.0980	.
release3SAabvFe	0.0120	1.0303	0.0120	0.9907	
release3SAblwAmer	0.4593	0.4845	0.9480	0.3431	
year1b.2010	-0.6858	0.2830	-2.4240	0.0154	*
log10(fd.flow)	2.3991	0.6976	3.4390	0.0006	***
daynightnight	0.5545	0.1735	3.1970	0.0014	**
rep_design20.Natural	0.6276	0.2137	2.9370	0.0033	**
rep_design2Bench_ten_to_1	-0.0314	0.1908	-0.1650	0.8691	
rep_design2No Bench	1.2646	0.2721	4.6480	<0.0001	***
Log(theta)	-15.3788	137.9563	-0.1110	0.9112	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	17.9127	1.7816	10.0540	< 2e-16	***
release3abvSA	-0.1131	0.2292	-0.4940	0.6216	
release3SAabvFe	1.3468	0.3758	3.5840	0.0003	***
release3SAblwAmer	0.1084	0.2695	0.4020	0.6875	
log10(fd.flow)	-4.5191	0.3856	-11.7190	< 2e-16	***
regionKK	0.6373	0.1317	4.8390	<0.0001	***
regionKL	-2.2417	0.3199	-7.0060	<0.0001	***
dr_num	-0.0043	0.0017	-2.5030	0.0123	*
daynightnight	-0.7441	0.0744	-9.9980	< 2e-16	***
rep_design20.Natural	-0.0020	0.1198	-0.0170	0.9866	
rep_design2Bench_ten_to_1	0.1082	0.1577	0.6860	0.4927	
rep_design2No Bench	0.1809	0.1732	1.0440	0.2963	

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-19.0174	125.9919	-0.1510	0.8800	
release3abvSA	-0.6719	0.4065	-1.6530	0.0983	.
release3SAabvFe	0.0114	1.0303	0.0110	0.9911	
release3SAblwAmer	0.4602	0.4846	0.9500	0.3423	
year1b.2010	-0.6863	0.2829	-2.4250	0.0153	*
log10(fd.flow)	2.4013	0.6977	3.4420	0.0006	***
daynightnight	0.5545	0.1735	3.1970	0.0014	**
rep_designBT0.Natural	0.6590	0.1826	3.6090	0.0003	***
rep_designBTDietl Ditch	0.0314	0.1908	0.1650	0.8692	
rep_designBTNo Bench	1.2963	0.2444	5.3040	<0.0001	***
Log(theta)	-15.1969	125.9558	-0.1210	0.9040	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	18.0209	1.7860	10.0900	< 2e-16	***
release3abvSA	-0.1131	0.2292	-0.4940	0.6216	
release3SAabvFe	1.3468	0.3758	3.5840	0.0003	***
release3SAblwAmer	0.1084	0.2695	0.4020	0.6875	
log10(fd.flow)	-4.5191	0.3856	-11.7190	< 2e-16	***
regionKK	0.6373	0.1317	4.8390	<0.0001	***
regionKL	-2.2417	0.3199	-7.0060	<0.0001	***
dr_num	-0.0043	0.0017	-2.5030	0.0123	*
daynightnight	-0.7441	0.0744	-9.9980	< 2e-16	***
rep_designBT0.Natural	-0.1102	0.1025	-1.0760	0.2821	
rep_designBTDietl Ditch	-0.1082	0.1577	-0.6860	0.4927	
rep_designBTNo Bench	0.0727	0.0978	0.7430	0.4573	

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-17.3274	102.9818	-0.1680	0.8664	
release3abvSA	-0.6709	0.4066	-1.6500	0.0989	.
release3SAabvFe	0.0110	1.0303	0.0110	0.9915	
release3SAblwAmer	0.4614	0.4846	0.9520	0.3410	
year1b.2010	-0.6865	0.2829	-2.4260	0.0153	*
log10(fd.flow)	2.4036	0.6978	3.4440	0.0006	***
daynightnight	0.5544	0.1734	3.1960	0.0014	**
rep_designNB0.Natural	-0.6377	0.2644	-2.4120	0.0159	*
rep_designNBBench_ten_to_1	-1.2966	0.2444	-5.3050	<0.0001	***
rep_designNBDietl Ditch	-1.2655	0.2721	-4.6500	<0.0001	***
Log(theta)	-14.7933	102.9381	-0.1440	0.8857	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	18.0936	1.7881	10.1190	< 2e-16	***
release3abvSA	-0.1131	0.2292	-0.4940	0.6216	
release3SAabvFe	1.3468	0.3758	3.5840	0.0003	***
release3SAblwAmer	0.1084	0.2695	0.4020	0.6875	
log10(fd.flow)	-4.5191	0.3856	-11.7190	< 2e-16	***
regionKK	0.6373	0.1317	4.8390	<0.0001	***
regionKL	-2.2417	0.3199	-7.0060	<0.0001	***
dr_num	-0.0043	0.0017	-2.5030	0.0123	*
daynightnight	-0.7441	0.0744	-9.9980	< 2e-16	***
rep_designNB0.Natural	-0.1829	0.1248	-1.4660	0.1426	
rep_designNBBench_ten_to_1	-0.0727	0.0978	-0.7430	0.4573	
rep_designNBDietl Ditch	-0.1809	0.1732	-1.0440	0.2963	

Chinook salmon, Upper 3, Step 2 (ck_Upper3_2)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-13.8266	164.2911	-0.0840	0.9329	
release3abvSA	-1.1249	0.4173	-2.6960	0.0070	**
release3SAabvFe	0.2815	1.0498	0.2680	0.7886	
release3SAblwAmer	-0.2015	0.4973	-0.4050	0.6854	
year1b.2010	-0.7060	0.2719	-2.5970	0.0094	**
log10(fd.flow)	1.4100	0.7176	1.9650	0.0494	*
daynightnight	0.6489	0.1734	3.7410	0.0002	***
shade_sum	1.1187	0.2338	4.7840	<0.0001	***
diversemeas	-3.3068	0.5672	-5.8300	<0.0001	***
avgLWMdensity	2.9009	0.7507	3.8640	0.0001	***
Log(theta)	-15.7162	164.2611	-0.0960	0.9238	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	18.2854	1.8768	9.7430	< 2e-16	***
release3abvSA	-0.7646	0.2747	-2.7840	0.0054	**
release3SAabvFe	1.3396	0.3764	3.5590	0.0004	***
release3SAblwAmer	-0.4742	0.3018	-1.5710	0.1161	
log10(fd.flow)	-4.4235	0.4123	-10.7290	< 2e-16	***
regionKK	0.7244	0.1035	6.9980	<0.0001	***
regionKL	-1.9268	0.3402	-5.6640	<0.0001	***
dr_num	-0.0046	0.0017	-2.6920	0.0071	**
daynightnight	-0.7605	0.0751	-10.1240	< 2e-16	***
year1b.2010	2.6381	0.5936	4.4440	<0.0001	***
shade_sum	-0.4714	0.1321	-3.5680	0.0004	***
BC_sum	-0.3801	0.1268	-2.9980	0.0027	**
bslope_sum	0.0742	0.0176	4.2060	<0.0001	***
avgLWMdensity	1.1349	0.4418	2.5690	0.0102	*
dr_num:year1b.2010	-0.0224	0.0050	-4.4470	<0.0001	***

Chinook salmon, Upper 3, Step 3 (ck_Upper3_3)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-17.7464	396.9338	-0.0450	0.9643	
release3abvSA	-0.9753	0.4269	-2.2850	0.0223	*
release3SAabvFe	-0.0518	1.0303	-0.0500	0.9599	
release3SAblwAmer	0.0813	0.5127	0.1590	0.8740	
year1b.2010	-0.8252	0.2853	-2.8920	0.0038	**
log10(fd.flow)	1.8260	0.7452	2.4500	0.0143	*
daynightnight	0.5809	0.1755	3.3100	0.0009	***
rep_designBench_ten_to_1	-0.2017	0.3780	-0.5340	0.5936	
rep_designDietl Ditch	-0.3002	0.3601	-0.8340	0.4044	
rep_designNo Bench	0.8771	0.4252	2.0630	0.0391	*
shade_sum	0.7750	0.4670	1.6590	0.0970	.
diversemeas	-1.3910	0.5293	-2.6280	0.0086	**
Log(theta)	-17.4429	396.9205	-0.0440	0.9649	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	17.0276	1.8924	8.9980	< 2e-16	***
release3abvSA	-0.7827	0.2751	-2.8450	0.0044	**
release3SAabvFe	1.2953	0.3772	3.4340	0.0006	***
release3SAblwAmer	-0.4881	0.3021	-1.6160	0.1061	
log10(fd.flow)	-4.3584	0.4142	-10.5210	< 2e-16	***
regionKK	0.8747	0.1438	6.0840	<0.0001	***
regionKL	-2.0284	0.3250	-6.2410	<0.0001	***
dr_num	-0.0047	0.0017	-2.7530	0.0059	**
daynightnight	-0.7870	0.0752	-10.4720	< 2e-16	***
rep_designBench_ten_to_1	0.3003	0.1092	2.7510	0.0059	**
rep_designDietl Ditch	0.2363	0.1259	1.8770	0.0605	.
rep_designNo Bench	0.7489	0.1674	4.4750	<0.0001	***
year1b.2010	2.5880	0.5971	4.3340	<0.0001	***
bslope_sum	0.0735	0.0155	4.7350	<0.0001	***
diversemeas	1.2760	0.2755	4.6320	<0.0001	***
dr_num:year1b.2010	-0.0226	0.0051	-4.4490	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-14.2909	60.9028	-0.2350	0.8145	
release3abvSA	-0.9757	0.4269	-2.2860	0.0223	*
release3SAabvFe	-0.0522	1.0303	-0.0510	0.9596	
release3SAblwAmer	0.0807	0.5128	0.1570	0.8750	
year1b.2010	-0.8253	0.2854	-2.8920	0.0038	**
log10(fd.flow)	1.8252	0.7452	2.4490	0.0143	*
daynightnight	0.5809	0.1755	3.3110	0.0009	***
rep_design20.Natural	0.2996	0.3602	0.8320	0.4055	
rep_design2Bench_ten_to_1	0.0987	0.1943	0.5080	0.6116	
rep_design2No Bench	1.1771	0.2844	4.1380	<0.0001	***
shade_sum	0.7762	0.4671	1.6620	0.0966	.
diversemeas	-1.3926	0.5293	-2.6310	0.0085	**
Log(theta)	-13.6913	60.8128	-0.2250	0.8219	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	17.2638	1.8820	9.1730	< 2e-16	***
release3abvSA	-0.7827	0.2751	-2.8450	0.0044	**
release3SAabvFe	1.2953	0.3772	3.4340	0.0006	***
release3SAblwAmer	-0.4881	0.3021	-1.6160	0.1061	
log10(fd.flow)	-4.3584	0.4142	-10.5210	< 2e-16	***
regionKK	0.8747	0.1438	6.0840	<0.0001	***
regionKL	-2.0284	0.3250	-6.2410	<0.0001	***
dr_num	-0.0047	0.0017	-2.7530	0.0059	**
daynightnight	-0.7870	0.0752	-10.4720	< 2e-16	***
rep_design20.Natural	-0.2363	0.1259	-1.8770	0.0605	.
rep_design2Bench_ten_to_1	0.0640	0.1595	0.4010	0.6883	
rep_design2No Bench	0.5126	0.1915	2.6770	0.0074	**
year1b.2010	2.5880	0.5971	4.3340	<0.0001	***
bslope_sum	0.0735	0.0155	4.7350	<0.0001	***
diversemeas	1.2760	0.2755	4.6320	<0.0001	***
dr_num:year1b.2010	-0.0226	0.0051	-4.4490	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-13.2226	37.8832	-0.3490	0.7271	
release3abvSA	-0.9771	0.4269	-2.2890	0.0221	*
release3SAabvFe	-0.0516	1.0304	-0.0500	0.9600	
release3SAblwAmer	0.0795	0.5127	0.1550	0.8769	
year1b.2010	-0.8237	0.2854	-2.8860	0.0039	**
log10(fd.flow)	1.8213	0.7450	2.4450	0.0145	*
daynightnight	0.5809	0.1755	3.3100	0.0009	***
rep_designBT0.Natural	0.2033	0.3780	0.5380	0.5906	
rep_designBTDietl Ditch	-0.0985	0.1943	-0.5070	0.6122	
rep_designBTNo Bench	1.0783	0.2639	4.0860	<0.0001	***
shade_sum	0.7742	0.4670	1.6580	0.0974	.
diversemeas	-1.3912	0.5293	-2.6280	0.0086	**
Log(theta)	-12.7371	37.7399	-0.3370	0.7357	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	17.3278	1.8881	9.1770	< 2e-16	***
release3abvSA	-0.7827	0.2751	-2.8450	0.0044	**
release3SAabvFe	1.2953	0.3772	3.4340	0.0006	***
release3SAblwAmer	-0.4881	0.3021	-1.6160	0.1061	
log10(fd.flow)	-4.3584	0.4142	-10.5210	< 2e-16	***
regionKK	0.8747	0.1438	6.0840	<0.0001	***
regionKL	-2.0284	0.3250	-6.2410	<0.0001	***
dr_num	-0.0047	0.0017	-2.7530	0.0059	**
daynightnight	-0.7870	0.0752	-10.4720	< 2e-16	***
rep_designBT0.Natural	-0.3003	0.1092	-2.7510	0.0059	**
rep_designBTDietl Ditch	-0.0640	0.1595	-0.4010	0.6883	
rep_designBTNo Bench	0.4487	0.1233	3.6370	0.0003	***
year1b.2010	2.5880	0.5971	4.3340	<0.0001	***
bslope_sum	0.0735	0.0155	4.7350	<0.0001	***
diversemeas	1.2760	0.2755	4.6320	<0.0001	***
dr_num:year1b.2010	-0.0226	0.0051	-4.4490	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-13.9183	90.9784	-0.1530	0.8784	
release3abvSA	-0.9755	0.4269	-2.2850	0.0223	*
release3SAabvFe	-0.0467	1.0329	-0.0450	0.9639	
release3SAblwAmer	0.0811	0.5127	0.1580	0.8743	
year1b.2010	-0.8248	0.2853	-2.8910	0.0038	**
log10(fd.flow)	1.8251	0.7451	2.4490	0.0143	*
daynightnight	0.5810	0.1755	3.3110	0.0009	***
rep_designNB0.Natural	-0.8758	0.4252	-2.0600	0.0394	*
rep_designNBBench_ten_to_1	-1.0784	0.2639	-4.0870	<0.0001	***
rep_designNBDietl Ditch	-1.1767	0.2844	-4.1370	<0.0001	***
shade_sum	0.7741	0.4670	1.6580	0.0974	.
diversemeas	-1.3919	0.5293	-2.6300	0.0085	**
Log(theta)	-14.4954	90.9202	-0.1590	0.8733	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	17.7765	1.8842	9.4340	< 2e-16	***
release3abvSA	-0.7827	0.2751	-2.8450	0.0044	**
release3SAabvFe	1.2953	0.3772	3.4340	0.0006	***
release3SAblwAmer	-0.4881	0.3021	-1.6160	0.1061	
log10(fd.flow)	-4.3584	0.4142	-10.5210	< 2e-16	***
regionKK	0.8747	0.1438	6.0840	<0.0001	***
regionKL	-2.0284	0.3250	-6.2410	<0.0001	***
dr_num	-0.0047	0.0017	-2.7530	0.0059	**
daynightnight	-0.7870	0.0752	-10.4720	< 2e-16	***
rep_designNB0.Natural	-0.7489	0.1674	-4.4750	<0.0001	***
rep_designNBBench_ten_to_1	-0.4487	0.1233	-3.6370	0.0003	***
rep_designNBDietl Ditch	-0.5126	0.1915	-2.6770	0.0074	**
year1b.2010	2.5880	0.5971	4.3340	<0.0001	***
bslope_sum	0.0735	0.0155	4.7350	<0.0001	***
diversemeas	1.2760	0.2755	4.6320	<0.0001	***
dr_num:year1b.2010	-0.0226	0.0051	-4.4490	<0.0001	***

