CHaMP | Columbia Habitat Monitoring Program

2012—Second Year Lessons Learned
Project Synthesis Report

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Columbia Habitat Monitoring Program: 2012—Second Year Lessons Learned Project Synthesis Report

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Prepared by:

Terraqua, Inc.

NOAA-Fisheries

Eco Logical Research, Inc.

South Fork Research, Inc.

Quantitative Consultants, Inc.

Sitka Technology Group

Prepared for and funded by:

Bonneville Power Administration

This document is a summary of the lessons learned from work conducted by the Columbia Habitat Monitoring Program (CHaMP) in the 2012 pilot year.

CHaMP Contributors

Sara Bangen, Utah State University
Chris Beasley, Quantitative Consultants, Inc.
Boyd Bouwes, Watershed Solutions, Inc.
Nicolaas Bouwes, Eco Logical Research, Inc.
Stephen Fortney, Terraqua, Inc.
Andrew Hill, Eco Logical Research, Inc.
Chris E. Jordan, Northwest Fisheries Science Center, NOAA– Fisheries
Philip Bailey, North Arrow Research
Alan Kasprak, Utah State University
David P. Larsen, Pacific States Marine Fisheries Commission
Claire McGrath, Quantitative Consultants, Inc.
Kris McNyset, South Fork Research, Inc.
Matt Nahorniak, South Fork Research, Inc.
Meagan Polino, Eco Logical Research, Inc.
Steve Rentmeester, Sitka Technology Group, Inc.
Kevin E. See, Quantitative Consultants, Inc.
Leigh Ann Starcevich, South Fork Research, Inc.
Carol Volk, South Fork Research, Inc.
Eric Wall, Utah State University
Sarah M. Walker, Terraqua, Inc.
Michael B. Ward, Terraqua, Inc.
Nicholas Weber, EcoLogical Research, Inc.
Kelly Whitehead, South Fork Research, Inc.
Joe Wheaton, Utah State University
Jody White, Quantitative Consultants, Inc.

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LIST OF ACRONYMS

AMIP	Adaptive Management Implementation Plan
AREMP	Aquatic and Riparian Effectiveness Monitoring Program
BPA	Bonneville Power Administration
CHaMP	Columbia Habitat Monitoring Program
CRITFC	Columbia Inter-Tribal Fish Commission
DEM	Digital Elevation Model
DEQ	Department of Environmental Quality
DPS	Distinct Population Segment
EMAP	Environmental Monitoring and Assessment Program
EPA	US Environmental Protection Agency
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GRTS	Generalized Random-Tessellation Stratified
IMW	Intensively Monitored Watershed
ISEMP	Integrated Status and Effectiveness Monitoring Program
ISRP	Independent Science Review Panel
NOAA	National Oceanic and Atmospheric Administration
NWFSC	Northwest Fisheries Science Center
NPCC	Northwest Power and Conservation Council
NREI	Net Rate of Energy Intake
ODFW	Oregon Department of Fish and Wildlife
PIBO	PACFISH/INFISH Biological Opinion
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
QA	Quality Assurance
QC	Quality Control
RBT	River Bathymetry Toolkit
SRSRB	Snake River Salmon Recovery Board (Washington)
TIN	Triangulated Irregular Network
UCSRB	Upper Columbia Salmon Recovery Board
USBR	US Bureau of Reclamation
USGS	US Geologic Society
UTM	Universal Transverse Mercator
VSP	Viable Salmonid Population
WDFW	Washington Department of Fish and Wildlife
YN	Yakama Nation

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I. EXECUTIVE SUMMARY

This document may be seen as the second installment in a trilogy of lessons learned project synthesis reports documenting the first three years of the Pilot Phase of the Columbia Habitat Monitoring Program (BPA Project #2011-006). Although the eventual duration of the pilot phase will be determined by decision makers evaluating this project, CHaMP has completed the second of its initial three-year rotating panel sampling design, is arguably two years through what may be a three year learning curve with eventually diminishing returns, and anticipates having enough data of the right type after the third year of sampling in 2013 to significantly elucidate relationships between salmonid fish and their habitats by mid-2014. This elucidation, which is grounded in the use of standardized datasets and empirical modeling, is critical for the successful implementation of the biological opinion (BiOp) for the Federal Columbia River Power System (FCRPS). This confluence of timelines seems to dovetail with mounting pressures and interest to implement more widespread habitat monitoring throughout the Columbia River Basin, and the expressed desire of managers and policy decision makers to have additional interpretive tools to support the 2015 Expert Panel process.

This document synthesizes lessons learned from the second year of implementation of the Columbia Habitat Monitoring Program (CHaMP, BPA Project #2011-006). Information is presented within the context of the first 2011 lessons learned report (Ward et al. 2012) and in anticipation of a third volume that will describe what is likely to be the completion of the project development (pilot) phase. Knowledge gained from 2011 that was described in the first report, especially regarding project implementation, initial data lessons and answers to BPA Fish and Wildlife Program key management questions (KMQs), is not repeated herein. Instead, this document builds upon the 2011 lessons learned report by describing changes in the program (e.g., additions, improvements, efficiencies) and new learning that occurred during 2012.

Habitat status and trends data collected during 2012 implementation provides the building blocks for answering primary BPA Key Management Questions (KMQs; see page 3) posed by BPA during CHaMP project development. The reason that it is stated that CHaMP only provides the building blocks for answering these KMQs is because such questions about habitat, limiting factors, and funds expenditure are posed within the context of realized changes to fish populations, which necessitates the interpretation of CHaMP habitat data and fish data together. While the first two years of implementation have shown the CHaMP protocol is extremely powerful at collecting habitat status data (see Chapter III, Habitat Status and Trends for examples); however, the nature of CHaMP's three-year rotating panel sample design precludes a robust assessment of habitat change over time, i.e., trends, at this time because a third year of sampling has not yet been completed.

Through its efforts in 2012, CHaMP actively supported the coordination and standardization of regional and project-specific monitoring efforts with other monitoring programs, including the development and adoption of standard requirements for metrics, sample designs, data collection protocols, data dictionary, metadata, and data access. In 2012, CHaMP collaborated with the U.S. Forest Service's PIBO program to compare 14 metrics collected by both programs. Based on the study, it could seem that the comparability, quality and reliability of the two protocols is high and that data from both could be used together to evaluate habitat conditions; however, in cases where the protocols from both programs resulted in metrics with great reliability, it is important not to forget the "value added" utility of the CHaMP data format and the role that the spatially-referenced data play in other ongoing efforts to evaluate habitat characteristics and change. Further, the metrics that were evaluated only explain a small amount of variability in fish abundance (not to mention survival and productivity) and only represent a small subset of all metrics collected by each group. A much larger comparative study would be needed to construct appropriate translations of one program's metrics to the other's, determine their utility, help identify whether there are efficiencies that may be gained through closer cooperation, and if modifications to the implementation of either program are warranted based on metric performance, as well as the value of the method(s) by which various habitat measurements are collected.

The roles of CHaMP collaborators evolved in 2012: all collaborators were more strongly involved in protocol development, analysis planning and implementation, and reporting than in 2011. In addition, CHaMP continued to demonstrate that several groups could collect a standard set of habitat metrics using comparable sampling designs, a common protocol with universal training, one data dictionary with standard metadata, and within a single integrated data management system that further enforced standardization by instituting common and rigorous quality control and quality assurance practices. The CHaMP standardized data set now represents 528 unique sites and 793 separate visits during 2011 and 2012. Standardization was improved in 2012 due to improved data capture tool, protocol refinements, additional QA/QC tools, and more detailed training,

CHaMP's web-based information system, CHaMPMonitoring.org, continues to be a key element in the Fish and

Wildlife Program's framework for data management, and improvements to the CHaMPMonitoring.org system occurred again in 2012. These enhancements were coupled with CHaMP's participation with three other applications (Monitoring Methods, Sample Designer, and Monitoring Site Explorer. This promoted sharing of CHaMP monitoring methodologies and protocols, tool building to develop and display GRTS sample designs for the Columbia Basin, and integrating CHaMP site data into and application that helps users discover locations where aquatic monitoring is taking place, respectively. The overall pace of information transfer increased from 2011 to 2012, with the first installment of CHaMP data released to the public by March 1, 2013, only four months after all sampling had concluded in November 2012.

In 2012, CHaMP explored a variety of habitat status display formats (see Chapter III) as part of efforts to improve reporting and meet the needs of multiple data end-users. These display formats were based, particularly, on input from expert panel representatives. In addition, CHaMP, in conjunction with ISEMP and other collaborators that are working on life-cycle models and fish-habitat relationships under the AMIP, is approaching the interpretation of habitat data by coupling it with elements of these types of models in order to inform discussions about how to best interpret CHaMP habitat data (see Chapter IV, Analytical Framework for Fish-Habitat Relationships, for a description of this approach and the analyses that comprise it).

The administrative agreements between BPA and CHaMP (Project #2011-006) collaborators remained unchanged from 2011 because the project remained in the pilot phase at the same level of implementation. In 2012, CHaMP began development of a governance document designed to outline the administrative agreements and standards that would necessary to support new collaborators within the pilot project period, while ensuring that data standardization and the ability of the development team to continue to support pilot watersheds would not be compromised. This is consistent with the incremental implementation approach that the CHaMP project used in 2011 and again in 2012.

In 2012, a number of improvements were made to data quality control and data capture tools, and more emphasis was placed on field data collection practices. These improvements, however, combined with the extra time that it took crews to conduct site revisits, had the unintended consequence of increasing the average amount of time it took for crews to complete a site survey by 20 to 30 percent. To address this and make 2013 sampling efforts more sustainable, for 2013, CHaMP analysts have begun to explore options to reduce the number of measurements required for a metric and/or overall sampling intensity, so that data collection time is reduced to at least the level of effort expended in 2011, if not less, without compromising metric performance.

Efforts to evaluate CHaMP metrics and performance in 2012 were similar in some ways to that of 2011, i.e., variance decomposition analyses were used again to evaluate metrics. New approaches applied as part of 2012 analyses included evaluations of the GRTS sampling design and weighting as a way to improve overall estimates of habitat status. Based on results from a suite of fish-habitat relationship analyses expected to be completed in July 2014 (see Chapter IV), the full set of CHaMP metrics being calculated now will be reduced to a working set of metrics that will be used for the remaining duration of CHaMP implementation, beginning in the 2015 field season.

In 2012, CHaMP continued its information exchange with other science/policy forums and advanced its application of adaptive approaches designed to respond to NPCC principles and ISRP concerns, as well as develop methods, data and interpretive tools to help validate the BiOp's use of tributary habitat improvements. Within the BPA's RM&E framework, CHaMP is a leading component of habitat status and trends monitoring, as the standardized data collection methods and analyses allow data from many areas to be analyzed together, increasing the strength and definition of results.

To continue exploration of how CHaMP data could be extrapolated to non-CHaMP watersheds, efforts were initiated in 2012 to review landscape classification systems, develop a rapid geomorphic assessment approaches, evaluate the use of remotely sensed data and modeling to facilitate comparisons between CHaMP site-specific data and remotely sensed data, and develop tools for extrapolating estimates of habitat quality and quantity to watersheds not sampled by CHaMP. These approaches will be further developed in 2013 to the extent that they can inform fish-habitat relationships and watershed production models developed by the CHaMP and ISEMP projects.

Lastly, field implementation in 2012 involved some modifications from 2011 related to the protocol, equipment and software used for data capture. Numerous improvements to the RBT, GIS, and data QC/QA tools were made in 2012, as well as enhancements to the CHaMP-Monitoring.org data management system (see Chapter V for details). An unexpected consequence of additional protocol detail and QC/QA was an increase in the average time it took for crews to complete a survey. Another challenge was related to the rate of total station point capture. This issue, first identified in 2011, continued in 2012 and, in turn, increased the average amount of time it took for crews to conduct their topographic surveys, particularly in hot weather. After the 2012 field season, CHaMP staff devoted a substantial amount of time to identifying and documenting the cause and nature of this issue in an attempt to improve the situation prior to the 2013 sampling season. At the time of publication of this report, replacement components and other total station models are still being tested in an effort to identify the best path forward to resolve this ongoing issue, and allow CHaMP crews to collect survey data more quickly during future field seasons.

II. LESSONS LEARNED: BPA FISH AND WILDLIFE PROGRAM KEY MANAGEMENT QUESTIONS, NPCC PRINCIPLES, AND ISRP CONCERNS

Introduction

Most of this chapter is devoted to answering a set of key management questions (KMQs) and other questions posed by BPA and regional decision makers to CHaMP during the process of developing the CHaMP project. In this 2012 installment of the CHaMP lessons learned report, updates and illustrative examples for those KMQs that have been further developed since 2011 are provided, starting in the section below. When the answers from 2011 remained stable and persisted through the second year of CHaMP's pilot phase, the reader is referred to answers in the CHaMP 2011 Lessons Learned report (Ward et al. 2012). A summary of how information is organized in subsequent chapters of this report follows the sections that address BPA KMQs, NPPC principles and ISRP concerns.

CHaMP provides the building blocks for answering three important KMQs:

- What are the tributary habitat limiting factors or threats preventing the achievement of desired tributary habitat performance objectives?
- What are the relationships between tributary habitat actions and fish survival or productivity increases, and what actions are most effective?
- Which actions are most cost-effective at addressing identified habitat impairments*?*

These and other KMQs presented in this chapter were drawn from several sources:

- The 2009 Columbia River Basin Fish and Wildlife Program document (http://www.nwcouncil.org/library/2009/2009-09/Default.asp) (also part of the 2008 FCRPS BiOp).
- Questions posed to CHaMP developers by the ISRP in March 2011 in its Review of the Columbia Habitat Monitoring Program (CHaMP) Protocols (ISRP 2011-10, March 30, 2011 http://www.nwcouncil.org/library/isrp/isrp2011-10.pdf)
- A set of important questions and directions put forth by the Northwest Power and Conservation Council (NPCC) in its June 10, 2011 decision document.

BPA Fish & Wildlife Program Key Management Questions (KMQs)

Prominent KMQs posed by the BPA's Fish and Wildlife Program include:

- What are the tributary habitat limiting factors or threats preventing the achievement of desired tributary habitat performance objectives?
- What are the relationships between tributary habitat actions and fish survival or productivity increases, and what actions are most effective?
- Which actions are most cost-effective at addressing identified habitat impairments*?*

The CHaMP project was funded to help answer these questions through the collection of standardized, spatially referenced data to characterize tributary habitat for salmon and steelhead major population groups (MPGs) in the Columbia River basin. Accordingly, the CHaMP protocol is very fish-habitat-centric and, necessarily, works within a geomorphological context to demonstrate how fish habitat changes over time. The CHaMP project is unique in that it was designed to look beyond site metric averages and examine the hierarchy of processes that influence fish production, i.e., how can habitat actions be related in an empirical fashion to changes in fish populations, at multiple scales—and how can this knowledge be used to focus restoration activities on true limiting factors. The first two years of the project have shown the CHaMP protocol is extremely powerful at collecting habitat status data; however, the nature of the three-year rotating panel sample design precludes a robust assessment of habitat change over time, i.e., trends, at this point because a third year of sampling has not yet been completed. Therefore, the full pilot dataset is not available for analysis and interpretation. While CHaMP habitat data may be used alone to estimate status and eventually trends, they are not enough to answer the other KMQs listed above because these questions about habitat change and funds expenditure are posed within the context of realized changes to fish populations, which necessitates the interpretation of CHaMP habitat data and fish data together.

At the end of CHaMP's pilot phase, three years of CHaMP habitat data will be available for analysis in conjunction with fish habitat data being collected by the ISEMP project, and used to provide complete responses to the KMQs. Chapter III, Status and Trends, provides examples of different types of habitat metric status displays and a glimpse at how CHaMP habitat data might be interpreted in conjunction with preliminary ISEMP fish-habitat modeling results to being answering KMQs about the relationship between habitat limiting factors, habitat change, and fish populations. Chapter IV, Analytical Framework for Fish-Habitat Relationships, details the overall strategy for ISEMP's development of the empirical models and decision-support tools that will utilize the full three years of CHaMP habitat data alongside fish data to help inform upcoming management and policy decision-making processes.

In 2011, the BPA, NPCC and ISRP posed many other KMQs and issues to the CHaMP development team. For the purposes of consistency, the questions from the 2011 report have been repeated, followed by a response to each based on two years of project implementation.

KMQ: Describe how your project actively supported the coordination and standardization of regional and project-specific monitoring efforts with other federal, state, and tribal monitoring programs including the development and adoption of standard requirements for metrics, sample designs, data collection protocols, data dictionary, metadata, and data access.

ISRP: Identify roles for each cooperator in CHaMP effort.

The CHaMP project was designed specifically to develop a coordinated and standardized approach to habitat monitoring for status and trends, as well as effectiveness monitoring at the project scale, across the Columbia Basin region. CHaMP demonstrated that it met these goals in nearly every regard in 2011 and 2012.

Collaboration: As in 2011, project collaborators in 2012 included federal (BPA, NOAA), state (ODFW), tribal (CRITFC), and private entities (see Table 2 in the 2011 report for a full description of collaborators and their roles). In addition to 2011 collaborators, CHaMP worked, in 2012, with the U.S. Forest Service's PIBO habitat monitoring program.

Collaboration between CHaMP and PIBO in 2012 is notable. At the request of the Columbia Basin Federal Caucus, CHaMP and PIBO began an exploration of ways to jointly use information collected by the two habitat monitoring programs. Please refer to page 8 for a more complete discussion of this collaboration. Analysis of these data is ongoing and results will be presented to the Federal Caucus at upcoming meetings in the winter-spring of 2013. Coordination with PIBO will continue in order to help identify whether there are potential efficiencies that may be gained through closer cooperation, and if modifications to the implementation of either program are warranted based on metric performance as well as the utility of the method(s) by which various habitat measurements are collected.

The roles of CHaMP collaborators evolved in 2012. While most collaborators focused on data collection, all collaborators were more strongly involved in protocol development, analysis planning and implementation, and reporting than in 2011. For example, CRITFC lead the development of the riparian monitoring module and ODFW began contributing fish data collected at CHaMP habitat monitoring sites for development, with ISEMP, of fish habitat relationships. Other collaboration in 2012 included training and supporting thesis research by a student at Oregon State University in conjunction with a project funded by the U.S. Bureau of Land Management.

CHaMP will continue to collaborate with other programs in the future. Although no specific plans have been announced by the decision makers for full build-out of the CHaMP program to the originally-conceived 26 focal species/ major population groups from 19 subbasins in the Columbia Basin, BPA and its federal partners completed development of a framework for the RM&E program that includes CHaMP, ISEMP, and other monitoring activities.

Standardization: During pilot project implementation in 2012, CHaMP data were collected at 344 unique sites representing 15 focal species/major population groups within eight BPA-funded subbasins during 375 separate visits (see Table 1). The total CHaMP data set, after the first two years of implementation, now represents 528 unique sites and 793 separate visits during 2011 and 2012. CHaMP continued to demonstrate that several groups could collect a standard set of habitat metrics using comparable sampling designs, a common protocol with universal training, one data dictionary with standard metadata, and within a single integrated data management system that further enforced standardization by instituting common and rigorous quality control and quality assurance practices.

Features that improved standardization in 2012 included improved data capture tools and software for easier and more consistent quality control (e.g., new data logger software, automated incoming solar radiation measurement tools, improvements to topographic data gathering), improved directions in the sampling protocol, improved training materials and guidance, and more rigorous quality assurance routines built into the CHaMPMonitoring.org database tools. Standardization will be further improved in 2013 by planned improve-

Table 1. Summary of sites surveyed with the standardized CHaMP protocol and tools in 2011 and 2012 within the BPA-funded CHaMP and ISEMP projects.

	2011	2012	Total Unique Sites Surveyed Using CHaMP *
Methow	25	19	35
Entiat	76	60	83
Wenatchee	23	22	33
Tucannon	24	29	39
South Fork Salmon	33	25	45
Lemhi	42	48	75
John Day	59	73	126
Upper Grande Ronde	56	56	86
CHaMP/PIBO	-	12	6
BPA-Funded Total**	335	344	528

*These totals count, only once, annual sites that were sampled in both 2011 and 2012. Altogether, 793 visits were conducted in these two years.

** Non-BPA-funded sites = 62 total. 19 sites in the Asotin were funded/surveyed by Washington SRSRB, 20 sites were surveyed in California by State Department of Fish and Game - Coastal Watershed Planning and Assessment Program, 3 sites surveyed for USBR in Methow, 3 sites in Meacham Creek, and 17 sites in Bridge Creek.

ments to the protocol, training, and data capture tools. In subsequent years, additional training sessions, to accommodate a larger student body, will need to be considered if CHaMP is implemented at its full design capacity.

KMQ: Describe how your project collaborated with regional federal, state and tribal agencies, and/or non-governmental entities to establish a coordinated, standardized, web-based distributed information network and a regional information management strategy for water, fish, and habitat data.

CHaMP's web-based information system, CHaMPMonitoring.org, continues to be a key element in the Fish and Wildlife Program's framework for data management, as will be described in a document currently being prepared by BPA. Development progress in 2012 included significant advancements in the functionality and usability of this system that remains the backbone supporting CHaMP's study designs, site selection, quality control/quality assurance, data management, and data sharing.

MonitoringResources.org is another key element in the Fish and Wildlife Program's framework for data management with which CHaMP has been actively participating. Monitoring Resources provides a network of information and tools to support many facets of ecological and biological monitoring. This site is funded by BPA and the Gordon and Betty Moore Foundation, is coordinated by PNAMP, and was designed, built and maintained by Sitka Technology Group, Inc. Three applications in particular are relevant to CHaMP:

- Monitoring Methods,
- Sample Designer, and
- Monitoring Site Explorer.

Monitoring Methods is an application that facilitates sharing of monitoring methodologies and protocols. The metadata library maintained within this application is the primary location for sharing metadata on CHaMP's methodology. When changes are made to CHaMP's methods, the relevant information is loaded for archiving and displaying at MonitoringMethods.org. Users of CHaMP data who may be unfamiliar with the definitions, calculations, and utility of individual CHaMP metrics can find that information at this site. Since the public release of 2011 CHaMP data, feedback has been provided to CHaMP by external data users and, in response, CHaMP will continue to update and improve the information stored at this site in 2013.

Sample Designer is an application that displays and shares monitoring project sample designs from the Columbia Basin thereby improving access to these designs and helping new projects to create their own designs. In 2012, CHaMP provided guidance to Sample Designer on the development of tools for creating Generalized Random-Tessellation Stratified (GRTS) designs. In 2013, CHaMP will beta test these GRTS tools with the final goal that Sample Designer will support, by 2014, the creation of GRTS designs for new CHaMP watersheds if a decision is made to expand the CHaMP project.

Monitoring Site Explorer is an application that helps users discover locations where aquatic monitoring is taking place in the Pacific Northwest and will eventually include data from many agencies and overlapping monitoring programs. In 2013, CHaMP sites will be loaded to this application and the site may be of use for finding locations where fish and habitat monitoring are co-located, especially if it is linked with other fish sampling databases such as PTAGIS.

Other significant advancements in data distribution and management in 2012 included the ability to support multiple sampling years, allow planning and updates on of individual organizations' activities within watersheds, and the ability to provide more accurate and timely visit progress reports.

Reporting: Displaying and reporting habitat status and trends data is a challenge for several reasons, including: the diversity of data users and reporting objectives; the variety of spatial scales of interest to different data users; and the sheer volume, diversity, and complexity of habitat information available for reporting. In their raw form, habitat data are often not intuitive, even for experts. Therefore, habitat data reporting requires a process or mechanism for interpretation to facilitate understanding of the habitat data.

CHaMP has developed, in conjunction with a forum of technical representatives of policy decision makers, expert panels, and other habitat data users convened in September 2012, a two-pronged approach. First, raw habitat metrics can be usefully employed for decision making if they are displayed and packaged in appropriate ways, and this type of information remains the common currency among all data users. Therefore, in 2012 CHaMP explored a variety of habitat status display formats (see Habitat Status at Multiple Scales on page 17) based, particularly, on input from expert panel representatives. Second, CHaMP, in conjunction with ISEMP and other collaborators that are working on life-cycle models and fish-habitat relationships under the AMIP, is approaching the interpretation of habitat data by coupling it with elements of these types of models, e.g., site-specific fish information, in order to inform discussions about how to best interpret CHaMP habitat data. The advantages of developing project-specific decision support tools in this manner include the inherent empiricism, regional specificity, biological mechanisms, and the focus on specific BiOp objectives (see Chapter IV for a discussion of this approach).

In 2013, CHaMP will begin to build the capacity for dynamic habitat data displays into CHaMPMonitoring.org. By the end of 2014, it is envisioned that CHaMPMonitoring.org will allow users to interactively display metric data at a range of spatial scales (e.g., site, assessment unit, subbasin) in a variety of integrated formats (e.g., maps overlaid with descriptive tables, charts, graphs, and plots). CHaMP's development of habitat data display and reporting tools will continue to be done in collaboration with known user groups including expert panels, fish life-cycle modelers, regional RM&E participants, and others, so that displays and reports generated using CHaMP data will meet specific needs of these users and be done in a standardized fashion intended to facilitate common discussions and understanding.

In 2013, CHaMP data will continue to be used by ISEMP to further their work on the development of mechanistic and watershed production models that are based on empirical fish and habitat data, in order to elucidate fish-habitat relationships in a manner that will inform decision making. The Analytical Framework for Fish-Habitat Relationships presented in Chapter IV outlines a proposed approach for integrating CHaMP habitat data with fish data to help answer the KMQs that focus on how changes in habitat ultimately affect fish populations and tributary performance measures.

KMQ: Describe how your project established necessary administrative agreements to collaboratively implement and maintain the network and strategy.

The nature of the administrative agreements between BPA and CHaMP (Project #2011-006) collaborators remained unchanged from that described in the 2011 lessons learned report because the project remained in the pilot phase at the same level of implementation in 2012.

BPA and CHaMP are developing a governance strategy for developing administrative agreements in cases where collaborators would participate in CHaMP (e.g., use the CHaMP protocol and tools) but would be funded from sources outside of the specific CHaMP project. This strategy will describe how voluntary collaborators could participate in CHaMP in 2013 while retaining the integrity and standardization of the project's habitat and monitoring data, and will ensure that the CHaMP development team retains sufficient capacity to serve its core purpose of supporting BPA's status and trends monitoring needs under Project #2011-006. Accommodating such requests from new collaborators is a key part of the overall strategy of facilitating coordination and standardization among entities conducting habitat monitoring within the Columbia Basin and the broader region. For example, exploratory discussions are underway with BPA-funded collaborators (e.g., entities funded through Accord agreements) as well as other non-BPA funded collaborators (e.g., U.S. Bureau of Reclamation IMW efforts in the Methow Subbasin) who would like to monitor habitat using the CHaMP protocol and tools in 2013.

NPCC Principles and ISRP Concerns

NPCC Principle: Implement CHaMP in an incremental approach in selected basins undergoing active restoration and fish and habitat monitoring.

ISRP: Field test protocols and habitat parameters in selected basins to test for appropriateness or value.

The CHaMP project was implemented, again in 2012, in its pilot phase with the same subset of eight watersheds as in 2011 and it is anticipated that it will remain in this pilot configuration for 2013 or until and if a decision is made to expand the project, up to the full proposed scope supporting as many as 26 focal species/major population groups in 19 subbasins in the Columbia Basin. Use of a pilot approach continues to be a wise choice as it has allowed for significant development to occur while still allowing collection of a subset of habitat data as decision makers evaluate the efficacy of the overall CHaMP approach for collecting habitat status and trend information.

NPCC Principle: The overarching program goal is cost-effectiveness.

ISRP: We think the statement that a 3-person crew could sample a site per day on average may be optimistic for sites that are located in roadless areas or sites that are otherwise difficult to access, given the large number of habitat attributes and the time required for digitizing channel morphology.

ISRP: We are unsure whether it will be possible for crews to address possible field constraints, such as limited time available for sampling, problems posed by weather conditions, and logistic difficulties in sampling particular sites., while still meeting the expectations of the CHaMP protocol.

A major focus for CHaMP in 2012 was improving the performance of certain habitat metrics that were identified during the 2011 lessons learned process as having higher-than-desired levels of inter-crew variability. The protocol was revised to include more explicit instructions; training approaches, automated data capture and processing tools were improved, and additional emphasis was placed on field data collection practices. Data analyses are currently underway to evaluate whether the training and protocol changes implemented in 2012 resulted in desired improvements in crew sampling and metric performance.

Unfortunately, the sum of these improvements resulted in the unintended consequence of field surveys and data processing taking 20 to 30 percent more time than in 2011. While most crews were still able to capture data from the target number of sites within contracted budgets, budget squeezes resulted from the extra effort required to improve metric performance. Most crews managed through these budget constraints by employing one-time, non-sustainable administrative approaches like shifting crews between projects and augmenting project staff with other salaried staff. These challenges did foster some learning that, in some situations, may be applied in future years to improve cost-efficiencies. In most cases, however, crews were lucky to find the capacity necessary to accommodate the extra work.

To be more predictable and sustainable, CHaMP will focus, in 2013, on ways to maintain metric performance while scaling back the amount of time it takes to complete each site to at least the level of effort expended in 2011, if not less (see Evaluating Sampling Intensity on page 28). In addition, after analysis of the third year of data to be collected in 2013, CHaMP will be in a position to evaluate the full suite of metrics and, we anticipate, to substantially reduce the amount of effort required to complete habitat surveys. Fortunately, some of the inefficiencies realized in 2012 were offset by improved automation of data capture and processing tools.

NPCC Principle: Develop information and technology transfer among CHaMP cooperators.

ISRP: Will cooperators eventually have the staff expertise not only to collect the data using CHaMP protocols, but to effectively understand and use the modeling programs and other analytical tools to support and document the benefits of their habitat restoration programs?

The rate of information transfer improved in 2012 as predicted. Whereas it took 16 months from the end of the 2011 data capture season to prepare that year's data for public release, the first data from 2012 were released to the public by March 2013, a mere four months after the end of the field season, which concludes in the Bridge Creek watershed in November. Continued improvements in all aspects of the CHaMP program will further reduce the delay between data capture and full information utility, with the expectation that, if not this year, by 2014, publication of the final dataset will be achieved by the end of the calendar year in which it is collected.

Technology transfer continued apace in 2012: new tools and software, and the understanding necessary to use them and to understand the information obtained through their use, were once again utilized by a representative cross-section of Columbia Basin collaborators in 2012 with few challenges. This aspect of CHaMP has been well tested and is ready for wider application if and when a decision is made to expand the CHaMP project scope.

NPCC Principle: Revise and develop CHaMP to address scientific review in collaboration with the ISRP, NPCC and other participants in habitat monitoring/evaluation.

ISRP: Field test protocols and habitat parameters in selected basins to test for appropriateness or value.

ISRP: Resolve differences in habitat monitoring approaches among other groups by coordinating and comparison testing protocols on site.

ISRP: Consider a cautionary approach to implementation in which different approaches to design, data collection, data storage, and data analysis, can be compared to provide a test of the efficacy of scaling up from past efforts while still allowing and encouraging other promising, or well proven, efforts to continue.

Appropriateness and Value: The full testing of the appropriateness and value of metrics will require at least one more year of data habitat collection (in pilot subbasins) and perhaps three years more in subbasins that have yet to be brought into the project. The reason that three years of data are important is that the study design used by CHaMP is a three-year rotating panel design. This means that a complete sample will take three years in each watershed to fully capture the spatial and temporal variability that we anticipate in the data. Furthermore, the information content of habitat metrics depends on quantifying relationships with fish metrics and the collection of these fish data will also take at least one more year because paired sampling of fish and habitat data at CHaMP and ISEMP sites only began in 2011. Additional time may be required to account for inter-annual and inter-generational variability in fish populations. Please refer to Chapter IV for a more complete discussion of fish-habitat relationships and the estimated amount of time it will take to completely assess the appropriateness and value of CHaMP metrics.

Variability Testing: CHaMP continued variability testing in 2012 to address several ISRP concerns (e.g., spatial roll-up of data from site to subbasin, demonstration of how CHaMP data be used to meet key management questions, repeatability, and comparability with other programs, etc.). Please refer to page 26 for information on the variance decomposition analyses performed in 2012.

Protocol Comparison Testing: In 2012, CHaMP continued to demonstrate that the topographic survey component of its habitat protocol, which enables the collection of spatially-referenced habitat data and the production of digital elevation models, is unique and produces powerful data outputs with a value-added component, i.e., they are being used as inputs to the RBT, to automate metric production; as the basis for geomorphic change detection analyses; and as empirical inputs to a number of the mechanistic models being developed by ISEMP.

Programming enhancements to the RBT in 2012 allowed CHaMP topographic data inputs to be used to automatically calculate most, if not all, "stick and tape" metrics that are generated by other programs. For example, the RBT is now programmed to generate approximately 25 metrics to specifically match those produced by the USEPA's Environmental Monitoring and Assessment Program (EMAP; see page 60 for additional information about RBT enhancements).

It is important to note that it is the way the CHaMP metric data are collected initially, i.e., spatial-referencing of the data through the application of survey procedures, easily facilitates the subsequent production of any number of metrics in an automated fashion — there is no additional on-the-ground "effort" required for the calculation of many of CHaMP's metrics. In addition, RBT de-

Table 2. Summary of the 14 CHaMP and PIBO program attributes evaluated during the 2012 protocol comparison study.

CHaMP-PIBO Metric Reliability

Attribute	Comparison	Reliability
Gradient	CHaMP > PIBO	Both great
Sinuosity	CHaMP > PIBO	Both great
Bankfull	PIBO > CHaMP	Both great
Width to depth	PIBO = CHaMP	Both great
Percent Pool	PIBO > CHaMP	Both great
Residual Pool Depth	CHaMP > PIBO	Both great
Wood Counts	PIBO = CHaMP	Both good
D50	PIBO = CHaMP	Both good
Pool-tail fines	PIBO = CHaMP	Both good
Bankfull CV	CHaMP > PIBO	Great vs. Good
Undercut	PIBO > CHaMP	Good vs. Poor
Width to Depth CV	PIBO = CHaMP	Both poor
Effective Ground Cover	PIBO > CHaMP	Both poor
D16	PIBO = CHaMP	Both poor

velopment costs are expected to decrease after the conclusion of the pilot.

In 2012, CHaMP collaborated with the U.S. Forest Service's PIBO monitoring program to compare the two programs' protocols to answer questions about the comparability, quality and reliability of the two protocols; to determine if there are ways to more efficiently collect these data; and to explore whether data from these two programs can be used together to make statements about the conditions of streams. To begin answering these questions, the two programs conducted a variability study in which three crews from each program each sampled 12 sites. Sample sites were purposefully selected to represent a range of habitats and included six sites from the CHaMP domain and six from the PIBO domain. Each site was located and flagged by the local program so that surveys by all six crews were conducted in the same spatial extent. Fourteen metrics resulting from these surveys were selected for comparison among and between programs: these metrics were chosen primarily because methodologies from the two programs seemed, in *a priori* discussions, similar enough to consider that the two programs were producing the "same" metric, and, in most cases, because these metrics have been shown to be related to salmonid use of streams. The performance of each metric was assessed on "reliability" (i.e., signal-to-noise ratios greater than 10 were considered "great," between 2 and 10 were "good," and less than 2 were "poor"), interpretation of linear relationships between crews, and an examination of how well the two programs estimated mean values of each metric.