Steelhead, All 4, Step 1 (sh_All4_1)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-13.4328	179.6033	-0.0750	0.9404	
release3abvSA	-1.7119	0.2545	-6.7270	<0.0001	***
release3SAabvFe	0.1189	0.5366	0.2220	0.8247	
release3SAblwAmer	0.1438	0.3366	0.4270	0.6692	
log10(fd.flow)	1.7509	0.4607	3.8010	0.0001	***
region2RV	-0.5831	0.1518	-3.8420	0.0001	***
fod_num	-0.0215	0.0035	-6.2350	<0.0001	***
rep_designBench_ten_to_1	0.0812	0.1631	0.4980	0.6185	
rep_designDietl Ditch	-0.1716	0.2103	-0.8160	0.4145	
rep_designNo Bench	0.1788	0.3424	0.5220	0.6016	
Log(theta)	-16.1258	179.5891	-0.0900	0.9285	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	10.1777	1.3350	7.6240	<0.0001	***
release3abvSA	-1.2179	0.2349	-5.1850	<0.0001	***
release3SAabvFe	-0.8019	0.3122	-2.5690	0.0102	*
release3SAblwAmer	0.6542	0.2929	2.2340	0.0255	*
year1b.2010	-0.2726	0.1242	-2.1960	0.0281	*
log10(fd.flow)	-1.9857	0.2335	-8.5030	< 2e-16	***
region2RV	1.2917	0.0750	17.2240	< 2e-16	***
fod_num	-0.0101	0.0019	-5.3130	<0.0001	***
dr_num	-0.0075	0.0041	-1.8200	0.0688	.
daynightnight	0.2227	0.0668	3.3320	0.0009	***
rep_designBench_ten_to_1	0.4126	0.0776	5.3160	<0.0001	***
rep_designDietl Ditch	0.7388	0.1011	7.3050	<0.0001	***
rep_designNo Bench	-0.1420	0.1449	-0.9800	0.3271	

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-12.7507	116.8869	-0.1090	0.9131	
release3abvSA	-1.7115	0.2545	-6.7240	<0.0001	***
release3SAabvFe	0.1194	0.5366	0.2220	0.8239	
release3SAblwAmer	0.1445	0.3366	0.4290	0.6678	
log10(fd.flow)	1.7520	0.4607	3.8030	0.0001	***
region2RV	-0.5832	0.1518	-3.8420	0.0001	***
fod_num	-0.0215	0.0035	-6.2330	<0.0001	***
rep_design20.Natural	0.1716	0.2103	0.8160	0.4145	
rep_design2Bench_ten_to_1	0.2528	0.1870	1.3520	0.1765	
rep_design2No Bench	0.3504	0.3460	1.0130	0.3112	
Log(theta)	-15.2665	116.8647	-0.1310	0.8961	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	10.9165	1.3371	8.1640	<0.0001	***
release3abvSA	-1.2179	0.2349	-5.1850	<0.0001	***
release3SAabvFe	-0.8019	0.3122	-2.5690	0.0102	*
release3SAblwAmer	0.6542	0.2929	2.2340	0.0255	*
year1b.2010	-0.2726	0.1242	-2.1960	0.0281	*
log10(fd.flow)	-1.9857	0.2335	-8.5030	< 2e-16	***
region2RV	1.2917	0.0750	17.2240	< 2e-16	***
fod_num	-0.0101	0.0019	-5.3130	<0.0001	***
dr_num	-0.0075	0.0041	-1.8200	0.0688	.
daynightnight	0.2227	0.0668	3.3320	0.0009	***
rep_design20.Natural	-0.7388	0.1011	-7.3050	<0.0001	***
rep_design2Bench_ten_to_1	-0.3262	0.0946	-3.4490	0.0006	***
rep_design2No Bench	-0.8808	0.1509	-5.8380	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-13.4042	184.4826	-0.0730	0.9421	
release3abvSA	-1.7120	0.2545	-6.7270	<0.0001	***
release3SAabvFe	0.1187	0.5366	0.2210	0.8249	
release3SAblwAmer	0.1438	0.3366	0.4270	0.6691	
log10(fd.flow)	1.7507	0.4607	3.8000	0.0001	***
region2RV	-0.5830	0.1518	-3.8410	0.0001	***
fod_num	-0.0215	0.0035	-6.2350	<0.0001	***
rep_designBT0.Natural	-0.0812	0.1631	-0.4980	0.6184	
rep_designBTDietl Ditch	-0.2528	0.1870	-1.3510	0.1766	
rep_designBTNo Bench	0.0977	0.3306	0.2960	0.7676	
Log(theta)	-16.1794	184.4687	-0.0880	0.9301	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	10.5903	1.3359	7.9280	<0.0001	***
release3abvSA	-1.2179	0.2349	-5.1850	<0.0001	***
release3SAabvFe	-0.8019	0.3122	-2.5690	0.0102	*
release3SAblwAmer	0.6542	0.2929	2.2340	0.0255	*
year1b.2010	-0.2726	0.1242	-2.1960	0.0281	*
log10(fd.flow)	-1.9857	0.2335	-8.5030	< 2e-16	***
region2RV	1.2917	0.0750	17.2240	< 2e-16	***
fod_num	-0.0101	0.0019	-5.3130	<0.0001	***
dr_num	-0.0075	0.0041	-1.8200	0.0688	.
daynightnight	0.2227	0.0668	3.3320	0.0009	***
rep_designBT0.Natural	-0.4126	0.0776	-5.3160	<0.0001	***
rep_designBTDietl Ditch	0.3262	0.0946	3.4490	0.0006	***
rep_designBTNo Bench	-0.5546	0.1404	-3.9500	0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-14.1975	287.9477	-0.0490	0.9607	
release3abvSA	-1.7119	0.2545	-6.7270	<0.0001	***
release3SAabvFe	0.1188	0.5366	0.2210	0.8248	
release3SAblwAmer	0.1438	0.3366	0.4270	0.6693	
log10(fd.flow)	1.7508	0.4607	3.8010	0.0001	***
region2RV	-0.5831	0.1518	-3.8420	0.0001	***
fod_num	-0.0215	0.0035	-6.2350	<0.0001	***
rep_designNB0.Natural	-0.1788	0.3424	-0.5220	0.6015	
rep_designNBBench_ten_to_1	-0.0976	0.3306	-0.2950	0.7677	
rep_designNBDietl Ditch	-0.3504	0.3460	-1.0130	0.3112	
Log(theta)	-17.0696	287.9385	-0.0590	0.9527	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	10.0357	1.3424	7.4760	<0.0001	***
release3abvSA	-1.2179	0.2349	-5.1850	<0.0001	***
release3SAabvFe	-0.8019	0.3122	-2.5690	0.0102	*
release3SAblwAmer	0.6542	0.2929	2.2340	0.0255	*
year1b.2010	-0.2726	0.1242	-2.1960	0.0281	*
log10(fd.flow)	-1.9857	0.2335	-8.5030	< 2e-16	***
region2RV	1.2917	0.0750	17.2240	< 2e-16	***
fod_num	-0.0101	0.0019	-5.3130	<0.0001	***
dr_num	-0.0075	0.0041	-1.8200	0.0688	.
daynightnight	0.2227	0.0668	3.3320	0.0009	***
rep_designNB0.Natural	0.1420	0.1449	0.9800	0.3271	
rep_designNBBench_ten_to_1	0.5546	0.1404	3.9500	0.0001	***
rep_designNBDietl Ditch	0.8808	0.1509	5.8380	<0.0001	***

Steelhead, All 4, Step 2 (sh_All4_2)

With BC:

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.8110	76.6633	-0.0760	0.9396	
release3abvSA	-2.9582	0.6302	-4.6940	<0.0001	***
release3SAabvFe	-1.5959	0.8520	-1.8730	0.0611	.
release3SAblwAmer	-1.6351	0.7537	-2.1700	0.0300	*
year1b.2010	-9.0130	1.4310	-6.2980	<0.0001	***
log10(fd.flow)	1.8584	0.4421	4.2040	<0.0001	***
region2RV	-0.4376	0.1536	-2.8480	0.0044	**
fod_num	-0.0372	0.0060	-6.1700	<0.0001	***
dr_num	-0.0192	0.0134	-1.4290	0.1529	
year1b.2010:fod_num	0.0198	0.0076	2.6220	0.0087	**
year1b.2010:dr_num	0.0323	0.0119	2.7160	0.0066	**
Log(theta)	-14.3327	76.6107	-0.1870	0.8516	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	13.0934	1.4013	9.3440	< 2e-16	***
release3abvSA	-1.7202	0.2596	-6.6260	<0.0001	***
release3SAabvFe	-1.3094	0.3395	-3.8570	0.0001	***
release3SAblwAmer	-0.1581	0.3160	-0.5000	0.6168	
year1b.2010	-2.7696	0.7489	-3.6980	0.0002	***
log10(fd.flow)	-1.8600	0.2371	-7.8450	<0.0001	***
region2RV	1.2360	0.0768	16.0860	< 2e-16	***
fod_num	-0.0334	0.0036	-9.2250	< 2e-16	***
dr_num	0.0012	0.0045	0.2780	0.7811	
daynightnight	0.2132	0.0673	3.1680	0.0015	**
bslope_sum	-0.0655	0.0176	-3.7170	0.0002	***
BC_sum	0.2614	0.0879	2.9750	0.0029	**
jam_area_pft	-0.0553	0.0099	-5.6020	<0.0001	***
year1b.2010:fod_num	0.0335	0.0041	8.1350	<0.0001	***
year1b.2010:dr_num	-0.0241	0.0049	-4.9350	<0.0001	***

Including BC resulted in loss of shade and IWM diameter variables.

Testing interactions with region:

Component	Model term	df	X2	Pr(>X2)
Base		27		
Count	region2:iwm_dia_in	2	1.6266	0.4434
	region2:jam_area_pft	2	1.3832	0.5008
Zero	region2:iwm_dia_in	2	19.6940	0.0001
	region2:jam_area_pft	1	3.8812	0.0488

Coefficients of main effects and interaction terms fit one at a time (significant interactions only):

Component	Term	Coefficient	SE	z value	Pr(>|z|)	
Zero	iwm_dia_in	-0.0527	0.0272	-1.9380	0.0527	.
	region2RV:iwm_dia_in	0.1408	0.0338	4.1680	<0.0001	***
	jam_area_pft	-0.0258	0.0177	-1.4570	0.1450	
	region2RV:jam_area_pft	-0.0468	0.0236	-1.9850	0.0471	*

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-5.8110	76.6633	-0.0760	0.9396	
release3abvSA	-2.9582	0.6302	-4.6940	<0.0001	***
release3SAabvFe	-1.5959	0.8520	-1.8730	0.0611	.
release3SAblwAmer	-1.6351	0.7537	-2.1700	0.0300	*
year1b.2010	-9.0130	1.4310	-6.2980	<0.0001	***
log10(fd.flow)	1.8584	0.4421	4.2040	<0.0001	***
region2RV	-0.4376	0.1536	-2.8480	0.0044	**
fod_num	-0.0372	0.0060	-6.1700	<0.0001	***
dr_num	-0.0192	0.0134	-1.4290	0.1529	
year1b.2010:fod_num	0.0198	0.0076	2.6220	0.0087	**
year1b.2010:dr_num	0.0323	0.0119	2.7160	0.0066	**
Log(theta)	-14.3327	76.6107	-0.1870	0.8516	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.7907	1.4072	9.0890	< 2e-16	***
release3abvSA	-1.7144	0.2607	-6.5750	<0.0001	***
release3SAabvFe	-1.2700	0.3381	-3.7560	0.0002	***
release3SAblwAmer	-0.1645	0.3164	-0.5200	0.6031	
year1b.2010	-2.6875	0.7582	-3.5450	0.0004	***
log10(fd.flow)	-1.8467	0.2377	-7.7680	<0.0001	***
region2RV	1.4950	0.1454	10.2860	< 2e-16	***
fod_num	-0.0330	0.0036	-9.1170	< 2e-16	***
dr_num	0.0010	0.0045	0.2270	0.8206	
daynightnight	0.2085	0.0675	3.0880	0.0020	**
bslope_sum	-0.0582	0.0204	-2.8510	0.0044	**
BC_sum	0.4308	0.1138	3.7860	0.0002	***
jam_area_pft	-0.0321	0.0185	-1.7330	0.0831	.
iwm_dia_in	-0.0481	0.0273	-1.7630	0.0779	.
year1b.2010:fod_num	0.0332	0.0041	8.0340	<0.0001	***
year1b.2010:dr_num	-0.0242	0.0049	-4.9200	<0.0001	***
region2RV:jam_area_pft	-0.0683	0.0244	-2.8010	0.0051	**
region2RV:iwm_dia_in	0.1509	0.0340	4.4330	<0.0001	***

Steelhead, All 4, Step 3 (sh_All4_3)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-7.7407	182.8513	-0.0420	0.9662	
release3abvSA	-2.9235	0.6212	-4.7060	<0.0001	***
release3SAabvFe	-1.5296	0.8440	-1.8120	0.0700	.
release3SAblwAmer	-1.5758	0.7442	-2.1170	0.0342	*
year1b.2010	-8.9666	1.4361	-6.2440	<0.0001	***
log10(fd.flow)	1.8530	0.4457	4.1570	<0.0001	***
region2RV	-0.4425	0.1598	-2.7690	0.0056	**
fod_num	-0.0370	0.0061	-6.1060	<0.0001	***
dr_num	-0.0184	0.0132	-1.3920	0.1641	
rep_designBench_ten_to_1	0.1475	0.1622	0.9090	0.3632	
rep_designDietl Ditch	-0.0635	0.2075	-0.3060	0.7596	
rep_designNo Bench	0.2047	0.3414	0.6000	0.5487	
year1b.2010:fod_num	0.0198	0.0076	2.6090	0.0091	**
year1b.2010:dr_num	0.0322	0.0120	2.6870	0.0072	**
Log(theta)	-16.0635	182.8297	-0.0880	0.9300	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.3596	1.4128	8.7480	< 2e-16	***
release3abvSA	-1.6460	0.2634	-6.2500	<0.0001	***
release3SAabvFe	-1.1507	0.3390	-3.3950	0.0007	***
release3SAblwAmer	-0.1602	0.3187	-0.5020	0.6153	
year1b.2010	-2.6747	0.7685	-3.4800	0.0005	***
log10(fd.flow)	-1.7818	0.2393	-7.4460	<0.0001	***
region2RV	1.6719	0.1349	12.3910	< 2e-16	***
fod_num	-0.0347	0.0036	-9.5640	< 2e-16	***
dr_num	0.0022	0.0045	0.4850	0.6274	
daynightnight	0.1826	0.0680	2.6850	0.0072	**
rep_designBench_ten_to_1	0.5178	0.1137	4.5520	<0.0001	***
rep_designDietl Ditch	0.8547	0.1142	7.4830	<0.0001	***
rep_designNo Bench	0.0533	0.1660	0.3210	0.7484	
iwm_dia_in	-0.0816	0.0263	-3.1020	0.0019	**
jam_area_pft	-0.0207	0.0181	-1.1470	0.2512	
year1b.2010:fod_num	0.0343	0.0042	8.2440	< 2e-16	***
year1b.2010:dr_num	-0.0251	0.0050	-5.0490	<0.0001	***
region2RV:iwm_dia_in	0.1858	0.0350	5.3090	<0.0001	***
region2RV:jam_area_pft	-0.0709	0.0249	-2.8460	0.0044	**

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-7.8959	191.5430	-0.0410	0.9671	
release3abvSA	-2.9236	0.6212	-4.7060	<0.0001	***
release3SAabvFe	-1.5299	0.8440	-1.8130	0.0699	.
release3SAblwAmer	-1.5759	0.7442	-2.1180	0.0342	*
year1b.2010	-8.9677	1.4361	-6.2440	<0.0001	***
log10(fd.flow)	1.8529	0.4457	4.1570	<0.0001	***
region2RV	-0.4425	0.1598	-2.7680	0.0056	**
fod_num	-0.0370	0.0061	-6.1060	<0.0001	***
dr_num	-0.0184	0.0132	-1.3920	0.1640	
rep_design20.Natural	0.0635	0.2075	0.3060	0.7596	
rep_design2Bench_ten_to_1	0.2110	0.1851	1.1400	0.2544	
rep_design2No Bench	0.2681	0.3457	0.7760	0.4380	
year1b.2010:fod_num	0.0198	0.0076	2.6100	0.0091	**
year1b.2010:dr_num	0.0322	0.0120	2.6870	0.0072	**
Log(theta)	-16.1564	191.5221	-0.0840	0.9328	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	13.2142	1.4159	9.3330	< 2e-16	***
release3abvSA	-1.6460	0.2634	-6.2500	<0.0001	***
release3SAabvFe	-1.1507	0.3390	-3.3950	0.0007	***
release3SAblwAmer	-0.1602	0.3187	-0.5020	0.6153	
year1b.2010	-2.6747	0.7685	-3.4800	0.0005	***
log10(fd.flow)	-1.7818	0.2393	-7.4460	<0.0001	***
region2RV	1.6719	0.1349	12.3910	< 2e-16	***
fod_num	-0.0347	0.0036	-9.5640	< 2e-16	***
dr_num	0.0022	0.0045	0.4850	0.6274	
daynightnight	0.1826	0.0680	2.6850	0.0072	**
rep_design20.Natural	-0.8547	0.1142	-7.4830	<0.0001	***
rep_design2Bench_ten_to_1	-0.3369	0.1033	-3.2600	0.0011	**
rep_design2No Bench	-0.8014	0.1566	-5.1170	<0.0001	***
jam_area_pft	-0.0207	0.0181	-1.1470	0.2512	
iwm_dia_in	-0.0816	0.0263	-3.1020	0.0019	**
year1b.2010:fod_num	0.0343	0.0042	8.2440	< 2e-16	***
year1b.2010:dr_num	-0.0251	0.0050	-5.0490	<0.0001	***
region2RV:jam_area_pft	-0.0709	0.0249	-2.8460	0.0044	**
region2RV:iwm_dia_in	0.1858	0.0350	5.3090	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-7.2891	157.0813	-0.0460	0.9630	
release3abvSA	-2.9232	0.6212	-4.7060	<0.0001	***
release3SAabvFe	-1.5296	0.8440	-1.8120	0.0699	.
release3SAblwAmer	-1.5757	0.7442	-2.1170	0.0342	*
year1b.2010	-8.9704	1.4359	-6.2470	<0.0001	***
log10(fd.flow)	1.8529	0.4457	4.1570	<0.0001	***
region2RV	-0.4424	0.1598	-2.7680	0.0056	**
fod_num	-0.0370	0.0061	-6.1070	<0.0001	***
dr_num	-0.0184	0.0132	-1.3910	0.1642	
rep_designBT0.Natural	-0.1475	0.1622	-0.9100	0.3631	
rep_designBTDietl Ditch	-0.2109	0.1851	-1.1400	0.2545	
rep_designBTNo Bench	0.0572	0.3302	0.1730	0.8625	
year1b.2010:fod_num	0.0198	0.0076	2.6100	0.0091	**
year1b.2010:dr_num	0.0322	0.0120	2.6890	0.0072	**
Log(theta)	-15.7596	157.0561	-0.1000	0.9201	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.8773	1.4175	9.0840	< 2e-16	***
release3abvSA	-1.6460	0.2634	-6.2500	<0.0001	***
release3SAabvFe	-1.1507	0.3390	-3.3950	0.0007	***
release3SAblwAmer	-0.1602	0.3187	-0.5020	0.6153	
year1b.2010	-2.6747	0.7685	-3.4800	0.0005	***
log10(fd.flow)	-1.7818	0.2393	-7.4460	<0.0001	***
region2RV	1.6719	0.1349	12.3910	< 2e-16	***
fod_num	-0.0347	0.0036	-9.5640	< 2e-16	***
dr_num	0.0022	0.0045	0.4850	0.6274	
daynightnight	0.1826	0.0680	2.6850	0.0072	**
rep_designBT0.Natural	-0.5178	0.1137	-4.5520	<0.0001	***
rep_designBTDietl Ditch	0.3369	0.1033	3.2600	0.0011	**
rep_designBTNo Bench	-0.4645	0.1444	-3.2180	0.0013	**
jam_area_pft	-0.0207	0.0181	-1.1470	0.2512	
iwm_dia_in	-0.0816	0.0263	-3.1020	0.0019	**
year1b.2010:fod_num	0.0343	0.0042	8.2440	< 2e-16	***
year1b.2010:dr_num	-0.0251	0.0050	-5.0490	<0.0001	***
region2RV:jam_area_pft	-0.0709	0.0249	-2.8460	0.0044	**
region2RV:iwm_dia_in	0.1858	0.0350	5.3090	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-7.3847	169.5711	-0.0440	0.9653	
release3abvSA	-2.9238	0.6211	-4.7070	<0.0001	***
release3SAabvFe	-1.5298	0.8440	-1.8130	0.0699	.
release3SAblwAmer	-1.5759	0.7441	-2.1180	0.0342	*
year1b.2010	-8.9636	1.4363	-6.2410	<0.0001	***
log10(fd.flow)	1.8529	0.4458	4.1570	<0.0001	***
region2RV	-0.4426	0.1598	-2.7690	0.0056	**
fod_num	-0.0370	0.0061	-6.1050	<0.0001	***
dr_num	-0.0184	0.0132	-1.3920	0.1639	
rep_designNB0.Natural	-0.2047	0.3414	-0.6000	0.5488	
rep_designNBBench_ten_to_1	-0.0573	0.3302	-0.1730	0.8623	
rep_designNBDietl Ditch	-0.2683	0.3457	-0.7760	0.4377	
year1b.2010:fod_num	0.0198	0.0076	2.6090	0.0091	**
year1b.2010:dr_num	0.0322	0.0120	2.6850	0.0073	**
Log(theta)	-15.9127	169.5476	-0.0940	0.9252	

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.4128	1.4247	8.7130	< 2e-16	***
release3abvSA	-1.6460	0.2634	-6.2500	<0.0001	***
release3SAabvFe	-1.1507	0.3390	-3.3950	0.0007	***
release3SAblwAmer	-0.1602	0.3187	-0.5020	0.6153	
year1b.2010	-2.6747	0.7685	-3.4800	0.0005	***
log10(fd.flow)	-1.7818	0.2393	-7.4460	<0.0001	***
region2RV	1.6719	0.1349	12.3910	< 2e-16	***
fod_num	-0.0347	0.0036	-9.5640	< 2e-16	***
dr_num	0.0022	0.0045	0.4850	0.6274	
daynightnight	0.1826	0.0680	2.6850	0.0072	**
rep_designNB0.Natural	-0.0533	0.1660	-0.3210	0.7484	
rep_designNBBench_ten_to_1	0.4645	0.1444	3.2180	0.0013	**
rep_designNBDietl Ditch	0.8014	0.1566	5.1170	<0.0001	***
jam_area_pft	-0.0207	0.0181	-1.1470	0.2512	
iwm_dia_in	-0.0816	0.0263	-3.1020	0.0019	**
year1b.2010:fod_num	0.0343	0.0042	8.2440	< 2e-16	***
year1b.2010:dr_num	-0.0251	0.0050	-5.0490	<0.0001	***
region2RV:jam_area_pft	-0.0709	0.0249	-2.8460	0.0044	**
region2RV:iwm_dia_in	0.1858	0.0350	5.3090	<0.0001	***