Each program collected 10 of the 14 metrics with either good or great reliability (i.e., S:N ratios greater than 10; Table 2). Some metrics were measured the same way between programs (i.e., note the regression slopes near 1.0 with r-squared values near 1.0; e.g., "gradient" in Figure 1) or in consistent ways where information could be transformed between programs based on strong relationships (i.e., note high r-squared values regardless of regression slope; e.g., bankfull width and D50 in Figure 1). In some cases (e.g., wood and pool depth, Figure 2), outliers from the predicted one-to-one line suggest areas for improvement in either methodology or training. In other cases (e.g. undercut banks, ground cover, Figure 2), the lack of strong linear relationships between programs suggest that, despite similar sounding metric names, the two programs are indeed measuring different features of the habitat. Finally, the Difference in Means (Figure 3 on the next page) displays the point estimate and 90% confidence interval of the average difference between

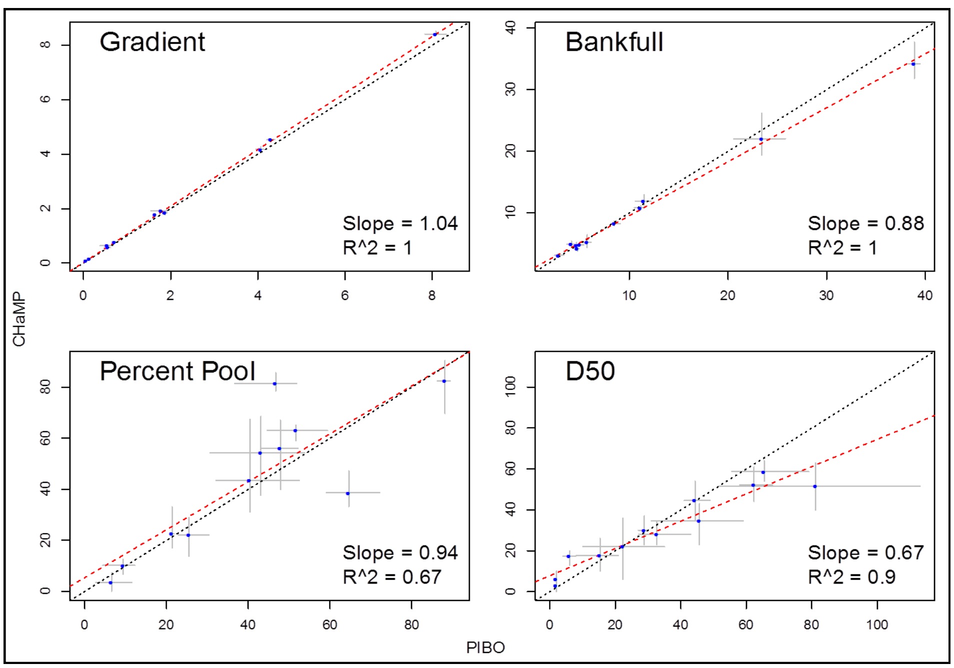


Figure 1. Examples of CHaMP and PIBO attributes evaluated during the 2012 protocol comparison study that were measured the same way or could be transformed between programs based on strong relationships.

CHaMP and PIBO for each metric, expressed as a percentage of the overall mean of that metric. Some metrics, like undercut banks and ground cover, showed clear differences. Others, such as wood, showed a difference, but the variability of this metric across both programs was large enough that it obscured program differences (as seen when the confidence interval encompasses 0). Still others, such as sinuosity and gradient, showed very small differences between the programs, but the metric measurements were so consistent that this difference was statistically significant, although perhaps biologically insignificant.

Based on these 14 metrics, the comparability, quality and reliability of the two protocols seems high in such a way that information from the two programs could be used together to evaluate stream conditions. In cases where the protocols from both programs resulted in metrics with great reliability, however, it is important not to forget the "value added" utility of the CHaMP data format and the role that the spatially-referenced data play in other ongoing efforts to evaluate habitat characteristics and change. Further, the 14 metrics that were evaluated only explain a small amount of variability in fish abundance (not to mention survival and productivity) and only represent a small subset of all metrics collected by each group. To enable such data sharing, a much larger comparative study would be needed to construct the appropriate translations of one program's metrics to the other's.

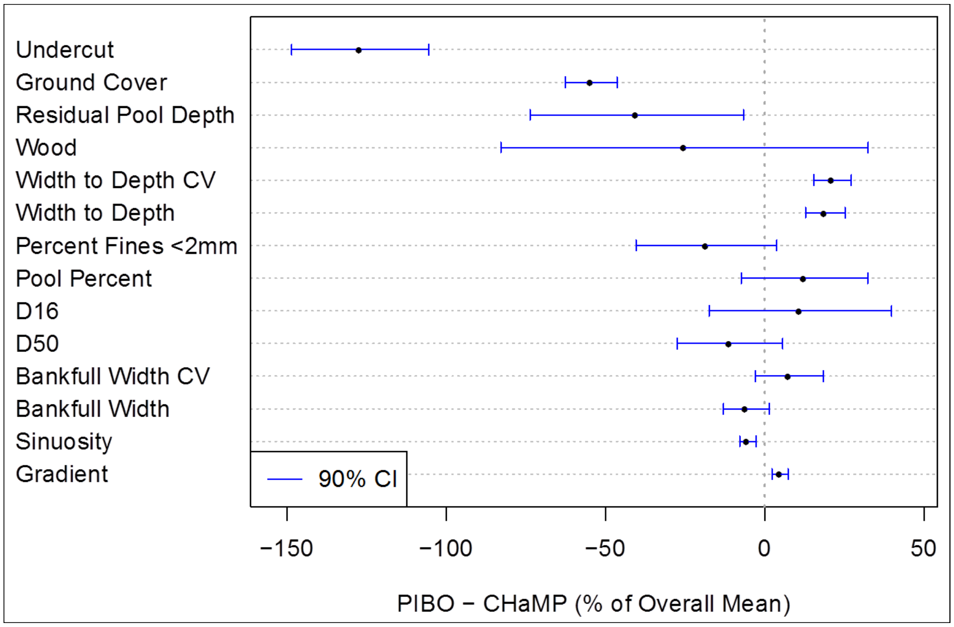


Figure 3. Difference in means of the 14 habitat metrics compared in the 2012 CHaMP and PIBO comparison study.

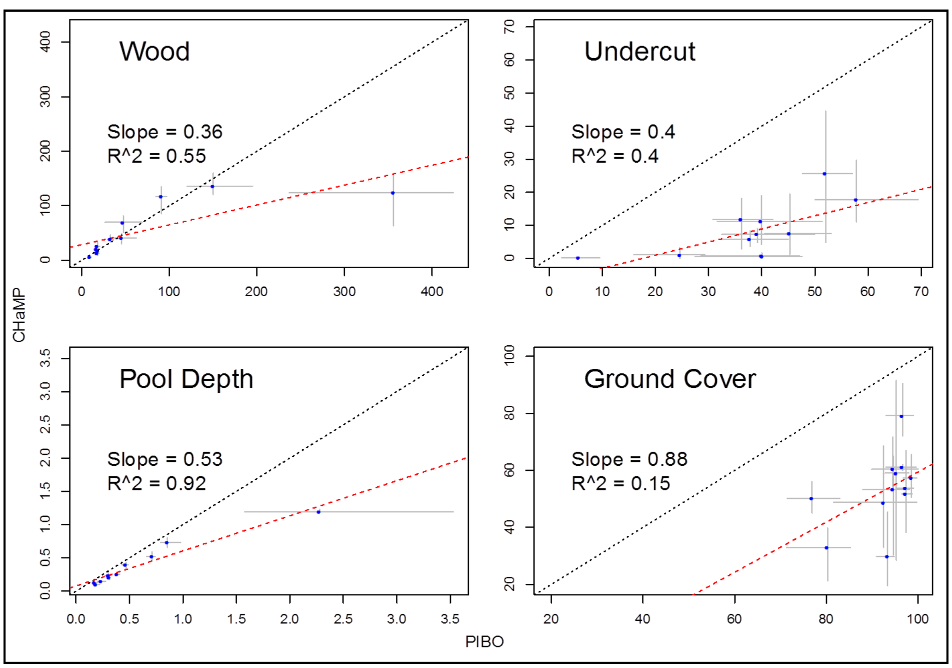


Figure 2. Examples of CHaMP and PIBO attributes evaluated during the 2012 protocol comparison study where outliers suggest areas for improvement in either methodology or training (left), or lack of strong linear relationships suggest that the two programs are measuring different features of habitat (right).

The 2012 analysis of the CHaMP-PIBO study data considered two modeling approaches, boosted regression tree (BRT, see page 33) and multiple linear regression. These models were fit using 136 reaches for steelhead and 117 reaches for Chinook sampled by CHaMP for habitat and by ISEMP for fish in 2011. In both types of models, fish per meter of stream was the dependent variable, and 12 of the 14 habitat metrics were the dependent variables. The predicted densities from each model were compared to the observed values, and the R^2 value was calculated as an approximation of the amount of variance in fish densities that was explained by these 12 habitat metrics.

The BRT models explained much more of the variance in fish densities than linear regression, for both Chinook ($R^2 = 0.41$) and steelhead ($R^2 = 0.61$) (see page 34). In contrast, linear regression models had an R^2 value of 0.18 for Chinook and 0.23 for steelhead (Figure 4, next page). In regression models where PIBO habitat data coincided with estimates of Chinook survival, an even larger set of metrics could account for only

15 to 20 percent of variation in survival (Charlie Paulsen, unpublished analyses). Some of the superiority of the BRT models can likely be attributed to the fact that they naturally handle interactions among the habitat covariates, while linear models do not, and there are significant correlations between some habitat metrics.

For these reasons, CHaMP and ISEMP will continue to develop habitat metrics under the hypothesis that new habitat metrics will prove to be more predictive of the key attributes of salmonid populations of interest to policy decision makers.

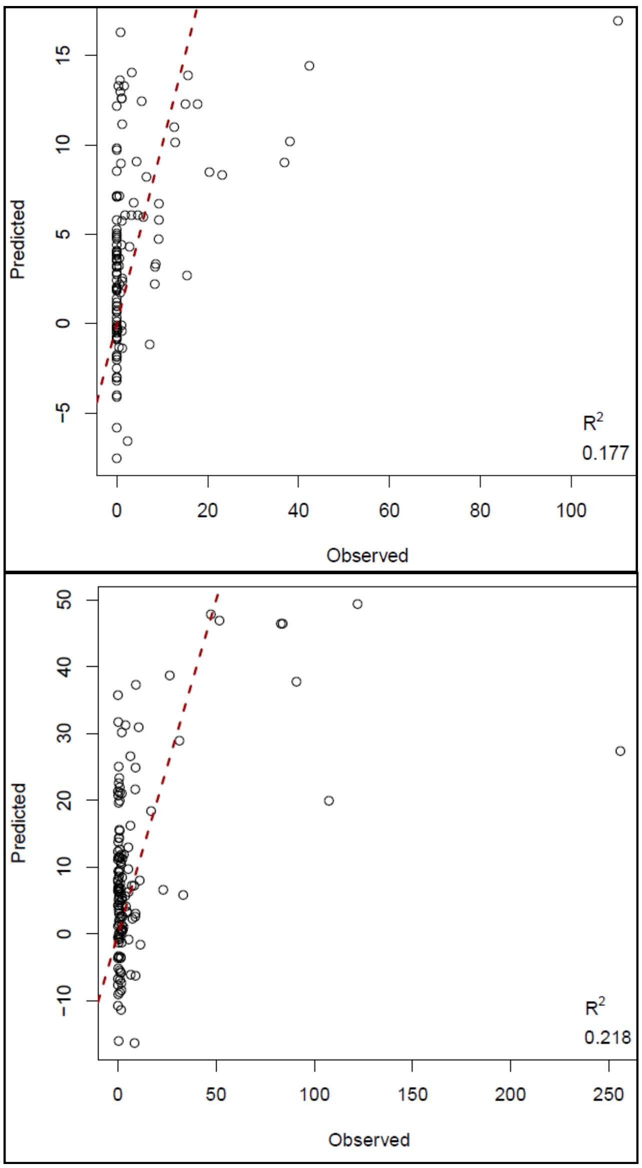


Figure 4. Linear models fit to 12 of the 14 habitat metrics in the 2012 CHaMP and PIBO study for Chinook (top) and Steelhead (bottom) densities (fish/m).

Linear regression and BRT models were both used to examine variability in fish densities explained by 12 habitat metrics from the CHaMP-PIBO comparison study.

Linear regression models had an R^2 value of 0.18 for Chinook and 0.22 for steelhead (Figure 4, top and bottom, respectively).

BRTs explained much more of the variance in fish densities, for both Chinook and steelhead (steelhead R^2 = 0.61, see page 34).

Some of the superiority of the BRT models can probably be attributed to the fact that they naturally handle interactions among the habitat covariates, while linear models do not, and there are significant correlations between some habitat metrics.

__NPCC Principle:__ Within one year, the agencies should develop the analytical, evaluation and reporting elements of habitat effectiveness monitoring to accompany CHaMP monitoring consistent with ISRP's review.

__NPCC:__ Complete the Lesson Learned Report including revisions, linkages/integration with fish monitoring and proposed expansions.

__NPCC:__ Bonneville and NOAA to meet quarterly with NPCC's Fish and Wildlife Committee to report progress regarding pilot phase testing.

__NPCC:__ Bonneville, the NPCC, and NOAA to prepare a transition plan describing implementation and/or phasing out other habitat monitoring projects.

__ISRP:__ The description of life stages influenced by various habitat measurements could be more refined. Where possible, illuminate how some restoration actions are influencing VSP parameters.

__ISRP:__ It was not clear to us how ISEMP and CHaMP, in evaluating restoration effectiveness, propose to accommodate factors affecting fish populations downstream from CHaMP sampling locations (non-wadeable areas downstream of CHaMP sampling sites, including the mainstem, estuary and ocean). — Tie to Trib Habitat RM&E effort

__ISRP:__ We are still not sure how habitat status and trend monitoring data will be related to (integrated with) status and trends of fish population data within CHaMP watersheds to evaluate the effectiveness of specific restoration strategies or general restoration effectiveness in a geographic area (e.g., are the co-managers in a given subbasin successful in restoring stream habitat in their area?).

__ISRP:__ It was unclear which entity or entities will be responsible for conducting fish status and trends monitoring at CHaMP sites, what kinds of fish data would be collected (e.g., site/reach-specific abundance sampling or fish in- fish out), and what kinds of analytical methods will be used to relate fish status and trends to habitat status and trends.

ISRP: We encourage the periodic exchange of habitat status and trend data and analyses through annual meetings of those organizations engaged in collecting both habitat and fish population information. Periodic (annual or 2-year) habitat workshops would be a useful forum for information exchange between monitoring organizations, particularly with respect to questions about which protocols are and are not working effectively.

ISRP: The utilization of CHaMP in or (non-IMW) watersheds where fish populations are being monitored was not thoroughly explained, including whether the sampling protocols would facilitate an evaluation of restoration effectiveness on fish populations.

NPCC/ISRP: In those CHaMP watersheds where restoration actions are taking place, but which do not have experimentally controlled restoration treatments as in the IMWs, the ISRP feels that there is still great value in collecting both habitat and fish data at as many sites as possible in order to verify assumptions about relationships between habitat conditions and fish populations.

In 2013, BPA completed a framework document, "Columbia Basin Tributary Habitat Improvement: A Framework for Research, Monitoring and Evaluation" that describes an aggressive and well-organized framework for research, monitoring and evaluation, also known as RM&E. At its simplest, RM&E documents whether habitat projects, many of which are funded by regional electric ratepayers, are completed as expected and deliver on their ecological goals. However, RM&E and associated analyses also go far beyond that to help identify the most effective types of restoration, improve its cost effectiveness and improve models that guide managers as they decide on future habitat improvement projects. This collection and analysis of information is vital to the BiOp's adaptive management mandate, which capitalizes on the latest science and research to inform management decisions and, ultimately, improve the effectiveness of actions on behalf of fish.

Continued research and monitoring is also essential to document the important relationship between habitat quality and fish survival. That relationship validates the BiOp's use of habitat improvements far from the federal dams to mitigate for the impacts of the dams on fish. Within the RM&E framework, CHaMP is a leading component of habitat status and trends monitoring. CHaMP employs standardized data collection and analysis so data from many areas can be analyzed together, increasing the strength and definition of results. The 2012 CHaMP pilot year included 10 watersheds, including the Asotin watershed funded by NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF) program and one region in California. Other watersheds are funded by the action agencies. In some cases where CHaMP and ISEMP overlap, CHaMP boosts coverage of IMWs with additional data. For more information about this set of KMQs, we respectfully refer the reader to the comprehensive RM&E document.

ISRP: Provide a clearer description of how site selection is influenced by proximity to ongoing instream or riparian restoration actions.

ISRP: Describe how the results obtained from monitoring individual sites will be "rolled up" to advance generalizations about status and trends in habitat condition for the watershed as a whole.

ISRP: Revisit the number of sites (more sites/less intensity vs. few sites of high intensity) .

ISRP: Given CHaMP's approach for selecting watersheds, it remains to be demonstrated how well the results obtained through the project can be extrapolated to unmonitored watersheds within the interior Columbia River Basin.

As described in 2011, watershed sampling designs provide some flexibility to accommodate the proximity of riparian restoration actions. In general, these are best handled by linking to complementary IMW sample designs, as is being done in Bridge Creek, the Entiat River, the Lemhi River, and Asotin Creek, where one design is used for the population of possible sites within the IMW study area and a GRTS design is used for the portion of the watershed outside the IMW study area. However, in 2012, improvements to the code used for site selection were made to facilitate the use of legacy sites (or other specific sites selected for study, like restoration project sites. These sites are included in the GRTS sample using an approach that retains the spatial balance of the entire sample. Many of the legacy sites were originally selected with a probability design, and their inclusion in the sample is justified by their unbiased selection. Non-probabilistic legacy sites were also included in some cases because their sampling history provided valuable temporal replication or monitoring of the site would be necessary due to restoration projects. Legacy sites and newly-selected sites are given equal weighting in the analysis because all sites represent the target population and provide a basis for inference. Comparisons of indicator means can be made to determine if legacy sites are significantly different from newly-selected probability sites.

The roll-up of site-level metrics to watershed-scale indicators is made possible in the GRTS design (see the 2011 report for more background) because each sample site is assigned a weight, the proportion of the population of all possible sites within the sample frame represented by the site. In 2012, significant effort was spent adjusting these weights (accounting for frame errors and nonresponse errors) and developing the code so that these weights can be more automatically adjusted based on realized field crew performance. Please refer to page 23, GRTS sample design weights, for more detail.

Based on results from a suite of fish-habitat relationship analyses expected to be completed in July 2014 (see Chapter IV), the full set of CHaMP metrics being calculated now will be reduced to a working set of metrics that will be used for the remaining duration of CHaMP implementation, beginning in the 2015 field season. The reduction in the list of metrics that are calculated now may translate into reduced field costs which could allow more sites to be sampled. In 2012, the effect of reducing intensity of sampling within sites, for selected metrics (see "Evaluating Sampling Intensity" on page 28 for detail), was characterized relative to effects on watershed-scale estimates. Because preliminary results showed that significant reductions in the number of measurements taken within a site has limited effect on watershed-scale estimates, sampling protocols will be scaled back for some metrics in 2013. Furthermore, analysis in early 2014 of data from the full three-year rotating panel design, especially in comparison to more intensively sampled IMW study areas, will be used to optimize such tradeoffs.

In 2013, CHaMP will focus on pulling together existing landscape classification systems, rapid geomorphic assessment approaches within the River Styles framework, advancements in stream temperature predictions from remotely sensed data, and comparisons between CHaMP site-specific habitat data and remotely sensed LiDAR-derived habitat, to develop tools for extrapolating estimates of habitat quality and quantity to watersheds not sampled by CHaMP (see page 43, Landscape Classification). These approaches will be developed to the extent that they can inform fish-habitat relationships and watershed production models developed by the CHaMP and ISEMP projects .

CHaMP 2012 Report Structure

The CHaMP 2012 Lessons Learned Report structure and content organization that follows differ slightly from that of the 2011 report. Information is presented within the context of the first lessons learned report. As such, knowledge gained from 2011 that was described in the first year report, especially regarding project implementation, initial data lessons and initial answers to key management questions (KMQs), is not repeated. Instead, the subsequent chapters of this document build upon the 2011 lessons learned report by describing the current state of CHaMP's work on status and trends (Chapter III), the proposed analytical framework for fish-habitat relationships (Chapter IV), and changes in the program (e.g., additions, improvements, efficiencies) and new learning that occurred during 2012 implementation (Chapter V). Each of these 2012 report chapters is described briefly, below.

Chapter III: Habitat Status and Trends

- **What we learned from the 2012 data and how to improve our displays and estimates**

Chapter III presents approaches that may be used to interpret and depict status, based on two years worth of project data; reviews analyses being used to evaluate metric variance and reliability based on 2011 and 2012 data; highlights additional work that was initiated in 2012 to help improve estimates of status; and how all of these elements will be used in conjunction with one another to analyze trends and evaluate project metrics, once a full three years of CHaMP pilot data are available after the 2013 sampling season.

Chapter IV: Analytical Framework for Fish-Habitat Relationships

- **What we learned from the 2012 data and proposed strategies and timelines for answering KMQs**

A new addition in the 2012 report is a comprehensive analytical framework, Chapter IV, which explores the data relevant to the questions being asked of the CHaMP project. The focus of this chapter is the presentation of the analytical framework that is being proposed to answer programmatic questions relating to the KMQs, NPCC principles, ISRP concerns, and project feasibility.

Chapter IV serves to describe and present:

- Approaches being used to respond to KMQs;
- Proposed fish-habitat relationship analysis strategies, deliverables and deliverable timelines;
- Methods being used to present, evaluate and/or improve estimates of status and trends; and
- How the development phase of CHaMP will have stabilized by 2014 and the highlights of what was learned in the past year of project implementation.

Interpretations and discussions based on data from the 2011 and 2012 years are presented within the context of the core interpretive tools that comprise the analytical framework and supporting data and analyses. Specific approaches to interpreting CHaMP data, and how CHaMP and ISEMP data may be used together to present fish-habitat relationships, are presented. In the future, other approaches will likely be possible as the utility of the CHaMP dataset increases in subsequent years through sampling size increases, and as more sophisticated/ predictive habitat indices are developed. Policy and technical input will be required to choose the best approach(es) and refine the tools to address KMQs.

Chapter V: Implementation Review:

- **What we learned from project implementation and how it could it be made more effective**

Chapter V summarizes the lessons learned during CHaMP project implementation in 2012 that are relevant to improving future efforts. Major project elements are presented by topic area, and information focuses on how different aspects of the project were implemented, as well as how each CHaMP element may have changed from 2011 to 2012. A common format is used so that information is easy to find, and a succinct summary of information is provided for each topic. Recommendations for improving each element in future years are provided along with options if more than one avenue is possible.

III. HABITAT STATUS AND TRENDS

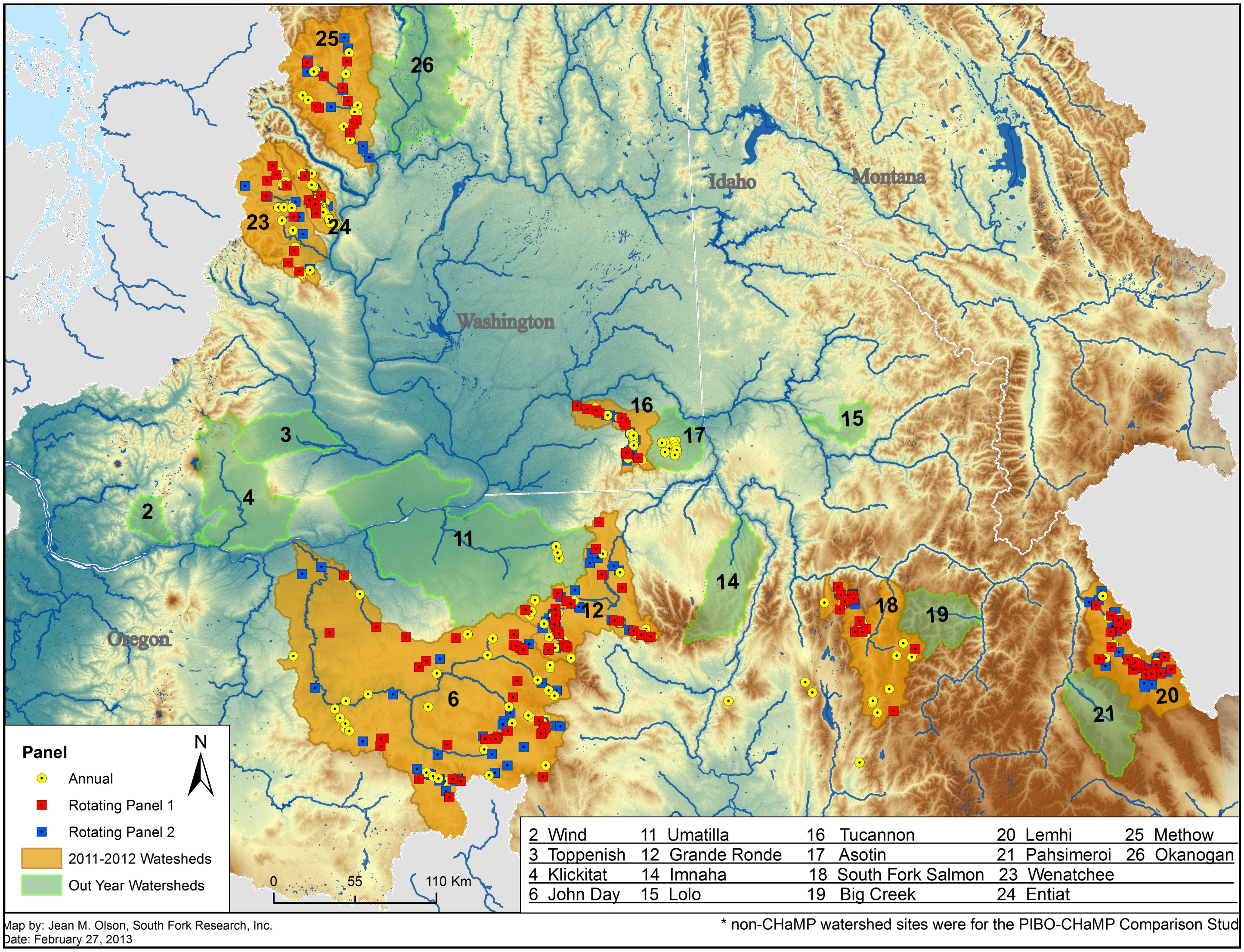


Figure 5. Location of CHaMP sampling sites in 2011 and 2012.

Estimating and Depicting Status and Trends

Introduction

As mentioned previously, the CHaMP project was designed to collect freshwater habitat data to elucidate status and trends in numerous watersheds important for anadromous salmonid recovery in the Columbia River Basin. Due to the successful completion of the 2012 sampling season, CHaMP now has two out of the three years of habitat data, collected in a standardized manner using a three-year rotating panel design, that are required to begin to answer questions about habitat trends.

The data collected during the 2011 and 2012 sampling seasons still serve a meaningful purpose with regard to habitat status in that they can be used to provide snapshots of habitat quality at the site-level and larger scales. In addition, the topographic surveying approach that is used by CHaMP to collect habitat attribute information makes it unique in that after only two years of data collection, physical habitat change from one year to the next can be accurately quantified using approaches like Geomorphic Change Detection (GCD, see page 41). This is possible because CHaMP habitat data are spatially referenced and designed to be used in conjunction with GIS software and analyses; to be used as inputs to other powerful tools, such as the River Bathymetry Toolkit (RBT), which enables automated metric generation and replication of other programs' metrics; and used in mechanistic models like NREI (described in Chapter IV).

As mentioned previously, all current CHaMP measurements and calculated metrics are fish-centric, and were selected for inclusion in the protocol based on a rigorous literature review and the understood value of the metrics for describing fish habitat (Table 3, next page).

Table 3. Site-level measurements and data collected by CHaMP, and relationship to metrics, indicators and limiting factors.

Indicator	Site level measurement / data collected on the ground	CHaMP Single and Multivariate Metrics (Note that many are autogenerated by the RBT)
Average Alkalinity	alkalinity	(Aux) Alkalinity
Average Conductivity	conductivity	(Aux) Conductivity
Average pH	pH	(Aux) pH
Growth Potential	drift biomass and temperature	(Aux) generated from product of drift biomass and temperature
Percent Below Summer Temperature Threshold	Year-round temperature logger data	(Aux) Site specific temperature logger data; used to calibrate continuous model inference for all stream reach-es in twatershed
Percent Above Winter Temperature Threshold		(Aux) Site specific temperature logger data used to calibrate continuous model inference for all stream reaches in the watershed
Velocity Heterogeneity	Discharge	(Aux) generated from algorithm for variance Froude number across a site.
Embeddedness of Fast water Cobble	Embeddedness measurements	(Aux) generated from algorithm for riffle cobble embeddedness.
Pool Frequency	Pool measurements	(RBT automated from Topo Survey): Pool area, count, spacing, volume, percent
Channel Complexity	Depth, width, and thalweg sinuosity	(RBT automated from Topo Survey): Thalweg depth, Site Water Surface Gradient, Site Sinuosity, Thalweg to Centerline Length Ratio, Sinuosity Via Centerline, Site Wetted Area, Site Bankfull Area, Integrated Wetted Width, Standard Deviation of the Detrended DEM, Integrated Bankfull Width, Site Length Wetted, Site Length Bankfull, Depth: Site Length Thalweg, Thalweg Depth Profile Mean, Thalweg Depth Profile CV, Centerline Depth Profile Mean, Centerline Depth Profile CV, Water Surface Gradient Profile Filtered Mean, Water Surface Gradient Profile Filtered CV, Thalweg Depth Profile Filtered Mean,Thalweg Depth Profile Filtered CV, Centerline Depth Profile Filtered Mean, Centerline Depth Profile Filtered CV, Bankfull Width Profile Filtered Mean, Bankfull Width Profile Filtered CV, Bankfull Width Constriction Profile Filtered Mean, Bankfull Width Constriction Profile Filtered CV, Bankfull WidthToDepth Ratio Profile Filtered Mean, Bankfull WidthToDepth Ratio Profile Fil-tered CV, Wetted Width Profile Filtered Mean, Wetted Width Profile Filtered CV, Wetted Width Constriction Profile Filtered Mean, Wetted Width Constriction Profile Filtered CV, Wetted WidthToDepth Ratio Profile Fil-tered Mean, Wetted WidthToDepth Ratio Profile Filtered CV
Channel Score	LWD and substrate. Site measure-ments of habitat unit volume,	(Aux plus RBT automated): Wetted Volume, metrics necessary for RP100 calculations as used by PIBO, AREMP, and EMAP. ***NOTE:*** Work to determine whether LWD frequency or volume will result in stronger LWD metric strength for these purposes is underway (see LWD volume for Frequency metrics), and part of the overall metric evalua-tion process that will conclude after the 2013 sampling season as part of the overall pilot evaluation.
Residual Pool Volume	Residual pool volume	(RBT automated from Topo Survey) ***Note:*** This was previously calculated in RBT for purposes of EMAP comparison; however, the metric was too sensitive and required additional hand calculation time and effort. RBT improvements in 2013 are expected to resolve this issue.
Subsurface Fines	Subsurface fines	***Note:*** Subsurface fines are not currently part of CHaMP protocol, due to challenges related to repeatability and consistency among crews. Efforts are ongoing to test different approaches. (Aux) Pool tail (surface) fines less than 2mm / 6mm are currently being measured as a proxy.
Total Drift Biomass	Total drift biomass	(Aux) Total drift biomass
LWD Volume	LWD and channel unit type	(Aux and RBT automated) Wetted Large Wood Frequency per 100m, Bankfull Large Wood Frequency per 100m, Wetted Large Wood Volume by Site, Bankfull Large Wood Volume by Site, Wetted Large Wood Volume in Pools, Bankfull Large Wood Volume in Pools, Wetted Large Wood Volume in Fast-Turbulent, Bankfull Large Wood Volume in Fast-Turbulent, Wetted Large Wood Volume in Fast-NonTurbulent, Bankfull Large Wood Volume in Fast-NonTurbulent ***Note:*** Wetted vs. bankfull metrics likely have different meanings for fish. The process is underway to identify different subsets of metrics for different analysis purposes, i.e., which are most correlated to fish, get rid of redundancy, and determine which metrics perform best and give us the most information. This process will culminate after the collection of a third year of CHaMP data in 2013.
Fish Cover	Fish cover	(Aux) Fish Cover Composition LWD, Fish Cover Composition Vegetation, Fish Cover Composition Undercut, Fish Cover Composition Artificial, Fish Cover Composition None, Fish Cover Composition Aquatic Vegetation
Channel Unit Volume	Channel unit type and volume (DEM, photos, site map)	(Aux and RBT automated): habitat unit volume from site DEM and habitat unit delineation.
Channel Unit Complexity	Habitat unit volume, LWD, and substrate	(Aux and RBT automated): Fast-Turbulent Area, Fast-Turbulent Count, Fast-Turbulent Spacing, Fast-Turbulent Volume, Fast-Turbulent Percent, Fast-NonTurbulent Area, Fast-NonTurbulent Count, Fast-NonTurbulent Spac-ing, Fast-NonTurbulent Volume, Fast-NonTurbulent Percent, algorithm for residual pool depth, subsurface fines and wood volume. A multivariate measure of habitat unit complexity, similar to DSM approach applied by AREMP and PIBO to habitat metrics to capture complexity. ***Note:*** (Aux) Undercut area and undercut volume were part of fish cover in 2011. In 2012 undercuts separated and done at site level and georeferenced. Metrics for undercut and area/volume showed poor signal-to-noise ratio (repeatability among crews), so in 2013 will be considered with respect to channel unity complexity.
Riffle Particle Size (D16, D50, D84)	D50, D16, D84	(Aux) D16, D50, and D84 in riffles
Riparian Structure	Riparian structure	(Aux) Big Tree Cover, Coniferous Cover, Ground Cover, Non-Woody Cover, Understory Cover, Woody Cover, Canopy No Cover, Understory No Cover, Groundcover No Cover
Solar Input	Solar input	(Aux) Solar Input

Fish Response Category	Life Stage	Limiting Factor-Ecological Concern	Potential Project Category
Survival	Parr to smolt	**Food** – Altered Primary Productivity	Plantings, Beaver Introduction, Channel Modification, Side Channel,
Survival	Parr to smolt	**Water Quality** - pH/Oxygen	Plantings, Beaver Introduction, Channel Modification, Side Channel,
Survival	Parr to smolt	**Water Quality -** pH/Oxygen	Plantings, Beaver Introduction, Channel Modification, Side Channel,
Growth	Parr to smolt	**Food -** Altered Prey Species Composition and Diversity	Instream complexity, Fertilization, Planting
Growth	Parr to smolt	**Channel Structure and Form** - Instream Complexity	
Growth	Parr to smolt	**Water Quality -** Temperature	Planting, Channel Modification, Beaver Introduction
Growth	Parr to smolt	**Water Quality -** Temperature	Instream complexity
Growth	Parr to smolt	**Water Quantity –** Increased Water Quantity/Decreased Water Quantity/Altered Flow Timing	Channel Form, Flood plain, wetland creation
Survival	Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity	Sediment Reduction, Planting
Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Com-plexity	Instream Complexity, Channel Modification
Growth	Parr to smolt	**Channel Structure and Form** - Bed and Channel Form	Channel Modification
Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Com-plexity	Instream Complexity, Riparian
Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Com-plexity	Instream Complexity,
Survival	Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity	Sediment Reduction, Planting
Growth	Parr to smolt	**Food -** Altered Prey Species Composition and Diversity	Instream complexity, Fertilization, Planting
Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Com-plexity	Instream Complexity, Riparian
Survival	Parr to smolt	**Habitat Quantity** - HQ-Competition	Instream Complexity,
Growth	Parr to smolt	**Peripheral and Transitional Habitats** - Side Channel & Wetland Conditions & **Habitat Quantity** - HQ-Competition	Channel Modification
Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Com-plexity	Instream Complexity, Side Channel
Survival	Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity; Decreased Sediment Quantity	Sediment Reduction, Gravel Plavcement
Growth	Parr to smolt	**Riparian Condition** - Riparian Condition	Planting, Fencing,
Growth	Parr to smolt	**Water Quality-**Temp, **Food** – Altered Primary Productivity	Planting, Channel Form

Table 3 on the preceding page is built from the Appendix 2 table "CHaMP Indicators and Related Limiting Factors" that begins on page 40 of the BPA RM&E document, "Columbia Basin Tributary Habitat Improvement: A Framework for Research, Monitoring and Evaluation " (January 2013). This table lists the site-level measurement/data collected on the ground during CHaMP sampling, as well as a description of the single or multi-variate metric that is produced from the measurement. The intent of this table is to depict how current CHaMP metrics tie (or will eventually tie) to indicators, the salmonid life-history stage to which metrics are relevant, and potential applicability to habitat limiting factors.

An important part of Table 3 relates to the number of metrics that are listed for some indicators, and overall in the Single and Multivariate metric column. Many, if not the majority of the metrics listed in this column, are the result of the RBT and calculations that have already been programmed into it or are being addressed through improvements to the RBT for 2013. Further, it is critical to note that many of the CHaMP metrics are generated automatically by the RBT using a combination of Auxiliary and Topographic data that are collected on-the-ground. Therefore, a one-to-one field measurement vs. metric produced relationship does not exist. In other words, the cost of producing many of the CHaMP metrics that are being evaluated for elucidation of fish-habitat relationships would not be reduced if certain field measurements/topographic point captures were removed from the CHaMP protocol. This is because the programming effort for data cleaning and metric production already exists within the functionality of the RBT.