Steelhead, Upper 3, Step 1 (sh_Upper3_1)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-4.1882	2.8817	-1.4530	0.1461	
release3abvSA	-0.4529	0.4157	-1.0890	0.2760	
release3SAabvFe	0.8044	0.5942	1.3540	0.1758	
release3SAblwAmer	0.7067	0.4369	1.6180	0.1058	
log10(fd.flow)	2.3726	0.5645	4.2030	<0.0001	***
dr_num	-0.0129	0.0065	-1.9860	0.0470	*
rep_designBench_ten_to_1	0.6970	0.2140	3.2560	0.0011	**
rep_designDietl Ditch	0.2446	0.2324	1.0530	0.2925	
rep_designNo Bench	0.3907	0.3002	1.3010	0.1931	
Log(theta)	-1.8066	0.1570	-11.5100	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	13.0503	2.0950	6.2290	<0.0001	***
release3abvSA	-2.0169	0.2264	-8.9100	< 2e-16	***
release3SAabvFe	-1.0152	0.3410	-2.9770	0.0029	**
release3SAblwAmer	0.1519	0.3220	0.4720	0.6370	
year1b.2010	-0.8564	0.1381	-6.2020	<0.0001	***
log10(fd.flow)	-2.2629	0.3946	-5.7340	<0.0001	***
fod_num	-0.0237	0.0035	-6.7350	<0.0001	***
daynightnight	-0.2640	0.0942	-2.8020	0.0051	**
rep_designBench_ten_to_1	-0.0581	0.1135	-0.5120	0.6088	
rep_designDietl Ditch	0.2928	0.1287	2.2760	0.0229	*
rep_designNo Bench	-0.2520	0.1631	-1.5450	0.1223	

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.9437	2.9187	-1.3510	0.1766	
release3abvSA	-0.4529	0.4157	-1.0890	0.2760	
release3SAabvFe	0.8044	0.5942	1.3540	0.1758	
release3SAblwAmer	0.7067	0.4369	1.6180	0.1058	
log10(fd.flow)	2.3726	0.5645	4.2030	<0.0001	***
dr_num	-0.0129	0.0065	-1.9860	0.0470	*
rep_design20.Natural	-0.2446	0.2324	-1.0530	0.2925	
rep_design2Bench_ten_to_1	0.4524	0.2095	2.1600	0.0308	*
rep_design2No Bench	0.1461	0.2988	0.4890	0.6250	
Log(theta)	-1.8066	0.1570	-11.5100	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	13.3432	2.0955	6.3680	<0.0001	***
release3abvSA	-2.0169	0.2264	-8.9100	< 2e-16	***
release3SAabvFe	-1.0152	0.3410	-2.9770	0.0029	**
release3SAblwAmer	0.1519	0.3220	0.4720	0.6370	
year1b.2010	-0.8564	0.1381	-6.2020	<0.0001	***
log10(fd.flow)	-2.2629	0.3946	-5.7340	<0.0001	***
fod_num	-0.0237	0.0035	-6.7350	<0.0001	***
daynightnight	-0.2640	0.0942	-2.8020	0.0051	**
rep_design20.Natural	-0.2928	0.1287	-2.2760	0.0229	*
rep_design2Bench_ten_to_1	-0.3510	0.1245	-2.8190	0.0048	**
rep_design2No Bench	-0.5448	0.1713	-3.1800	0.0015	**

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.4913	2.9111	-1.1990	0.2304	
release3abvSA	-0.4529	0.4157	-1.0890	0.2760	
release3SAabvFe	0.8044	0.5942	1.3540	0.1758	
release3SAblwAmer	0.7067	0.4369	1.6180	0.1058	
log10(fd.flow)	2.3726	0.5645	4.2030	<0.0001	***
dr_num	-0.0129	0.0065	-1.9860	0.0470	*
rep_designBT0.Natural	-0.6970	0.2140	-3.2560	0.0011	**
rep_designBTDietl Ditch	-0.4524	0.2095	-2.1600	0.0308	*
rep_designBTNo Bench	-0.3063	0.2858	-1.0720	0.2838	
Log(theta)	-1.8066	0.1570	-11.5100	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.9922	2.0952	6.2010	<0.0001	***
release3abvSA	-2.0169	0.2264	-8.9100	< 2e-16	***
release3SAabvFe	-1.0152	0.3410	-2.9770	0.0029	**
release3SAblwAmer	0.1519	0.3220	0.4720	0.6370	
year1b.2010	-0.8564	0.1381	-6.2020	<0.0001	***
log10(fd.flow)	-2.2629	0.3946	-5.7340	<0.0001	***
fod_num	-0.0237	0.0035	-6.7350	<0.0001	***
daynightnight	-0.2640	0.0942	-2.8020	0.0051	**
rep_designBT0.Natural	0.0581	0.1135	0.5120	0.6088	
rep_designBTDietl Ditch	0.3510	0.1245	2.8190	0.0048	**
rep_designBTNo Bench	-0.1939	0.1591	-1.2180	0.2231	

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	-3.7981	2.9366	-1.2930	0.1960	
release3abvSA	-0.4529	0.4158	-1.0890	0.2760	
release3SAabvFe	0.8045	0.5942	1.3540	0.1760	
release3SAblwAmer	0.7069	0.4369	1.6180	0.1060	
log10(fd.flow)	2.3727	0.5645	4.2030	<0.0001	***
dr_num	-0.0129	0.0065	-1.9860	0.0470	*
rep_designNB0.Natural	-0.3906	0.3002	-1.3010	0.1930	
rep_designNBBench_ten_to_1	0.3062	0.2858	1.0710	0.2840	
rep_designNBDietl Ditch	-0.1461	0.2988	-0.4890	0.6250	
Log(theta)	-1.8067	0.1570	-11.5090	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	12.7983	2.1008	6.0920	<0.0001	***
release3abvSA	-2.0169	0.2264	-8.9100	< 2e-16	***
release3SAabvFe	-1.0152	0.3410	-2.9770	0.0029	**
release3SAblwAmer	0.1519	0.3220	0.4720	0.6370	
year1b.2010	-0.8564	0.1381	-6.2020	<0.0001	***
log10(fd.flow)	-2.2629	0.3946	-5.7340	<0.0001	***
fod_num	-0.0237	0.0035	-6.7350	<0.0001	***
daynightnight	-0.2640	0.0942	-2.8020	0.0051	**
rep_designNB0.Natural	0.2520	0.1631	1.5450	0.1223	
rep_designNBBench_ten_to_1	0.1939	0.1591	1.2180	0.2231	
rep_designNBDietl Ditch	0.5448	0.1713	3.1800	0.0015	**

Steelhead, Upper 3, Step 2 (sh_Upper3_2)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	3.9839	3.9524	1.0080	0.3135	
release3abvSA	-1.9281	0.5062	-3.8090	0.0001	***
release3SAabvFe	-1.9376	0.8660	-2.2370	0.0253	*
release3SAblwAmer	-1.5241	0.6833	-2.2300	0.0257	*
log10(fd.flow)	1.6818	0.6649	2.5290	0.0114	*
fod_num	-0.0435	0.0088	-4.9390	<0.0001	***
year1b.2010	-8.2776	1.6892	-4.9000	<0.0001	***
BC_sum	0.7963	0.2656	2.9990	0.0027	**
diversemeas	1.7098	0.5843	2.9260	0.0034	**
fod_num:year1b.2010	0.0462	0.0093	4.9910	<0.0001	***
Log(theta)	-1.6991	0.1449	-11.7230	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	15.6405	2.2495	6.9530	<0.0001	***
release3abvSA	-2.6545	0.2779	-9.5500	< 2e-16	***
release3SAabvFe	-1.9668	0.4268	-4.6080	<0.0001	***
release3SAblwAmer	-0.8113	0.3900	-2.0810	0.0375	*
year1b.2010	-6.6899	1.0651	-6.2810	<0.0001	***
log10(fd.flow)	-2.0288	0.4026	-5.0400	<0.0001	***
fod_num	-0.0411	0.0051	-8.0830	<0.0001	***
daynightnight	-0.2957	0.0950	-3.1130	0.0019	**
bslope_sum	-0.0412	0.0201	-2.0450	0.0409	*
avgLWMdensity	-1.3216	0.4479	-2.9510	0.0032	**
year1b.2010:fod_num	0.0324	0.0058	5.5950	<0.0001	***

Steelhead, Upper 3, Step 3 (sh_Upper3_3)

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	5.5157	3.8159	1.4450	0.1483	
release3abvSA	-2.1149	0.5252	-4.0270	0.0001	***
release3SAabvFe	-2.3294	0.9058	-2.5720	0.0101	*
release3SAblwAmer	-1.7886	0.6903	-2.5910	0.0096	**
log10(fd.flow)	1.6410	0.6571	2.4970	0.0125	*
fod_num	-0.0464	0.0090	-5.1340	<0.0001	***
year1b.2010	-9.1158	1.8130	-5.0280	<0.0001	***
rep_designBench_ten_to_1	0.3185	0.2351	1.3550	0.1754	
rep_designDietl Ditch	-0.1617	0.2478	-0.6520	0.5141	
rep_designNo Bench	0.3989	0.3220	1.2390	0.2155	
EV_Apr	0.8976	0.5033	1.7830	0.0745	.
fod_num:year1b.2010	0.0504	0.0099	5.0990	<0.0001	***
Log(theta)	-1.6981	0.1449	-11.7160	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	15.4357	2.2482	6.8660	<0.0001	***
release3abvSA	-2.6273	0.2788	-9.4250	< 2e-16	***
release3SAabvFe	-1.8495	0.4206	-4.3970	<0.0001	***
release3SAblwAmer	-0.8332	0.3898	-2.1370	0.0326	*
year1b.2010	-6.7130	1.0732	-6.2550	<0.0001	***
log10(fd.flow)	-2.0143	0.4032	-4.9960	<0.0001	***
fod_num	-0.0415	0.0051	-8.1440	<0.0001	***
daynightnight	-0.2951	0.0949	-3.1090	0.0019	**
rep_designBench_ten_to_1	-0.0777	0.1142	-0.6810	0.4962	
rep_designDietl Ditch	0.3072	0.1295	2.3710	0.0177	*
rep_designNo Bench	-0.2593	0.1642	-1.5800	0.1142	
year1b.2010:fod_num	0.0325	0.0058	5.5700	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	5.3541	3.8153	1.4030	0.1605	
release3abvSA	-2.1149	0.5252	-4.0270	0.0001	***
release3SAabvFe	-2.3294	0.9058	-2.5720	0.0101	*
release3SAblwAmer	-1.7886	0.6903	-2.5910	0.0096	**
log10(fd.flow)	1.6410	0.6571	2.4970	0.0125	*
fod_num	-0.0464	0.0090	-5.1340	<0.0001	***
year1b.2010	-9.1158	1.8130	-5.0280	<0.0001	***
rep_design20.Natural	0.1617	0.2478	0.6520	0.5141	
rep_design2Bench_ten_to_1	0.4802	0.2074	2.3150	0.0206	*
rep_design2No Bench	0.5606	0.3535	1.5860	0.1128	
EV_Apr	0.8976	0.5033	1.7830	0.0745	.
fod_num:year1b.2010	0.0504	0.0099	5.0980	<0.0001	***
Log(theta)	-1.6981	0.1449	-11.7160	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	15.7430	2.2478	7.0040	<0.0001	***
release3abvSA	-2.6273	0.2788	-9.4250	< 2e-16	***
release3SAabvFe	-1.8495	0.4206	-4.3970	<0.0001	***
release3SAblwAmer	-0.8332	0.3898	-2.1370	0.0326	*
year1b.2010	-6.7130	1.0732	-6.2550	<0.0001	***
log10(fd.flow)	-2.0143	0.4032	-4.9960	<0.0001	***
fod_num	-0.0415	0.0051	-8.1440	<0.0001	***
daynightnight	-0.2951	0.0949	-3.1090	0.0019	**
rep_design20.Natural	-0.3072	0.1295	-2.3710	0.0177	*
rep_design2Bench_ten_to_1	-0.3849	0.1251	-3.0780	0.0021	**
rep_design2No Bench	-0.5665	0.1724	-3.2870	0.0010	**
year1b.2010:fod_num	0.0325	0.0058	5.5700	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	5.8343	3.7849	1.5410	0.1232	
release3abvSA	-2.1149	0.5252	-4.0270	0.0001	***
release3SAabvFe	-2.3294	0.9058	-2.5720	0.0101	*
release3SAblwAmer	-1.7886	0.6903	-2.5910	0.0096	**
log10(fd.flow)	1.6410	0.6571	2.4970	0.0125	*
fod_num	-0.0464	0.0090	-5.1340	<0.0001	***
year1b.2010	-9.1159	1.8130	-5.0280	<0.0001	***
rep_designBT0.Natural	-0.3185	0.2351	-1.3550	0.1754	
rep_designBTDietl Ditch	-0.4802	0.2074	-2.3150	0.0206	*
rep_designBTNo Bench	0.0803	0.3471	0.2310	0.8170	
EV_Apr	0.8976	0.5033	1.7830	0.0745	.
fod_num:year1b.2010	0.0504	0.0099	5.0990	<0.0001	***
Log(theta)	-1.6981	0.1449	-11.7160	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	15.3580	2.2470	6.8350	<0.0001	***
release3abvSA	-2.6273	0.2788	-9.4250	< 2e-16	***
release3SAabvFe	-1.8495	0.4206	-4.3970	<0.0001	***
release3SAblwAmer	-0.8332	0.3898	-2.1370	0.0326	*
year1b.2010	-6.7130	1.0732	-6.2550	<0.0001	***
log10(fd.flow)	-2.0143	0.4032	-4.9960	<0.0001	***
fod_num	-0.0415	0.0051	-8.1440	<0.0001	***
daynightnight	-0.2951	0.0949	-3.1090	0.0019	**
rep_designBT0.Natural	0.0777	0.1142	0.6810	0.4962	
rep_designBTDietl Ditch	0.3849	0.1251	3.0780	0.0021	**
rep_designBTNo Bench	-0.1816	0.1600	-1.1350	0.2565	
year1b.2010:fod_num	0.0325	0.0058	5.5700	<0.0001	***

Count model coefficients (truncated negbin with log link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	5.9147	3.8036	1.5550	0.1199	
release3abvSA	-2.1149	0.5252	-4.0270	0.0001	***
release3SAabvFe	-2.3294	0.9058	-2.5720	0.0101	*
release3SAblwAmer	-1.7886	0.6903	-2.5910	0.0096	**
log10(fd.flow)	1.6410	0.6571	2.4970	0.0125	*
fod_num	-0.0464	0.0090	-5.1340	<0.0001	***
year1b.2010	-9.1158	1.8130	-5.0280	<0.0001	***
rep_designNB0.Natural	-0.3989	0.3220	-1.2390	0.2155	
rep_designNBBench_ten_to_1	-0.0803	0.3471	-0.2310	0.8170	
rep_designNBDietl Ditch	-0.5606	0.3535	-1.5860	0.1128	
EV_Apr	0.8976	0.5033	1.7830	0.0745	.
fod_num:year1b.2010	0.0504	0.0099	5.0990	<0.0001	***
Log(theta)	-1.6981	0.1449	-11.7160	< 2e-16	***

Zero hurdle model coefficients (binomial with logit link):

	Estimate	Std. Error	z value	Pr(>|z|)	
(Intercept)	15.1764	2.2529	6.7360	<0.0001	***
release3abvSA	-2.6273	0.2788	-9.4250	< 2e-16	***
release3SAabvFe	-1.8495	0.4206	-4.3970	<0.0001	***
release3SAblwAmer	-0.8332	0.3898	-2.1370	0.0326	*
year1b.2010	-6.7130	1.0732	-6.2550	<0.0001	***
log10(fd.flow)	-2.0143	0.4032	-4.9960	<0.0001	***
fod_num	-0.0415	0.0051	-8.1440	<0.0001	***
daynightnight	-0.2951	0.0949	-3.1090	0.0019	**
rep_designNB0.Natural	0.2593	0.1642	1.5800	0.1142	
rep_designNBBench_ten_to_1	0.1816	0.1600	1.1350	0.2565	
rep_designNBDietl Ditch	0.5665	0.1724	3.2870	0.0010	**
year1b.2010:fod_num	0.0325	0.0058	5.5700	<0.0001	***

APPENDIX I.

Summary Tables of Telemetry GLM Output (Residency and Design Type)

Table I-1. Chinook Salmon Design Type Differences Summary, Steps 1 and 3 Results Summary Based on "Hurdle" Model Fit to All Data.

Better/Worse	Residency Duration		Stay vs. Go	
	Step 1	Step 3	Step 1	Step 3
Better	No Bench	No Bench	Dietl Ditch	Dietl Ditch
Intermediate 1	Natural		Bench/10:1*	No Bench Bench/10:1
Intermediate 2			No Bench	
Worse	Bench/10:1 Dietl Ditch	Natural Bench/10:1 Dietl Ditch	Natural	Natural

*Stay vs. Go/Step 1 (Bench/10:1 vs. No Bench)

Table I-2. Chinook Salmon Design Type Differences Summary, Steps 1 and 3 Results Summary Based on "Hurdle" Model Fit to the "Upper" River above RM 20.

Better/Worse	Residency Duration		Stay vs. Go	
	Step 1	Step 3	Step 1	Step 3
Better	No Bench	No Bench	No differences	No bench
Intermediate	Natural			Bench/10:1 Dietl Ditch*
Worse	Dietl Ditch Bench/10:1	Natural Dietl Ditch Bench/10:1		Natural

* Stay vs. Go/Step 3 (Dietl Ditch vs. Natural).

Table I-3. Steelhead Design Type Differences Summary, Steps 1 and 3 Results Summary Based on "Hurdle" Model Fit to All Data.

Better/Worse	Residency Duration		Stay vs. Go	
	Step 1	Step 3	Step 1	Step 3
Better	No differences	No differences	Dietl Ditch	Dietl Ditch
Intermediate			Bench/10:1	Bench/10:1
Worse			Natural No Bench	No Bench Natural

Table I-4. Steelhead Design Type Differences Summary, Steps 1 and 3 Results Summary Based on "Hurdle" Model Fit to the Upper River above RM 20. Note that No Habitat Variables Were Retained in Step 3, So Result Is Identical to Step 1.

Better/Worse	Residency Duration		Stay vs. Go	
	Step 1	Step 3	Step 1	Step 3
Better	Bench/10:1	Bench/10:1	Dietl Ditch	Dietl Ditch
Indeterminant	No Bench	No Bench Natural		
Worse	Dietl Ditch Natural	Dietl Ditch	Natural Bench/10:1 No Bench	Natural Bench/10:1 No Bench

APPENDIX J.

Summary Tables of Telemetry GLM Output (Residency and Habitat Features)

Table J-1. Chinook Salmon Relationships with Habitat Variables, Results Summary Based on Hurdle Model Fit to All Data. Lower Region Variables Are Noted where Different from the Upper Region.

Region	Sig/NS	Residency Duration		Stay vs. Go	
		Step 2	Step 3	Step 2	Step 3
Upper	Significant (p<0.05)	Shade (+) %Boulder/ cobble (+)	Shade (+)	Shade (-) Bank slope (-) %Boulder/ cobble (+) IWM diameter (-) Jam area (-)	Bank slope (+) IWM diameter (-) Jam area (-)
Lower	Significant (p<0.05)*			IWM diameter (+) Jam area (-, <Upper)	IWM diameter (+) Jam area (-, <Upper)

* Significance of the interaction term, region: X, where X is a habitat variable, based on addition of interaction terms one at a time.

Table J-2. Chinook Salmon Relationships with Habitat Variables, Results Summary Based on Hurdle Model Fit to Upper River above RM 20 Only.

Sig/NS	Residency Duration		Stay vs. Go	
	Step 2	Step 3	Step 2	Step 3
Significant (p<0.05)	Shade (+) IWM diversity (-) LWM density (+)	IWM diversity (-)	Shade (-) %Boulder/ Cobble (-) Bank slope (+) LWM density (+)	Bank slope (+) IWM diversity (+)
Inconclusive (0.05<p<0.10)		Shade (+)		

Table J-3. Steelhead Relationships with Habitat Variables, Results Summary Based on Hurdle Model Fit to All Data. Lower Region Variables Are Noted where Different from the Upper Region.

Region	Sig/NS	Residency Duration		Stay vs. Go	
		Step 2	Step 3	Step 2	Step 3
Upper	Significant ($p<0.05$)			Bank slope (-) %Boulder/cobble (+)	IWM diameter (-)
	Inconclusive ($0.05<p<0.10$)			IWM diameter (-)	
	Not significant ($p>0.10$)			Jam area (-)	Jam area (-)
Lower	Significant ($p<0.05$)*			IWM diameter (+) Jam area (-, <Upper)	IWM diameter (+) Jam area (-, <Upper)

* Significance of the interaction term, region: X, where X is a habitat variable, based on addition of interaction terms one at a time.

Table J-4. Steelhead Relationships with Habitat Variables, Results Summary Based on Hurdle Model Fit to Upper River above RM 20 Only.

Sig/NS	Residency Duration		Stay vs. Go	
	Step 2	Step 3	Step 2	Step 3
Significant ($p<0.05$)	%Boulder/Cobble (+) IWM diversity (+)		Bank slope (-) LWM density (-)	
Inconclusive ($0.05<p<0.10$)		Submerged vegetation (+)		

APPENDIX K.

Response to Agency Comments

H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

December 30, 2010

Bill O'Leary
Department Of Water Resources
Critical Repairs Branch
Division of Flood Management
2825 Watt Avenue, Suite 100
Sacramento, CA 95821-9000

Subject: Final Interim (Year-3) Critical Erosion Levee Repair Sites Fish and Habitat Monitoring Report and Response to Year-3 Report Comments

Dear Bill,

Enclosed please find the revised Year-3 Critical Erosion Levee Repair Sites Fish and Habitat Monitoring Report and H. T. Harvey & Associates response to Year-3 report comments. The revised report is enclosed in track changes. We have listed the comments in regular bolded text below and provided our responses in italics.

DEPARTMENT OF WATER RESOURCES COMMENTS

General Comments

1. **Most of the comments made by DWR were additional explanatory text in the Executive Summary and Introduction sections.**

   Added insertions.

Specific Comments

2. **Pg. 35, under Analysis of Fish Data, first paragraph under Table 4.5: Define: "During each step, variables were dropped one at a time, and likelihood ratio tests were used to compare successive models."**

   Added text.

3. **Pg. 36, under Analysis of Fish Data, first paragraph under Table 4.5: Define/ Explain: "Likelihood ratio tests with p>0.10 led to the variable being removed; otherwise it was retained".**

   See response to previous comment.

4. **Page 36, under Analysis of Fish Data, first paragraph under Table 4.5: Explain why or maybe provide examples of how or where these approaches were used before successfully. Also explain why date is unknown. "We used R (RDCT [date unknown] #2211) for all analyses."**

Noted, completed reference and added text.

5. **Page 41, last paragraph under 4.5.1.3 IWM point-scale measures compared with IWM site-scale measures: Does this need to be explained? "We used AIC (Akaike Information Criterion) as a measure of overall model fitness to compare models.**

   Added text.

6. **Page 41, second paragraph under section 4.5.2 Telemetry Data Analysis: I am not sure I understand this. Could it be described more? Or refer to 4.5.2.1 ?**

   Noted. Referred reader to section 5.4.1, Figure 5-17.

7. **Page 69, Footnote concerning "gmlss" reference to first paragraph under 5.3 Results of Electrofishing: Should more be explained here? "gamlss" is a term used in the R language, which stands for "Generalized Additive Models for Location, Scale and Shape"**

   Deleted "gmlss" reference altogether, GLM replaces gamlss and gmlss, as this was the statistical method used rather than the function's name.

8. **Page 73, footnote to Table 5-9: There is a discrepancy as nothing in the table refers to NA. "NA = this analysis was not available but will be forthcoming. "**

   Noted. Deleted; this was a remnant from a prior version.

U.S. ARMY CORPS OF ENGINEERS COMMENTS

No comments received.

NATIONAL MARINE FISHERIES SERVICE COMMENTS

Comments by Kenneth Cummings

General Comments

1. **Naturalize implies that the unmanaged sites were somehow deliberately influenced by man's actions when these sites are the result of volunteer development in natural succession. Possibly endemic versus engineered would be a better description of what is the case. In this paper it would seem that natural sites are really reference or background sites**

Thanks for your insight with this term. Unfortunately, this term has been used throughout the project including in the monitoring plan and Year 1 and Year 2 reports. Thus, if we changed this now we would be inconsistent with all previous work on the project. We did, however, expand the definition in the report so the reader understands that these naturalized sites are indeed reference sites.

2. **Editorially, Table legends are not sentences, so shouldn't end in a period unless they are followed by complete sentences.**

   Noted. It is H. T. Harvey & Associates' style standard to format tables with a period in the titles.

3. **I couldn't download the Appendices pdf files from Pat's e-mail.**

   Appendices were given.

Specific Comments

4. **Pg. iii, under Executive Summary, Table ES2. Study results address study objectives and inform our methodology:**

   - **Check on other slash drops.**

     Noted

   - **In reference to the word "confounding", this term usually means to confuse, mix up, or bewilder. A better term would be uncertain relationship.**

     Noted. Changed to more appropriate phrase; confounding is not the appropriate term here, though it is later (see response to next comment).

5. **Pg. iv, in the Executive Summary, fourth paragraph: This is not the commonly understood definition of confounded. In reference to: "We identified confounding factors and determined that the very habitat features that look to be important in explaining differences in fish behavior are the same features that are confounded with (that is, associated with) design type."**

Noted. Edited text somewhat, though the term confounded was kept here. It is appropriate to use in this context, but we revised the text around it to read better. Within statistical context, a confounding factor is one that is associated with both the dependent variable (i.e., fish presence/absence) and one of the independent variables (i.e., design type), interfering with the ability to interpret model results regarding the independent variable of interest.

6. **Pg. 1, Table 1.1, in reference to Bench design features. The benches are also inundated by high flows.**

Changed text.

7. **Pg. 1, Section 1.1 Introduction, third paragraph "has been performed for three years following construction". Were these fishing events executed at the same solar time for each electrofishing sampling? If not, do you assume that fish will behave the same at any time of the day or season?**

Methods section describes that efishing occurs only during the day. Within a day, it is unlikely that solar time has any effect; we assume that fish behave the same at any time of day during daylight hours. We wouldn't make the same assumption about day vs. night however. Differences due to season are actually accounted for in all analyses by inclusion of month and appropriate interaction terms with month as independent variables.

8. **Pg. 3, Section 1.2 Background, fourth paragraph, "habitat features are". Plural?**

Noted and changed.

9. **Pg. 3, Section 1.2 Background, fifth paragraph, "to adversely affect". This is a split infinitive here and several other places.**

Changed.

10. **Pg. 4, Section 2, last paragraph, in reference to "steep": Change to in flow gradient?**

Changed.

11. **Pg. 5, Table 2.1. Change from "riparian species" to "riparian plant species"**

Changed.

12. **Pg. 7, Section 3.2 Objectives of Fish Monitoring, first bullet point, "abundance use". Abundance does not imply that the fish is using this site for some purpose. Their presence could be simply passive occurrence.**

We dropped "abundance" from this objective, since our analyses rely strictly on presence/absence of fish.