Lastly, the "Notes" in Table 3 highlight the iterative nature of the process that CHaMP has been using to evaluate its metrics. In 2013, this work will continue and involve the start of a review of all metrics and calculations to eliminate potential redundancy, identify metrics that have the greatest information content with respect to fish-habitat relationships, determine which metrics are the most repeatable, etc. Again, this work will culminate after 2013 CHaMP data collection is complete and the full three-year dataset may be evaluated.

ISEMP and CHaMP Collaboration

At this juncture it is important to reiterate that CHaMP was developed as one product of the broader ISEMP project whose original mission included development of spatially explicit fish-habitat relationship models that link to fish productivity. CHaMP is a "child" of ISEMP and data from CHaMP necessarily feeds into ISEMP's analysis of fish-habitat relationships.

This report includes a substantial amount of information about research and analyses being performed by ISEMP to define and describe fish-habitat relationships. This collaboration with ISEMP is necessary, however, because the ISEMP fish dataset, which includes multiple years of data collection within and across watersheds, must be used in conjunction with CHaMP habitat data to elucidate fish-habitat relationships and generate decision-support models to help answer KMQs.

CHaMP and ISEMP are working together to develop a data analysis framework built around a package of analyses proposed for interpreting CHaMP habitat data and ISEMP fish data. Ultimately, the intent of the analytical framework is to relate tributary habitat quality and quantity in a spatially explicit manner to fish population response. However, there is no single best way to build the framework. Therefore, multiple lines of inquiry, each with its own strengths and weaknesses, are required to construct this decision support tool.

A number of empirical approaches are proposed to help define relationships between habitat and fish metrics of CHaMP and ISEMP, respectively. These empirical approaches are possible because both programs' data collection and sampling designs were developed with such applications in mind. Interpretations based on these approaches will allow for the use of the full suite of CHaMP habitat metrics, can provide managers with information that directly support answers to key management questions, can be reduced to simple visual and numerical scores that are easy to comprehend, and will be validated for the Columbia Basin and supported by rigorous science.

Due to the breadth and diversity of CHaMP metrics, and the fact that there are functional, logistical, methodological, and relevance questions to consider for each metric., different metrics are often used in different analyses. However, when combined, the complete package of analyses offers a robust multi-spatial and temporal suite of products that can be utilized to meet habitat status and trend monitoring needs of ESA listed fish populations and restoration activities.

Since 2011, CHaMP has explored several multi-dimensional ways to display habitat status information, often combining spatial data with tabular data, in ways that hopefully foster and facilitates the human penchant for pattern detection and recognition. In 2012, using significant feedback from representatives of expert panels, CHaMP continued to respond to requests by managers for displays that could be used to inform other processes, such as the upcoming 2015 expert panel process. Beginning on page 18, examples of how CHaMP data can be used and leveraged with ISEMP fish-habitat relationship model results to produce powerful displays of habitat status at different scales are presented.

Efforts planned for 2013 involve exploration of how habitat status displays could be automated to serve a variety of end-user needs by allowing users to explore data from the geographical, temporal, and scientific areas that interest them. The next generation of these displays is being built to support the upcoming round of expert panel assessments coming in 2015. Starting in 2013, development of these displays will shift to CHaMPMonitoring.org, where interactive, user-defined, on-line displays of CHaMP habitat data will be built that will have customizable templates that users can select from to compare data from sample sites of their choice. Dynamic fish-habitat models and watershed production model results may eventually be a component of the online, interactive displays.

Also in 2012, CHaMP initiated an analysis of GRTS sample design and sampling errors to identify options to improve estimates of habitat status (and eventual estimates of trends). Information on this effort is presented beginning on page 23 of this chapter.

Variance decomposition analyses were performed again in 2012, using a larger dataset consisting of 2011 and 2012 CHaMP data, to estimate the difference components of variance for each metric—see page 26). Once a third year of data are available, variance decomposition analysis efforts will culminate in a concerted review of all CHaMP metrics and data, and discussion about which metrics are performing well already, and may be appropriate for use in generating indicators of interest; which metrics may still be useful but need additional measurement protocol refinements; and which metrics may be appropriate to replace or eliminate due to either the availability of more accurate information from an alternate source, or lack of information content, etc.

Finally, in 2012 an evaluation of sampling intensity was initiated to help better address ISRP questions about CHaMP protocol efficacy and efficiency. While these analyses are still underway, a preliminary discussion about the potential for reduction(s) in sampling intensity, and how information from this type of analysis may be used to inform decisions about protocol changes, may be found beginning on page 28.

Habitat Status at Multiple Scales

The habitat status maps presented in this section illustrate how CHaMP metric data from 2011 and 2012 might be used to depict habitat status, and when these data are used in conjunction with ISEMP 2011 fish data in fish-habitat relationship models, empirical model outputs could be used help meet the objectives of the Fish and Wildlife Program to:

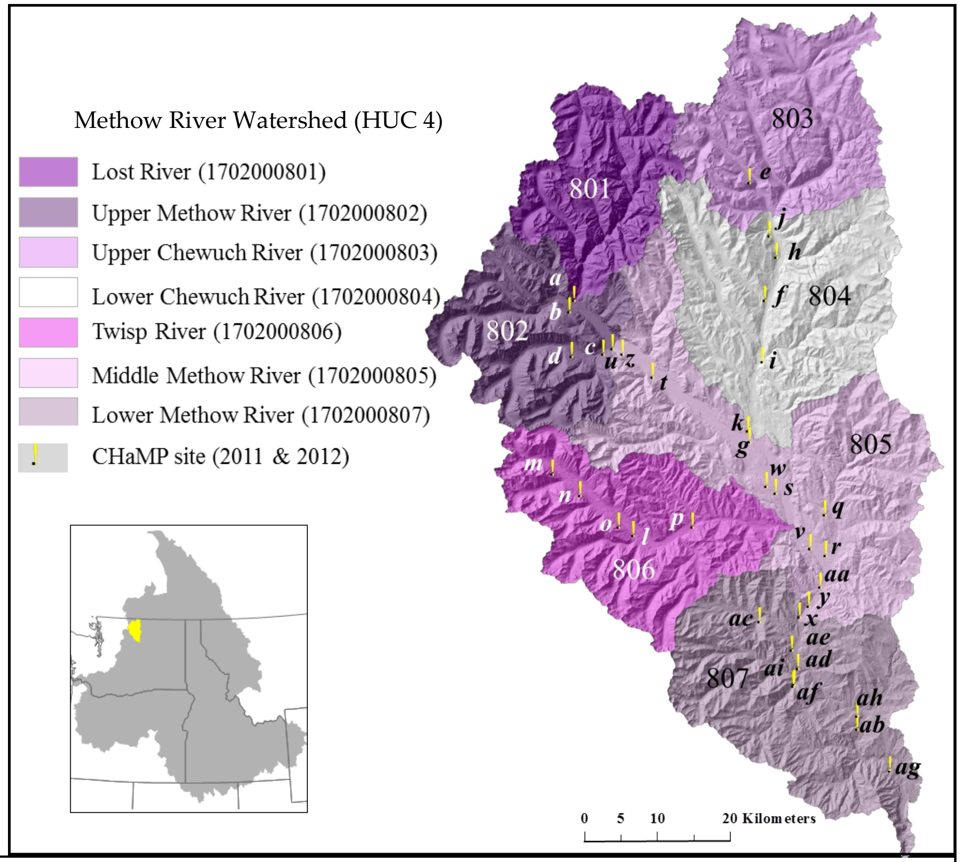
1. Determine limiting factors, i.e. specific physical or biological components of a stream that limit its capacity to support fish populations,
2. Prioritize restoration actions, and
3. Guide the development of salmon recovery plans.

Please note that the thresholds (horizontal black lines in Figures 6, 7, 8 and 9) from the partial dependence plots generated from BRT model results used in the displays of habitat status are preliminary and subject to change. Further refinement of the model may yield different results and thresholds. Nonetheless, evaluating metric values in relation to BRT model results augments the utility of CHaMP data for management and scientific applications.

Figures 6 and 7 on the next pages depict 35 CHaMP sites that were sampled in the Methow River watershed (HUC 4, 17020008) and 29 sites that were sampled in the Wenatchee River watershed (HUC 4, 17020011), respectively, in 2011 and 2012. Values for the top four habitat metrics that were identified as having a strong correlation with fish density by BRT modeling work conducted in 2011 are depicted for each site (note that average metric values are depicted if the site was sampled in 2011 and 2012). Partial dependence plots generated from the results of BRT modeling indicate the occurrence of thresholds for certain fish habitat metrics; these thresholds and values are depicted using horizontal black lines in the plots below. Above a lower threshold for some metrics, BRT models predict juvenile fish densities to increase rapidly, whereas above an upper threshold, fish densities are expected to stabilize.

Data presented in the next sections of this chapter are for display purposes only and are not ready for use in management decision making.

- Comparisons between subbasins should not be made with the data displayed in this chapter as the habitat metric values for sites represent either a single measurement or an average of two visits if the site was sampled during both the 2011 and 2012 field seasons.
- Partial dependence plot thresholds depicted in plots are marginal thresholds generated using 2011 fish data and modeling results only, and are subject to substantial revision.
- Scaling of habitat quality indices is not standardized among all subbasins and is subject to substantial revision.
- Boosted regression trees are one method to analyze the fish-habitat relationships. Although we believe this approach has several advantages over other methods, additional analyses may be carried out with CHaMP data.



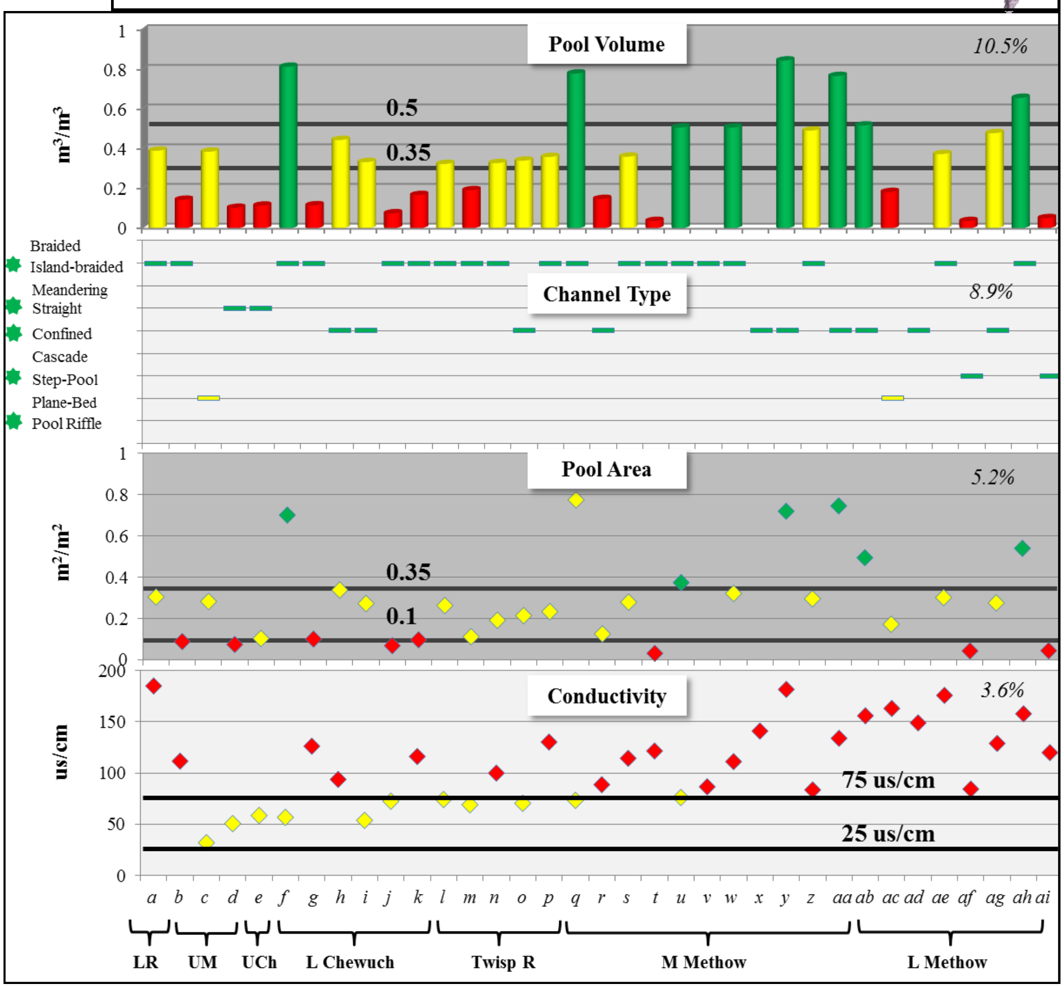
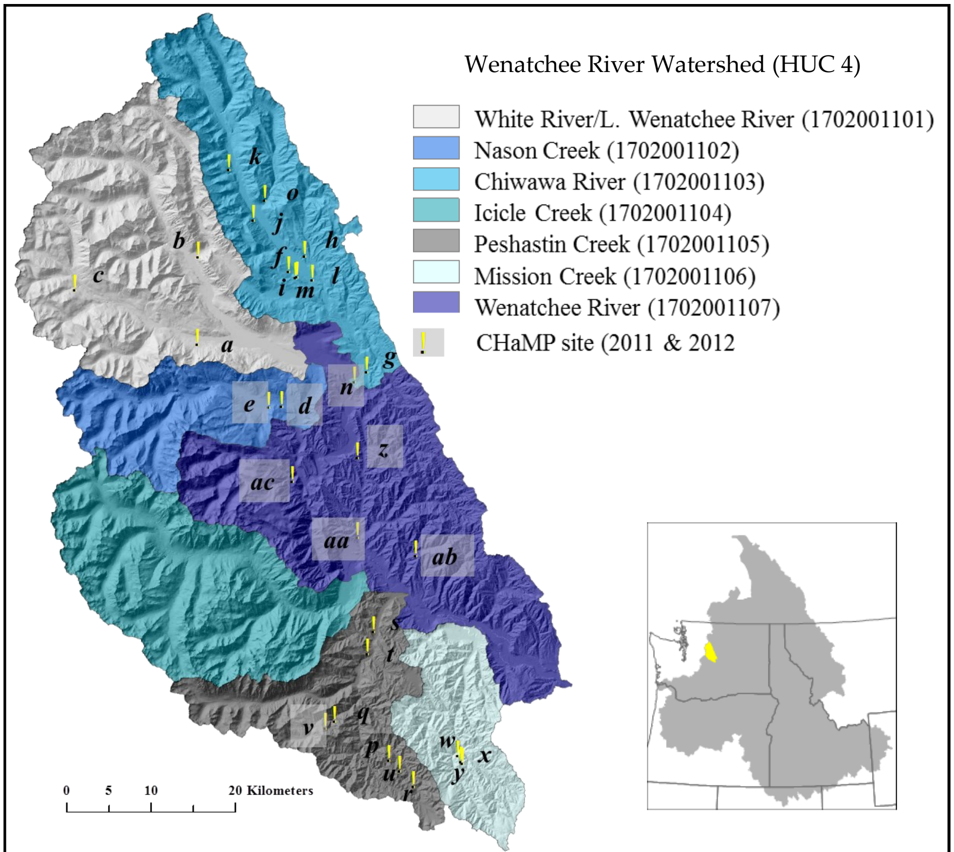


Figure 6a (top). Thirty-five (35) CHaMP sites sampled in the Methow River watershed during 2011 and 2012.

Figure 6b (right). Values of the top four metrics identified by BRT modeling results as important for predicting juvenile Chinook salmon densities, for each of the 35 sites.

About these plots:

- The relative importance of each metric for predicting fish density is shown as a percentage in italics.
- Thresholds from the partial dependence plots generated from BRT model results are shown as black horizontal lines.
- Metric values are coded red, yellow or green based whether the metric value was above, within or below the threshold values associated with higher fish densities. For example, at sites with conductivity metric values/averages $\geq$ 75 us/cm (red dots), fish density was less.
- Metric value averages were used for sites sampled multiple times.
- For channel type, the types predicted by the BRT to equate with higher fish densities are starred.



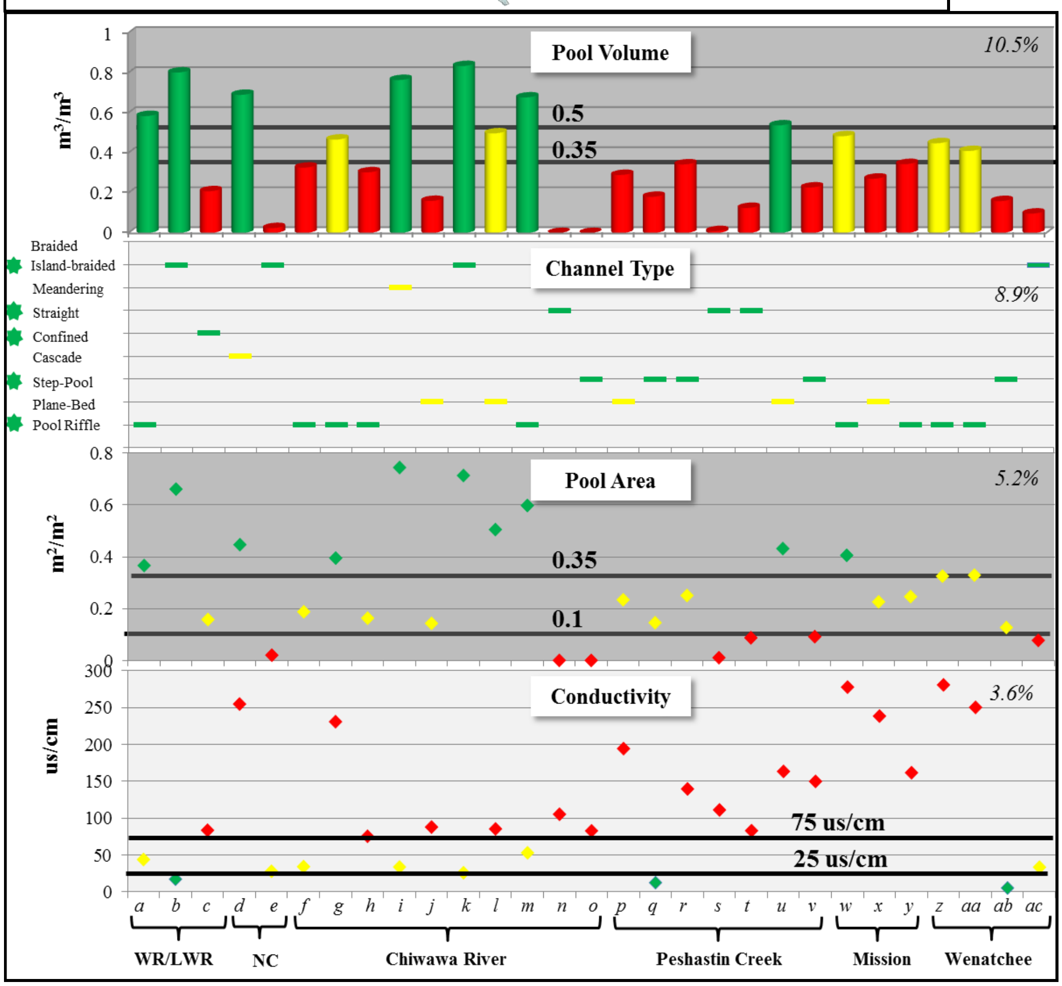


Figure 7a (top). Twenty-nine (29) CHaMP sites sampled in the Wenatchee River watershed during 2011 and 2012.

Figure 7b (left). Values of the top four metrics identified by BRT modeling results as important for predicting juvenile Chinook salmon densities, for each of the 29 sites.

About these plots:

- The relative importance of each metric for predicting fish density is shown as a percentage in italics.
- Thresholds from the partial dependence plots generated from BRT model results are shown as black horizontal lines.
- Metric values are coded red, yellow or green based whether the metric value was above, within or below the threshold values associated with higher fish densities. For example, pools with a volume ≥ 0.5 had higher densities, whereas pools with a volume ≤ 0.35 had relatively low fish density.
- Metric value averages were used for sites sampled multiple times.
- For channel type, the types predicted by the BRT to equate with higher fish densities are starred.

By combining fish-habitat modeling results with values of CHaMP habitat metrics, it is possible to assess the condition of fish habitat in relation to juvenile salmon densities. For example, in the Wenatchee watershed, the amount of pool volume at 17 sites falls below the lower threshold, and five sites fall within the two thresholds. In a habitat restoration context, these data would indicate that fish densities at 22 sites might benefit from increases in pool volume.

The plots on the previous pages also depict how CHaMP habitat data could be used on their own, e.g., pool volume metric values for all 29 sites in the Wenatchee could be used to calculate an average watershed pool volume, pool volume could be compared across all HUC 5 watershed, or site metric values could be compared between the Methow and the Wenatchee sites.

The real power of CHaMP metric data is seen, however, whey they are used in fish-habitat modeling and interpreted in conjunction with resultant fish density thresholds to help clarify how different habitat metric values may relate to changes to fish density.

Figure 8 depicts values for a different set of four metrics for 10 of the Wenatchee HUC 4 CHaMP sites (labeled with letters 'f' through 'o' in Figure 19), which lie within the Chiwawa River subwatershed (HUC 5, 1702001103). The Chiwawa River plots illustrate how CHaMP data could be evaluated at a finer scale and could be useful for informing and evaluating restoration actions. For example, bankfull large wood volumes at three sites in the Chiwawa subwatershed cross the threshold beyond which fish densities might not be expected to increase with increasing volumes of wood; however, there is a likelihood that fish densities could increase at the other seven sites if large wood was added.

Finally, at the site scale, differences among habitat attributes indicate possible limiting factors (Figure 9). For example, pool metrics may be a limiting factor for fish populations at the Rock Creek or

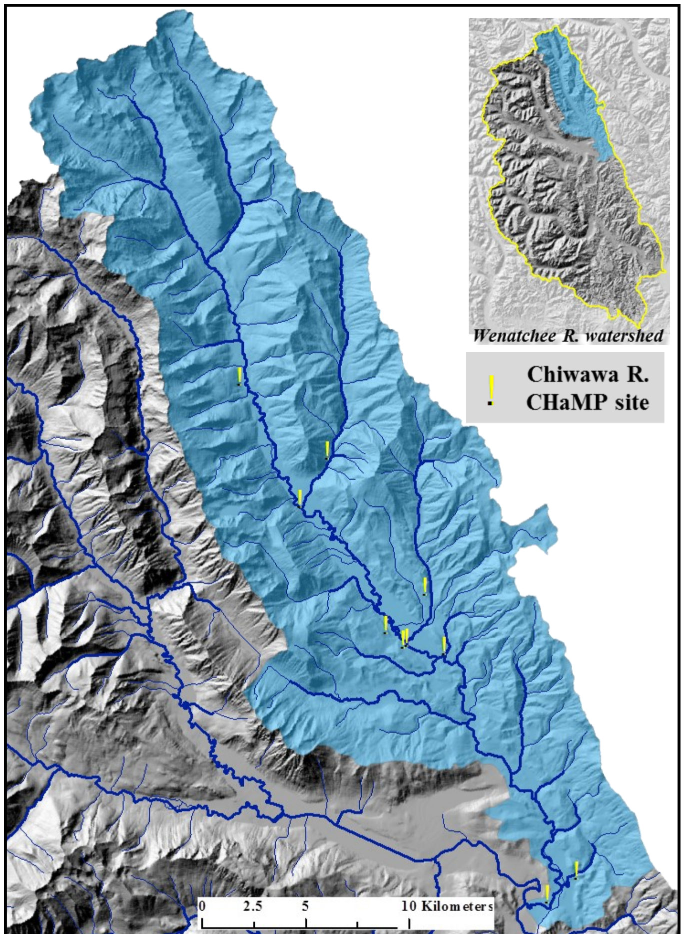


Figure 8a. (Left) Ten CHaMP sites sampled in the Chiwawa River watershed in 2011 and 2012.

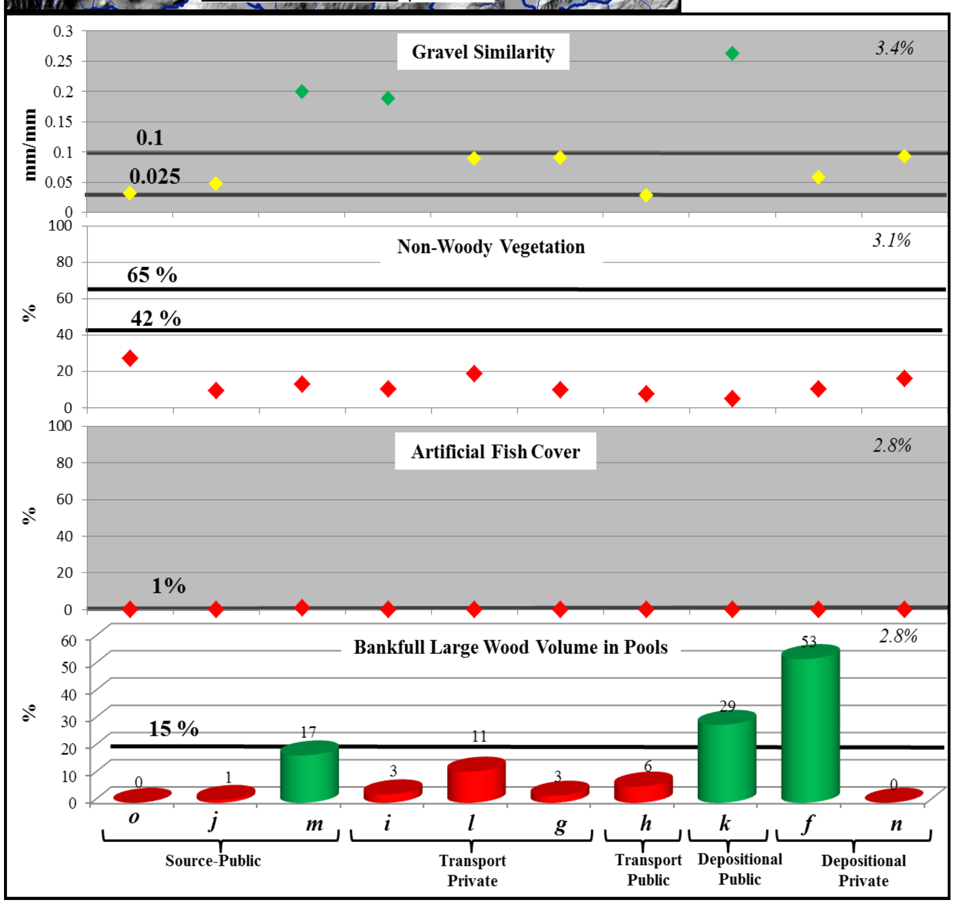
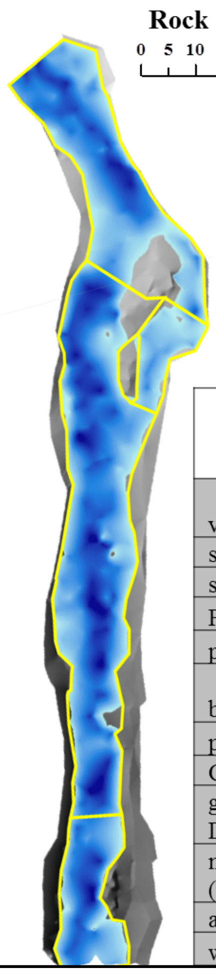
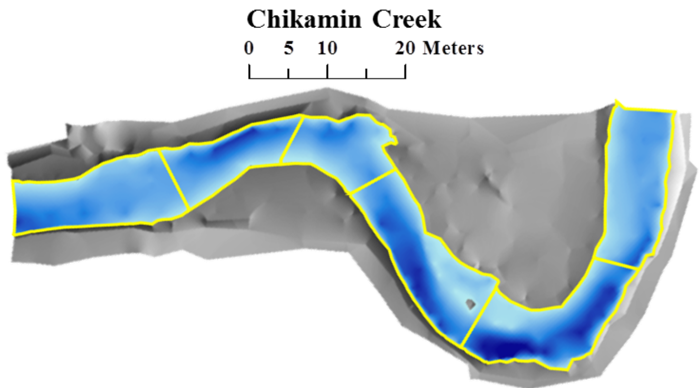


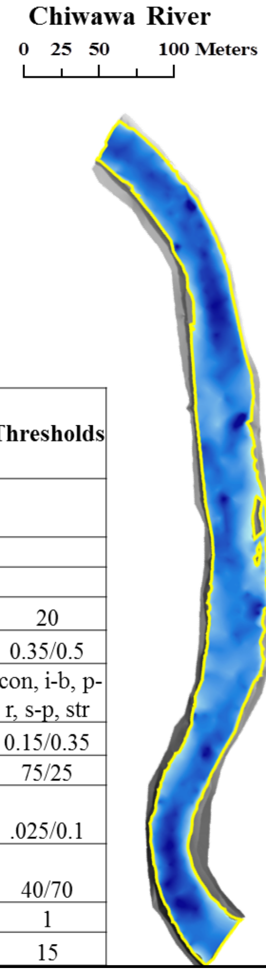
Figure 8b. (Bottom) Plots depicting the values of four metrics identified as important for predicting juvenile salmonid densities, at each the 10 Chiwawa sites.

About these plots:

- The relative importance of each metric is shown as a percentage in italics.
- Thresholds are shown as black horizontal lines.
- Each value is colored red, yellow or green based whether it was above, within or below the threshold associated with higher fish densities. For example, at 7 sites, fish densities might benefit from the addition of large wood.







Metric	Relative Importance (%)	Rock Creek	Chikamin Creek	Chiwawa River	Thresholds
valley class	-	source-public	transport-private	depositional-private	
site length bf (m)	-	172	113	580	
site gradient (m/m)	-	4.2	1.0	0.6	
Flow (m^3/s)	18.1	6.0	0.3	1.6	20
pool volume (m^3/m^3)	10.5	0.0	0.15	0	0.35/0.5
beechie class	8.9	Step-pool	Pool-riffle	Straight	con, i-b, p-r, s-p, str
pool area (m^2/m^2)	5.2	0.0	0.73	0	0.15/0.35
Conductivity (us/cm)	3.6	82.9	58.4	105.4	75/25
gravel similarity D16/D84 (mm)	3.4	0.03	0.11	0.09	.025/0.1
non woody vegetation (%)	3.1	27	19.2	15.9	40/70
artificial fish cover (%)	2.8	0	0	0	1
wood in pools (m^3)	2.8	0	1.9	0	15

Figure 9. Site-scale images and values for nine metrics at three sites (Rock Creek, Chikamin Creek, and Chiwawa River) in the Chiwawa River subwatershed. Metrics were chosen based on the high relative importance for predicting juvenile Chinook salmon densities. The colors used to highlight metric values indicate a coarse categorization of each metric as it relates to thresholds and predicted fish densities. Red indicates low fish densities, yellow indicates moderate fish densities, and green indicates high predicted fish densities. Tabular metric values are based on habitat data collected in 2011 at the Rock Creek and Chikamin Creek sites, and Chiwawa River data collected in 2012. Relative importance and threshold values are based on ISEMP BRT modeling and partial dependence plots from 2011.

Chiwawa River sites, whereas the Chikamin Creek site already has the quantity of pool volume and area to support high juvenile Chinook densities.

Partial dependence plots generated from BRT model results are also being used as the monitoring engine in the restoration effectiveness study design of intensively monitored watersheds (IMWs, see Watershed Experiments, page 39). In the Entiat IMW, annual monitoring is conducted using the CHaMP protocol at 60 sites in the lower 26 miles of the mainstem Entiat River, in addition to the monitoring that is conducted at GRTS sampling sites. As a result, it is possible to track changes in habitat condition across multiple spatial scales, including the site, the reach, and the valley segment. Figure 10 on the next page depicts site values for four habitat metrics, including two related to channel complexity—bed profile complexity and thalweg sinuosity. Channel complexity, which is a likely habitat indicator for juvenile salmonid survival, growth, and abundance is highest between river miles 16 and 21 and is also high between miles 21 and 26. Sites in these mainstem reaches, where the majority of salmonid spawning habitat is found in the Entiat River, also have naturally higher large wood and pool volume metric values. Results from metrics and displays like these that have high information content may increase the success of future habitat restoration projects by providing a scientific basis for choosing the most appropriate type of restoration project.

After the 2013 sampling season, data collected at all rotating and annual sites will be used in conjunction with additional years of ISEMP fish data to refine fish-habitat relationship modeling results and thresholds, such as what have been presented in this section of status displays, and begin habitat trends evaluations in CHaMP pilot watersheds.

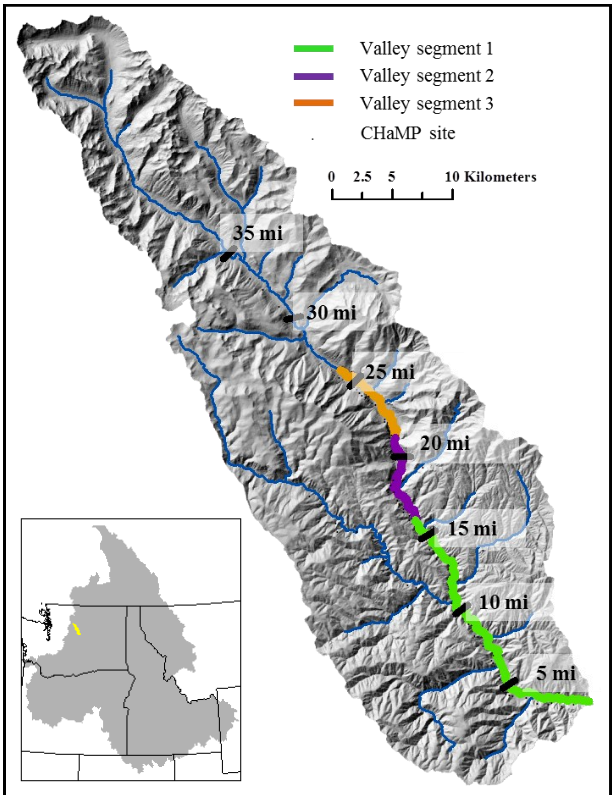


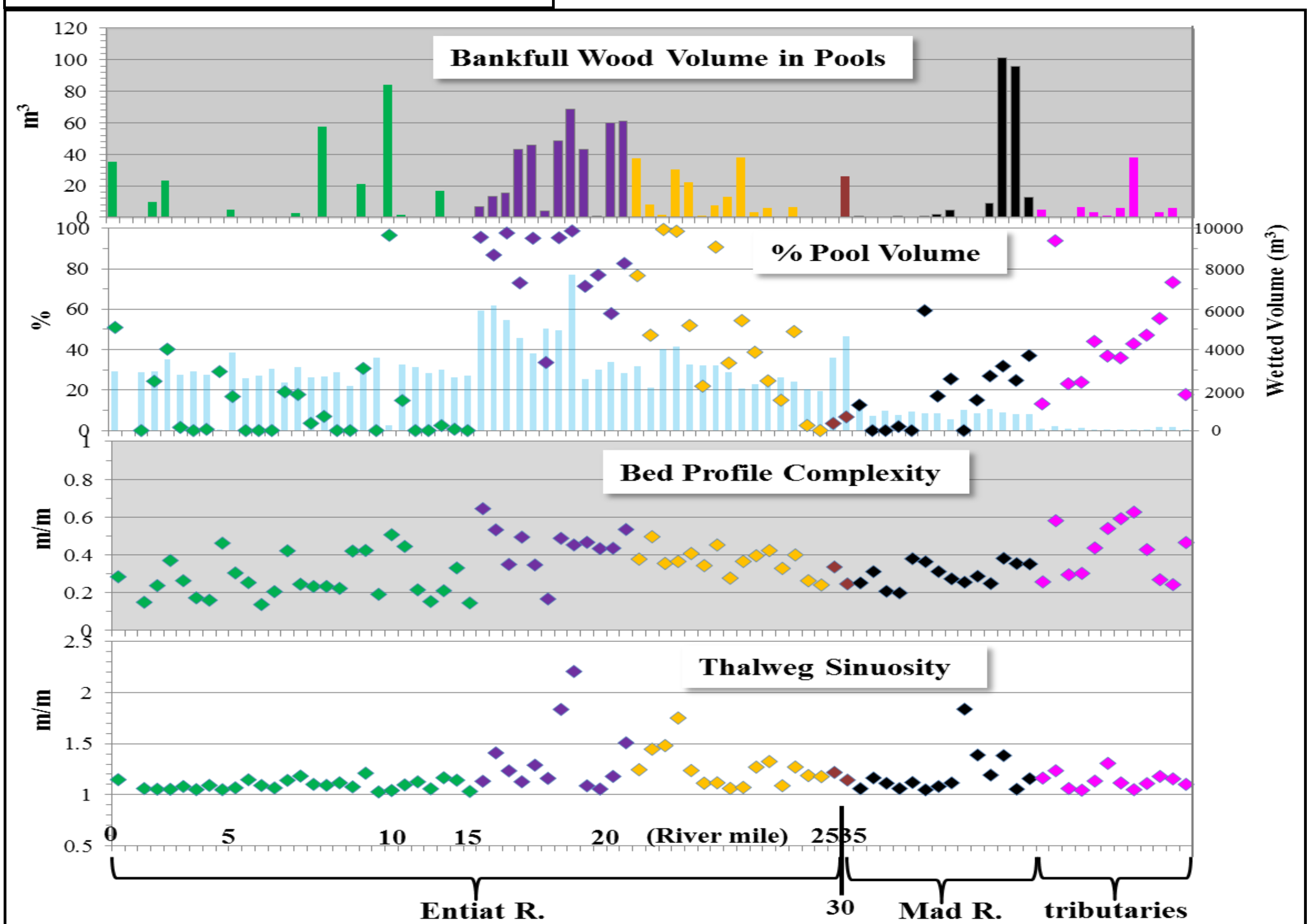
Figure 10a. (left) Depiction of the 71 monitoring sites (status and trends and annual IMW sites), in the Entiat River watershed (HUC 4), colored according to valley segment.