13. **Pg. 7, Section 4 Methods, second paragraph, "statistical methods". Where do you present the formulas and application of the actual models that you use? The mixed effects models are very complex with stringent use constraints. You assume that they are appropriate for this analysis without developing the limitations of their use in this study.**

We made substantial revisions to all results sections pertaining to these statistical analyses to help address this. These included addition of coefficient tables, formulas, and text to help explain these.

14. **Pg. 10, Table 4.1, "*Electrofishing was not conducted at these sites due to restrictions associated with delta smelt." So, there were only 15 sites that were electrofished.**

    Correct.

15. **Pg. 17, Table 4.4. What are the units of measurements?**

    Added text.

16. **Pg. 18-19, Section 4.5 Analysis of Fish Data, 3-Step… Approach. This text box is too simplistic as an explanation for what you did in this study. You seem reluctant to attempt to explain to your reviewers in a schematic how you derive the answers you put in the Results section.**

    Our revisions as noted above should help bridge the gap between the methods and results a bit better. Also, we provide additional detail explaining the link between the statistical modeling and the results using an example in Section 5.3.2.

17. **Pg. 43, Table 5-6. This acronym "AIC" needs more explanation.**

    Added text in Section 4.5.1.3.

18. **Pg. 52, Figure 5-15. There are only 14 fishing sites for these 206 juveniles. This also suggests that there are 12 sites with less than 24 fish per site and spread over the 2 years of sampling. How confident can you be that this small number of fish will give you reliable relationships? There is a definite need for a table of fish species and age group caught per site per sampling time for all design types.**

    The study design incorporated a relatively large number of sites, allowing us to be more confident of the relationships. Also, data with no or very few fish are important data. Added table D-4 in Appendix D that summarizes the numbers captured per site and effort.

Comments By Michael Hendricks

General Comments

19. **I would delete terms such as "relatively simple" and "more advanced", as these are subjective.**

    Accepted deletions.

20. **Use "downstream" instead of "below" and "upstream" instead of "above" in reference to river mile locations.**

Corrected.

21. **General wording changes and insertions throughout document.**

    Any wording changes and corrections made were accepted.

Specific Comments

22. **Pg. ii, under Executive Summary, first paragraph under Introduction and Methods: I am pretty sure emergency repairs occurred on levees prior to 2006.**

    Text added by Bill O'Leary and DWR that more thoroughly explains the background of the project.

23. **Pg. ii, under Executive Summary, first paragraph under Introduction and Methods: Is this true that all mitigation measures were based on SAM? In reference to: "Mitigation measures for channel and river bank modifications were designed based on the Standardized Assessment Methodology (SAM).**

    Yes, we believe that to be true, although we were not involved in the design.

24. **Pg. ii, under Executive Summary, second paragraph under Introduction and Methods: define what n=13 and n=8 means in reference to the levee repair sites.**

    Added text.

25. **Pg. iii, under Executive Summary, Table ES2. Study results address study objectives and inform our methodology:**

    - **IWM has not been defined.**

      Added text.

    - **Explain the "3-step approach".**

      Removed reference to "3-step approach" here. It is now explained at first mention in the text.

26. **Pg. iii, in the Executive Summary, second paragraph under results and discussion: in reference to the word "both" in the sentence: "The IWM site-scale measurements were modeled using both years of electrofishing data and all other IWM sampling efforts (not just April 2010);" Do you mean two years**?

    Changed text.

27. **Pg. iv, in the Executive Summary, fifth paragraph. Several comments pertaining to the following sentence and its corresponding paragraph: "A major finding of these analyses is that results differ considerably comparing above RM 20 and below RM 20.**

    - **It should be made clear that you are discussing the Sacramento River. It is mentioned later in the paragraph, perhaps bring this to the front.**

        Changed text.

    - **It is more appropriate to use "upstream" and "downstream" as opposed to "above" and "below".**

        Changed text.

28. **Pg. iv, in the Executive Summary, sixth paragraph: "There is no simple answer to the question, "Which levee designs and habitat features are "best" for each species and life stage being considered?" This seems to contradict the first sentence in two paragraphs above that starts "The statistical models…"**

    Deleted this sentence.

29. **Pg. iv, in the Executive Summary, seventh paragraph: "Very few steelhead (i.e., 15) were captured…" "Very is subjective. I would delete.**

    Deleted this finding.

30. **Pg. iv, in the Executive Summary, second to last paragraph: "However, bass predators are also associated with the Dietl Ditch design…" Yes, this is definitely a big concern. On a side note, when you are electrofishing, feel free to keep all the bass you want, I will not tell anyone.**

    Thanks. We will keep this in mind during 2011 sampling.

31. **Pg. 1, Section 1 Introduction. See comments in Executive Summary section concerning year of critical levee repairs and SAM methodology mitigation measures.**

    Text added by Bill O'Leary and DWR more thoroughly explains the background of the project.

32. **Pg. 2, Section 2.1 Background, second paragraph. Standardized Assessment Methodology (SAM) is already defined above.**

    Deleted.

33. **Pg. 2, Section 2.1 Background, second paragraph. "Attempts"? is this the best word, does it quantify or not?**

Changed text.

34. **Pg. 2, Section 2.1 Background, third paragraph. Similar to comment above, does it "intend"? I would delete.**

    Deleted.

35. **Pg. 8, Section 4.1 Site Selection, paragraph 2, "habitat features". What habitat features? Explain or define.**

    Added text.

36. **Pg. 9, Section 4.1 Site Selection, paragraph 2. Did I miss what happened to Reach 3?**

    Noted. Please refer to sentence prior to commented sentence.

37. **Pg. 10, Section 4.2 Measurement of Habitat Features, "Habitat feature data were also collected in 2010 but these data were not used for this report." Is this due to a time issue? If you have the 2010 data, not sure why you would not want to use that? Is the data incomplete?**

    A decision was made early in the project by the agency group to relate the fisheries data collected in the winter/spring to the habitat characteristics data collected in the proceeding summer/fall. Thus, the 2010 habitat characteristics data that was collected will be compared to the 2011 fisheries data to be collected. The text was modified to clarify this approach.

38. **Pg. 10, Section 4.2.1 Water Surface Elevations. Is USGS defined previously?**

    Added text.

39. **Pg. 10, Section 4.2.1 Water Surface Elevations. In reference to rive miles, RM, use "downstream" instead of "below"**

    Changed text throughout.

40. **Pg. 12, Section 4.2.6 Bank Substrate Size. The bank substrate size (in units of inches) was characterized for each selected site at and below each permanent transect. Do you mean downstream or below?**

    Below. We added some qualifying text to make this clearer.

41. **Pg. 12, Section 4.2.7 Aquatic Vegetation, paragraph 2. Same comment as above, do you mean downstream or below?**

    Below. We added some qualifying text to make this clearer.

42. **Pg. 13, Section 4.3 Instream structure and IWM measurements, fifth paragraph, "During the 2010 electrofishing surveys". Looks like you are using this 2010 data, is this a consistency issue w/ not using the 2010 habitat data?**

    It was decided as a group to use this approach for the project. The timing of the survey is such that it is offset several months from the electrofishing efforts whether you use the year prior or the year following. Either one seems valid to us but the habitat characteristics data from the year before is likely a more accurate representation of what the fish are actually using.

43. **Pg. 20, Table 4.5 Interpretations of habitat features and design types possible from 3-step GLM approach. This is great, but why not include all scenarios in this Table?**

    All relevant scenarios now included.

44. **Pg. 22, Section 4. 5.1.1 Generalized Linear Mixed Models (GLMM) by month, fourth paragraph. Is LWM defined previously?**

    Added text.

45. **Pg. 24, Section 4.5.1.2 Mixed Effect Models, Combined Analysis, last paragraph, "Analysis for bass predators consisted of all three possible efforts (January/February, March, and April)". Not sure what is meant by "all three possible efforts"?**

    Changed text.

46. **Pg. 26, Section 4.5.2.1 Generalized Linear Model Analysis, second paragraph, "Spatial variables were release location and region (river segments identified by clusters of study sites or proximity by river mile); temporal variables were date of release, first date of detection at a station, whether the first detection at a station occurred during day or night, and measured flow during the first day of residency at a station.' This sentence is confusing, suggest re-write**

    Changed text.

47. **Pg. 26, Section 4.5.2.1 Generalized Linear Model Analysis, second paragraph, "Not sure I know what "Jam area per feet" means?**

    Added text.

48. **Pg. 31, Section 5.1.2 Aquatic Vegetation, paragraph one. Define "1-SE".**

    Added text.

49. **Pg. 33, Figure 5-4. Question on IWM, if this was mentioned earlier, I apologize. Is it possible that the IWN is higher in the repair sites due to this being a part of the mitigation and in the natural sites the IWM tends to be removed?**

    To our knowledge, IWM is not regularly removed from natural sites as part of any on-going maintenance or flood control work. DWR confirmed this as well.

50. **Pg. 43, Table 5-6. Still not exactly sure what is meant by "Jam area"?**

    Jam area is the estimated area occupied by two or more overlapping logs that are at least 4 inches in diameter. Text was added to clarify this.

51. **Pg. 45, Section 5.3 Results of Electrofishing, paragraph 2, "Conversely we assumed that the "worst" designs and habitats were where fish were least likely to occur. Best and worst design types were significantly better or worse, respectively, than at least one other design type". Are we comfortable saying this since these repair sites are relatively "young"?**

    We added text that notes that the sites are relatively young and as a result fish responses could change as the sites evolve.

52. **Pg. 61, Section 5.4.1.1 Residency Criteria in Relation to Design Type, "We interpreted "best" as having the longest residency duration and strongest relationship with fish staying, and "worst" the shortest residency duration and strongest relationship with fish leaving". Is there literature that actually states that it is a good thing to have salmonids "stay" in one location for an extended duration? Seems like this would add to predation risk and other issues.**

    Yes. Citations and clarifying text were added.

53. **Pg. 65, Section 5.4.2.2 Residency Criteria in Relation to Habitat Features, second paragraph, "seriously confounded". Confusing statement, not sure what is meant here?**

    Added text.

54. **Pg. 65, Section 5.4.2.2 Residency Criteria in Relation to Habitat Features, fourth paragraph, Due to the much wider river channel in this tidally influenced area, this is perhaps not surprising. The likelihood of a fish keying in on relatively small bankline features when faced with such a great extent of area seems somewhat unlikely. Agreed, temperatures probably play a factor here as well.**

    Noted.

55. **Pg. 67, Section 6.1 Evaluating the Methodology, second paragraph. Interesting observations, perhaps this information will be used in future designs that depend on river location.**

Agreed. It is our hope that the findings of this study influences future designs.

56. **Pg 67, Section 6.1 Evaluating the Methodology, third paragraph, "all 4 regions (Appendices I and J)". Here I have a bit of confusion , the tables and figures only indication region 1a, 1b, and 2, and not region 3.**

    Added regions and explanation to first table in text (Table 4-1).

57. **Pg. 68, Section 6.2 Meeting the Study Objectives, paragraph 2 on juvenile steelhead. How do we know this is minimal? Do we know the overall juvenile population in the area at this time? I am sure the numbers are higher, but do we have anything concrete that we can use?**

    Changed this section to emphasize telemetry results.

U.S. FISH AND WILDLIFE SERVICE COMMENTS

Comments by Steven Schoenberg

General Comments

1. **Reader was unable to find a definition for IWM diversity.**

   Noted. See Section 4.5.1.1 for definition.

2. **General Comment on document in total: 1) text mostly reads easier as to what is intended, made more sense by end; but 2) conclusions in 1) based on statistical analyses in appendices that were, perhaps by nature, insufficiently reader-friendly to verify. 3) statistical approach - use of significance testing - did not yield a quantifiable sense of "how much" and in what terms, the use parameters differed.**

   Glad that the text was easier to read. We made substantial revisions to provide a better balance between readability and more quantitative detail, putting some key model outputs into the text. These revisions also provide a better sense for relative magnitude of differences and relationships.

Specific Comments

3. **Pg. iv, in the Executive Summary, second paragraph: "point-scale". Description "above", and citation elsewhere, is inadequate. Please describe here how the designated reaches differ**

   This comment appears to be a repeat of the comment below. We added a paragraph in the document to better describe the reaches and also changed how we used the term *"point-scale"; it no longer refers to measurements, simply the spatial scale used for analysis.*

4. **Pg. 5, Section 2 Study Area Description, first paragraph under Table 2-1: "** Based on the differences in reach geomorphology and vegetation as described above…" Differences are not adequately described "above", and citation is inadequate. Please describe the designated reach differences briefly.

   Please see response above.

5. **Pg. 7, Section 3.1: "These data will be collected…" Should be "These data were collected…", correct?**

   Changed text.

6. **Pg. 14, under section 4.3 Instream Structure and IWM Measurements, fourth paragraph.**

   - **This is the only sentence that informs to the potential differences/definition of the terms, pt-scale and site-scale, that are used repeatedly throughout the rest of the document. Somehow, this section (4.3) needs to be restructured and re-written so these important terms are more clearly defined, and more easily understood by the reader. In plain language - what I get out of this is that site scale are SAM measurements measured on the sites, and pt scale are some other measurements measured at the electrofishing points. But it's not stated like that. Rather, reviewer is forced to re-read 10X to figure it out and is not sure.**

     Section was rewritten.

   - **It is not at all clear what is being measured, or what "density" means, in this context. Is this the % of ground surface covered by wood? Is it the somehow related to total amount of wood? How is thickness of the debris considered?**

     Added text.

7. **Pg. 15, Section 4.4.1 Electrofishing, second paragraph: "Each selected site above RM 20 was electrofished during daylight hours from a boat..." It isn't clear exactly where, in relation to the bank, electrofishing was done. Please indicate how close to bank this was done; if this distance to bank varied between sites, and why (e.g., possibly depth). Did sampling distance of e-fishing to bank vary in some way between design types? If so, discuss potential bias/error which may have resulted.**

   Added text.

8. **Pg. 15, Section 4.4.1 Electrofishing, second paragraph: "Sites were electrofished three times between late January and April in 2009 and 2010…" It is unclear if all sites were**

measured concurrently on the same three dates, or if sites were measured on different dates, three times each. It may have this somewhere in an appendix, and that can be cited also, but you should say here what was done, not just reference a citation.

Added text.

9. **Pg. 20, second paragraph under Table 4.5: We used R (RDCT [date unknown] #2211) for all analyses." Unknown what this means. It may be some kind of reference/citation placeholder. Please change.**

   Changed.

10. **Pg. 21, third paragraph under Section 4.5.1 Electrofishing Analysis. I'm a bit lost as to what is done here. Are these two steps done for each of the 3-steps previously described? Or for one particular step of the 3-steps? I see something called "random effects" in some tables in Appendix E, but recall no discussion of this or what the analysis may have meant.**

    Changed text. See following paragraph for meaning of "random effects".

11. **Pg. 24, Section 4.5.1.3 IWM point-scale measures compared with IWM site-scale measures.**

    - **The referenced section 4.2.8 is about overhead shade; perhaps you mean section 4.3? Please check/correct.**

      Corrected.

    - **Again, this terminology is not remembered by this reader as to what it meant; going back to p. 14 - I think what is lacking there at least is a defining sentence. I can only think the lack of reader comprehension begs for a better choice of terms than pt.-scale and site-scale, which are more self-defining.**

      We changed the way that we used these terms. For measurements, we use electrofishing-based and transect-based to describe the method that was used for collection, and for the analyses, we bring in the terms point scale and site scale to describe the spatial scale. These are explained in the text.

    - **Reader is further confused as to what step 1 does; back on p. 18, document says this step "indicates whether fish use differs due to design type"; now, it appears the document is saying that it is done at some other step ("later").**

      Added text to clarify. Sorry to confuse the reader.

    - **Reader does not recall definition of this: "IWM Diversity"**

Added reference to section 4.5.1.1, where this term is defined.

12. **Pg. 26, Section 4.5.2.1 Generalized Linear Model Analysis: "but only included the habitat variables in common with the telemetry analysis done for 2009 data." Why is there no "jam area/sqft" in the 1st set of bullets, above, since the 2nd set of bullets has this (and these are variables in common for 2009), shouldn't the 1st set also have "jam area/sqft"? (since the 1st set was "based on 2009 analyses").**

    Added text.

13. **Pg. 29, Section 5.1 Results of Habitat Features Monitoring, paragraph 1. Add "Table D1"; it was tedious for this reader to find it amongst the assorted information in Appendix D.**

    Added reference to Table D1.

14. **Pg. 29, Section 5.1.1 Bank Substrate Size, paragraph 2. Appendix D doesn't have that data by design type; it only states natural vs. repair. Check/correct reference.**

    Thanks. We updated the text to accurately reflect what is in Appendix D.

15. **Pg. 37, Section 5.2.1 IWM % of Bankline Measured, last paragraph: Reader suspects high elevation wood (and no low elevation wood) may also be due to buoyancy and tidal action in that higher elevations are more subject to catch wood because of the wood floats at the surface, where it is deposited as highest tides recedes. You are welcome to speculate further as appropriate.**

    Thanks. Your thoughts we added to the report.

16. **Pg. 43, Section 5.2.3.1, second paragraph. Definition of terms needed here. It's not clear what the meaning/definition is of "pt-level IWM" versus "summary/average of pt. level IWM"; as to exactly what was averaged and summarized, and what it is when it is not averaged. Looking back, it is not adequately discussed, if at all, in the methods (p. 24). Reader is not sure of the statistical validity of using an average of many numbers, as an input to a model - as opposed to the actual observations; please comment on this. Also, reader struggled (unsuccessfully) with associating the analyses in Table 5-6 with anything in Appendix E; or what model in Appendix E is associated with point or averages there.**

    Made substantial revisions to Section 4.5.1.3 to explain the process better and also revised Appendix E so that it is easier to follow. Averaging/summarization was necessary to characterize the site using the electrofishing-based IWM measures, and is a valid way. Note too that the SAM variables were also averaged (using data from bankline transects) to characterize the site.

17. **Pg. 57, Section 5.3.6 Implications for Levee Design**

- **Need to be careful here. The proper meaning of the data is that overlaps in use show that those habitats benefit both species; not that the co-benefit necessarily means that salmonids would be attracted there and then eaten by bass more than they would if such habitat elements were not there. For example, in the absence of structural cover, bass still associate with steep banks, such as naked riprap. One could argue that the presence of habitat cover is beneficial in such areas (i.e. steep banks), as these are the areas where predators are, and predation risk to salmonids is reduced if they can use this cover.**

  We agree; co-occurrence doesn't mean predation is occurring. Added text to reflect.

  The interactions are more complex than bass and salmon presence/absence. Bass are but one predator; birds are another, and they may prey more in shallow, wadeable waters, than the bass do in deeper areas. But the characteristics of Dietl Ditches might promote avian predation as well. Bass do not necessarily overlap temporally in activity with salmon due to occurrence/thermal preferenda. Bass probably remove more competitors of juvenile salmon, than the salmon themselves. This study is not designed to determine what factors reduce predation; presence of predators is one such factor - presence of cover is another.

  This is absolutely correct. Edited the text to reflect.

  The conclusion on design focus is based on one possible implication of design on predation, and is at best restricted to areas where there is a potential choice of design. Where situations do not merit modification of bank slope, more cover such as provided by Dietl Ditch or some other design, is better than bare rock, reviewer suspects, because it provides more cover/protection from predators, food (insect production surface in water, insect drop).

  Noted. We agree with the idea that cover is probably better than no cover. Co-occurrence doesn't necessarily mean greater predation, but it does mean greater risk. We edited the text to reflect this idea.

- **See previous comment. If there is evidence elsewhere that such co-benefit actually results in so much additional predation, that it would offset the benefit, then that argument and citations supporting it should be added. Otherwise it becomes a general assumption that whatever habitat co-benefits bass is bad for salmonids. The phrasing" Overall, existing information indicates...." is a bit misleading; what I believe is meant is more limited, namely, that this document assumes a co-association of bass and salmon to mean more predation, co-association of both species being e-fished near some designs therefore means more predation, so these are concluded to be the "worst".**

  See previous responses to similar comments.

18. **Pg. 61, Section 5.4.1.1 Residency Criteria in Relation to Design Type**

- **This reviewer noted figure 5-15 showing relatively long mean durations for natural and 10:1 bench, yet these show up as "worst" in the next sentence. Reviewer guesses this is somehow relate to the statistics. Explain.**

  The analysis breaks the data into stay vs. go and residency duration components. The mean is not necessarily a good measure of either component, and also doesn't account for spatial, temporal, or habitat variables that may be affecting residency. We added text to explain this.

- **Check. 10:1 design is shown to be best in 2010, worst in 2009. See Table 5-19.**

  We replaced this with analysis of 2009/2010 data, so these tables now reflect the new results.

- **General comment - reviewer is having hard time grasping the relative magnitudes of the differences, since conclusions rely on statistics in appendices. Is there any other way to summarize/state "how much" better one design is from another?**

  Substantial revisions noted earlier regarding adding more quantitative detail to the text help to identify relative magnitudes of differences.

19. **Pg. 68, Section 6.2 Meeting the Study Objectives, Second Paragraph. The low number of Steelhead found at these sites may be a reflection of small numbers of that species overall, not lack of importance of designed habitat. It would seem that something should be said about what you did, or did not, determine from the telemetry data here; since you had many more observations there (Table 5-18).**

    We agree. We eliminated this particular finding, and replaced with a finding based on the telemetry results.

20. **Pg. 68, Section 6.2 Meeting the Study Objectives, Section on smaller Chinook salmon. Was this based on electrofishing alone? Also, not clear to reviewer how one can change (habitat?) conditions in one month**

    Changed text to reflect. Idea is to consider the implications of the design type under typical April flow conditions.

21. **Pg. 68, Section 6.2 Meeting the Study Objectives, last paragraph. Reviewer concurs with this paragraph, and the recc. for additional control.**

    Noted.

Comments by Jennifer Hobbs

General Comments

22. **You use LWM and IWM within the document. Do you mean for there to be a difference. If so I didn't see where it was explained.**

    Yes, LWM refers to IWM >4" in diameter; see Section 4.5.1.1 for more detail.

Specific Comments

23. **Pg. 2, Section 1.2 Background, second paragraph. Mitigation was not a part of the SRBPP for much of the work occurring in the 1960's and 1970's, however compensation for project effects to listed fish species is now part of the SRBPP.**

    Noted.

24. **Pg. 3, Section 1.2 Background, fourth paragraph. The BO's don't approve the sites they analyze the effects to listed species and provide a jeopardy analysis. The Corps and DWR approve the sites.**

    Edited text.

25. **Pg. 36, Section 5.1.5 Implications for Levee Design, second paragraph, in reference to "Over time". I don't agree. Deposition may provide a substrate that is more similar to natural sites but it is not likely that all sites will experience deposition and if they do then future scour of the sites will result in a riprap substrate that is not similar to natural sites.**

    Agreed. We modified to text to reflect this.

26. **Pg. 37, Section 5.2.1 IWM % of Bankline Measured, last paragraph: I don't believe driftwood is providing habitat for fish species. The drift wood I've seen in the delta tends to be large with little to no fine textured branches and is not likely to provide cover for fish.**

    We agree that most driftwood typically does not provide the same habitat values as wood with complex branch patterns. We have modified the text to reflect this.

27. **Pg. 45, Section 5.2.4 Implications for Levee Design. So are you suggesting that for purposes of refining the SAM curves data should be taken at a point-scale, but for purposes of using SAM they could still be measured at a site-scale?**

    Not necessarily. The SAM variables as currently measured are not as strongly related to fish use as electrofishing-based measures, but this probably has more to do with location relative to where the fish are more likely to be and also the types of variables being measured; for instance, the % bankline measure in SAM doesn't give any indication of structural complexity. We tried to capture this with variables such as IWM diversity, but *accurately characterizing the wood from a fish eye's perspective is something that will probably require further refinement in the future.*

28. Pg. 68, Section 6.2 Meeting the Study Objectives, Second paragraph. Don't you only have 2 years of e-fish and telemetry data?

Changed text.

Please let us know if you have any questions regarding the revised report and our response to comments before we finalize and send out.

Sincerely,

Patrick Reynolds
Senior Restoration Ecologist

H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

January 10, 2011

Bill O'Leary
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Critical Repairs Branch
Division of Flood Management
2825 Watt Avenue, Suite 100
Sacramento, CA 95821-9000

Subject: Response to Second Round of Comments on Final (Year-3) Critical Erosion Levee Repair Sites Fish and Habitat Monitoring Report (H. T. Harvey & Associates Project Number 2899-01)

Dear Bill,

This letter provides our response to comments on our December 29, 2010 revised Year-3 Critical Erosion Levee Repair Sites Fish and Habitat Monitoring Report. The only comments received on the revised report were from Steve Schoenberg of the USFWS and his comments are specific to how we addressed his comments on the November 15, 2010 initial draft report. Thus, this letter describes how we responded to Mr. Schoenberg's comments on the November 15, 2010 report. We have listed the comments in regular bolded text in quotations below and provided our responses in italics.

U.S. FISH AND WILDLIFE SERVICE COMMENTS

Comments by Steven Schoenberg

1. Comment on November 15, 2010 Draft: **"Reader was unable to find a definition for IWM diversity."**

   Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

   Noted.

2. Comment on November 15, 2010 Draft: **"General Comment on document in total: 1) text mostly reads easier as to what is intended, made more sense by end; but 2) conclusions in 1) based on statistical analyses in appendices that were, perhaps by nature, insufficiently reader-friendly to verify. 3) statistical approach - use of significance testing - did not yield a quantifiable sense of "how much" and in what terms, the use parameters differed."**

   Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Can not tell if addressed."**

We made substantial and intensive efforts to address this comment within every section of the Results. We're assuming that you can't tell because of insufficient time for review.

3. Comment on November 15, 2010 Draft: **"Pg. iv, in the Executive Summary, second paragraph: "point-scale". Description "above", and citation elsewhere, is inadequate. Please describe here how the designated reaches differ."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Duplicate comment."**

Noted.

4. Comment on November 15, 2010 Draft: **"Pg. 5, Section 2 Study Area Description, first paragraph under Table 2-1: Based on the differences in reach geomorphology and vegetation as described above…" Differences are not adequately described "above", and citation is inadequate. Please describe the designated reach differences briefly."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

Noted.

5. Comment on November 15, 2010 Draft: **"Pg. 7, Section 3.1: "These data will be collected…" Should be "These data were collected…", correct? "**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

Noted.