Figure 10b. (bottom) Values for four metrics at all sites in the Entiat River, and sites on the Mad River and other tributaries. All sites are displayed in order from downstream to upstream within the stream network.

- Green, purple and orange sites correspond to the different valley segments.
- Maroon data points indicate Status and Trends sites on the mainstem Entiat River
- Black data points are sites on the Mad River
- Pink data points are sites on tributaries other than the Mad River.

The metrics bed profile complexity and thalweg sinuosity are related to channel complexity, which is a likely habitat indicator for juvenile salmonid survival, growth, and abundance. These metric values are naturally highest between river miles 16 and 21 and between miles 21 and 26 of the mainstem. These reaches, which contain the majority of salmonid spawning habitat in the Entiat River, also have higher large wood and pool volume metric values.

The higher bed profile complexity, pool volume and wood volume metric values in the lower river miles are likely tied to recent habitat restoration actions. Results from metrics and displays like these that have high information content may increase the success of future habitat restoration projects by providing a scientific basis for choosing the most appropriate type of restoration project.



Evaluating and Improving Estimates

In 2012, efforts to evaluate and potentially improve the performance of CHaMP habitat metrics were multi-pronged.

- The quality of the sampling design was improved,
- Metric performance with respect to the ability to detect signals in the measurement — does a high amount of variation (noise) obscure any signal—was further evaluated, and
- Exploration of whether the number of measurements collected or the intensity of sampling could be reduced to save crew field time without sacrificing confidence in metrics was initiated.

This work will continue in 2013, and data from the 2012 CHaMP-PIBO comparison study (see page 8) will be further analyzed and used to evaluate the performance of CHaMP measurements and metrics relative to those of other monitoring programs, identify a potential set of programmatic crosswalks, and help identify any areas where CHaMP metrics, particularly the method(s) used to collect the data, may have advantages or disadvantages compared to other measurement protocols. This type of comparative analysis will be incorporated as another way to evaluate the full suite of CHaMP metrics in 2013-14, after the end of the pilot period.

Details about the approaches that CHaMP initiated in 2012 to evaluate and improve metric estimates through sample design weighting, ongoing variance decomposition analyses, and how CHaMP began its examination of options to reduce sampling intensity are presented in the next sections.

GRTS Sample Design Weights

Each year, CHaMP samples about 25 sites, out of possibly thousands of candidate sites, in each watershed using a The basic CHaMP sampling design uses the Generalized Random-Tessellation Stratified (GRTS) algorithm for site selection. In order to be extrapolated to the whole watershed, each of the 25 sites is asigned a "weight" corresponding the the proportion of the watershed that the site represents. While these weights are defined through the initial GRTS design, they must be adjusted at the end of the season before extrapolation occurs because two errors can arise from the imperfect implementation of the sampling design: frame errors and nonresponse errors. In both cases, only by adjusting the weights can the necessary extrapolation occur. The process of adjusting weights has been laborious and highly technical.

In 2012, CHaMP began work to automate the process of adjusting weights, which will eventually remove a step of manual data processing and facilitate automated displays of habitat status and trends information. Through weight adjustments, CHaMP estimates of status are also expected to improve.

Background

The basic GRTS design is modified in CHaMP as necessary to meet the different needs and sampling histories within each watershed. For example, legacy sites from previous monitoring efforts are integrated in the CHaMP design to continue consistent long-tem data collection. legacy sites can be included while retaining the spatial balance of the entire sample. Sample stratification within watersheds is based on factors such as the Beechie valley class, priority drainages within a watershed, or stream order. Post-hoc stratification by land ownership type is also used in some watersheds to form blocks within which substitute sites are obtained. This design feature was included to reduce nonresponse bias encountered by landowner denials of access.

Annual status estimates are obtained from design-based inference. Unbiased design-based inference is obtained by weighting each site appropriately. The design weight of a site is the inverse of the probability of inclusion of the site in the sample and signifies the number of sites represented in the population. Determining a site's design weight is often straightforward given a clearly-defined sampling design.

Nonsampling errors arise from the imperfect implementation of the sampling design. When these errors occur, calculating the appropriate design weight may require additional steps. For example, if frame overcoverage occurs, then the design weights based solely on the sampling design are too large and should be reduced. If nonresponse occurs, then the design weights for the accessible sites are too small and should be increased.

Types of nonsampling error include frame error and nonresponse error (Lessler and Kalsbeek 2002). Frame error affects the frame extent and occurs when the target population and sampling frame do not match. Frame error consists of overcoverage (including sites that are not members of the target population) and undercoverage (omitting sites from the sampling frame that are members of the target population). Overcoverage is addressed in this section by accounting for sites that were included in the sample but are not members of the target population. Undercoverage (the exclusion of target sites) is assumed to be minimal and not addressed in this analysis.

Nonresponse error affects effective sample size and occurs when a complete set of metrics cannot be obtained for every site in the sample, such as when a site is not accessed due to unsafe conditions or restrictions from landowners. The metric of interest for these "nonresponding" sites may differ systematically from the metrics obtained from sampled sites, leading to biased inference. Incorrect weighting that does not account for these sources of nonsampling error may lead to biased inference and confidence interval undercoverage.

Weighting adjustments are required when the sampling design is subject to nonsampling errors. If frame overcoverage occurs, then the design weights based solely on the sampling design are too large. If nonresponse occurs, then the design weights for the accessible sites are too small. Weights must be adjusted for these errors to obtain unbiased estimates. The weights of the sampled units will sum to the population extent when the weights are correctly calculated.

An example: 2011-2012 frame error assessment

Frame overcoverage error affected some but not all watersheds (Table 4). It was most extensive in the Entiat River, Secesh River, and Wenatchee River sampling frames where natural barriers were found to block fish passage.

Frame overcoverage can be accounted for by simply calculating the weights with the original frame extent and summing the design weights across only the sampled target sites. This approach implicitly reduces the population extent to which inference is made by a factor equal to the proportion of sites meeting the definition of the target population. CHaMP site evaluations made prior to sampling provided the basis for determining the extent of frame error (overcoverage) within each watershed (see Table 4).

Table 4. Number of sites evaluated and the number and proportion determined to be non-target sites for 2011 and 2012. Frame error is most extensive in the Entiat and Wenatchee River sampling frames.

	2011			2012		
Watershed	Sites Evaluated	Non-Target Sites	Frame Error Rate	Sites Evaluated	Non-Target Sites	Frame Error Rate
Entiat	145	44	0.30	154	51	0.33
John Day	107	6	0.06	108	9	0.08
Lemhi	64	1	0.02	72	3	0.04
Methow	47	2	0.04	47	4	0.09
Secesh	46	7	0.15	44	6	0.14
South Fork Salmon	40	0	0.00	-	-	-
Tucannon	43	0	0.00	46	0	0.00
Upper Grande Ronde	101	6	0.06	111	3	0.03
Wenatchee	73	31	0.42	77	13	0.17

Nonresponse error assessment

Nonresponse error affected nearly all of the watersheds, with nonresponse rates ranging from 0 to 0.22 in 2011 and from 0.11 to 0.48 in 2012 (Table 5). Landowner denials of access provided the largest number of nonresponding sites in the John Day, Lemhi, Upper Grande Ronde, and Wenatchee watershed (Table 6).

Table 5. CHaMP 2011 and 2012 nonresponse error summary by watershed.

	2011			2012		
Watershed	Sites Attempted	Non-responding Sites	Non-response Rate	Sites Attempted	Non-responding Sites	Non-response Rate
Entiat	81	5	0.06	59	7	0.12
John Day	76	13	0.17	81	11	0.14
Lemhi	47	6	0.13	64	17	0.27
Methow	29	4	0.14	23	4	0.17
Secesh	29	4	0.14	28	3	0.11
South Fork Salmon	10	0	0.00	0	0	NA
Tucannon	32	7	0.22	33	5	0.15
Upper Grande Ronde	72	16	0.22	75	20	0.27
Wenatchee	35	11	0.31	42	20	0.48

Adjusting weights for unbiased inference

Design weights are a function of the frame extent and the effective sample size. Frame error affects the former while nonresponse error affects the latter. The effective sample size depends on the population to which inference is made. When nonresponse occurs, the sample that is obtained is described as coming from the "sampled population." The sampled population is what remains of the target population after accounting for nonsampling error. Inference to the sampled population is justified from the obtained sample and does not require further assumptions, but the sampled population may not match the target population well. Inference to the target population may be made but will require additional assumptions. Note that estimates of the mean are unaffected by the choice of inferential population. Estimates of the total will be smaller for the sampled population than for the target population because the sampled population represents a subset of the extent of the target population. When nonresponse occurs, inference to the target population requires an estimate of the metric for nonresponding sites. Three possible approaches to this problem are to:

1. assume that the mean metric is the same for responding and non-responding sites,
2. identify covariates related to the "missingness" and obtain design-based inference within levels of the covariate, and
3. model the metric of interest for non-responding sites. Sufficient information for modeling is unlikely to be available.

Currently, the first approach is being used but the second deserves consideration. The second requires identifying covariates related to the "missingness" and conducting a nonresponse weighting adjustment. Furthermore, the variance of the estimator should reflect this additional level of uncertainty so that confidence interval coverage is not compromised by the nonresponse error. However, if the means of responding and nonresponding sites are significantly different and information from the sample is insufficient to explain the missing metrics, then unbiased inference to the target population may be tenuous. Further considerations

Table 6. Reasons for 2011 and 2011 nonresponse error by watershed.

Watershed	2011 Landowner Denial	2011 Not safe/ Physically in-accessible	2012 Landowner Denial	2012 Not safe/ Physically inaccessible
Entiat	1	4	5	2
John Day	13	0	8	3
Lemhi	3	3	17	0
Methow	3	1	3	1
Secesh	2	2	2	1
South Fork Salmon	0	0	0	0
Tucannon	7	0	4	1
Upper Grande Ronde	16	0	20	0
Wenatchee	7	4	15	5

Table 7. CHaMP 2011 and 2012 Mean Pool Frequency by Watershed.

Watershed	2011 Est. Mean	2011 95%-CI	2012 Est. Mean	2012 95%-CI
Entiat	1.25	(0.75, 1.75)	1.43	(0.82, 2.03)
John Day	Data not currently available.			
Lemhi	3.29	(1.75, 4.84)	2.23	(1.70, 2.76)
Methow	6.97	(3.66, 10.29)	3.86	(2.68, 5.04)
Secesh	2.61	(1.70, 3.51)	3.26	(2.39, 4.13)
South Fork Salmon	2.00	(1.31, 2.69)	No surveys in 2012.	
Tucannon	1.78	(1.36, 2.20)	1.95	(0.93, 2.97)
Grande Ronde (Chinook)	1.95	(1.63, 2.27)	1.81	(1.47, 2.14)
Grande Ronde Steelhead)	0.95	(0.77, 1.13)	1.24	(1.09, 1.38)
Wenatchee	3.32	(0.53, 6.11)	2.14	(0.37, 3.92)

of modeling and sensitivity analyses would be helpful in assessing the impact of nonresponse on estimates of status.

Estimating population extent and summary statistics for key metrics

Assuming that the mean metric for responding and nonresponding sites are equal, the *cont.analysis* function from the R package, spsurvey, can be used with the adjusted design weights to obtain status estimates. The inputs of the *cont.analysis* function include the metric of interest, the design weights, design features such as stratification, and definitions of subsets or domains of interest. Output includes estimates of the mean, total, percentiles, variance, and cumulative distribution functions (CDF's). Status estimates can be reported across watersheds in summary tables (Table 7) and plots (Figure 11) (both are preliminary).

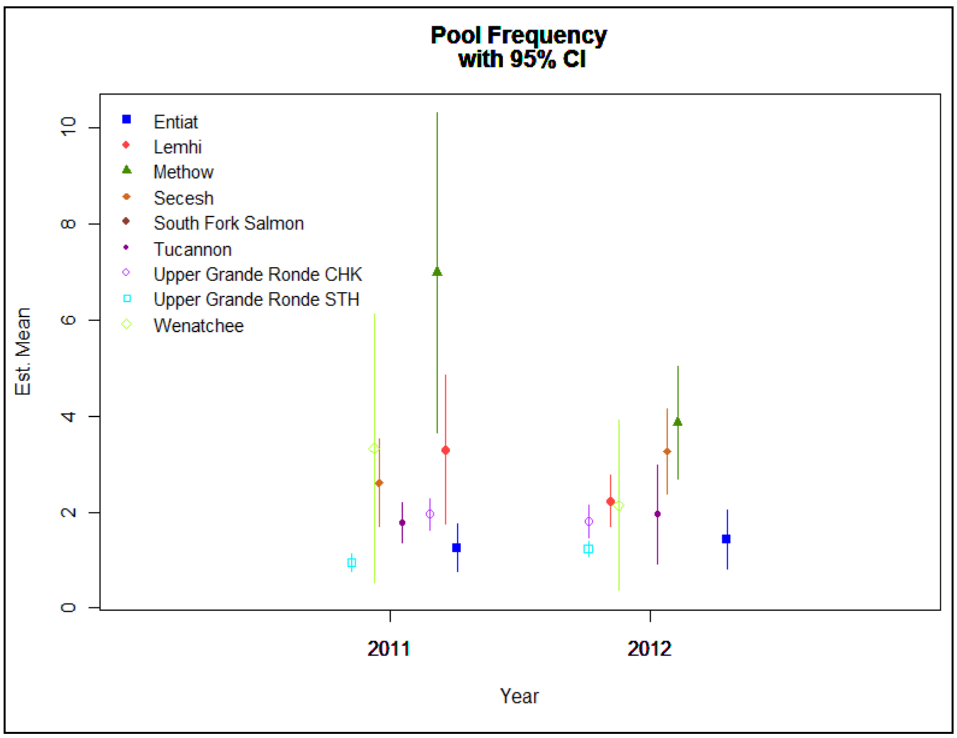


Figure 11. 2011 and 2012 Mean Measurement of D50 by Watershed with 95%-confidence intervals. (Note that zero estimates in 2012 represent unsurveyed watersheds or watersheds for which estimates are currently unavailable.)

Variance Decomposition

CHaMP's rotating panel design with repeat visits during an 'index window' allows estimation of major components of variation for the metrics calculated at each site. A hierarchical framework is used to organize the components of variation and facilitate identification of those that are relevant to objectives at hand and those that are 'noise'. At the coarsest level, these are a spatial component (site), a temporal component (across years), and a residual component. The temporal component consists of two parts: a synchronous and an interaction component. Synchronous temporal variance arises if an external factor drives metric values to be higher or lower together in a particular year, whereas interaction variance describes the independent site to site differences in yearly temporal variation. Additional information describing these four major variance components may be found in the CHaMP 2011 report (Ward et al.(2012).

CHaMP has conducted two years of monitoring that includes sampling a subset of sites in each of the two years, and a subset of sites twice during each year's index window. Figure 22 depicts estimates the four major variance components for each metric and compares the 'performance' of the metrics relative to each other, based on two year's worth of data. Information from 2012 variance decomposition analyses may be used to refine the protocol for the 2013 sampling season. For example, drift macroinvertebrate metric performance remained poor in 2012, which indicates that sampling methods and approaches to collecting fish food information should be reexamined. This type of metric evaluation will be performed again at the end of the pilot period, using the combined three-year dataset, which will provided a larger sample size on which to base metric performance evaluations.

The additional variance decomposition analyses that will be performed after conclusion of the third year of sampling will be used to examine metric performance relative to core indicators, focus on metrics for which there are alternates that may be used, and help guide decision-making about changes to the CHaMP protocol and metrics based on a rigorous and comprehensive review of all metrics based on the variance decomposition framework and the other efforts to evaluate and improve metric estimates and performance that are described in this section.

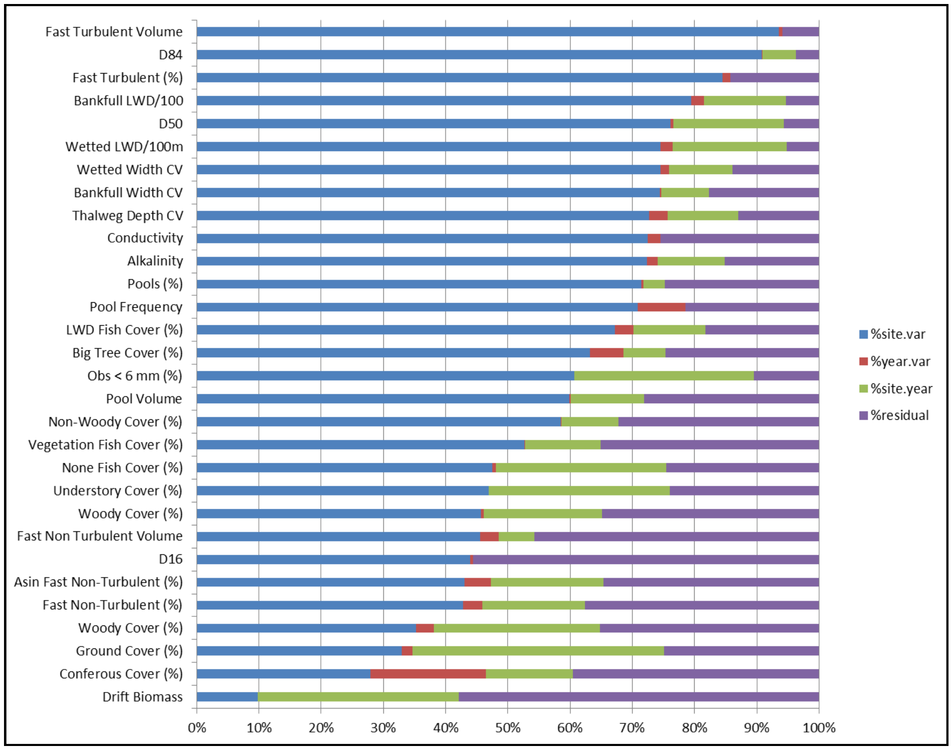


Figure 12. Comparison of the relative magnitude of four major components of variation for a series of CHaMP's candidate metrics, based on combined 2011 and 2012 datasets. The metrics are arranged from greatest to least 'site' variance (as a proportion of total variance).

An example: interpreting the relative components of variance

The metric D84 is illustrative of metrics with high relative site variation and correspondingly relatively little year to year or residual variation (Fig. 12). This can be seen by the strong relationship between 2011 and 2012 for those sites at which measurements were made both years (Figure 13). As well, a strong relationship is evident between the first and second within year visits for those sites with revisits (Figure 13). Classification and modeling of metrics with high site variation can be expected to perform well if temporally stable independent factors can be identified that are associated with the metric's variation, such as stream geomorphic type, basin geology, or stream gradient. These metrics should also be sensitive to changes due to restoration if restoration is designed to affect them (i.e., detection of differences between treatment and controls).

If temporal and/or residual variation is relatively large, plots of year to year or visit 1 to visit 2 can indicate outliers that might reflect 'quality' problems with the data. For example, temporal and residual variation in the metric 'pool volume' is relatively high. Plots of 2011 vs. 2012 and visit 1 vs. visit 2 indicate some questionable data points that distort a strong relationship between the sets of pairs (Figure 14). These outliers may be 'correct', or the cause may be resolvable.

Metrics with low site variation such as drift biomass or coniferous cover imply that there is either high year-to-year or residual variation, or both (Figure 12). For those metrics illustrated in Figure 12

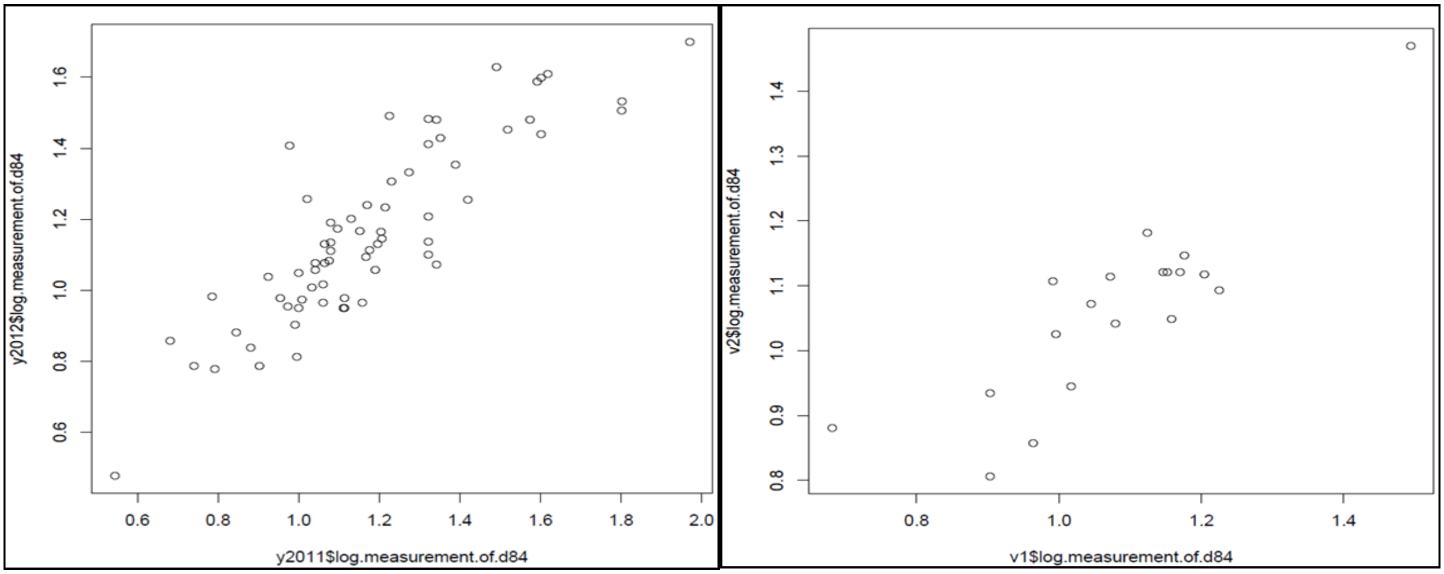


Figure 13. As illustrated in Figure 12, the relative magnitude of 'site' variance for metric 'D84' is high; the expectation is that there is a consistent relationship between plots of 2011 vs. 2012 metric scores and visit 1 and visit 2 metric scores, as illustrated by these graphs.

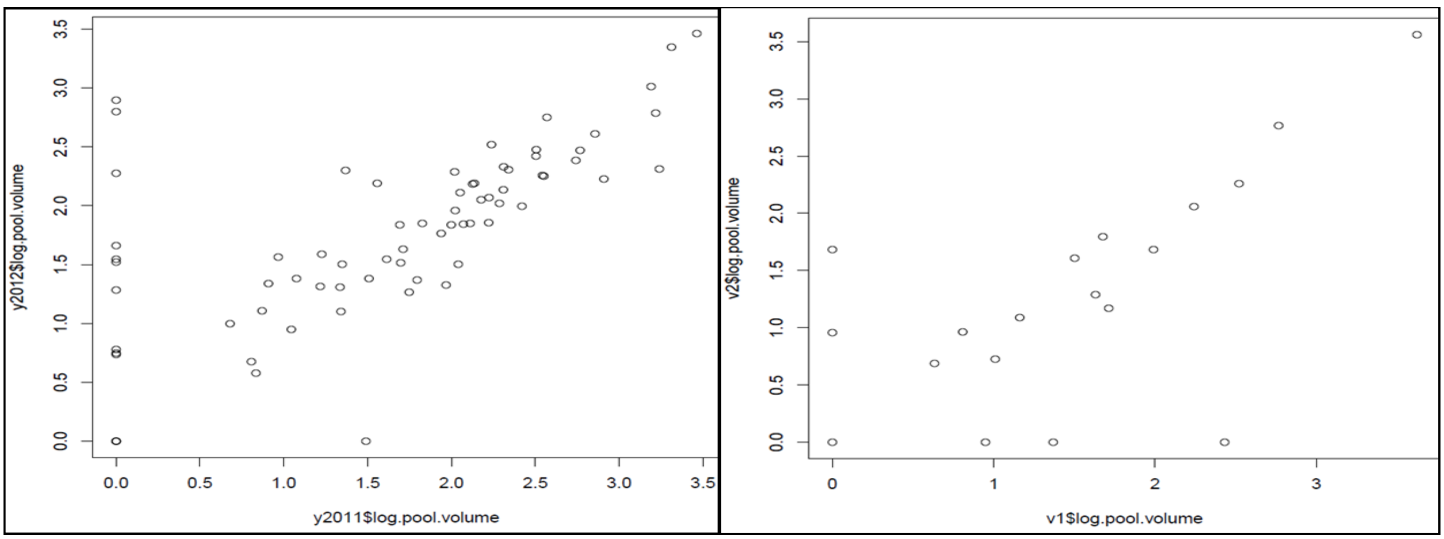


Figure 14. This pair of the metric 'pool volume' plots illustrates a strong relationship between years and revisits within years. However, it also indicates some outliers that might require investigation to evaluate whether they are 'correct', or whether they are due to resolvable problems, e.g., how measurements were taken at those sites/times or data processing.

with low site variation, both high year-to-year and high residual variation are apparent (i.e., the relative size of the proportions of total variation attributable to these components is similar). In some cases, metric plots of 2011 vs. 2012 or visit 1 vs. visit 2 reveal possible QA issues with respect to one or another year's or visit's metric scores (Figure 13). In other cases, absence of clear outliers (e.g., Figure 15) could indicate that the measurement protocol is not very repeatable, or that there is a large component of natural temporal variation. Metrics with low site variation can be expected to perform poorly in classification and modeling (unless the independent variables are temporally varying in concert with the metrics' temporal variation). It will also be difficult to detect restoration effects on these metrics because they are so noisy.

The relative magnitude of the interaction and residual components of variation can be informative with respect to evaluating internal consistency of the decomposition framework. In most cases, these two components are about the same size implying that there is roughly as much year-to-year variation as there is within the index window. However, the metric bankfull large wood frequency indicates that there is relatively more year-to-year variation than residual variation (Figure 12). Plots comparing 2011 to 2012 and visit 1 to visit 2 display

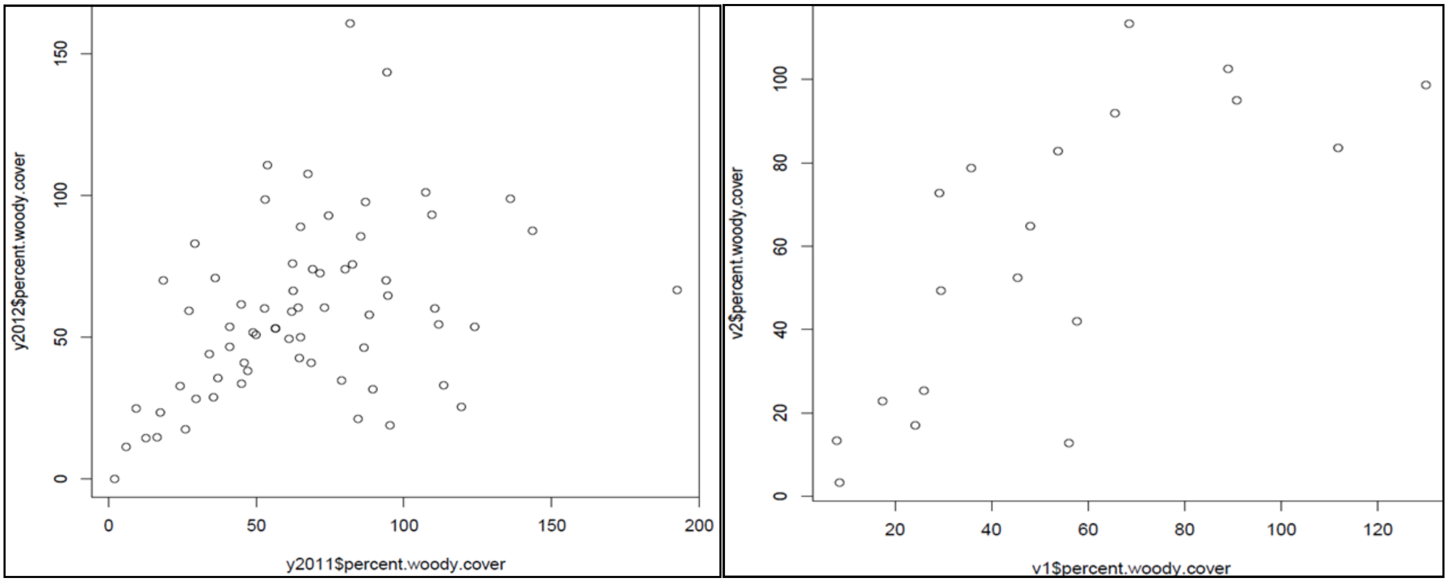


Figure 15. This pair of metric 'percent woody cover' plot indicates low 'site' variance (see Figure 12) compared with 'site.year' and residual, suggesting that plots of 2011 vs. 2012 and visit 1 vs. visit 2 would be noisy, without evidence of clear outliers, as illustrated here. For example, compare with Figure 12 that contains clear outliers.

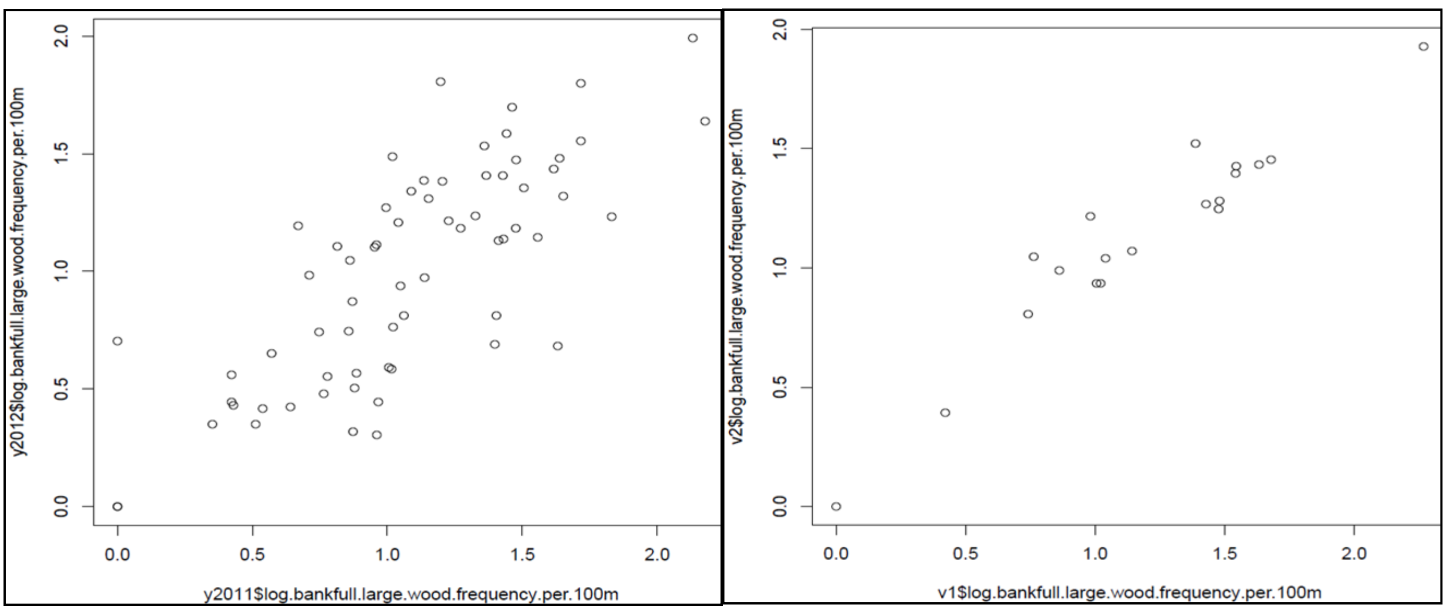


Figure 16. The relative magnitude of the interaction vs. residual variance component for the metric 'bankfull large wood frequency' is high, implying that there should be a noisier relationship in the 2011 vs. 2012 plots compared with the visit 1 vs. visit 2 plots, as illustrated by this pair of plots.

differences in the patterns in that there is a close relationship between visit 1 and 2 vs. 2011 and 2012 (Figure 16). Metrics with this type of pattern imply that the metric is stable within the index window (and the measurement protocol is repeatable) and that most of the non-site variation is associated with likely natural year-to-year variation.

Evaluating Sampling Intensity

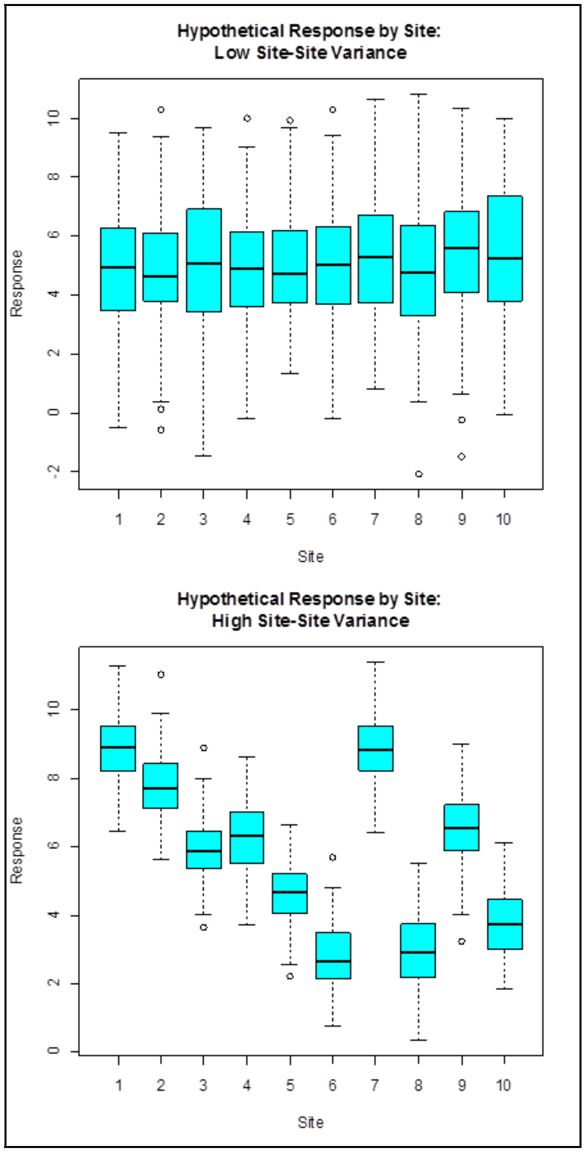
In 2012, CHaMP initiated an evaluation of metric performance within the project's operational goal of a field protocol that can be implemented at one site by crews of three persons during one day of field work. Changes in measurement protocols and total number of sites sampled across a watershed, on the standard errors of estimates of pool tail fines, particle size distribution, and particle embeddedness, were examined at the watershed level and site level. CHaMP plans to use the information from these analyses to optimize the use of limited crew resources, and help sampling efforts come closer to attainment of an average of one day per site as is intended by the protocol. This in turn is anticipated to result in significant project cost-savings.

In general, preliminary results show that significant reductions in the number of measurements taken within a site would have limited effect on standard errors of watershed level metric estimates. If researchers determine that the precision of watershed level estimates is of higher importance than site level measurements, there may be advantages to adjusting the measurement protocol to reduce the intensity of within site measurement, by reducing the total number of points measured within a site, especially if this allows for a greater number of total sites to be measured within a given measurement season.

An example:: exploring how sampling reductions affect metric estimates

A study was conducted in 2012 to quantify the effects of adjusting within-site sampling intensities, as well as changing the total number of sites sampled within a watershed sampling frame, based on the standard errors of estimates at the site level and at the watershed level. It should be recognized, however, that "effort" is not interchangeable between site and sampling frame for any given metric. It presumably requires less effort to take a given number of individual measurements by sampling at a high intensity at a low number of sites than it does to take the same number of measurements at a greater number of sites at lower sampling intensity per site, due to requirements for additional travel, site preparation, etc., when moving from site to site.

The metrics considered in this analysis are those associated with pool tail fines: percent of substrate less than 2mm and percent of substrate between 2 and 6 mm; and particle size distribution and embeddedness. Each of these metrics is assessed at each site in the survey, and the site level assessment for each metric is made from measurements at multiple locations within each site, per the current protocol for each site. The set of graphs in Figure 18 on the following page depict actual site-site and within-site values for pool tail fines (<2mm and <6mm), substrate size, and embeddedness.



In general, sample size tradeoffs such as those being considered by CHaMP are dependent on the within-site and site-to-site variance for a given metric.

(Top) An example of how a metric could be distributed identically within each site, indicating very low site-to-site variation. In this case, all information about the watershed would be contained within each site, and a sampling plan designed to estimate the mean response in the watershed could include only a few sites and a large number of measurements per site, or the sample size could cover an ever increasing number of sites. In reality, such a spatial distribution is rare.

(Bottom) A more realistic scenario for the distribution of a spatially varying metric across sites. In this case, if only a few sites were chosen, the estimated mean would never converge to the true population mean, even if an infinite number of within site measurements were taken. Note, however, that as the number of sites sampled approaches infinity (assuming this were possible), the estimated population mean would approach the true population mean, even if the number of samples per site were only 1 and that single sample resulted in a site level estimate with very low precision.

Figure 17. A hypothetical example of how a metric could be distributed identically within each site (top), meaning there is very low site-to-site variation, or how a metric could vary spatially across sites (bottom, a more realistic scenario).

In general, using greater numbers of measurement locations within a site will produce a more precise site level estimate of the metric being assessed. For a sample (such as a GRTS sample) of sites sampled from a broader spatial frame, such as a watershed, more precise site level estimates will, generally, yield higher precision estimates of watershed level means, standard deviations, or other statistics for any given metric. However, another method to achieve greater precision at the watershed level, or any other aggregated spatial level, is to increase the total number of sites sampled while maintaining, or possibly even reducing, site level measurement intensity.

Given the realities of limited crew resources, conducting measurements at many locations within each site may limit the number of sites than can be sampled in a given season; conversely, specifying a high number of sites for sampling may limit the intensity at which within site measurements can be taken. The scientist will ultimately have to weigh "effort" tradeoffs based on these results and the actual logistics of sampling during a season.

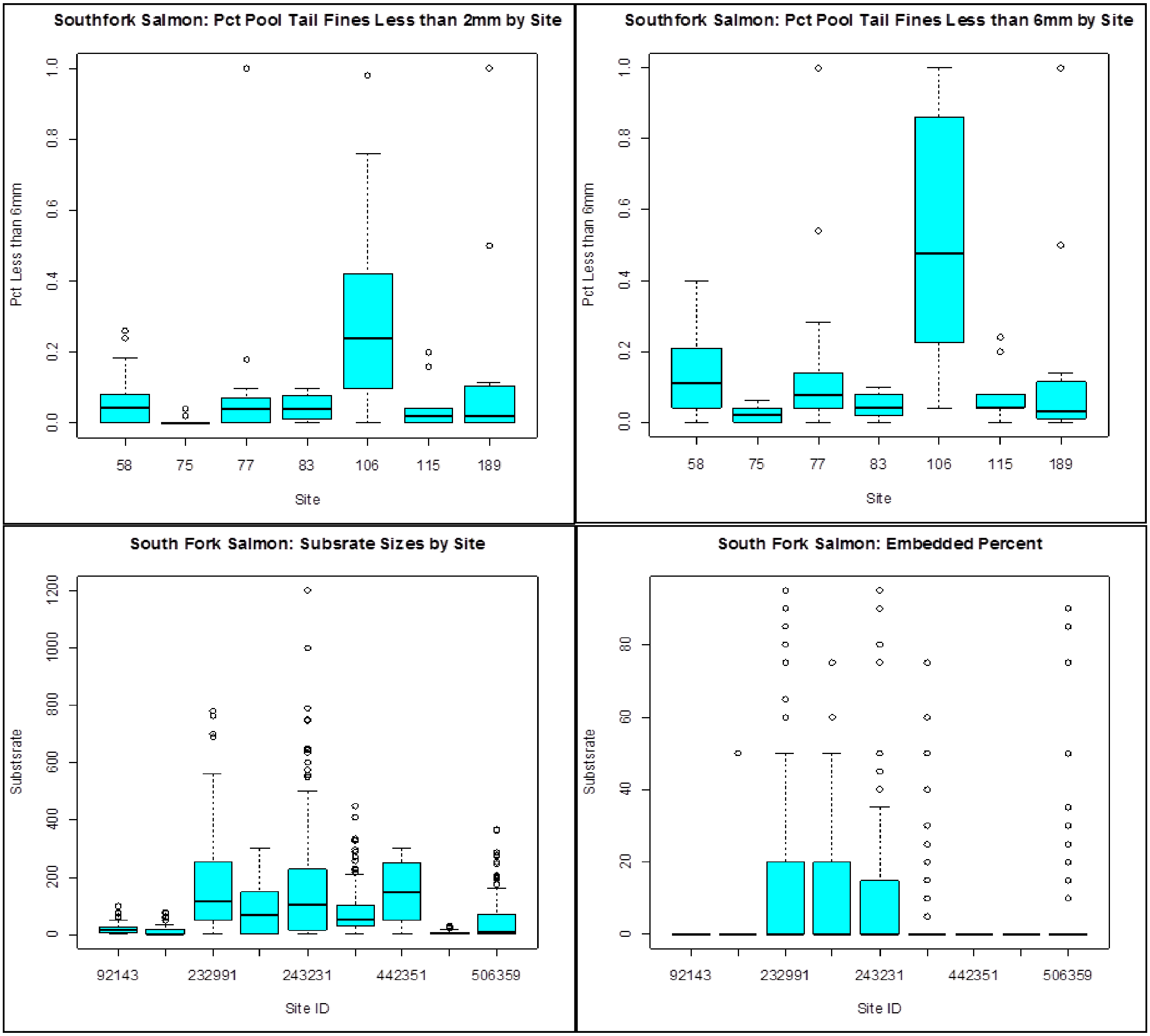


Figure 18. Actual site-to-site and within-site values for pool tail fines (<2mm and <6mm), substrate size, and embeddedness in the South Fork Salmon. Note that, as in the second/bottom example in Figure 17 on the previous page, there is considerable site-to-site variation.

III. ANALYTICAL FRAMEWORK FOR FISH-HABITAT RELATIONSHIPS

Introduction

The CHaMP 2011 Lessons Learned report documented that the focus of the first year pilot effort was on establishing a working habitat monitoring program. Descriptions of habitat status and trends were not comprehensively documented in 2011 for insufficient data (only one year of a three year sampling design) and for the lack of interpretive tools. The lack of interpretive tools was addressed with a general, multi-year plan and a proposal for creating an analytical framework, in conjunction with ISEMP and policy decision makers, to address how and when the necessary interpretive tools would be developed.

This chapter presents the proposed analytical framework for fish-habitat relationships that will be used to develop the tools necessary for interpreting the growing body of habitat data that CHaMP is amassing each year, so that answers can be provided for each Key Management Question. This framework is presented within the context of the goal of completing and validating the ISEMP watershed model for application in each Columbia River subbasin for which both CHaMP habitat and ISEMP fish data are currently available. These subbasins necessarily represent a variety of landscapes and habitats for salmonids of interest under the BiOp.

Watershed production model development is being informed by numerous correlative analyses that fall along continuums of "level of proof", "certainty of mechanisms", "applicability across watersheds" and "ease of accomplishment". CHaMP intends to use the watershed production model and the supporting data and analyses to develop final tools to translate CHaMP data into answers to KMQs (Figure 19).

The approaches, deliverables, dates and responsible parties that the CHaMP-ISEMP team is proposing to further its work on the model and validation of theoretical assumptions about CHaMP metrics and indicators are presented in this chapter, along with information about the supporting data and analyses that are utilizing CHaMP and/or CHaMP and ISEMP data.

As planned, this analytical framework was developed in conjunction with policy decision makers, and ISEMP, through a series of discussions beginning in December 2011 and including an analysis strategy meeting in September 2012. These discussions suggested that the CHaMP analytical framework:

- Immediately target, for presentation and the facilitation of presentation by others, interpretable habitat status and trends data in time to support the 2015 expert panel process.
- Guide, during the intervening time, the development of interpretive tools that emphasize empirical interpretations rather than interpretations of habitat data based on theoretical approaches described in the 2011 report.
- Continue close collaboration with ISEMP and policy decision makers.

As in 2011, the interpretations from 2012 that underpin the framework (1) will require collaboration between technical developers and policy decision makers before they are finalized and (2) will clearly need to be based on either theoretical or empirical relationships between fish and fish habitat.

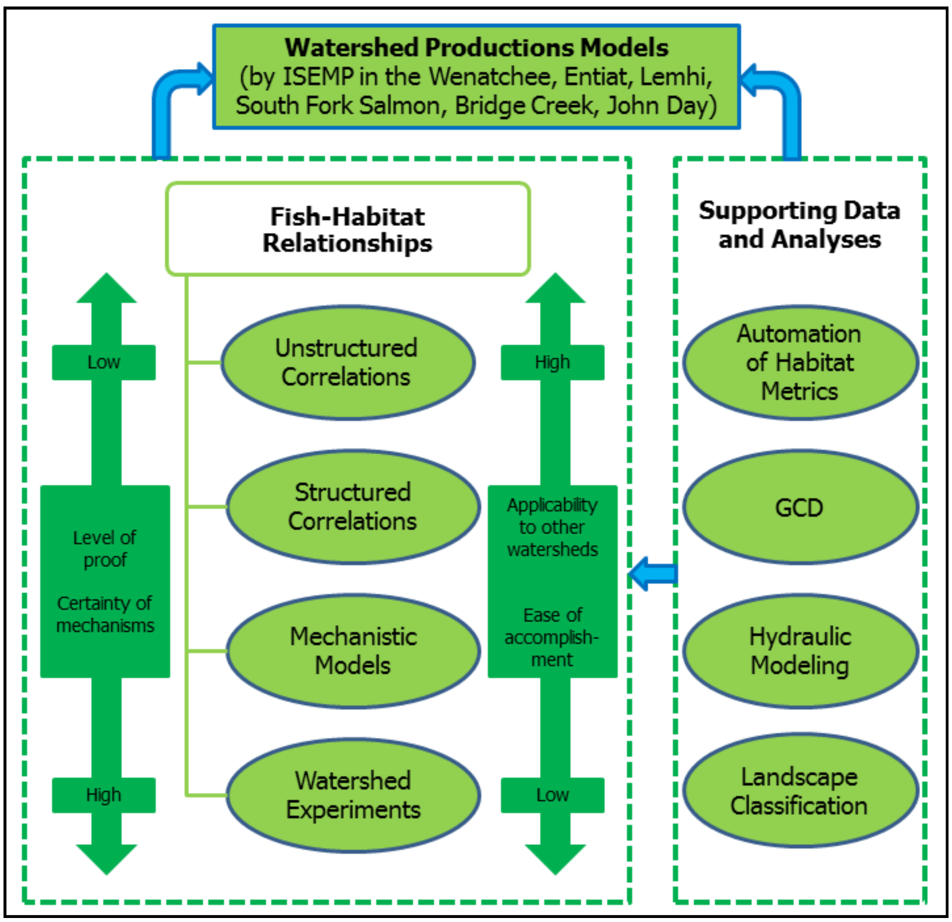


Figure 19. Proposed analytical framework for answering Key Management Questions about the relationships between fish and habitat condition.

Watershed Production Model

ISEMP has decided to expand the use of its watershed production model, which it pioneered in the Lemhi, to the Entiat and Bridge Creek, as a vehicle for consolidating the different methodologies and approaches used in these pilot watersheds. By having a common predictive framework, ISEMP will be able to more effectively leverage its work to date into predictive models that will be used to answer KMQs. These watershed production models will be useful to CHaMP as they will provide a common platform for developing fish-habitat relationships.

The ISEMP watershed production model was developed to identify limiting factors, simulate alternative restoration scenarios, and evaluate the efficacy of completed restoration actions. The model is based on a Beverton-Holt stock recruit relationship (Beverton and Holt 1957), modified to include life stage specific survival (Moussalli and Hilborn 1986) and to include the interactions of habitat, hatchery production, harvest, and climate (Sharma et al. 2006). Habitat and population status and trends monitoring data from the South Fork Salmon River (SFSR) watershed, and habitat action effectiveness monitoring data from the Lemhi River watershed are being joined through the model. The ISEMP watershed model views fish vital rates (survival productivity, abundance, and condition) as a function of the quantity and quality of available habitat. Additionally, the model includes survival functions that enable the user to alter survival rates (juvenile to emigrant and emigrant to adult) as necessary to compensate for hatchery production., and it also allows use of direct empirical measurements in addition to estimated attributes based on remote sensing data.

CHaMP is providing the fish habitat measurements and metrics that will be used in concert with ISEMP data to validate the watershed model and provide a statistical framework to evaluate the effects of different classes of habitat actions on the life-stage specific vital rates of salmonids. The watershed model is intended to serve as an empirically-based decision support tool to help managers evaluate restoration actions and management goals under the BiOp, at multiple scales. The utility of these alternative approaches will be assessed by their information value with regard to fish – habitat relationships.

The ultimate intent of this work is to be able to develop a watershed production model within watersheds of interest under the BiOp across the Columbia River Basin. ISEMP implementation in the Lemhi was designed to fully populate the watershed production model with empirical data. Therefore, the model is currently most applicable to this watershed. In 2013, the ISEMP watershed production model will be populated with a single brood year of spring/summer Chinook information for the Lemhi River and South Fork Salmon River, and CHaMP habitat data, to:

- empirically generate fish and habitat relationships
- identify which of those relationships may be common to other subbasins.
- identify minimum data requirements to effectively utilize the model.

Transferability of the model to other watersheds will be assessed by testing the sensitivity of model results to differing data types by utilizing information collected by ISEMP in the Entiat and Bridge Creek watersheds. Model reduction will commence in 2013, and development of an exportable model is anticipated in 2014.

Watershed Production Model for Use in Select Columbia River Watersheds

Deliverable Schedule:

- By November 2013: Assemble working versions of a watershed production model for each ISEMP watershed (Wenatchee River, Entiat River, Lemhi River, South Fork Salmon River (Secesh), John Day River (South Fork and/or Middle Fork)).
- By April 2014: Develop a draft of the July 2014 synthesis report using the final QA/QC'ed habitat and fish data set.
- By July 2014: A synthesis of results from the working versions of watershed production models developed for ISEMP watersheds. Provide a working version of all models via interpretive tools that can be used by decision makers to derive answers for all relevant KMQs.
- From 2014 – 2018: Adaptively update the working version of each watershed production model with new information as it becomes available.
- By 2018: Final product for inclusion in BiOp reporting summarizing/compiling results from watershed production models in each ISEMP watershed; preliminary IMW results will be included.

Approach:

Parameterize existing watershed productions models with data collected by ISEMP and other sources for watersheds with existing models (South Fork Salmon, Lemhi, Wenatchee), adapt existing models and parameterize with ISEMP and other available data (e.g. Entiat), or develop new production models in watersheds without existing models. Work with policy decision makers in winter 2013-2014 to decide which output products and interpretive tools will be most useful. Develop output products and interpretive tools. Present these tools in 2014 to aid in understanding and measure progress in answering key management questions; to begin a process of regional buy-in; and as a draft effort for 2018 BiOp reporting. Update models to continue the measurement of progress, to incorporate best available science, and to foster learning.

Task Lead: ISEMP project

References:

Beverton, R. J. H. and S. J. Holt. 1957. *On the Dynamics of Exploited Fish Populations*. Chapman & Hall, New York.

Mousalli, E. and R. Hilborn. 1986. Optimal stock size and harvest rate in multi-stage life history models. Canadian Journal of Fisheries and Aquatic Sciences 43:135-141.

Sharma, R., G. Morishima, S. Wang, A. Talbot, and L. Gilberstons. 2006. An evaluation of the Clearwater River supplementation program in western Washington. Canadian Journal of Fisheries and Aquatic Sciences 63:423-437.

Fish-Habitat Relationships

Fish habitat affects the abundance of salmonids, how well they grow, and how well they survive. At this time, the relationships between habitat and these fish metrics is not well understood. The combination of the CHaMP habitat data set with fish data collected by ISEMP at the same sites represents the best available opportunity to elucidate fish-habitat relationships .

Fish-habitat modeling is performed in an attempt to quantify relationships between fish and various habitat characteristics so that habitat monitoring programs such as CHaMP can focus on those metrics most important to fish, and restoration projects can be designed to provide the largest benefit to fish populations.

Habitat and fish monitoring performed by CHaMP and ISEMP, respectively, is structured to enable development of fish – habitat relationships at the site, tributary, and population scales. This is important to note because fish behavior and habitat selection, and habitat productivity, respond to multiple ecological factors at a range of spatial scales (Calfoun and Martin 2007).

ISEMP analysts are using multiple lines of inquiry to describe fish-habitat relationships (see Figure 5). For each approach, life-stage specific abundance, growth, and survival data collected by ISEMP are used to describe fish population performance, while CHaMP surveys provide standardized habitat assessment data. Identification of fish-habitat relationships will facilitate the recommendation of habitat actions that are most likely to benefit fish populations. A summary of the work being performed to develop fish-habitat relationships that capitalize on and maximize the nature of CHaMP habitat data is presented in the discussion that follows.

Unstructured Correlations Between Fish and Habitat Metrics

Correlative models attempt to describe correlations between physical habitat and fish population abundance and performance (i.e., density, growth, and survival), and come in many forms including:

- multiple linear regressions
- generalized linear models
- generalized additive models
- machine-learning models, such as random forests and boosted regression trees.

The objective of this work is to identify key factors associated with fish population performance across species, life stages, and watersheds. A larger goal is to extrapolate findings to watersheds that are not intensively studied, in order to support broad scale habitat assessments and maximize the utility of regional monitoring data.

Habitat metrics for a subset of CHaMP sites where ISEMP fish abundance, growth, or survival data are available are being summarized and related to fish performance metrics through a variety of unstructured correlation approaches (e.g., generalized linear models, boosted regression trees, and random forest models). Success will be measured by how well the models predict fish abundance, growth, or survival. Results may identify spatial variability in habitat associations, which would suggest that the factors limiting fish vary with location or spatial scale.

Boosted regression tree (BRT) model

In 2012, BRT models were fit to both steelhead and Chinook as the target species using ISEMP fish abundance esti-

Fish-Habitat Relationships

Deliverable Schedule:

- By November 2013: Continue progress on existing fish-habitat models and develop additional models (see the remainder of this Chapter for details on individual models).
- By December 2013: Assemble working data set of three years of CHaMP habitat and ISEMP fish data at sites.
- By April 2014: Develop a draft of the July 2014 synthesis report using the final QA/QC'ed data set of habitat and fish data.
- By July 2014: A synthesis of fish-habitat relationship results from the first three years of CHaMP habitat and ISEMP fish data collection. This synthesis will incorporate a landscape-scale extrapolation process in which habitat quality and quantity estimates are also projected to both CHaMP and non-CHaMP watersheds where fish and habitat sampling did not occur. Provide a working version of all models including: unstructured correlations (BRT, etc.), structured correlations (habitat suitability indices, structural equations), and mechanistic models (ecohydraulics models). Provide these models in the form of interpretive tools that can be used by decision makers to derive answers for, in particular, the three KMQs listed on page 3.
- From 2014 – 2018: Update the working version of all models with new information if/as it becomes available.
- By 2018: Final product for inclusion in BiOp reporting summarizing/compiling each of ISEMP/CHaMP's fish-habitat investigative threads including unstructured correlations, structured correlations, and mechanistic models. Preliminary results from IMW's will also be included.

Approach:

Complete individual analyses (see details in green text boxes in the rest of this chapter). Develop the landscape-scale extrapolation process for projecting habitat quality/ quantity estimates to unsampled areas.

Task Leaders:

CHaMP and ISEMP projects.

References:

Calfoun, A. D. and T. E. Martin. 2007. Assessments of habitat preferences and quality depend on spatial scale and metrics of fitness. Journal of Applied Ecology 44:983-992.

mates at sites from 2011 and a set of about 20 CHaMP habitat metrics from 2011 and 2012, including CHaMP-PIBO protocol comparison study metrics.

All of these models were fit with fish and habitat data at the site level, and compared by root mean squared error. To avoid over-fitting, each data point was left out and then predicted from a model fit based on the rest of the data. The best models from this exercise were then fit with the entire data set, and model selection was done where appropriate to narrow down the list of habitat metrics. The predicted results from the top six correlative models for steelhead are shown as an example in Figure 20. The prevalence of BRT and random forest models suggests the benefits of being able to capture non-linear fish / habitat associations.

To explore the effect of incorporating data on non-target fish species into these types of analyses, different data, i.e., ISEMP fish abundance estimates from the Salmon subbasin collected from 2009 -2012, were used (Figure 21). Habitat metrics were assumed to be constant across those four years, and were drawn from CHaMP surveys as much as possible but supplemented by pre-CHaMP habitat surveys conducted in 2009 and 2010 where needed. A similar suite of models and analyses was conducted, with the addition of one covariate to the suite of habitat metrics: the density of non-target fish species at a site. Models were fit using four different target species: steelhead, Chinook, Chinook and steelhead combined, and all salmonids. The correlation between observed and predicted values increased substantially, suggesting that fish/habitat relationships will be impacted by the rest of the fish community at a site, and this should be accounted for (Figure 22).

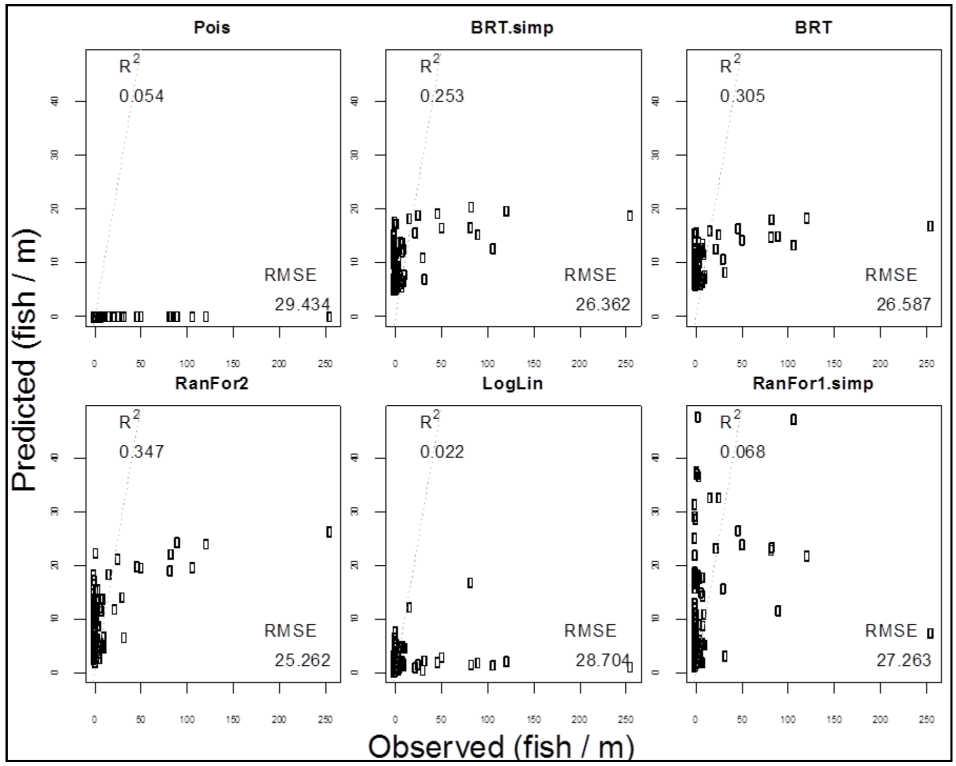


Figure 20. Observed fish / m values vs. predicted values produced from the 6 best correlative models using 2011 ISEMP site abundance data and 2011 and 2012 CHaMP metrics. Steelhead density was the dependent variable. Root mean squared error (RMSE) is shown in the lower right corner (lower is better), and the squared Pearson correlation coefficient (R^2) is shown in the upper left corner (higher is better). The mean fish density across all sites included was 8.75 fish / m.

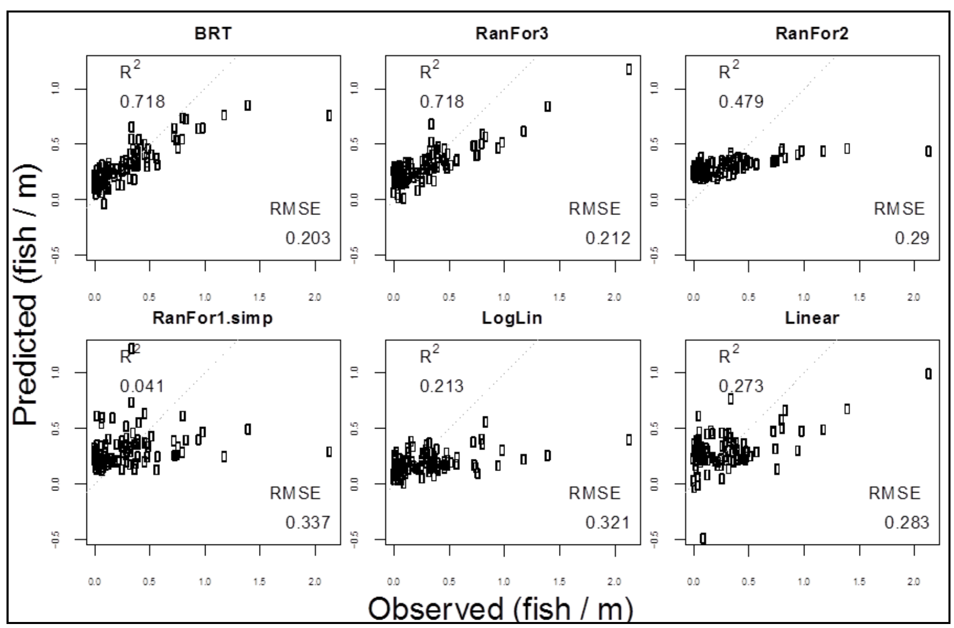


Figure 21. These plots show the observed fish / m values vs. the predicted values for the 6 best correlative models using ISEMP site abundance data from the Salmon subbasin from 2009-2012. Steelhead density was the dependent variable, but the density of all other species was included as a covariate. Root mean squared error (RMSE) is shown in the lower right corner (lower is better), and the squared Pearson correlation coefficient (R^2) is shown in the upper left corner (higher is better). The mean fish density across all sites included was 0.31 fish / m.

(Figure 20—Left)
Four of the six best correlative models for steelhead are either BRT (BRT.simp, BRT), or random forest (RanFor2 and RanFor1.simp) models, suggesting their value at being able to capture non-linear fish/habitat metric associations.

—The best model for steelhead was the BRT model. From it, the relative importance of each covariate can be compared, and the marginal relationships between each covariate and expected steelhead density can be seen on a graph.

(Figure 21—Left)
When non-target fish species information was incorporated through use of data from the Salmon subbasin, and one covariate (density of non-target fish species at a site) was added to the suite of habitat metrics, the correlation between o observed and predicted values increased substantially.

—This suggests that fish/habitat relationships will be impacted by the rest of the fish community at a site, and this should be accounted for.

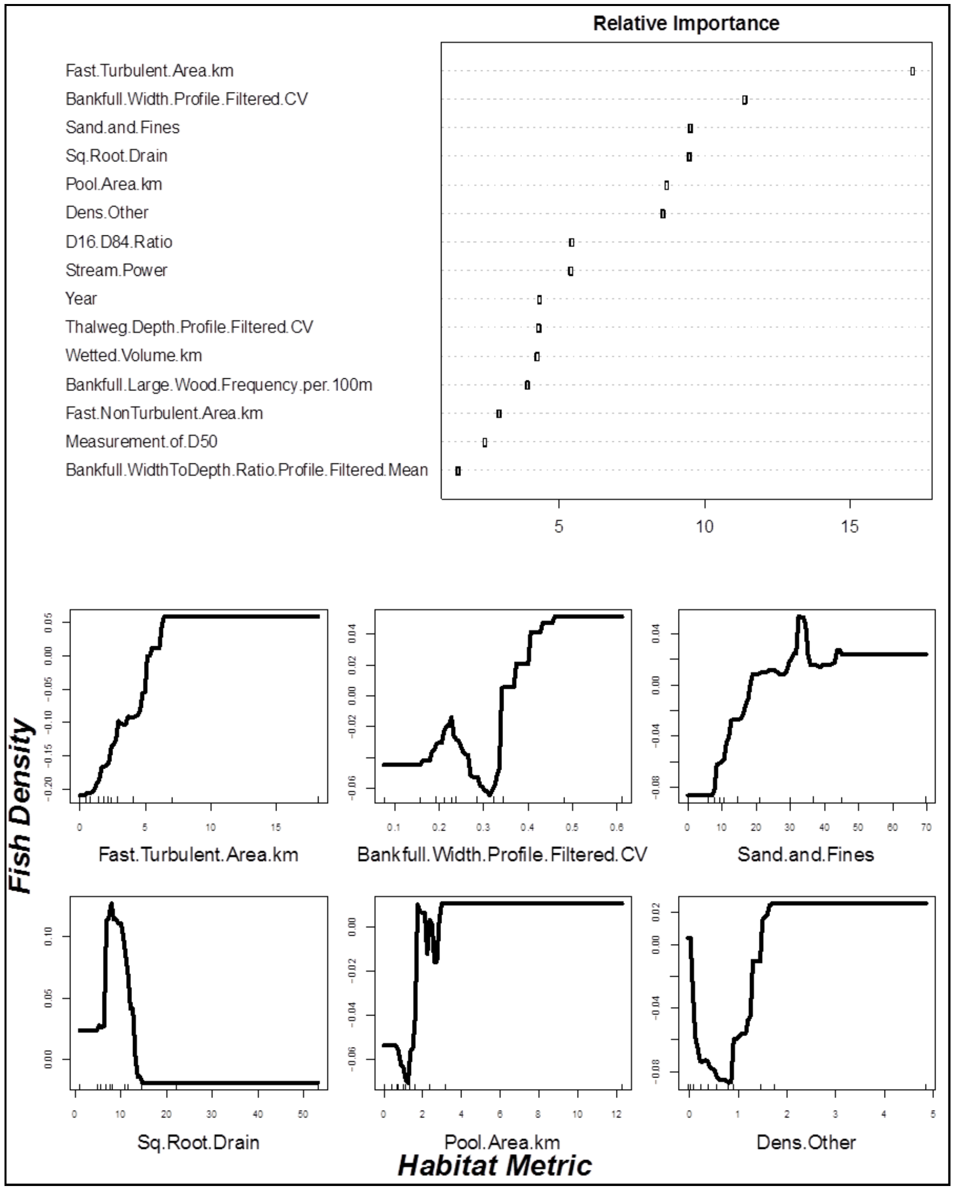


Figure 22. All of the covariates used in the BRT model fit for steelhead, ranked by relative importance, and the marginal relationships for the six most important covariates, including the density of non-steelhead fish.

Important takeaway message from Figure 22 (above):

When all of the covariates used in the BRT model for steelhead are ranked by relative importance (top), preliminary results based on the marginal relationships for the six most important covariates, including the density of non-steelhead fish (bottom), support some theoretical expectations about steelhead density:

- Steelhead are predicted to be found where there is more fast, turbulent water.
- As the coefficient of variation for bankfull width, a measure of stream complexity, increases, higher densities of steelhead are predicted.
- Higher steelhead densities are predicted in smaller streams, closer to the headwaters.
- A drop in steelhead density is predicted, presumably due to competition, as non-steelhead fish density increases from 0 to about 1 per meter.
- As non-steelhead fish density increases further, the model predicts higher steelhead densities, perhaps because those sites have a higher carrying capacity for all fish.
- This non-linear relationship between target and non-target fish densities is clearly is an important factor that should be considered and explored further.

Structured Correlations Between Fish and Habitat Metrics

Habitat suitability indices (HSIs)

Habitat suitability indices (HSIs) are based on observed correlations between distribution or abundance of a target species and physical habitat features. For fish, the habitat features typically include attributes of hydrology including depth, velocity, cover, and substrate; therefore, hydraulic modeling is required. Life-stage specific habitat preference curves, which may vary by river type (e.g., determined by River Styles analysis), allow for the estimation of weighted useable areas (WUAs) of habitat at different flows where habitat data are available.

The feasibility of using CHaMP data to drive ecohydraulic models (e.g., PHABSIM, INSTREAM, CASiMiR) for quantifying multidimensional salmonid habitat and predicting distributions of spawning and rearing fish will be assessed alongside existing HSIs and expert-based fuzzy inference systems. Each method's potential to provide realistic assessments of habitat quality for juvenile salmonids will be examined.

Habitat Suitability Indices

Deliverable Schedule:

- By November 2013: Review literature values and assess need/develop basin-specific habitat suitability rearing curves for all CHaMP watersheds.
- Use River 2D to run hydraulic models (PHABSIM, fuzzy models) driven by CHaMP habitat data at 22 sites to evaluate spawning and incorporate into Life-cycle model, and test River 2D and Delf3D model using 22 and 30 sites, repectively, for rearing and incorporate into life-cycle model.
- By July 2014: Test life-stage specific HSI models in one basin to estimate available spawning and rearing habitat.
- From 2014-2018: Automate habitat suitability mapping capabilities for Chinook and steelhead spawning and rearing within the RBT or compatible GIS application, and test across all CHaMP sites.

Approach:

- Develop an initial HSI model.
- Build habitat mapping tools and test.

Task Leaders:

- Claire McGrath, Joe Wheaton, Nick Bouwes

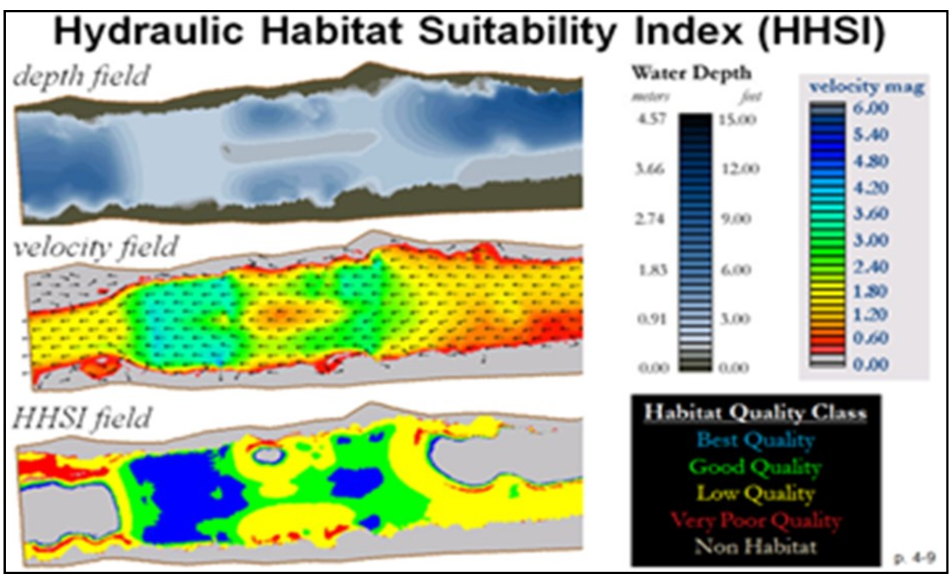


Figure 23. An example: using spatial habitat data to map habitat quality using the Hydraulic Habitat Suitability Index.

Structural equation models (SEM)

Structural equation modeling is a statistical approach to hypothesis testing that accounts for direct and indirect relationships among variables (Grace 2006). It evolved from path analysis with several notable improvements including analysis of covariance among variables (versus analysis of correlations), incorporation of hierarchical modeling approaches, and the use of latent variables.

SEM is an appropriate tool for fish-habitat modeling when the interrelationships among factors influencing fish abundance, growth, or survival are of interest. For example, in the upper Grande Ronde River juvenile Chinook salmon rearing densities were directly affected by large woody debris and abundance of pools, but also indirectly through the influence of large woody debris and stream flow on pool formation (White et al., in prep). In addition to testing hypotheses about interrelationships between fish and their habitat, SEM can also be used to predict fish habitat conditions in unsampled areas. These predictions based on observed relationships can then be incorporated into simulation analyses such as life cycle modeling.