6. Comment on November 15, 2010 Draft: **"Pg. 14, under section 4.3 Instream Structure and IWM Measurements, fourth paragraph: This is the only sentence that informs to the potential differences/definition of the terms, pt-scale and site-scale, that are used repeatedly throughout the rest of the document. Somehow, this section (4.3) needs to be restructured and re-written so these important terms are more clearly defined, and more easily understood by the reader. In plain language - what I get out of this is that site scale are SAM measurements measured on the sites, and pt scale are some other measurements measured at the electrofishing points. But it's not stated like that. Rather, reviewer is forced to re-read 10X to figure it out and is not sure."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Still not right. Took out most of "point-scale"; but still doesn't have a definition where it is first used (e.g., p. 22)."**

Removed use of these terms from p. 22, and added explicit definition on p. 26, where this term first appears.

7. Comment on November 15, 2010 Draft: **"Pg. 15, Section 4.4.1 Electrofishing, second paragraph: "Each selected site above RM 20 was electrofished during daylight hours from a boat..." It isn't clear exactly where, in relation to the bank, electrofishing was done. Please indicate how close to bank this was done; if this distance to bank varied between sites, and why (e.g., possibly depth). Did sampling distance of e-fishing to bank vary in some way between design types? If so, discuss potential bias/error which may have resulted."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Can't tell if addressed, especially as to potential bias as in original comment."**

See 4th paragraph of Section 4.4.1. Text was added to note that we typically sampled from 0 to 5 m from shoreline, ensuring at least >0.5 ft depth. For further clarification, we added: "Depth ranges were relatively consistent among sampled points, and any potential bias due to depth was therefore minimized."

8. Comment on November 15, 2010 Draft: **"Pg. 15, Section 4.4.1 Electrofishing, second paragraph: "Sites were electrofished three times between late January and April in 2009 and 2010…" It is unclear if all sites were measured concurrently on the same three dates, or if sites were measured on different dates, three times each. It may have this somewhere in an appendix, and that can be cited also, but you should say here what was done, not just reference a citation."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

Noted.

9. Comment on November 15, 2010 Draft: **"Pg. 20, second paragraph under Table 4.5: We used R (RDCT [date unknown] #2211) for all analyses." Unknown what this means. It may be some kind of reference/citation placeholder. Please change."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

Noted

10. Comment on November 15, 2010 Draft: **"Pg. 21, third paragraph under Section 4.5.1 Electrofishing Analysis: I'm a bit lost as to what is done here. Are these two steps done for each of the 3-steps previously described? Or for one particular step of the 3-steps? I see something called "random effects" in some tables in Appendix E, but recall no discussion of this or what the analysis may have meant."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Slight edits made; however, this reviewer found it impenetrable and impossible to understand what was done."**

The edits were made to clarify that for each of the 3 steps, there were 2 parts to the model fitting (i.e., GLM and GLMM).

11. Comment on November 15, 2010 Draft: "**Pg. 24, Section 4.5.1.3 IWM point-scale measures compared with IWM site-scale measures"**

- Comment on November 15, 2010 Draft: **"The referenced section 4.2.8 is about overhead shade; perhaps you mean section 4.3? Please check/correct."**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

  Noted.

- Comment on November 15, 2010 Draft: **"Original Comment November 20, 2010: Again, this terminology is not remembered by this reader as to what it meant; going back to p. 14 - I think what is lacking there at least is a defining sentence. I can only think the lack of reader comprehension begs for a better choice of terms than pt.-scale and site-scale, which are more self-defining."**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Now, response says it "changed way" that term "point and site scale" are used. It says these are "explained in the text", but I did not find such explanation."**

  Point scale and site scale are used now only in the context of analyses. The point and site scale refer to the smaller and larger scales explained in detail in section 4.5.1.3. We have added additional text at first mention of these terms as well as explicit definitions, to be clearer (point-scale = at electrofishing points, site-scale = used to characterize a site).

- Comment on November 15, 2010 Draft: **"Reader is further confused as to what step 1 does; back on p. 18, document says this step "indicates whether fish use differs due to design type"; now, it appears the document is saying that it is done at some other step ("later")."**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Not sure. Insufficient time to review/determine.**

  Noted.

- Comment on November 15, 2010 Draft: **"Reader does not recall definition of this: "IWM Diversity""**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

  Noted.

12. Comment on November 15, 2010 Draft: **"Pg. 26, Section 4.5.2.1 Generalized Linear Model Analysis: "but only included the habitat variables in common with the telemetry analysis done for 2009 data." Why is there no "jam area/sqft" in the 1st set of bullets, above, since the 2nd set of bullets has this (and these are variables in common for 2009), shouldn't the 1st set also have "jam area/sqft"? (since the 1st set was "based on 2009 analyses")."**

    Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Probably addressed. Insufficient time to review/determine."**

    Noted.

13. Comment on November 15, 2010 Draft: **"Pg. 29, Section 5.1 Results of Habitat Features Monitoring, paragraph 1: Add "Table D1"; it was tedious for this reader to find it amongst the assorted information in Appendix D."**

    Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

    Noted

14. Comment on November 15, 2010 Draft: **"Pg. 29, Section 5.1.1 Bank Substrate Size, paragraph 2: Appendix D doesn't have that data by design type; it only states natural vs. repair. Check/correct reference."**

    Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

    Noted

15. Comment on November 15, 2010 Draft: **"Pg. 37, Section 5.2.1 IWM % of Bankline Measured, last paragraph: Reader suspects high elevation wood (and no low elevation wood) may also be due to buoyancy and tidal action in that higher elevations are more subject to catch wood because of the wood floats at the surface, where it is deposited as highest tides recedes. You are welcome to speculate further as appropriate."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **“Addressed.”**

Noted

16. Comment on November 15, 2010 Draft: **“Pg. 43, Section 5.2.3.1, second paragraph: Definition of terms needed here. It's not clear what the meaning/definition is of "pt-level IWM" versus "summary/average of pt. level IWM"; as to exactly what was averaged and summarized, and what it is when it is not averaged. Looking back, it is not adequately discussed, if at all, in the methods (p. 24). Reader is not sure of the statistical validity of using an average of many numbers, as an input to a model - as opposed to the actual observations; please comment on this. Also, reader struggled (unsuccessfully) with associating the analyses in Table 5-6 with anything in Appendix E; or what model in Appendix E is associated with point or averages there.”**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **“Insufficient time to review/determine if addressed (response refers to "substantial revisions to Section 4.5.1.3 to explain the process better and also revised Appendix E").”**

Noted

17. Comment on November 15, 2010 Draft: **“Pg. 57, Section 5.3.6 Implications for Levee Design”**

- Comment on November 15, 2010 Draft: **“Need to be careful here. The proper meaning of the data is that overlaps in use show that those habitats benefit both species; not that the co-benefit necessarily means that salmonids would be attracted there and then eaten by bass more than they would if such habitat elements were not there. For example, in the absence of structural cover, bass still associate with steep banks, such as naked riprap. One could argue that the presence of habitat cover is beneficial in such areas (i.e. steep banks), as these are the areas where predators are, and predation risk to salmonids is reduced if they can use this cover.”**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **“Response says "we agree" but revision still says "minimizing use by bass should be a consideration". Why? Both species can benefit from the same cover at the same place. Response says "agree" but text still emphasizes predatory interaction as if it is a known fact.”**

  “To put this in context, the amended language says this: "Additionally, as described below, certain levee types and habitat features may increase co-occurrence of predatory bass and juvenile Chinook salmon. Future research should assess whether this increased co-occurrence results in increased predation of Chinook salmon by predatory bass. However, when comparing the benefits and costs of different levee types, minimizing potential use by predatory

bass should be a consideration, irrespective of potential increases in predation that may be associated with certain levee types."”

This response was based largely on discussion at the DWR Critical Repairs Technical Task Group meeting. We softened the language to reflect your concerns. We still, however, believe that co-occurrence is worse than when predator and prey do not occur together. When they don’t co-occur, there is 0% chance of predation; when they co-occur, you simply cannot rule out the risk of predation.

- Comment on November 15, 2010 Draft: **“The interactions are more complex than bass and salmon presence/absence. Bass are but one predator; birds are another, and they may prey more in shallow, wadeable waters, than the bass do in deeper areas. But the characteristics of Dietl Ditches might promote avian predation as well. Bass do not necessarily overlap temporally in activity with salmon due to occurrence/thermal preferenda. Bass probably remove more competitors of juvenile salmon, than the salmon themselves. This study is not designed to determine what factors reduce predation; presence of predators is one such factor - presence of cover is another.”**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **“Response says "absolutely correct. edited text"; but I don't see any edits to reflect the comment; in fact, it still says that "overall, Dietl ditch is the worst" - unchanged from the prior draft. This is based on presumed interactions/effects of bass that are simply not established by this study. In fact, later in this section, the text reads to imply Dietl ditch is the best, based on residency. How is it overall the worst, yet the best? By the way, this conclusion does not match the definition of best and worst provided in the text (p. 49).”**

  We did not presume interaction, but still believe that co-occurrence is worse than not (see previous response to response). Also, the residency analysis targets different-sized fish, large hatchery juveniles unlikely to stop vs. smaller juveniles and fry that could potentially rear; we don’t expect telemetry to tell us the same thing as the electrofishing analyses, so we don’t find this to be contradictory. Finally, it is true that we use worst in the literal sense here rather than how previously defined; we removed the statement that Dietl Ditch is the worst, to avoid confusion.

- Comment on November 15, 2010 Draft: **“The conclusion on design focus is based on one possible implication of design on predation, and is at best restricted to areas where there is a potential choice of design. Where situations do not merit modification of bank slope, more cover such as provided by Dietl Ditch or some other design, is better than bare rock, reviewer suspects, because it provides more cover/protection from predators, food (insect production surface in water, insect drop).”**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **“Again, response says one thing, while saying another,**

e.g., "Noted. We agree with the idea that cover is probably better than no cover. Co-occurrence doesn't necessarily mean greater predation, but it does mean greater risk. We edited the text to reflect this idea." I don't see what is edited in the text, to reflect this idea on risk. Associated with certain levee types."

At the end of the first paragraph of this section, it states: "Additionally, as described below, certain levee types and habitat features may increase co-occurrence of predatory bass and juvenile Chinook salmon. Future research should assess whether this increased co-occurrence results in increased predation of Chinook salmon by predatory bass. However, when comparing the benefits and costs of different levee types, minimizing potential use by predatory bass should be a consideration, irrespective of potential increases in predation that may be associated with certain levee types." In essence, we agree that you can't assume predation necessarily (therefore suggest further research), but there is clearly greater risk when there is co-occurrence compared to when there isn't (see previous responses to 17a and 17b).

- Comment on November 15, 2010 Draft: **"See previous comment. If there is evidence elsewhere that such co-benefit actually results in so much additional predation, that it would offset the benefit, then that argument and citations supporting it should be added. Otherwise it becomes a general assumption that whatever habitat co-benefits bass is bad for salmonids. The phrasing" Overall, existing information indicates...." is a bit misleading; what I believe is meant is more limited, namely, that this document assumes a co-association of bass and salmon to mean more predation, co-association of both species being e-fished near some designs therefore means more predation, so these are concluded to be the "worst"."**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"This response says see other responses, which invited writers to provide citation to authority to substantiate their argument, does not respond (it says see other responses)."**

  Your original comment d) was simply a continuation of your thoughts from 17a, b, and c. We essentially responded to your thoughts in 17 by the edits we refer to above.

18. Comment on November 15, 2010 Draft: **"Pg. 61, Section 5.4.1.1 Residency Criteria in Relation to Design Type"**

- Comment on November 15, 2010 Draft: **"This reviewer noted figure 5-15 showing relatively long mean durations for natural and 10:1 bench, yet these show up as "worst" in the next sentence. Reviewer guesses this is somehow relate to the statistics. Explain."**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed, I think, but not enough time to review/verify."**

  Noted.

- Comment on November 15, 2010 Draft: **"Check. 10:1 design is shown to be best in 2010, worst in 2009. See Table 5-19."**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed, I think, but not enough time to review/verify."**

  Noted.

- Comment on November 15, 2010 Draft: **"General comment - reviewer is having hard time grasping the relative magnitudes of the differences, since conclusions rely on statistics in appendices. Is there any other way to summarize/state "how much" better one design is from another?"**

  Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Not enough time to review/verify. Not sure if addressed or how/where."**

  Note that substantial efforts were made to address this comment, and are reflected in all results sections.

19. Comment on November 15, 2010 Draft: "**Pg. 68, Section 6.2 Meeting the Study Objectives, Second Paragraph: The low number of Steelhead found at these sites may be a reflection of small numbers of that species overall, not lack of importance of designed habitat. It would seem that something should be said about what you did, or did not, determine from the telemetry data here; since you had many more observations there (Table 5-18)."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Not addressed. You say that: "We agree. We eliminated this particular finding, and replaced with a finding based on the telemetry results." But I checked the language and find the finding still there, and based on electrofishing."**

The new finding is in fact based on the telemetry analyses, with some additional support from the electrofishing capture data. This is in contrast with the old finding, which relied entirely on the electrofishing data.

20. Comment on November 15, 2010 Draft: **"Pg. 68, Section 6.2 Meeting the Study Objectives, Section on smaller Chinook salmon: Was this based on electrofishing alone? Also, not clear to reviewer how one can change (habitat?) conditions in one month."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

Noted.

21. Comment on November 15, 2010 Draft: "Pg. 68, Section 6.2 Meeting the Study Objectives, last paragraph: **Reviewer concurs with this paragraph, and the recc. for additional control."**

Comment on how the December 29, 2010 draft was revised in response to November 15, 2010 draft comment: **"Addressed."**

Noted.

Please let us know if you have any questions regarding the revised report and our response to comments before we finalize and send out.

Sincerely,

Patrick Reynolds
Senior Restoration Ecologist