In evaluating whether or how SEM can be used for ISEMP and CHaMP analyses, the following advantages and caveats should be considered :

Advantages:

- Involves developing and testing *a priori* hypotheses, rather than data mining;
- Good at teasing apart direct vs. indirect relationships;
- Models are presented graphically for effective communication; and
- Through the use of latent variable modeling, SEM can help evaluate measurement error.

References:

Grace, J.B. 2006. *Structural Equation Modeling and Natural Systems.* Cambridge University Press.

White, S.M., C. Justice, and D. McCullough, (In prep). The landscape context of fish-habitat relationships: implications for restoring wood recruitment processes in U.S. Pacific Northwest rivers. Intended for Ecological Restoration.

Caveats:

- SEM is based on multiple linear regression; therefore, it is subject to many of the same assumptions—mainly linearity and multivariate normality, though advanced approaches can account for these;
- Complex models can become data intensive, with roughly 10 observations required for every variable in the model; and
- As is true with other regression analyses, hypotheses supported using SEM do not guarantee the direction of causal association (i.e., the "causation vs. correlation" problem).

Mechanistic Models

While empirical models are based on direct observation and data measurements, mechanistic modeling assumes that a complex system can be understood by examining the workings of its individual parts and the manner in which they are related.

The Net Rate of Energy Intake (NREI) mechanistic modeling approach (Hayes et al. 2007) incorporates components of foraging theory, physiology, distribution of individuals, and spatially explicit, three-dimensional representations of the streambed. Exploration of the NREI model since 2011 suggests that it is too computationally intensive for use by CHaMP at all sites; however, it holds promise to help identify mechanisms limiting fish distributions, which can help managers target restoration efforts. To that end, ISEMP is developing a more appropriate modification of NREI model that could be applied to all CHaMP sites. Major goals of this approach are to provide a basis for monitoring program refinement and a knowledge base for restoration planning. Model results are also expected to be used directly as input into life-cycle models that will likely be used in regional population assessments.

Please refer to the 2011 CHaMP report for more background on the NREI model.

Ecohydraulic models

The NREI "ecohydraulic" model incorporates how water flows through the reach (hydraulic model), how food is delivered throughout the reach (drift transport model), how fish capture drifting prey (foraging model) and expend energy in the process (water velocity).

The CHaMP protocol is customized to provide data inputs for different components of ISEMP NREI modeling. CHaMP field derived inputs (DEM, stream substrate roughness estimates, and a discharge measurement) are used in the River2D and Streamtubes programs (Steffler et al. 2003) to facilitate hydraulic flow modeling. Macroinvertebrate drift data collected using the CHaMP protocol are then used in combination with hydraulic model outputs to feed the drift transport model, which predicts spatial variation in drift density available to salmonids throughout the stream sampling reach. Lastly, the foraging model incorporates information derived from the hydraulic flow and drift transport models to calculate the gross rate of energy intake and the energetic costs of swimming to predict the NREI for drift-feeding salmonids, i.e., the difference in the energy gained from foraging and energy lost through swimming. The NREI then can be converted into growth rates of salmonids and the model can map areas of a reach where fish have positive NREI. The number of foraging areas that have a positive NREI can serve as an estimate of carrying capacity of the reach.

In 2012, ISEMP began using CHaMP data in combination with fish data to further develop and test the River2D and NREI models in the John Day and Asotin. In 2013, flow validation and incorporation of a 3D hydraulic model, and additional macroinvertebrate sampling are planned along with testing to evaluate the utility of the NREI approach, refine the model as appropriate, and automate aspects of the hydraulic model in the RBT.

Structural Equation Models

Deliverable Schedule:

- By November 30, 2013: Derive shear zones from 2011-2012 CHaMP topographic data from 60 sites and compile associated macroinvertebrate, temperature information and other CHaMP data.
- By January 31, 2014: Develop an annotated working list of each SEM under development describing model structure and fit initial SEMs with CHaMP and ISEMP data to describe fish abundance.
- By July 2014: Develop final SEM structure and fit three years of CHaMP and ISEMP data. Incorporate results into fish-habitat modeling and watershed-production models.

Task Leaders:

- Seth White, Andy Hill, Kevin See, Nick Bouwes

References:

Hayes, J. W., N. F. Hughes, and L. H. Kelly. 2007. Process-based modeling of invertebrate drift transport, net energy intake and reach carrying capacity for drift-feeding salmonids. Ecological Modeling 207:171-188.

Steffler, P., A. Ghanem and J. Blackburn. 2003: River2D Version 0.90 – computer program. University of Alberta, Canada. http://www.River2D.ualberta.ca/index.htm

Ecohydraulic Model

Deliverable Schedule:

- By November 2013: Test NREI using 20-30 reaches in the John Day and Asotin that have CHaMP and ISEMP data to determine utility of modeling approach.
- By April 30, 2014: Change drift model if appropriate based on additional drift evaluation planned in 2013.
- By July 2014: Test NREI model ability to estimate carrying capacity again, using three years of CHaMP data. Test watershed to estimate carrying capacity via GRTS.
- From 2014-2018: Incorporate NREI or surrogate model into fish-habitat modeling, watershed production models.

Task Leaders:

- Delf3D hydraulic model: Matt Nahorniak, Joe Wheaton;
- NREI: Eric Wall, Nick Bouwes, Andy Hill

An example: estimating how stream channel changes affect NREI and carrying capacity in the Asotin IMW

Changes in the stream channel can translate in to changes in NREI and carrying capacity much like the way DEMs can be used to evaluate changes in stream topography (see Figure 29 on page 42). CHaMP surveys were conducted pre– and post-treatment at a site within the Asotin IMW in 2012 and again in early 2013. DEMs of Difference were created to evaluate how the treatment influenced water depth (Figure 24) and velocity (Figure 25), and how this, in turn, influenced NREI. The pre-treatment NREI surface was subtracted from the post-treatment surface to create an NREI difference surface that intuitively explains how the restoration could potentially create higher quality fish habitat (Figure 26). Only one modest flow event had occur following restoration, thus the changes observed are very subtle at this point. Even so, the change in mean NREI value relative to the maintenance threshold value (energy required for a fish to grow) increased by 33%.

ISEMP used CHaMP survey data in the John Day (14 sites) and Asotin (eight sites) to estimate NREI and carrying capacity. Carrying capacity calculated from the model was then compared to observed fish numbers. The model performed as expected when predicted vs. observed density of fish were compared across the 22 CHaMP sites (r^2=0.56, p<0.0001). Although ISEMP has begun to test this model to predict growth, abundance and production of a reach, it has not been calibrated and several large simplifying assumptions were made to complete these analyses for this report. Still the model performed remarkably well, so analysts are optimistic that further development will produce a product that synthesizes several metrics collected from CHaMP and describes what they mean to salmonids. The application of this approach can be many fold from evaluating limiting factors, assessing the benefits of stream restoration, and production of accurate information to be used in other analytical frameworks.

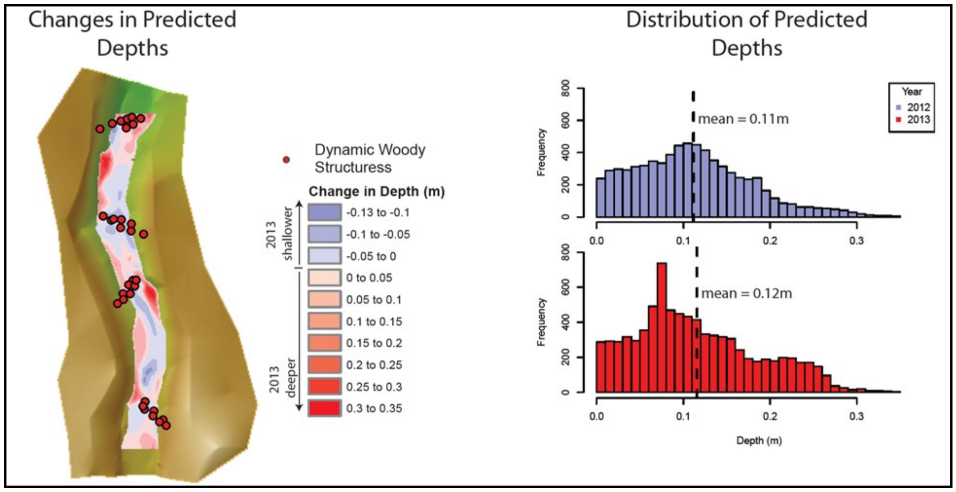


Figure 24. The difference in water depths pre-treatment (Before) and post-treatment (creation of pools via wood additions) in a reach of the South Fork of the Asotin. If depth (Before) is subtracted from depth (After) for each pixel that has an XY coordinate, another surface is created that spatially describes the change in depth of the reach due to restoration.

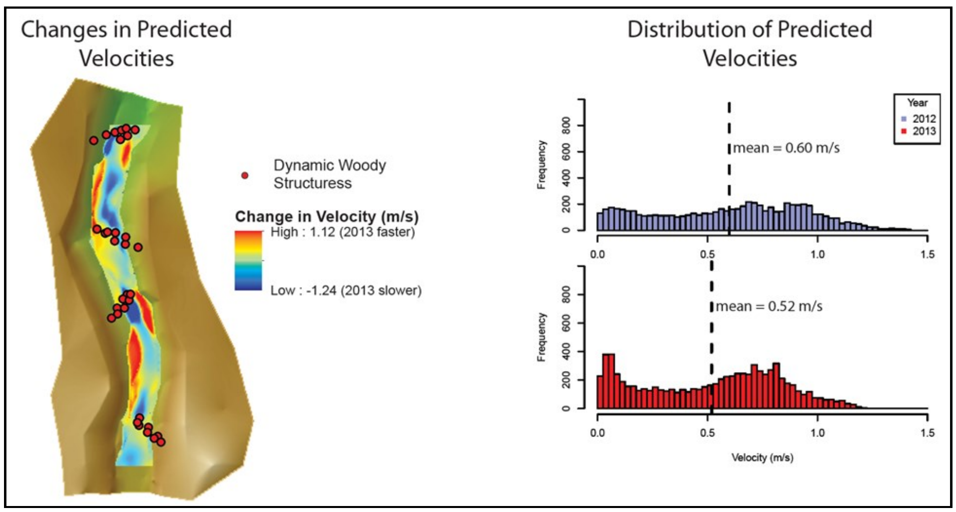


Figure 25. The difference in water velocities pre-treatment (Before) and post-treatment (creation of pools via wood additions) in a reach of the South Fork of the Asotin. Velocity (Before) is subtracted from velocity (After) to create another surface.

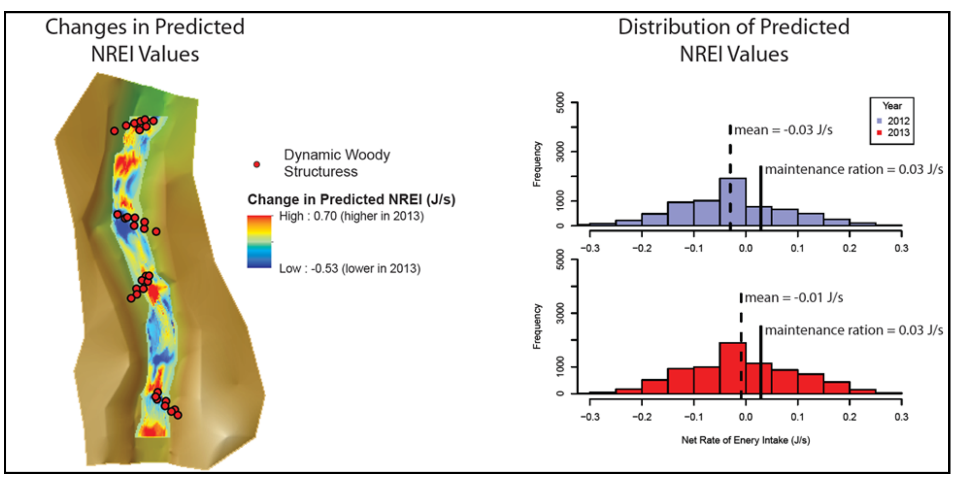


Figure 26. Difference in the energy available (NREI) pre-treatment (Before) and hypothetical post-treatment (creation of pools via wood additions) in a reach of the South Fork of the Asotin. NREI (Before) is subtracted from NREI (After), another surface is created that spatially describes the change in energy available and carrying capacity of the reach due to restoration, pixel by pixel.

Watershed Experiments

Experimental manipulation of habitat provides the approach to developing fish-habitat relationships that will provide the most certainty in the underlying mechanisms between the physics of the stream environment with the biology of the responding salmonids. On the other hand, experimental approaches are the most difficult to accomplish and have the least general applicability of the suite of approaches being used. ISEMP is using CHaMP data in several experimental settings to further refine our understanding of fish-habitat relationships.

To develop fish-habitat relationships, contrasts in habitat must be measured in time and space in order to distinguish restoration effects from natural variability. An effective way to achieve contrasts is to directly manipulate the factors expected to cause a fish response. Stream restoration is the direct manipulation of habitat that will be leveraged to help us understand fish habitat relationships. If done using an experimental design, these contrasts and responses can be maximized and quantified to best detect changes to habitat on salmonids.

Whole watershed experiments will likely have a far greater chance of detecting a population level response because they are more likely to trigger a population response that can be detected above the considerable natural variability of natural systems (Roni et al. 2010). Intensively monitored Watershed (IMW) studies are designed using the principles of ecosystem-scale experiments to detect a population or environmental response to management actions. Accordingly, ISEMP is using the IMW approach in the Entiat River (Figure 27), Lemhi River, and Bridge Creek watersheds (and is collaborating in the NOAA-funded Asotin IMW) to test the effectiveness of the restoration at improving fish habitat and increasing productivity of salmon and steelhead. In these IMWs, watershed-scale restoration projects are being designed and implemented using the principles of ecosystem-scale experiments, i.e., project types, locations and the overall monitoring framework are designed to detect a population or environmental response to management actions. Because the CHaMP protocol is powerful at detecting site-level changes in physical habitat characteristics, it naturally lends itself to incorporation within each IMW study.

References:

Roni, P., G. Pess, T. Beechie and S. Morley. 2010. Estimating changes in coho salmon and steelhead abundance from watershed restoration: how much restoration is needed to measurably increase smolt production? *North American Journal of Fisheries Management:* 30, 1469-1484.

Watershed Experiments (IMWs)

Deliverable Strategy:

- By April 2014: Collate existing results, focused on findings relevant to fish-habitat relationships, into a draft of the July 2014 synthesis report using the final QA/QC'ed data set of habitat and fish data through 2013.
- From 2014 – 2018: Adaptively update findings from the IMWs on the watershed-specific time tables and include that new information into the working version of each watershed production model as it becomes available.
- By 2018: Final product for inclusion in BiOp reporting summarizing/compiling results from watershed production models in each ISEMP watershed. Preliminary results from IMW's will also be included.

Task Leaders:

- ISEMP contractors in the Entiat, Lemhi and Bridge Creek watersheds.

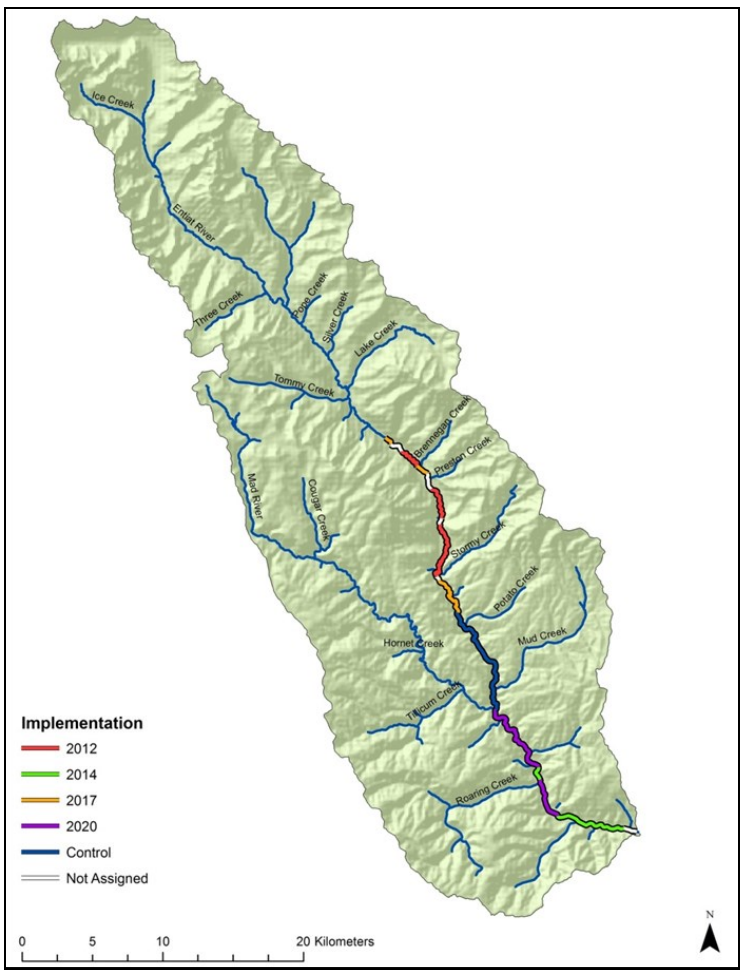


Figure 27. ISEMP is using the Intensively Monitored Watershed (IMW) approach in the Entiat River watershed and other watersheds to test the effectiveness of restoration at improving fish habitat and increasing salmonid productivity.

Supporting Data and Analyses

Introduction

This portion of the Analytical Framework describes additional research and analyses that are being performed by CHaMP and ISEMP projects to support the development and application of the fish-habitat modeling approaches described previously, or as part of ongoing efforts to improve metric reliability and identify efficiencies in the way metric data are collected.

Automation of Habitat Metrics

Metric derivation using RBT

The River Bathymetry Toolkit (RBT) provides a spatially-explicit view of stream habitat that allows one to move from viewing habitat as discrete units (pools, riffles) to a seeing it as a spatially continuous set of habitat features to which fish respond, such as depth, substrate, and velocity. This tool is a critical component of ongoing fish – habitat analyses, in that it is the automated source of all topographic metrics for CHaMP.

In 2013, further development of the CHaMP RBT will involve development and testing of RBT-derived metrics that can serve as surrogate measures of freshwater habitat and hydraulic process. A goal is to develop CHaMP RBT capability to take topography and hydrology and create evidence-based rules that result in the production of discrete calculations of habitat, e.g., fuzzy habitat units (Figure 28). The promise of this approach is that it may eliminate the need for human classification of habitat units, which has proved to be subjective and unreliable, thereby reducing field efforts and improving reliability.

Eventual products may include simulation, quantification, and visualization of stage-dependent fish habitat. For information about changes to the RBT in 2012 and additional enhancements planned for 2013, see Chapter V.

Metrics from CHaMP bathymetry data

Continuing the development and refinement of habitat metrics at a variety of spatial scales will directly support the study of fish – habitat relationships. Currently, CHaMP metrics include those measured during field surveys, from remotely sensed data (e.g., land surface temperature, leaf area index), and calculated using stream bathymetry data, such as what is collected by CHaMP topographic surveys. Examples of such metrics include those derived from geomorphic change detection (GCD) analysis, and other novel metrics that are quantified using stream bathymetry.

By coupling bathymetric data and spatial analysis tools (GIS, RBT) large amounts of spatial data may be quantified at a variety of scales. In 2013, CHaMP bathymetric data will be used identify and summarize key stream habitat characteristics and evaluate fish-habitat relationships at a variety of scales.

Automatically-derived Habitat Metrics

Deliverable Strategy:

- By June 2013: Demonstrate a tool that automatically classifies habitat units.
- By November 2013: Quantify and summarize fish habitat characteristics at a variety of spatial scales and evaluate fish-habitat relationships using two years of CHaMP bathymetric data.
- By November 2013: Demonstrate that auto-units explain fish densities as-well-as or better-than field classified units using 2 years of CHaMP and ISEMP fish data. Demonstrate that auto-metrics explain fish densities as-well-as or better-than field-derived data using two years of CHaMP and ISEMP fish data. Refine methods if necessary; discontinue if not fruitful.
- By April 2014: Revise CHaMP sampling protocol if auto-units or auto-metrics are more cost effective than field-derived units/metrics.

Task Leads:

- Philip Bailey and Joe Wheaton

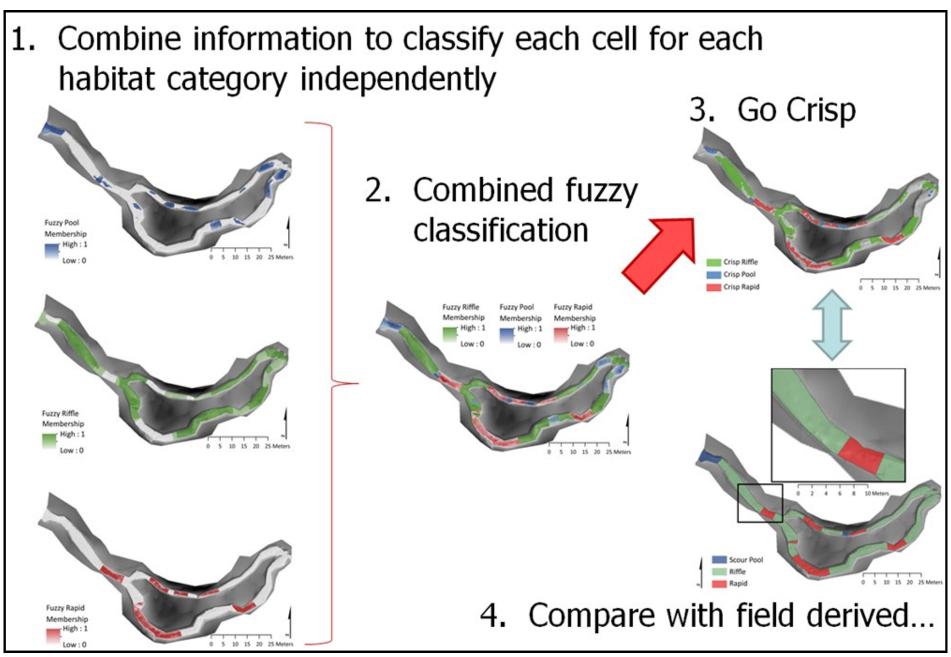


Figure 28. Using the RBT and many lines of evidence to derive fuzzy habitat units

Stream bathymetry from CHaMP and green LiDAR surveys

The approaches proposed for evaluating fish-habitat relationships rely on stream bathymetry data. Currently, these data are provided by CHaMP topographic surveys at the site scale for sites within the GRTS sample domain. Stream bathymetry data may also be obtained from green LiDAR, which provides a direct measurement of habitat at broader spatial scales that better match the spatial distribution of salmon from egg through juvenile rearing life stages. Because of its ability to cover large areas, green LiDAR data may also be used to help generate bathymetric data for larger rivers that are not within the GRTS sample domain but are known to provide rearing habitat for juvenile salmonids (e.g., the mainstem of the South Fork Salmon River).

Attempt to obtain green LiDAR data that have been collected from the vendor have been unsuccessful to date; however, this is still being pursued. When the data are available for post-processing and analysis, overlap in CHaMP and green LiDAR data for one or more populations will be used to evaluate how assessments of habitat status and fish-habitat relationships are influenced by the two types of bathymetric data.

CHaMP and Green LiDAR Data for Stream Bathymetry

Deliverable Schedule (contingent on availability of LiDAR data and staff resources at the time of receipt):

- By November 2013: Quantify and summarize fish habitat characteristics using green LiDAR bathymetry data. Develop QA/QC measures and quantify the degree of automatic vs. manual iteration necessary for automatic model simulations.
- By July 2014: Demonstrate relationships between LiDAR-derived habitat metrics and ISEMP fish data. Demonstrate the utility of using LiDAR data to landscape-scale habitat characterizations. Refine methods if necessary; discontinue if not fruitful.

Task Leads:

- Jody White, Phillip Bailey, Joe Wheaton

Geomorphic Change Detection (GCD)

In 2012, CHaMP developed GCD tools to capture river channel dynamism and changes in sediment storage that occurred between the 2011 and 2012 field surveys (See Figure 29 on the following page). More importantly, physical changes in stream topography that resulted in specific changes to habitat for salmonids were quantified, using repeat topographic surveys at approximately 120 annual sites. To fully automate the analysis process, the GCD tool was incorporated into the cloud-based CHaMP River Bathymetry Toolkit (RBT, see Chapter V). This allowed the automatic derivation of error surfaces for every survey at every site, as well as quantification of geomorphic changes in sediment storage at every site with repeat surveys.

Initial QA/QC of the first-cut of automated processing results indicat--ed that over 90% of sites produced reliable results. Roughly 5% of the annual sites revealed problems with surveys that are easily rectifiable with post-hoc data repairs and another 5% required further investigation. As powerful as the automated processing was, data interpretation still required a high degree of manual analysis and figure production. These routine tasks will be automated, streamlined and rolled in as standard reporting functions in 2013.

Given that such GCD analyses have historically been quite laborious, requiring at least two to five days per site, the automation of such analyses is a major accomplishment. These gains in efficiency would not have been possible were it not for the consistent quality of the topographic data produced by CHaMP surveys, the organization and management of all data on champmonitoring.org, and the development of automatable algorithms to centralize the analyses.

Initial analyses revealed ways that the GCD analysis itself could become part of the topographic data QA/QC process, and that the potential may exist to increase the number of sites with reliable results from 95% (based on 2012 data) to 99%. In 2013, CHaMP will experiment with sharing the error surface models with crews at the time of DEM construction to help provide positive feedback on how their survey practices translate into topographic data quality. In addition, CHaMP will improve the GCD to make it simpler to synthesize results at individual sites and make inter-comparisons across multiple sites.

Geomorphic Change Detection

Deliverable Schedule:

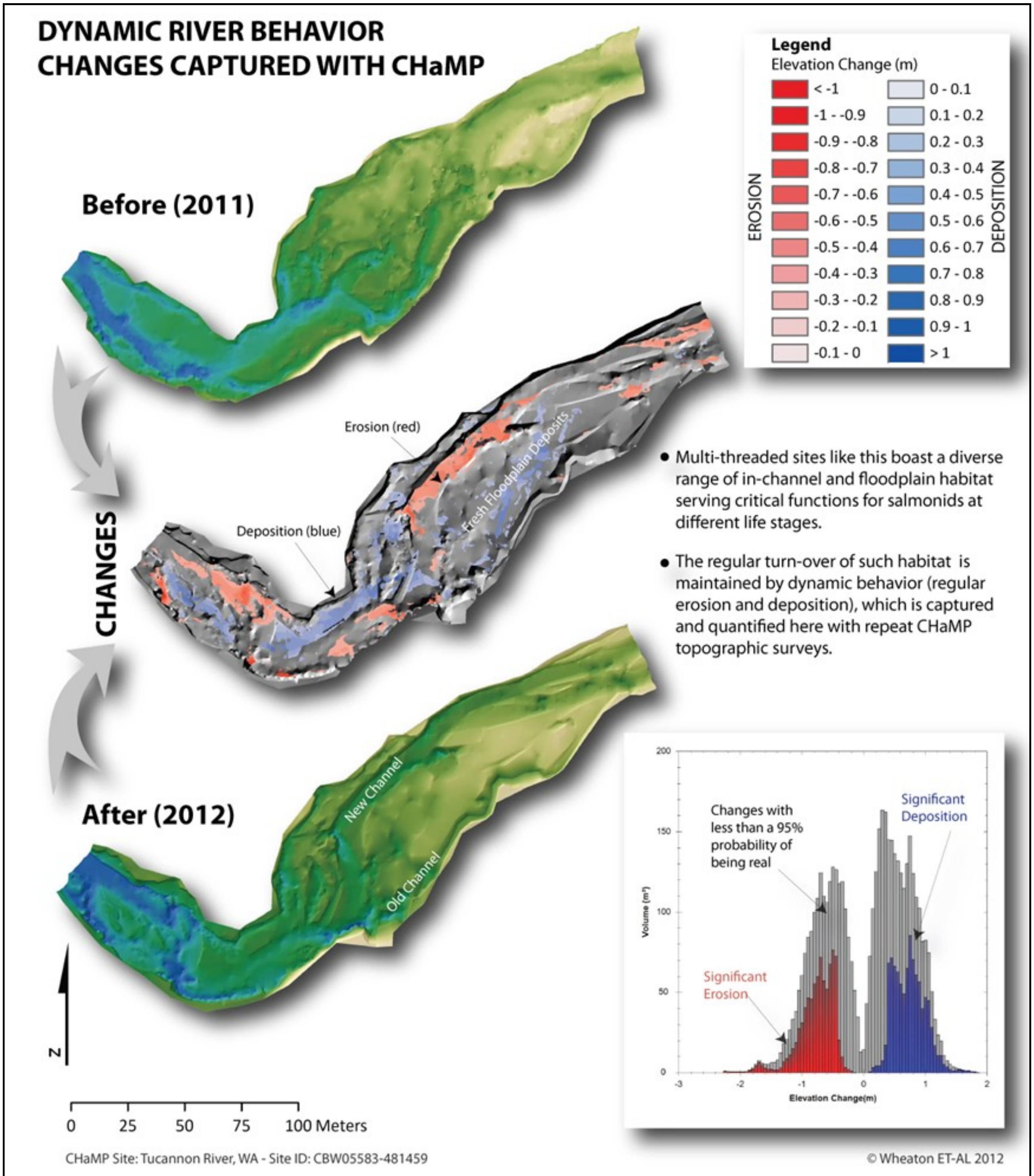
- By November 2013: Improve automated GCD analysis to make site level summaries quicker and largely possible from a web browser.
- Re-build GCD to facilitate within-and between-site queries, comparisons and summary analyses and mapping.
- Refine 'site-specific' error models in which the underlying fuzzy inference system model is calibrated to site conditions based on RBT and CHaMP habitat metrics.
- Provide a tool to share uncertainty analysis and GCD results with crews to improve their appreciation of uses for topography and the quality of their surveys, and leverage crew judgment in confirming automated results.
- Identify coherent watershed-scale and basin-wide trends in behavior inferred from GCD within a River Styles context.
- Provide testable hypotheses about what future patterns of behavior should look like, including a hypothesis about habitat heterogeneity and quality being linked to higher rates of dynamism.
- By February 2013: Demonstrate GCD habitat metrics are useful at explaining fish data at releant spatial scales. Feed GCD habitat metrics into fish-habitat relationship development and watershed production modeling.

Approach:

- Coding to alter existing and test new tools. Use 2011-2012 data to test error models, but include 2013 data in final error models. Use results to identify coherent patterns and develop hypotheses for testing and proposal about how to test them.

Task Leads:

- Joe Wheaton and Philip Bailey



Attribute	Thresholded DoD Estimate:		
AREAL:			
Total Area of Erosion (m²)	1,304		
Total Area of Deposition (m²)	1,452		
VOLUMETRIC:		± Error Volume	% Error
Total Volume of Erosion (m³)	840 ±	78	9%
Total Volume of Deposition (m³)	969 ±	87	9%
Total Volume of Difference (m³)	1,810 ±	165	9%
Total Net Volume Difference (m³)	**129 ±**	**117**	91%

Figure 29. Geomorphic change detection analysis results from CHaMP 2012-2011 topographic surveys on the Tucannon River, WA (Site ID: CBW05583-481459).

Hydraulic Modeling

At large spatial scales, one dimensional (1D) hydrologic models may provide sufficient information for interpolating data between observation points. At finer spatial scales, such as those appropriate for application in the HSI and NREI models discussed previously, more complex hydraulic models are needed. Although HSI models were developed using one dimensional hydraulic models, these often produce unsatisfactory results and two dimensional approaches are more promising; the NREI model also requires a two dimensional hydraulic model.

A time consuming component of the NREI work to date has been use of the River2D hydraulic model. River2D was used originally simply because it is freely available. Many other hydraulic models exist including commercial software, freeware, and open-source codes. The process of preparing and running these models is manual and time-consuming, largely because of issues with construction of the computational mesh. To address this, ISEMP is working to automate the hydraulic modeling process by constructing the computational mesh with rectilinear, raster-based meshes and automatically extracting model boundary conditions (flow and topography) and parameters such as roughness from CHaMP or aerial green LiDAR surveys. This will enable automatic simulation of steady-state hydraulics for flow conditions at the time of each CHaMP survey, and implementation of associated ecohydraulic and habitat models.

Hydraulic Modeling

Deliverable Schedule:

- By July 2013: QA/QC measures and identification of suitable CHaMP sites.
- By November 2013: Validate River2D and Delf3D hydraulic models with additional flow information and test 3D model on 25-30 sites. Provide synthesis of results and continue work on other sites.
- By July 2014: Automate hydraulic model in RBT and test.

Approach:

- Automate construction of the computational mesh to extract model boundary conditions (flow and topography) and parameters such as roughness from CHaMP surveys, enable automatic simulation of steady-state hydraulics at the time of each CHaMP survey, and implementation of associated ecohydraulic, bioenergetics, and habitat models.

Task Leads:

- Matt Nahorniak, Joe Wheaton, Philip Bailey (RBT)

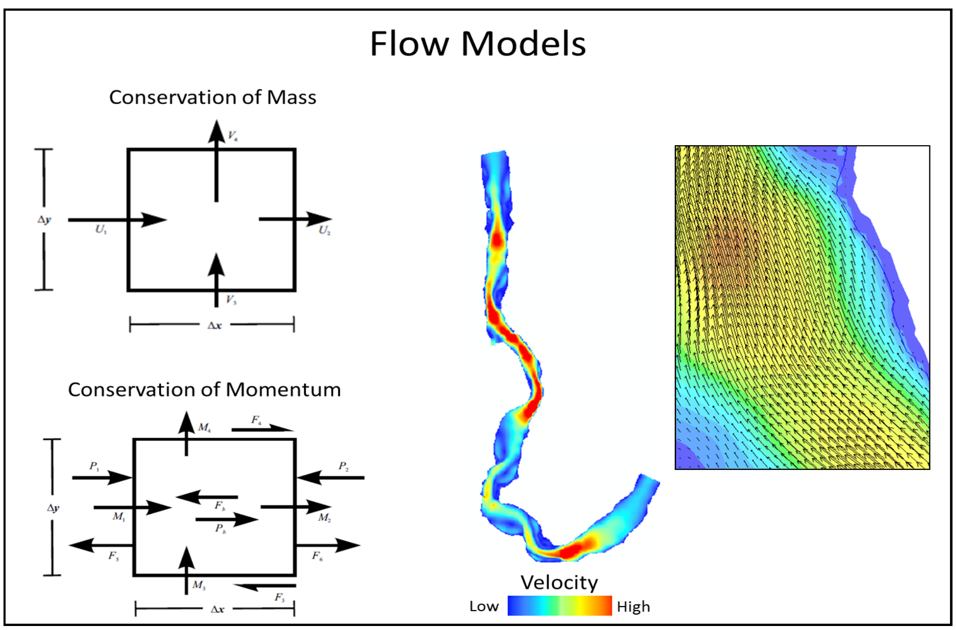


Figure 30. Example of hydraulic model computational mesh and graphical output.

Landscape Classification

Introduction

CHaMP has produced habitat quality/quantity assessments for the network of sites at which fish and habitat data are collected, but is also expected to be developing watershed and subbasin assessment products to support management decision-making at all salmonid bearing stream reaches in the interior Columbia River basin. Thus, in order to be useful for the region, this management decisions support framework must take into account the impressive range of biological and physical conditions in the Columbia River basin. As such, the variation in expectation and response of fish populations to habitat actions must be built in, but how will this diversity itself be managed? That is, can the relationships between fish population response and habitat condition manipulation be expressed as functions of landscape-scale features?

A landscape classification based on natural features known to be associated (positively or negatively) with salmon production could define areas of similar potential and thus management decision making. Such a geographic framework could indicate areas where particular restoration actions could be expected to have similar results, as well as areas dissimilar enough to indicate less certainty about the chances of success. This framework could also be useful for evaluating if habitat actions are sufficiently well distributed across the natural feature landscape classes to support the ongoing development and testing of spatially explicit decision support systems. The appeal of this idea is reinforced by the practical use such regionalizations have for natural resource managers who must influence biological phenomena that vary with landscape characteristics such as physiography, climate, geology, soil type, vegetation, and land use. Regionalizations also help managers develop and implement management strategies that address how the causes of degradation may interact with the landscape, and then communicate those relationships to the public.

There are multiple landscape classification systems based on various combinations of mapped natural features and human uses of the land that divide large geographic areas into hierarchies of ecological regions (ecoregions) (e.g., Omernik 1987; Bailey 1976). Each of these classifications was developed to support different intended applications (e.g., water quality assessment, conservation planning) often for different agencies or organizations (Loveland and Merchant 2004). Most of the widely used regionalization systems were developed with qualitative methods to combine mapped landscape characteristics to delineate relatively homogenous regions (Omernik 2005; Loveland and Merchant 2005). In the last couple of decades, increased computing power and data storage, improved GIS software, matched with more detailed, consistently developed GIS coverages of ecological landscape data have led to increased interest in using multivariate techniques to develop data-driven landscape classifications, assumed to be more objective (Hargrove and Hoffman 2005).

While the concept of regionalization is an intuitively satisfying concept and landscape classifications account for more biotic variation than would be expected by chance alone, the amount of variation related to landscape features is not large (Hawkins et al. 2000). Thus, large-scale regionalizations, if used alone to specify expected biotic conditions, will likely have limited use in management decision support systems. However, because some spatial variability is accounted for by landscape features, classification systems can play an important role by providing a spatial framework for sampling of site locations to ensure that landscape features are adequately captured.

There is no ideal scale at which to describe a landscape as diverse as the Columbia River basin, so it is appropriate to believe that a tiered classification based on both reach-level and larger-scale landscape features is needed to accurately capture patterns and the determinants of these patterns over such a large extent (Hawkins et al. 2000). CHaMP incorporates multi-scale data in its development of watershed status and trends assessments and decision support products. CHaMP uses landscape classification in three main ways:

- to allocate sampling sites within subbasins to ensure that these sites reflect the true distribution of such sites within the watershed,
- to generate habitat metrics more efficiently with remotely-sensed data than can be accomplished on-the-ground, and
- to facilitate the extrapolation of data from CHaMP watersheds to other watersheds without CHaMP sampling.

CHaMP and ISEMP use using existing classifications systems as well as adapting a new classification system (i.e., the River Styles Framework developed in Australia by Brierly and Fryirs (2005)).

Site allocation and interpretation using existing classification systems

Within CHaMP and many other large -scale site-based monitoring programs (e.g., PIBO), site selection is completed remotely using geomorphic attributes (stream slope, valley confinement, elevation) and sites are then field-checked to ensure that they meet the criteria previously mapped out in a desktop environment. While site selection via this method is statistically robust and likely captures a good deal of the channel types found within a watershed, several underlying problems may complicate the success of such a survey design:

- Difficulty capturing the full range of basin variability.

Channel forms represent a continuum of several variables, including gradient, substrate size, flow, and channel dimensions. It is nearly impossible to account for all of these when selecting sites in a remotely-based manner that attempts to group like sites together for purposes of statistical analyses and measurement interpretations. The selection of sampling locations would be aided by prior field-based knowledge of site conditions.

- Difficulty capturing within-channel variability

Streams are unique systems that transport sediment, water, and nutrients. At any particular location along the channel, eco-geomorphic conditions are driven by a combination of upstream conditions along with site characteristics. While CHaMP is designed to monitor these site conditions, upstream eco-geomorphic variables, which play a ma-

References:

Bailey, R.G. 1976. Ecoregions of the United States (1:7,500,000-scale map). Intermountain Region, USDA Forest Service, Ogden, Utah.

Hargrove, W.W. and F.M. Hoffman. 2005. Potential of multivariate quantitative methods for delineation and visualization of ecoregions. Environmental Management 34(Suppl.1): S39-S60.

Hawkins, C.P., Norris, R.H., Gerritsen, J., Hughes, R.M., Jackson, S.K., Johnson, R.K., and R.J. Stevenson. 2000. Evaluation of the use of landscape classifications for the prediction of freshwater biota: synthesis and recommendations. J. NABS, 2000, 19(3):541-556

Loveland, T.R. and J.M. Merchant. 2005. Ecoregions and ecoregionalization: geographic and ecological perspectives. Environmental Management. 34 (Suppl 1): S1-S13.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers. 77:118-125.

Omernik, J.M. 2005. Perspectives on the nature and definition of ecological regions. Environmental Management. 34(Suppl 1):S27-S38.

jor role in driving site-based characteristics, are largely unknown.

- Untangling form and process - snapshots in time

Site selection for large-scale monitoring programs such as CHaMP may be unable to adequately capture a) the evolution of sites that will be visited over time, which would give insight into the upstream processes that deliver water, sediment, wood, and nutrients to the channel are acting to shape that particular channel reach, and/or b) the current disturbance regime (e.g. magnitude and frequency formative processes) that are driving channel morphology at a site. Given the difficulty in characterizing the forms and processes (both current and through time) at potential sampling sites, interpretation of both geomorphic and biotic data may be difficult.

Rapid geomorphic assessment (RGA) methodology

ISEMP has been working from 2010-2012, across two summer field seasons and using associated desktop analyses, to develop a methodology for conducting a rapid geomorphic assessment (RGA) that may help guide both the selection of sites and interpretation of data collected there by placing it in the broader context of a) the continuum of geomorphic characteristics found along the entire channel where the sampling site is found, b) the similarity or differences between that channel and others in the watershed, and c) regional characteristics of watersheds in the Columbia River Basin. The ISEMP RGA methodology is largely based on the River Styles Framework (Brierley and Fryirs 2005), and also includes elements of the fluvial audit approach advanced by Sear et al. (2010), along with landscape assessments completed via aerial surveys. Bouwes et al. (2013) details the methodology entailed in conducting the RGA. The overarching River Styles Framework on which the ISEMP RGA is based is described briefly, below, along with information about how fluvial audits and aerial surveys are being used to develop the RGA.

The River Styles Framework

The River Styles Framework (Brierley and Fryirs 2005), aims to develop a process-based, watershed-specific, and repeatable classification system for rivers in particular watershed. The framework ties together description of river forms with process-based explanation of the drivers behind those forms. Subsequently, an understanding of past behavior and current morphology is used to predict future river behavior and subsequently prioritize restoration actions in impaired basins.

Although numerous such river classification systems exist, they may not be process-based (cf. Rosgen 1994; Simon et al. 2007), and are almost never specific to the particular watershed of interest (cf. Montgomery and Buffington 1997). Channel classifications are typically used in framing reach-scale geomorphology as it fits into the broader watershed context, and have been applied in studies of stream biota (Frissell et al. 1986; Hawkins et al. 1997); two of the primary goals for development of the RGA detailed here.

Application of the River Styles Framework is completed in four distinct stages (Brierley and Fryis 2005). Stage 1 is a catchment-wide baseline survey of the river character and behavior and classification of the River Styles. Stage 2 is a catchment-framed assessment of geomorphic condition, analyzed in terms of potential for adjustment and associated geoindicators for each River Styles. Stage 3 is an assessment of the future trajectory of change and geomorphic river recovery potential, framed in terms of evolutionary adjustments of each reach, related to catchment-wide geomorphic changes. Stage 4 is to describe river management applications and implications: catchment-based vision building, identification of target conditions and prioritization of management efforts. ISEMP has completed the first two of the above steps in select watersheds within the John Day subbasin.

Fluvial audits

A fluvial audit is intended to establish a semi-quantitative, first-approximation understanding of the reach-scale sediment budget, the geomorphological processes operating in the channel and the causes of instability or other sediment-related problems (Sear et al. 2010). This approach aims to classify the channel into discrete reaches based on the sediment dynamics at that location - whether the reach is functioning as a sediment source, transfer zone, or sink.

In the summer of 2011 two or three man crews completed fluvial audits in the John Day subbasin by walking the full length of two mainstem channels in study watersheds (Bridge Creek and Murderers Creek). While in the field, crews made notes regarding each of the

References:

Bouwes, N., N. Weber, S. Bennett, J. Wheaton, A. Kasprak, S. Bangen, M. Blanchard, C. E. Wall, C. Jordan, M. Pollock, J. Hall, C. Volk, J. Goldsmith. 2013. The Integrated Status and Effectiveness Monitoring Program: John Day Basin Pilot Project, 2011-2012. BPA project #2003-0017

Brierley, G., Fryirs, K., 2005. Geomorphology and River Management. Blackwell Publishing.

Frissell, C., Liss, W. J., Warren, C. E., Hurley, M. D., 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management 10 (2), 199-214.

Hawkins, C., Hogue, J., Decker, L., Feminella, J., 1997. Channel morphology, water temperature, and assemblage structure of stream insects. Journal of the North American Benthological Society 16 (4), 728-749.

Sear, D., Newson, M., Thorne, C., 2010. Guidebook of Applied Fluvial Geomorphology. Thomas Telford Ltd.

variables listed in Table 8. ISEMP extended the fluvial audit in the John Day subbasin to not only make observations and inferences regarding reach-scale sediment budgets but also to observe several geomorphic variables along the course of the channel, taking time to walk up the valley-sides and tributary streams when further observation was necessary. Notes and GPS point locations of other observed features, e.g., geologic unit boundaries and point-sources of sediment, such as landslides or fires were recorded. Additionally, a GPS-enabled camera was used to document, via photographs and videos, the appearance of the stream, riparian zone, and valley corridor.

The goal of the extended fluvial audits was to collect as much information as possible (via georeferenced notes and photographs) on the variables and observations discussed above to use it back in the office in Google Earth and ArcGIS. These tools allowed for rapid visualization of the landscape and integration of field observations. In this manner, final reach breaks could be more reliably made; often a 'first-cut' of breaks was made in the field and subsequently refined using a desktop platform. Audit outputs included a stream line shapefile broken into segments describing the sediment dynamics (e.g., zones of sediment sources, transfer, and sinks) in that reach of the channel; each segment is attributed with descriptions of the variables in Table 8, and the character of each reach with regard to these variables was also described.

Table 8. Variables and categories noted in 2011 ISEMP fluvial audits in the John Day subbasin. Fluvial audit information is being used in RGA tool development.

Variable	Categories
Gradient	Flat/Moderate/Steep
Substrate	Silt/Mud/Clay/Sand/Gravel/Cobble/Boulder
Pool Density	Low/Moderate/High
LWD Density	Low/Moderate/High
Valley Confinement	Narrow/Moderate/Wide/Very Wide
Sediment Dynamics	Source/Transfer/Sink
Montgomery and Buffington Reach Type	Pool-Riffle/Plane-Bed/Step-Pool/Cascade

Fixed-wing aircraft overflights

While ground-based surveys such as fluvial audits and River Styles validation are valuable for gaining fine-scale perspective into channel types and geomorphic dynamics found in a study watershed, more general observations can prove essential for understanding the range of forms found across that watershed. As such, in the summer of 2012 ISEMP chartered a single-propeller aircraft for overflights around each of the three study watersheds. The goals of the overflight campaign were twofold: to attempt to validate the previously-delineated landscape units for use in Stage One of the River Styles methodology, and to record (via photographs) the range of landforms and channels observed across the three basins.

River Styles-based RGA for Sites

Deliverable Schedule:

- By May 31, 2013: Develop River Styles framework Stage One of rapid geomorphic assessment for East Fork Beech and North Fork Cable.
- By June 15, 2013: Review other geomorphic assessments, e.g., USBR, in ISEMP watersheds.
- By October 2013: Develop fluvial audit and application and perform field validation at CHaMP sampling sites.
- By November 30, 2013: Complete River Styles stages for select watersheds Middle or South Fork, maybe Asotin, Tucannon, Bridge Creek. Start work in other ISEMP watersheds (Entiat, Lemhi)

Task Leads:

- Nick Bouwes, Joe Wheaton, Steve Fortney

Remotely-sensed landscape data for metric and indicator generation

CHaMP is exploring the utility of remotely sensed landscape data for metric and indicator generation. For example, remotely sensed water temperature data may be more robust and efficient to use than the existing data logger approach, which requires field installations that are prone to failure, can be difficult to process, and are limited in their ability to make basin-wide inferences. CHaMP is considering the use of spatially continuous measures of land surface temperature (LST), which are publicly available from NASA's Earth Observing System Moderate Reso-lution Imaging Spectroradiometer [MODIS] sensor (http://reverb.echo.nasa.gov) and can be calibrated and validated with CHaMP's site-wide data loggers (Figure 31). The resulting continuous estimates of stream temperature regime in each CHaMP watershed across the year can be characterized, and any temperature metrics deemed useful for indicators of fish habitat at local and regional scales can then be generated.

Currently, CHaMP temperature estimates are based on relatively few data points, but as more sites in more watersheds are included as the project continues, we can expect these temperature estimates to become more accurate and robust. Formal error estimates derived from bootstrap analyses will be generated once all the basin-level analyses are complete. A similar process could also be undertaken with the Solarmetric Suneye data (see Chapter V for information on these auxiliary data) and MODIS FPAR and LAI coverages once an appropriate analytical approach is defined by CHaMP-ISEMP analysts in 2013.

Once continuous temperature estimates have been generated for all CHaMP watersheds, it will be possible to generate any temperature metrics deemed useful for indicators of fish habitat at both local and regional scales. Examples of the types of indicators and data displays that could be used are presented for the John Day (Figures 32a&b).

Field Temperature Metrics and Status Estimates at Different Scales

Deliverable Strategy:

- By July 2013: Provide LST derived estimates of 8-day mean, minimum, and maximum stream temperature and errors for May 1, 2011 – December 31, 2012 for each confluence-to-confluence stream reach in each 2012 CHaMP watershed.
- By September 2013: Provide summary metrics of the temperature estimates, e.g., annual mean min, mean, max temp for each CHaMP watershed.
- By November 2013: Identify and generate temperature threshold metrics specific to ESUs listed in the ICRB TRT for each basin as needed. These metrics will be time and life-history stage specific as warranted. Spatially aggregate these metrics at sub-basin to watershed scales to summarize the status of these watersheds in relation to target ESUs.
- By January 2014: Demonstrate applications for landscape-scale extrapolation of results and tie in with watershed production models.

Task Lead:

- Kristina McNyset

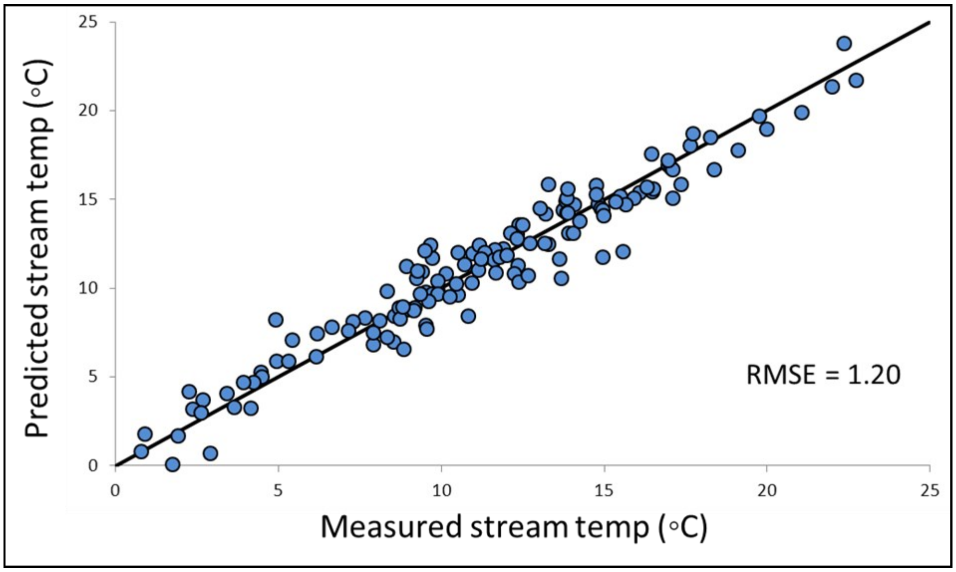
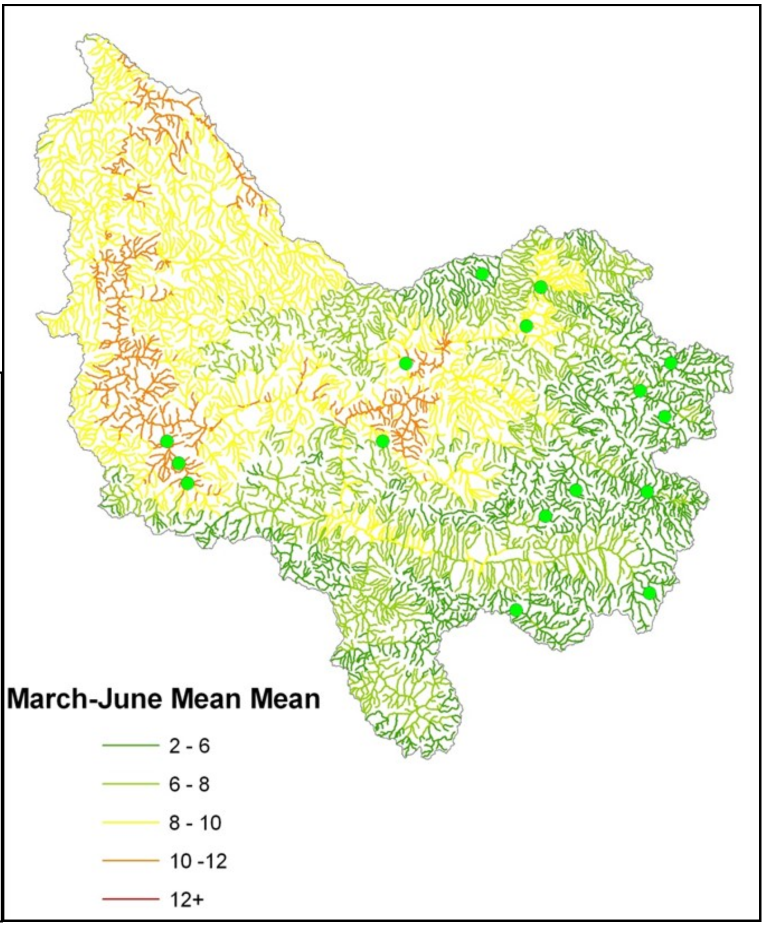


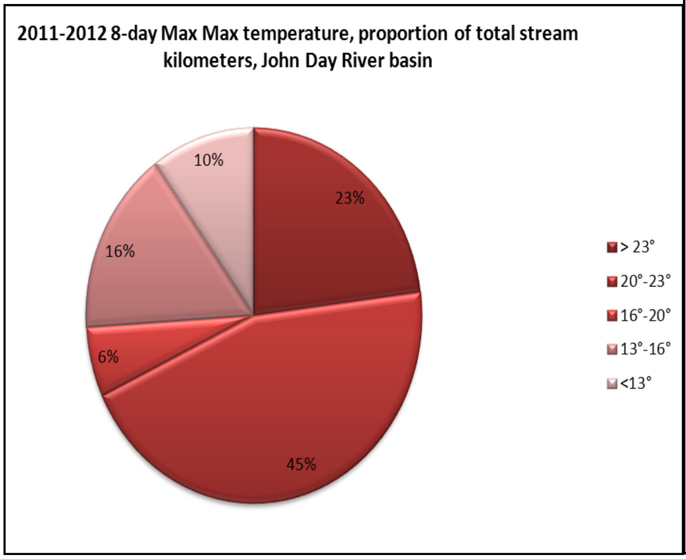
Figure 31. A simple linear relationship between measured stream temperature data retrieved from CHaMP sites in the Wenatchee River in the summer (July 1 – Sept 30) of 2012 and concurrent LST measures can be derived. The quality of these temperature estimates varies among watersheds, with an average RMSE of <2°C. For all sites and all days in the Wenatchee, the RMSE = 1.20°C.

The simple linear relationship depicted above can be leveraged with the spatial nature of the LST data to generate continuous estimates of stream temperature for every stream reach in a given basin. Continuous estimates of stream temperature can then be used in a variety of summary metrics deemed useful for indicators of fish habitat at local and regional scales (see examples, below).

Figure 32a. (Right) An example showing the March-June 2012 8-day mean mean predicted for the John Day (CHaMP survey sites are shown as green dots).

Figure 32b. (Bottom) An example showing how the proportion of total stream kilometers predicted to experience maximum temperatures above lethal thresholds for steelhead in the John Day River watershed in 2011-2012 can be quantified and easily displayed using a pie chart.





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V. IMPLEMENTATION REVIEW: LESSONS FROM 2012

Introduction

The sections in this chapter provide detail on coordination of the CHaMP project as a whole, as well as how individual elements were implemented in 2012. Compared to the 2011 Lessons Learned report, fewer elements are discussed and the level of detail presented for the elements that are discussed may be less than in the previous report.. This is because 2011 was the first year of the pilot and reporting provided an exhaustive review of every aspect of CHaMP, whereas the goal of this second year lessons learned report is to present the most important aspects of project implementation and highlight significant changes and advancements from 2011 to 2012. Please refer to the 2011 lessons learned report (Ward et al. 2012) for the baseline overview of all project elements.

Program-wide Coordination

CHaMP coordination improved from 2011 to 2012 due largely to the fact that implementation in the second pilot year was enhanced by lessons learned in 2011, and existing budgets and contracts were able to serve as templates for the second year of CHaMP implementation. Contracting proceeded according to schedule in 2012, which enabled a much greater amount of preparation and coordination time to be devoted to all aspects of the project, from preseason tool development through field season and data management. The overall workplan for 2012 (Figure 33, next page) had additional milestones and check-in points defined early on, which facilitated overall project coordination and tracking.

Coordination With Managers (NPCC, BPA, NOAA)

As in 2011, coordination occurred throughout 2012 through a series of phone calls, emails and meetings.

A notable improvement was the addition of a data analysis strategy workshop in September 2012 where technical representatives of the policy decision-makers met with CHaMP developers, analysts, and other CHaMP data users. Input provided at this forum was instrumental in establishing the goals, objectives and milestones in the CHaMP Analytical Framework for Fish-Habitat Relationships (Chapter IV).

The November post-season workshop provided an excellent opportunity to align CHaMP reporting with other key policy and management decision-making processes that are occurring in 2013 and subsequent years, e.g., ISAB/ISRP, BiOP, and other processes.

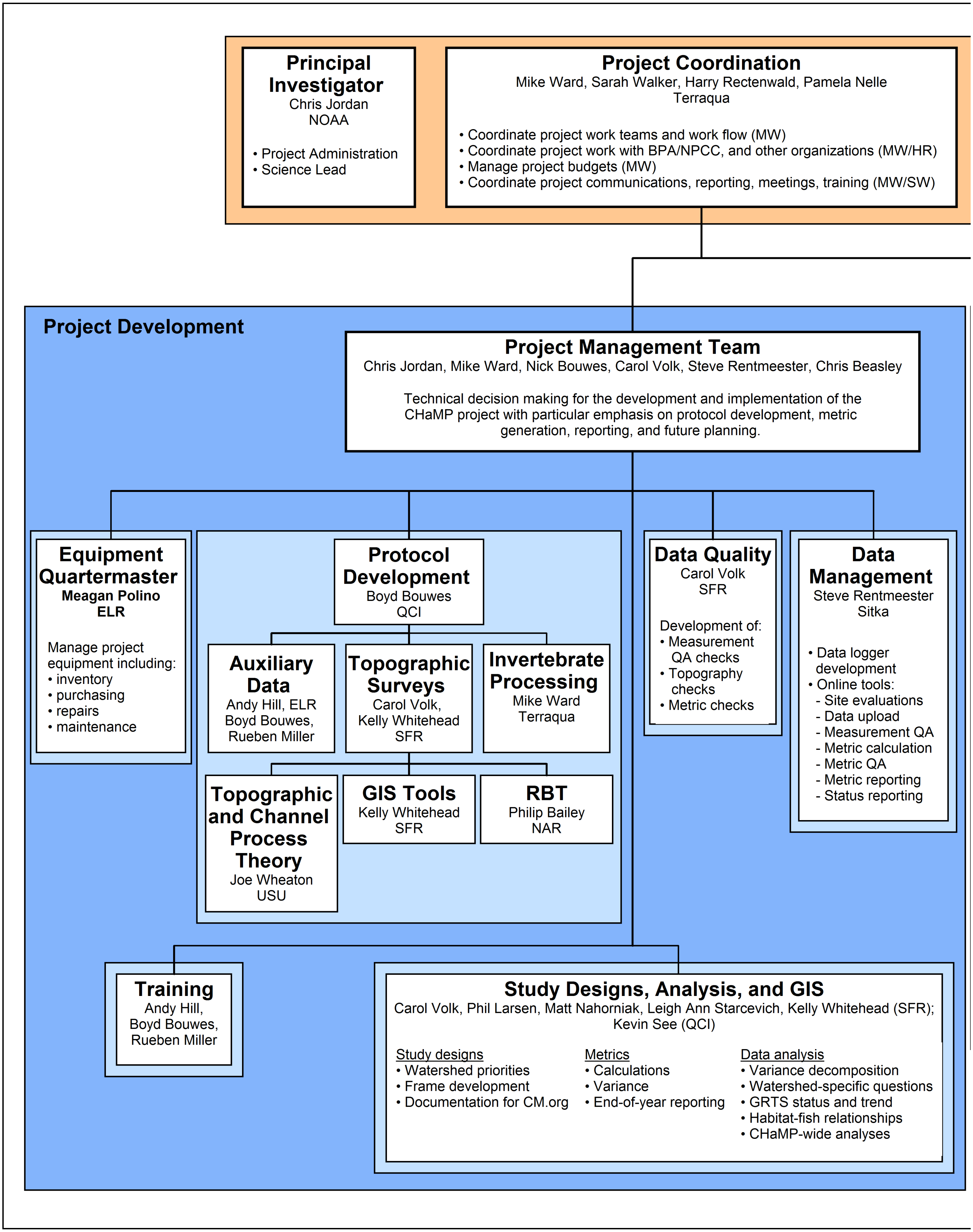
Coordination With Regional Programs

The role of the various collaborators evolved in 2012. While most collaborators focused on data collection, all collaborators were more strongly involved in protocol development, analysis planning and implementation, and reporting than in 2011. For example, CRITFC lead the development of the riparian monitoring module and ODFW is contributing fish data collected at CHaMP habitat monitoring sites for development, with ISEMP, of fish habitat relationships. Figure 32 on the next page displays the 2012 organizational structure., including new collaboration with researchers at Oregon State University that were interested in using CHaMP methods for work in the Umpqua watershed.

The collaboration between CHaMP and PIBO in 2012 is notable. At the request of the Columbia Basin Federal Caucus, CHaMP and PIBO began an exploration how the two programs collect habitat information for a number of metrics, the quality and comparability of the data that are collected, whether the information collected by the two habitat monitoring programs could be used together, and whether there are efficiencies that might be gained through future protocol/programs modifications. Please refer to page 8 for a more complete discussion of this collaboration. Analysis of these data is ongoing and results will be presented to the Federal Caucus at upcoming meetings in the winter-spring of 2013. Additional discussion with PIBO staff is planned for 2013, and is a necessary part of the process to further evaluate how both programs and protocols are designed and implemented. These additional discussions with help inform decision making about whether changes to either or both monitoring programs are warranted.

Program-wide Coordination: Changes from 2011 to 2012

- Lessons learned from 2011 improved overall coordination in 2012.
- Contracts from 2011 served as templates for 2012 collaborators, and the overall contracting timeline was not compacted as it has been prior to the start of the first pilot year.
- The workplan from the first year was enhanced and served as an excellent tool for tracking the different CHaMP development and implementation threads, e.g., data management, protocol development and field implementation, data analysis.
- The addition of a September Data Analysis Strategy meeting allowed technical representatives of policy decision-makers and data users to interact with CHaMP development team members and help establish key elements and deliverable schedules in the Analytical Framework.
- All collaborators from 2011 were more strongly involved in 2012 protocol development, analysis planning, implementation and reporting.
- New collaboration with Oregon State University researchers resulted in the use of CHaMP methods in the Umpqua watershed.
- Notable collaboration between CHaMP and PIBO occurred in 2012 as the programs explored the utility of and use options for the information collected by each other, and how efficiencies might be gained through closer cooperation.


Principal Investigator
Chris Jordan
NOAA
• Project Administration
• Science Lead
Project Coordination
Mike Ward, Sarah Walker, Harry Rectenwald, Pamela Nelle
Terraqua
• Coordinate project work teams and work flow (MW)
• Coordinate project work with BPA/NPCC, and other organizations (MW/HR)
• Manage project budgets (MW)
• Coordinate project communications, reporting, meetings, training (MW/SW)
Project Development
Project Management Team
Chris Jordan, Mike Ward, Nick Bouwes, Carol Volk, Steve Rentmeester, Chris Beasley
Technical decision making for the development and implementation of the CHaMP project with particular emphasis on protocol development, metric generation, reporting, and future planning.
Equipment Quartermaster
Meagan Polino
ELR
Manage project equipment including:
• inventory
• purchasing
• repairs
• maintenance
Protocol Development
Boyd Bouwes
QCI
Auxiliary Data
Andy Hill, ELR
Boyd Bouwes,
Rueben Miller
Topographic Surveys
Carol Volk,
Kelly Whitehead
SFR
Invertebrate Processing
Mike Ward
Terraqua
Topographic and Channel Process Theory
Joe Wheaton
USU
GIS Tools
Kelly Whitehead
SFR
RBT
Philip Bailey
NAR
Data Quality
Carol Volk
SFR
Development of:
• Measurement QA checks
• Topography checks
• Metric checks
Data Management
Steve Rentmeester
Sitka
• Data logger development
• Online tools:
- Site evaluations
- Data upload
- Measurement QA
- Metric calculation
- Metric QA
- Metric reporting
- Status reporting
Training
Andy Hill,
Boyd Bouwes,
Rueben Miller
Study Designs, Analysis, and GIS
Carol Volk, Phil Larsen, Matt Nahorniak, Leigh Ann Starcevich, Kelly Whitehead (SFR);
Kevin See (QCI)
Study designs
• Watershed priorities
• Frame development
• Documentation for CM.org
Metrics
• Calculations
• Variance
• End-of-year reporting
Data analysis
• Variance decomposition
• Watershed-specific questions
• GRTS status and trend
• Habitat-fish relationships
• CHaMP-wide analyses

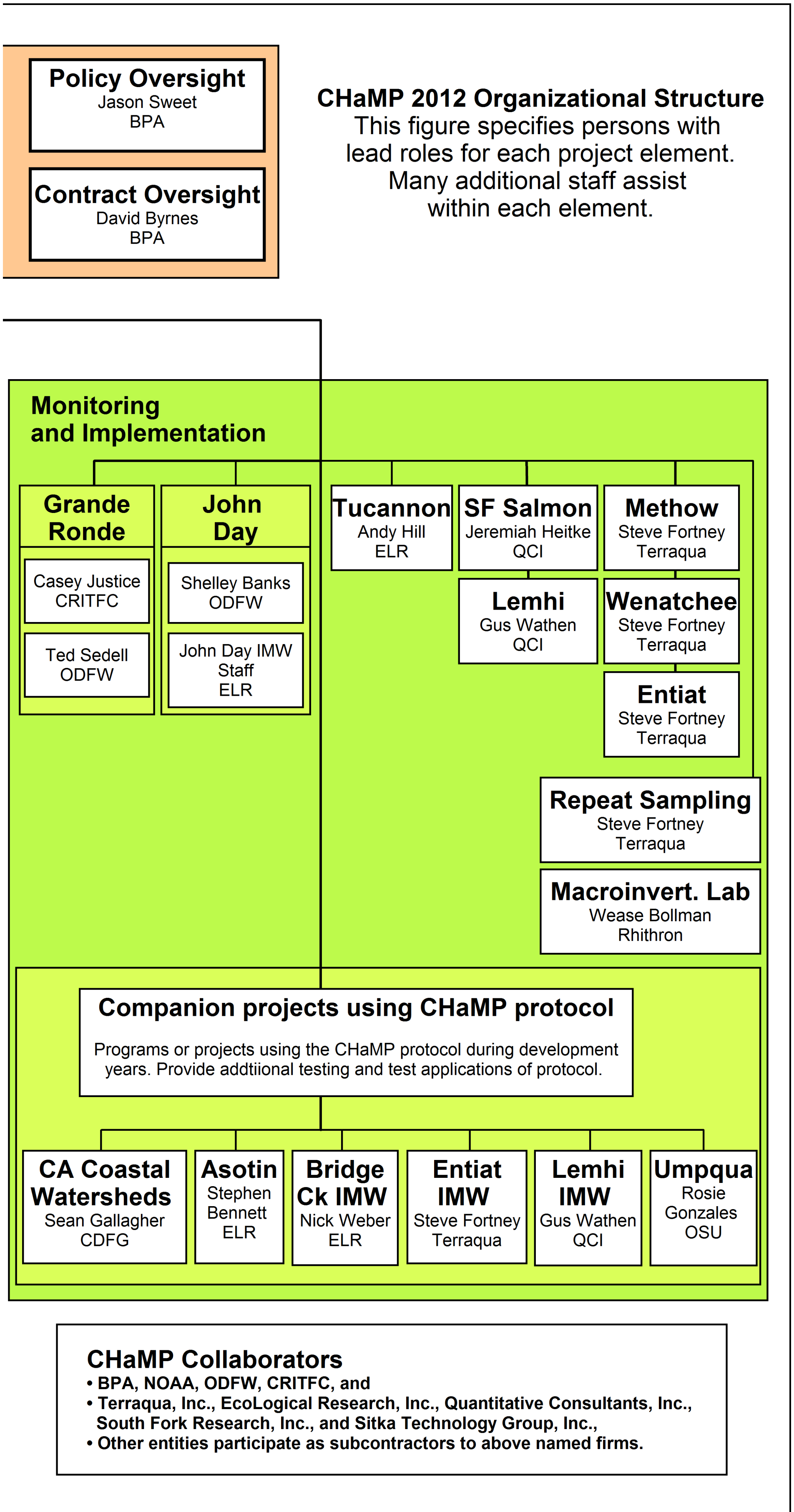


Figure 33. CHaMP 2012 organizational structure.

Habitat Protocol: Changes from 2011 to 2012

- The 2012 protocol added 5 more channel classifications for sites with >8 m bankfull (BF) widths in an attempt to improve the repeatability of this metric.
- A channel unit key was added to improve crews' ability to delineate Channel Units.
- Spatially-explicit undercut bank information was collected.
- A gravelometer was added to improve the overall substrate protocol.
- Another embeddedness measurement that examines a 5 cm ring around the particle (for particles between 65 mm-256 mm) was added.

CHaMP Habitat Protocol

This section provides a brief summary of how information from 2011 was used to refine and revise the CHaMP protocol for 2012. Updates to the protocol will occur again prior to the start of the 2013 training and field sampling season. To help effectively track protocol versions and updates, the 2012 CHaMP protocol includes a revision history that includes the protocol version number, revision dates, changes made, the rationale for the changes, and the author that made the changes. Please refer to Appendix B of the CHaMP 2012 habitat protocol for a complete list of all protocol changes that were made between 2011 and 2012. Specific discussion about data collection tool changes may be found in the Equipment section of this chapter.

Changes From 2011 to 2012

Most of the CHaMP habitat protocol changes from 2011 to 2012 involved adding text, graphics and dichotomous keys to clarify methods and improve observer repeatability for both the auxiliary data capture methods and the topographic survey. In addition, method applications were added to increase data richness. Additions were also made to provide detail about how to address and resample revisit sites.

Recommendations for 2013

The CHaMP protocol team is developing a framework to analyze the effectiveness of the changes that were made to auxiliary and topographic habitat data collection methods between 2011 and 2012. Tasks proposed include:

- Evaluate the 2012 Channel Class data that were collected using 9 (vs. previous 4) classifications.
- Analyze data from the 2012 crew variability and PIBO comparison studies to determine whether changes from 2011 improved crews' ability to delineate channel units.
- Evaluate the Signal:Noise ratio of both areas and volumes of undercut bank habitats, to determine if method changes are needed, and applications of the spatial component.
- Analyze if the added measurement helped improve the performance of the embeddedness metric.
- Evaluate existing riparian metrics and decide if they can be replaced by Solometric SunEye output data or represented through a GIS analysis that is broader spatially but which could produce more informative outputs.

Other areas of evaluation for 2013 include the utility of LWD jams and air temperature data. Any recommendations for major revisions, such as a complete change in method, will be evaluated by the CHaMP development team with the support of other technical experts. For more specific information about Topographic and Auxiliary changes that occurred from 2011 to 2012, please refer to those sections later in this chapter.

Preseason Planning

Training

The 2012 "CHaMP Camp" pre-field season training was held in from June 3 to June 13 in Cove, Oregon. The timing allowed all crews to start their field season by June 15 and accommodated those agencies who did not start hiring staff until June 1.

As in 2011, standardized training was provided to all 2012 crews primarily by staff from the CHaMP and ISEMP projects. All returning 2011 crew participants were required to return and complete the full training in 2012.

Approximately 80 participants were trained at stream-side field locations, classroom settings, and in computer labs. Participants were taught how to conduct habitat surveys according to the CHaMP protocol, as well as the basic aspects of fish ecology affected by physical habitat.

The 2012 training remained structured like the training in 2011 to maximize training time and minimize outside distractions. The cost of instruction, facilities, meals, vehicles, and equipment for almost all participants was covered by the CHaMP project. Facilities and meal costs were maintained within allowable levels based on federal per diem regulations.

The Ascension Conference & Retreat Center in Cove, Oregon was selected for "CHaMP Camp 2012". The grounds included camping sites, bunkhouses with shared bathrooms, a large cafeteria and commercial kitchen for meals, rooms for group instructions, multiple "out-buildings" for classroom space, a separate teacher/trainer quarters, space for gear storage and charging in a locked building, access (within 20 minutes) of several stream sites, proximity to local businesses and services, and amenities including a pool and recreational facilities. Trainees were transported to stream locations in vans to minimize logistics.

In 2012, added emphasis was placed on the importance of standardization, repeatability, and overall data quality. To improve training on topographic surveying techniques and data post-processing, which were identified as areas for improvement in 2012, the material was broken up into introductory and advanced modules. In addition, more trainers, including professional surveying staff from Utah State University, were added to help crews through these survey and GIS-intensive portions of the curriculum.

Overall feedback, particularly from returning trainers and participants, was that the 2012 training was better planned and executed than the 2011 training, and that the facility was better suited overall for this type of event, in a location with access to a wider variety of sites. The improved training in 2012 is attributable to a number of things including:

- CHaMP development team and coordination staff had significantly more time to prepare for training.
- Early season venue selection allowed trainers to plan and execute reconnaissance missions to Cove to pick streams within a short distance from the training site that would be well-suited for teaching the different protocol methods. This also gave trainers a wider variety of streams with which to teach crews all aspects of each methodology.
- The addition of the Quartermaster on-site prior to and throughout training improved gear management, distribution to crews, accounting, and training.
- More trainers, another coordination staff member, and two additional event-production staff provided extra administrative and logistics support.
- The site had buildings available for use as classrooms during bad weather, and areas around the grounds provided outdoor learning space as an alternative to the classroom setting.

Recommendations for 2013:

Several recommendations have been made to improve training in 2013. These include:

- Provide the 2012 lessons learned report, the draft 2013 sampling protocol, short instructional videos and more background information on CHaMP to crews for review and viewing prior to arrival at training.
- Set clear expectations prior to and at the very start of training about training participation and post-training practice.
- Provide more training in data management, including more training time for topographic data post-processing, and the process of downloading, uploading and storing data on CHaMPMonitoring.org.
- Use the time between the end of training and start of the field season for CHaMP development team members to spend time with individual crews to address potential issues, such as misunderstandings about the protocol or a particular process.
- If feasible, hold field training at the same site in 2013 to decrease pre-planning and scouting time and allow trainers to focus more on the content of training materials.
- Explore options to provide more breaks for trainers.
- Explore the feasibility of training crew supervisors ahead of CHaMP camp to help reinforce their skills and potentially include them as trainers at camp.
- Assess the potential for additional in-basin training after camp prior to season start.

If additional watersheds are added after 2013, it would be prudent to add an additional training and/or more trainers in 2014, perhaps by using staff from the collaborating agencies as trainers. This would also help ensure consistency among trainers from year to year and provide additional trainers for total station and post-processing components.

Training: Changes from 2011 to 2012

- Training moved to Cove, Oregon
- Venue offered access to a wider variety of sites and streams than 2011.
- Site and grounds provided a variety of learning environments during all types of weather.
- Available trainer prep-time was greater and allowed reconnaissance of stream training sites, better overall event execution and training for students.
- Quartermaster provided gear assistance prior to and throughout event, and also provided training help.
- More trainers participated and professional surveying staff added to teach crews.
- Additional coordination and event staff provided administrative and logistical support.

Equipment: Changes from 2011 to 2012

- Global Water Flow Probes were replaced with Hach FL950 Electro-magnetic Velocity Meters and incremental top-setting rods.
- Solar Pathfinders were replaced with the Solometric Suneye 210 and accompanying software.
- Allegro MX data loggers were equipped with GPS pods to enable easy geotagging of all data collection events.
- "Traverse kits", which included an extra tripod, tribrach, prism, and adapter, were added to crew gear so the surveyor could conduct a direct switch between backsight and total station occupy point during the traversing process.

The CHaMP project uses a large amount of gear for topographic and auxiliary survey data collection.

In 2012, different stream flow and solar insolation measurement devices were used, and a "traverse kit" was added to crews' gear to help improve CHaMP topographic surveys.

Equipment Management and Changes

The CHaMP 2011 pilot year revealed the need for a standardized approach to project gear organization, distribution, and management. As a result, an equipment manager, or "Quartermaster", was appointed shortly after the start of the 2011 season to oversee all equipment related business. The designation of a Quartermaster and development of specific programmatic gear management tasks and frameworks progressively improved equipment management.

Use of a Quartermaster and detailed gear management framework was continued and further improved during the 2012 pilot year. Quartermaster tasks in 2012 included but were not limited to the following:

- Formulate prospective equipment budget for upcoming seasons
- Research and evaluate available products that meet project needs and perform field testing prior to purchase.
- Purchase all necessary equipment and gear items and clearly outline consumables to be acquired by collaborators
- Develop reciprocal business relationships with dealers and manufacturers and act as the voice of field crews in discussions with dealers and manufacturers about issues so that customized product development is based on constructive feedback
- Develop and maintain a comprehensive database used to track each equipment item's current condition and whereabouts
- Collect and initiate annual service, maintenance, and necessary repairs for all CHaMP project gear
- Provide annual delivery and distribution of all CHaMP gear, and year-round storage of idle equipment
- Assist the protocol development team by formulating instructional tools and presentations, and training crew members.

The existing CHaMP equipment management structure should be continued and refined further in 2013 and future years., particularly if the project is expanded after 2013.

Hardware

- Global Water Flow Probe (2011) vs. Hach FL950 Flow meter (2012)

In 2011 and 2012, CHaMP collaborators encountered a diversity of habitats and flow conditions. Based on crews' experiences capturing low flow data at sites in 2011, the decision was made to replace the Global Water Flow Probe with a higher quality meter that would be more robust in the field and be able to read almost undetectable current. The Hach FL950 flow meters proved a large improvement over the 2011 meter. Although the weight and bulk of the unit increased if accompanied by the steel topset rod, the meter proved significantly more robust in the field and produced much more accurate readings, particularly at low flows.

Overall, the results from the 2012 flow meter equipment change were positive. The only major downfall of the Hach meter was the sensitivity of the logger portion of the system to water.

- Solar Pathfinder (2011) vs. Solometric Suneye (2012)

The switch from the more 'manual' Solar Pathfinder to the all digital Solmetric Suneye 210 between 2011 and 2012 produced mixed reviews. The digital Suneye system is arguably better than the Solar Pathfinder, both in terms of field data capture and office post-processing. Unfortunately, the Suneye proved to be extremely sensitive to water and therefore not highly compatible with the CHaMP protocol. A number of units were lost due to in-stream use: when a unit encountered even slight amounts of water, it broke irreparably.

Data from 2012 indicate that ongoing Suneye replacement at the same rate and cost is not sustainable—or desirable. The per unit cost ($2000) should be weighed against the number that could be damaged during the field season.

- Allegro MX Data Logger

Based on lessons learned and recommendations from 2011, each Allegro MX was retrofitted with a WAAS-Enabled GPS. Having the GPS onboard the data logger allowed all data collected during the 2012 field season to be spatially referenced, which is highly relevant to CHaMP field work.

The application used to collect auxiliary data on the Allegro MX loggers was completely rewritten prior to the start of the 2012 field season. In addition, a "data broker" software program was developed between 2011-2012 and installed on all CHaMP laptops for the 2012 field season. The data broker applies an initial layer of QC/QA to non-topographic survey data when they are downloaded from the logger to the laptop. According to feedback from field crews and supervisors, the 2012 data logger applications were far better than ones used in 2011; however, software users still experienced some glitches.

- Traverse Kits

In 2012, significantly more time was spent fine-tuning CHaMP topographic survey data collection methods and protocols for using total stations. (see the Topographic Data Collection section on the next page). As part of this effort, traverse kits containing an extra tripod, tribrach, prism, and adapter were provided to crews to encourage use of proper survey techniques when traversing with the total station, i.e., setting up and using a proper backsight whenever possible. When crews were forced to pack gear long distances to a site, they typically resorted to a more minimal set of equipment. Fortunately, many CHaMP reaches are easily accessible and crews are able to transport an extensive set of surveying tools with them.

Recommendations for 2013:

- Continue use of the Hach FL 950 meter and assess use of its data storage capabilities to enhance field efficiency and maximize product utility.
- Supply crews with a longer cable between the flow meter logger and sensor to allow most logger operations to happen on shore, or use a custom-made watertight case or bag with the logger while in the stream.
- Supply a waterproof bag in which to carry the Suneye during in stream travel.
- Evaluate whether crews could be issued both a Suneye and a Solar Pathfinder and substitute the Pathfinder for the Suneye where there was any chance of the instrument coming in contact with water.
- Improve the data logger application to enhance field workflow, and two rigorous stages of software testing ahead of training.

Study and Sampling Designs

Initially, CHaMP was developed as a status and trend monitoring program and sampling locations were to be drawn as a stratified random sample from a GRTS master sample (see 2011 report). The original template study design for CHaMP watersheds was developed as a three year, four panel design (one annual and three rotating panels) that were drawn at the beginning of 2011. However, in 2011 and again in 2012, CHaMP study designs were modified for a variety of reasons:

- alignment of multiple monitoring programs to increase data utility
- frame reductions based on field information collected in 2011
- frame and strata adjustments to meet new sampling objectives
- supplemental oversample sites due to site shortages within strata

Study and Sampling Designs: Changes from 2011 to 2012

- In 2012, a more moderate amount of updates was made to the status and trend monitoring designs of CHaMP watersheds.
- Lemhi, South Fork Salmon, Methow, John Day (ODFW): No changes to designs
- Wenatchee and Entiat: frame reduction and supplemental oversample sites added
- Tucannon: new sampling objectives that resulted in new strata
- John Day (ELR): changed site and location of several focal watersheds and drew new sites
- Upper Grande Ronde: adjusted Steelhead strata sites to align with Steelhead spawning ground monitoring; adjustment of Chinook strata and draw to expand sampling frame and adjust panel effort

Field Sampling: Changes from 2011 to 2012

- Crew leaders generally felt they were able to complete parts of field sampling more quickly in 2012 compared to 2011 due to protocol improvements, better trained and more experienced crews, and higher quality equipment and software.
- Crews reported that the average amount of time it took to for them to complete a single site survey increased from 2011 to 2012. This is likely due to a combination of factors, including added detail in the protocol, changes that were made to the auxiliary portion of the data logger application, and the addition of the field laptop data broker, which required that crews spend time in the field on data QC/QA.
- The coverall complexity of field season logistics increased from 2011 to 2012 due to the addition of site revisits at roughly 60% of all CHaMP survey sites.

In 2012, a more moderate amount of updates was made to the status and trend monitoring designs of CHaMP watersheds. The reasons for modification requests fell within those described above. Therefore, the requests were considered valid reasons for study design updates, and new draws of GRTS sites, panel adjustments, and strata adjustments were made as needed to meet each watershed's needs. After two years of sampling it is evident that funding limitations, project objective changes, field knowledge updates, and opportunities for collaboration may require some annual adjustment of designs, especially in the early years of implementation within watersheds. The CHaMP design team will plan accordingly for potential adjustments; however, design updates will continue to require solid rationale and review of the inference consequences. In 2013 few design changes are expected. Solicitation for and finalization of these changes is scheduled for early in 2013 so that the design process does not interfere with the timeline of spring site evaluation and summer field sampling.

Sample Designer tool

In 2011 and 2012 there was an expressed need to constrain modifications to study designs during the active field season. During the past two years, the utility of the CHaMP protocol has been demonstrated and opportunities have arisen to implement the protocol at sampling locations that may not initially be included in the pre-field season study design. Many of these opportunities stem from the desire to perform effectiveness monitoring at new restoration sites. To support these spontaneous opportunities to collect data using the CHaMP protocol, there is now the need to be able to upload new sites to the CHaMPMonitoring.org data management system during the active field season, and for the upload process to be completed with a much shorter turn-a-round time (days, not weeks as was the norm with the former manual CHaMPMonitoring.org upload process).

Recommendations for 2013

For the 2013 field season, the process for adding sites to the study design will be modified to allow opportunistic sampling and facilitate the potential expansion of CHaMP watersheds. Enhancements to the CHaMPMonitoring.org sample designer tool are planned to support the upload of a set of site coordinates (latitude and longitude in decimal degrees). Once the coordinates have been upload, an ArcGIS process will be run to generate the standard CHaMP spatial covariates (e.g., valley class, ecoregion, landscape class, annual precipitation, drainage area, etc.) and then add the site to a new block (combination of panel and category) within the study design: adding the sites to a new block avoids confounding the weight calculation for the status and trend blocks within the study. Once the new sites have been added to the design, they will be available for site evaluation, hitch planning, and downloading to the Data Broker.

Field Sampling and Protocol Implementation

This section summarizes new and returning field crew and supervisor feedback on this year's sampling and protocol implementation efforts. Information presented in this section is built from crew survey responses, feedback received at a two-day post-season workshop held in Portland, OR in November 2012, and insights gained during the second year of CHaMP field implementation.

Site Surveys and Repeat Visits

Overall, the 2012 field sampling was a success. Crew leaders generally felt they were able to complete parts of the field sampling more quickly in 2012 compared to 2011 due to:

- 2012 protocol improvements,
- better trained and experienced crews, and
- higher quality equipment and software.

Collaborators reported the amount of time it took to complete surveys increased in 2012 from 2011. Therefore, the goal of sampling one site per day on average became harder to attain. This may be attributable to a combination of factors that include:

- added detail in the 2012 protocol,
- the new data logger auxiliary data collection application,
- the addition of the data broker and new post-processing techniques that required more time but ensured high quality and complete datasets from the data collection to the post processing.

Other factors influencing the 2012 field season include increases to logistical and survey complexity, described next.

Logistics

As in 2011, field season logistics varied by subbasin. For example, areas with more private landowners require additional planning and coordination at the local level because permission from private landowners is required for site access. Overall, the complexity of field season logistics increased from 2011 to 2012 due to the addition of site revisits.

Site revisits

In 2012, a subset of the sites that were surveyed in 2011 were revisited. Revisit surveys added another layer of complexity to hitch planning and data collection at roughly 60% of all CHaMP site surveys conducted in 2012. Revisits require reoccupation of previously established sites; therefore, the amount of hitch preparation time was greater due to the need to create site revisit packets for crews. These essential information packets contain photos, control files, data logger site downloads, and the topographic survey extent associated with each revisit site. Crew work at revisit sites was also greater because, in many cases, sites set up in 2011 needed to be modified (re-set up) to facilitate the visit. This was a one-time situation at most sites because the revisit site setup protocol had not been thoroughly developed by the time of training in 2011.

In 2012, a subset of sites was also revisited by a second crew during the same sampling window as part of an ongoing assessment of crew variability within the program. For the second crew to locate the site, the survey control point files containing the UTM coordinates for the site had to be transferred from the first crew's total station to that of the second crew. At times, transferring the proper control files and data to the second crew that would be visiting site presented challenges. In addition, auxiliary data needed to be uploaded by the first crew to the CHaMP monitoring website for the second crew to be able to retrieve and download on to their data logger to prepopulate it with the revisit site information. All of the complexities of this process cost crews time and effort.

Recommendations for 2013

A number of improvements are planned for logistics and revisits in 2013.

- Develop a "revisit protocol" to help streamline the preparation process and address the increase in logistical complexity that was seen between the 2011 and 2012 project seasons.
- Create a formal "preseason and hitch planning protocol" to guide people through specific CHaMP logistics issues that need to be addressed prior to sending crews in the field to sample., e.g., land owner contact policies, temperature downloading and probe placement.
- Make a more concerted effort to evaluate and prevent "protocol drift" that may result from delays between training and field data collection start time, or mild shifts by experienced crew members over time.

The above recommendations, combined with the lessons learned from field sampling this year and the outcomes of the discussions about protocol changes for 2013, are anticipated to reduce the complexities of field implementation and the amount of time that it takes crews to complete site surveys in 2013.

Auxiliary Data Collection

Auxiliary data collection methods, the data logger application, and data post-processing and upload procedures changed significantly from 2011 to 2012. (see page 62 for a discussion of data logger, post-processing and upload changes). These changes added QA checks that helped crews identify and clarify potential data capture issues and ensure data completeness of a dataset while still at the site. Other auxiliary data collection changes were made to capture data in a spatially-explicit context, when feasible, and enhance data accuracy.

Temperature logger and data retrieval

With the addition of site revisits, the 2012 CHaMP data includes the first project year of stream temperature logger data collection. In 2012, temperature loggers were retrieved from loggers that were deployed during the 2011 field season. Not all temperature loggers deployed in 2011 had data recovered from them in 2012. Some loggers simply went missing, while other loggers suffered technical failures and subsequent data loss.

Like all stream temperature logger data, the 2011-2012 CHaMP data required significant post-processing. Initial review of 2011-2012 temperature dataset revealed inconsistencies among how field crews initialized, deployed and launched the sensors. For example, some loggers recorded temperature in °C, others in ° F. In some cases, the time between when a

Auxiliary Data Collection: Changes from 2011 to 2012

- Additional time was required to retrieve temperature data loggers that were deployed in 2011.
- A number of equipment changes were made from 2011 to 2012 (see Equipment for details)
- The auxiliary data collection application for the data logger, data post-processing and upload changes improved overall QC/QA (see Data Management System section for details)

Topographic Surveys: Changes from 2011 to 2012

- Standard surveying techniques were emphasized at 2012 training to help ensure a high-integrity topographic survey.
- The use of standardized survey forms improved topographic survey data integrity.
- Additional knowledge and time was required to complete topographic surveys at revisit sites.
- CHaMP GIS post-processing tools such as the desktop River Bathymetry Toolkit (RBT) enabled crews to visually compare the 3D elevations model they created in GIS to what they saw on the ground in the field, and helped identify problematic surveys.

logger was deployed and when it was launched varied, resulting in leading and trailing air temperature records (Figure 30). Many of these data inconsistencies can be dealt with using automated, scripted editing, while others have to be done by hand.

A standardized set of data scrubbing protocols is in development to check for unit consistency, logger failure, and leading and trailing air temperatures. As further protocols are developed both in the field and for post-processing, the data will be made available more quickly and with fewer requirements for by-hand QA/QC scrubbing.

Solar input sensor data

As mentioned in the equipment section, in 2012 CHaMP changed from using Solar Pathfinder to Solometric Suneye sensors for collecting solar input data. The Suneye was used at each site to take a digital image of the sky from mid-stream. This image is used to generate a skyline including the area of open sky vs. canopy cover. Locality information, along with historical climate data from the nearest weather station, is used to generate an estimate of total potential and actual insolation (insolation accounting for shading) (wh/m2) for every 15 minutes across the year for the site. These 15 minute estimates are then aggregated up to daily and monthly summaries. Actual and potential insolation are used to calculate the

Figure 34. (Right) Like all stream temperature logger data, the 2011-2012 CHaMP data required significant post-processing.

Figure 35. (Below) Although annual solar access profiles can be generated for each site, it is unclear at this time what the data will be used for analytically.

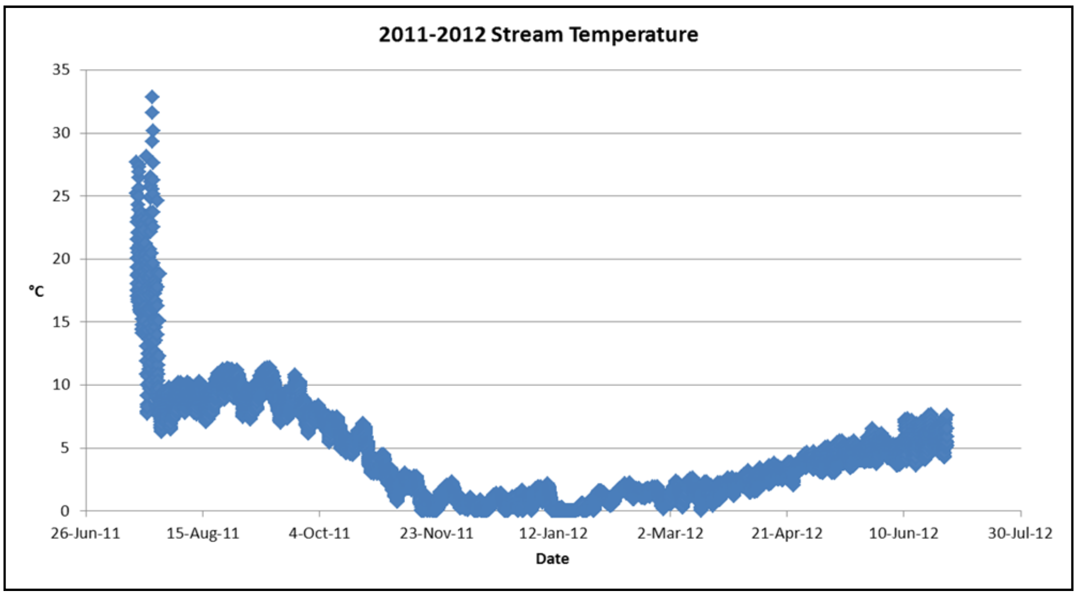
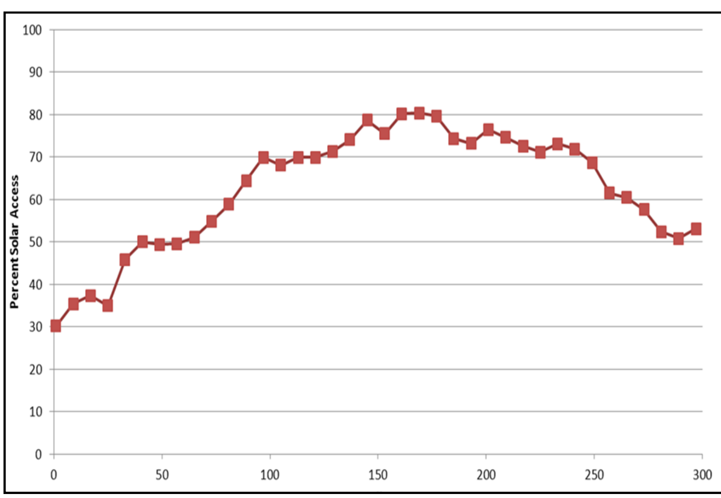


Figure 34. A typical temperature profile graph for a CHaMP site in the Wenatchee River watershed that includes a week of leading air temperature readings.



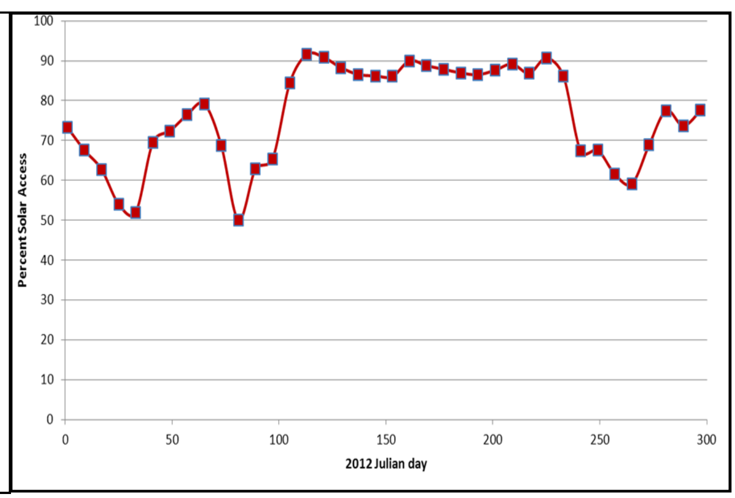


Figure 35. Annual profiles of the 2012 8-day mean percent solar access for Camas Creek (left), which lies in a relatively arid landscape in the John Day basin, and a more wooded site, Chickamin Creek, in the Wenatchee River basin (right).

percent Solar Access ((actual insolation/ potential insolation)*100). An example of the annual profile of the 8-day mean percent Solar Access for Camas Creek in the John Day subbasin is shown in Figure 35 (left). Camas Creek is in a relatively arid landscape. The annual profile of the 8-day mean percent Solar Access for a more wooded site, Chickamin Creek, in the Wenatchee River subbasin, is presented in Figure 35 (right). Although an annual profile can be generated for each CHaMP site, it is unclear at this time how the SunEye data will be used analytically.

Topographic Surveys

As mentioned previously, in 2012 CHaMP placed increased emphasis on capturing topographic survey data efficiently and accurately. Crews were rigorously trained in standard surveying techniques to help ensure a high-integrity topographic survey. Due to repeat surveys, crews had to "tie into" an established control network at each revisit site, which required finding and reoccupy existing benchmarks, as well as establishing new benchmarks. The ability to assess and resurvey old benchmarks requires a working knowledge of basic surveying skills, and this process added some additional time to surveys in 2012.

Topographic survey data integrity was improved in 2012 through the use of standardized survey forms, which were given to crews to help them double check rod and instrument heights, control point locations, and to record and track potential topographic point collection issues. Crews were able, during their hitch, to use the CHaMP GIS post-processing tools (GIS extension, desktop river bathymetry toolkit, transformation tool extension, and the CHaMP GIS tool) to visually compare the 3D elevation model they created in GIS to what they saw on the ground, and improve their identification of problematic surveys. Based on crew feedback, additional training is needed to help with advanced surveying techniques.

Nikon Novo C Total Station

Unfortunately, the performance of the Nikon total station continued to be problematic in 2012. This particular make and model of total station was originally selected after significant research and purchased in May 2011 because it seemed to best fit the specific needs of the CHaMP project (i.e., it is compact, has a long battery life, 18X eyepiece to assist with close shots in small canopied streams, lightweight, user-friendly, etc..) yet remained within the target price range. During the 2011 field season, crews began to experience frequent issues such as slow point collection (especially during the heat of the day), complete freeze up requiring removal of batteries and restarting the software program, and unexplainable vertical errors.

In an attempt to remedy the performance issues identified in 2011, all 25 total stations received cleaning, recalibration and firmware updates prior to the 2012 field season. The crew debriefing process conducted as part of the November post-season meeting revealed that the same issues had occurred again in 2012. In particular, crews reported that the speed at which the total station is able to consistently collect and record points is too slow and holds up overall crew progress.

Since the conclusion of the November workshop, the CHaMP Quartermaster and other development team staff have been devoting significant time and resources towards identifying and documenting the exact nature of the ongoing total station performance issues (i.e., are the issues related to the software or hardware itself, can the issue of slow point capture be reproduced, do different environmental conditions such as hot weather play a factor, etc.). Discussions with the dealer and the manufacturer are still occurring in an attempt to resolve this major issue prior to the 2013 field season. Other total station models may be required, which would likely require new software platforms. A total station model change would also necessitate protocol and training material revisions. At the time of publication of this report, the issue is unresolved. Extensive field testing that CHaMP surveying staff has performed under conditions similar to what are experienced by crews during the summer months indicates that an upgrade of the existing unit's electronic distance measurement (EDM) component could improve the issues associated with delayed point capture; however, a change to new total stations may be the best solution to improve things for future seasons.

Troubleshooting and Field Season Assistance

Troubleshooting and effort to provide field season assistance in 2012 was minimal compared to 2011. Significantly fewer calls

Troubleshooting and Assistance: Changes from 2011 to 2012

- Significantly fewer emails were sent to the CHaMPemergencies account, and no emails or calls were received after August 15.
- Most troubleshooting was related to data management and included problems with data download and upload, post-processing and storage.
- All issues, except for those involving the total stations, were resolved quickly and requests for assistance diminished as the field season progressed.

Topo Survey Data Processing: Changes from 2011 to 2012

- Approximately 10 custom tools to improve survey data quality control and geodatabases.
- Incorporated 2011 GIS Tools
- Added some RBT functionality.
- Added new functions to accommodate addition of repeat visit workflow tasks.
- Greatly improved overall topo data QA process
- Reduced amount of off-season QA and data repair that was necessary
- Added additional tasks to the crew data processing workflow.

and emails were sent directly to CHaMPemergencies.com, and none were sent to the account as either direct or forwarded messages past August 15, 2012.

Most of the troubleshooting was related to data management and included problems with post- processing of the data (i.e., ensuring accurate file management); challenges with downloading and uploading equipment (data loggers, cameras, SunEye, temperature loggers); and, complexities associated with the data storage process. Sitka staff addressed each of these issues with the crews quickly as they arose, and overall issues (other than those related to the total stations) diminished as the field season progressed.

Topographic Survey Data Processing

CHaMP Topo Toolbar

Several steps were taken to improve topographic survey data processing for the 2012 field season. The primary enhancement was the creation of the CHaMP Topographic Processing Toolbar for ArcGIS. The topo toolbar integrated the 2011 GIS Tools with some of the functionality developed for the River Bathymetry Toolkit (RBT, discussed in the next section), with the goal of improving survey data quality control.

The 2012 topo toolbar centralized a set of approximately 10 custom tools developed by SFR and NAR staff members for use by the field crews during topographic data post-processing (see the wiki web site: https://sites.google.com/a/northarrowresearch.com/champtools). The workflow starts with raw survey data and leads the field crew through each step of the process to generate a TIN, DEM and all the other layers needed by CHaMP. The toolbar helped field crews produce quality controlled survey geodatabases ready for metric calculation. Toolbar functions were also added to accommodate the addition of repeat visits workflow tasks.

The CHaMP topo toolbar greatly improved the overall QA process by moving key data quality checks to the field crew stage in the workflow. This strategy added additional tasks to the crew data processing workflow, but data published in 2012 were much cleaner. In addition, the crew-level QA greatly reduced the amount of off-season QA and data repair that was necessary. Crews also indicated that they liked both the simplified 2012 toolbar interface and the ability to create and edit many RBT GIS products locally.

Recommendations for 2013

For the upcoming field season, recommendations to improve the CHaMP topographic processing and the toolbar include:

- Incorporate the survey data validation system being developed for RBT to enforce data validation at the processing, upload, and RBT analysis stages, and reduce the number of errors encountered when running RBT.
- Make minor toolbar additions and enhancements to:
  - Improve the centerline/thalweg tools,
  - Further develop the scout map and control network tools,
  - Refine error reporting and logging,
  - Increase the reliability of the publishing tools.

Other options being considered to improve topo data processing in 2013 include:

- Replace or eliminate the need for ForeSight survey processing software,
- Analyze the 2011 and 2012 Topo QA/QC tables to find areas for improving data collection quality and efficiency,
- Improve training and supplemental information materials,
- Upgrade GIS tools to run in ArcGIS version 10.1.

River Bathymetry Toolkit

The RBT is a suite of free GIS tools that work within the ArcGIS software environment. It uses the CHaMP high resolution digital elevation models (DEM) to describe and measure river channels. RBT functionality includes the ability to:

- Detrend a DEM to remove the longitudinal valley slope.
- Cut user-defined cross sections through the DEM and define the bathymetry in each cross section.
- Compute stream gradient and sinuosity.
- Vary the water level in a detrended DEM to investigate the distribution of water depths inside a stream and the extent of "off-

channel" habitat still hydraulically connected to the main stem flow.

- Locate residual pools, which may be used to identify fish habitat.

Typical RBT outputs include GIS maps of channel features and tabular data of measurements, such as gradient, that are commonly used by hydrologists, aquatic ecologists, and geomorphologists. The CHaMP development team includes North Arrow Research staff, who is customizing the RBT and its outputs to support the CHaMP protocol, topographic data processing and analysis, and automated metric generation.

A number of enhancements were made to the RBT in 2012. The RBT was extended to accept multiple visits for a single site. The visits can be from different field seasons and/or crews, but must be for the same site. A new mode for checking input digital elevation models (DEM) orthagonality was added to allow the RBT to check the corner coordinates of the DEM raster datasets, flag those DEMs that have corners with arbitrary coordinate values (i.e., not on whole meter values), and warn the CHaMPMonitoring.org environment that there is a problem. The RBT was also enhanced to fix the corner coordinate orthogonality, one visit at a time. To do this it requires information about each all other visits to the same site. The coordinates of the fixed DEM are specified as the union of all other visits, plus a buffer of 10m. A new, corrected DEM is added to the survey geodatabase ready for the RBT metrics to be calculated.

An important feature in 2012 was the addition of geomorphic change detection between visits of the same site. These visits can vary either by field crew, by time, or by both. The change detection isolates the differences in the topographic survey and removes the portion of the change that is uncertain (either because the change was too small or because there was an error with one of the surveys). The GCD analysis outputs the area and volume of change, and segments this change into erosion, deposition, by tier1 and tier 2 channel units, inside and outside the channel (Figure 36).

Minor RBT enhancements were made to adapt to the 2012 survey protocol. These included things such as the new topo codes for in-flow and out-flow points. The names of some datasets also changed for 2012.

__Recommendations for 2013__

Changes that are currently planned for the CHaMP RBT for 2013 include:

- Redesign the RBT engine to perform more comprehensive QC of topographic survey data, i.e., provide exhaustive testing of the topo survey data, including more informative reporting to users (both of the toolbar, but also the server RBT tool) about problems with the survey data prior to it being run through the RBT metric calculation process.
- Restructure the RBT GCD analysis so that results are output to a new file structure that is consistent with the desktop GIS GCD software.
- Test RBT automated habitat feature identification to complement (not replace) existing, manual field crew identification of channel units. The RBT will attempt to identify tier 1 (and in some cases) tier 2 channel units using just the channel topography. These automated features will be cross referenced with crew channel unit data and a metric of correspondence will be included in the RBT output.
- Further develop cross-walk metrics for comparing the CHaMP RBT with other protocols (PIBO, AREMP, EMAP, etc.).
- Adjust the 2012 RBT to align it with protocol changes for 2013. This will require minor tweaks to the RBT to adapt to the new way(s) that CHaMP data may be collected.

RBT: Changes from 2011 to 2012

- Extended to accept multiple visits for a single site. The visits can be from different field seasons and/or crews.
- Addition of new mode for checking the orthogonality of input DEM.
- Addition of geomorphic change detection between visits of the same site. These visits can vary either by field crew, by time, or by both.
- Enhancements to adapt RBT to 2012 protocol changes, such as addition of in-flow and out-flow points and codes.
- Incorporation of several new metrics for the purposes of cross walking the results of the CHaMP RBT with the Environment Protection Agency's (EPA) Environment Monitoring and Assessment Program (EMAP) protocol.
  - The new metrics include (RP100, AreaSum, Bankfull areas and volumes, channel capacity).
  - This enhancement included the development of a new cross section layout and numbering system, consistent with the EMAP protocol.

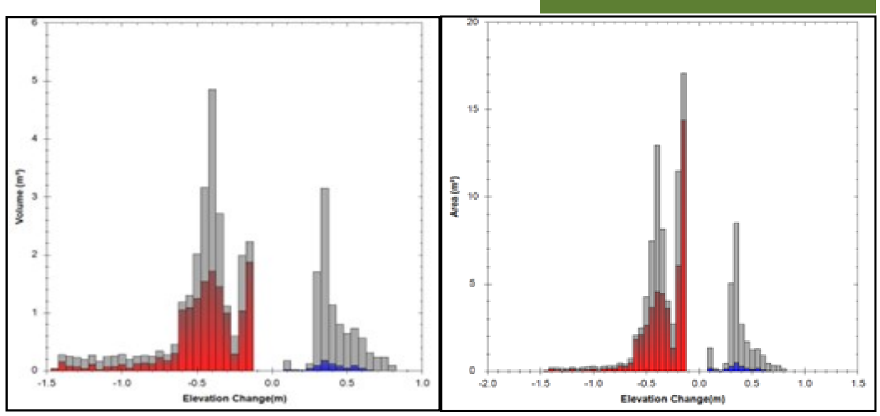


Figure 36. In 2012, GCD between visits of the same site was added to the RBT. The change detection isolates the differences in the topographic survey and removes the portion of the change that is uncertain (either because the change was too small or because there was an error with one of the surveys). The GCD analysis outputs the area and volume of change, as well as segmenting this change into erosion, deposition, by tier1 and tier 2 channel units, inside and outside the channel.

Data Broker and Logger: Changes from 2011 to 2012

Laptop Data Broker

- A software application was developed and installation on all CHaMP laptops to add additional QC/QA features for crews.

Handheld Data Logger

- The auxiliary data collection software application was enhanced to:
  - Update data dictionary and data entry screens to reflect changes to the protocol
  - Improve Quality Control - Enforce data dictionary rules
  - Improve Data Flow / Efficiency
  - Improve QA - Support "end of day" validation or "closeout" of a site
  - Conduct usability/beta testing of new handheld software

Data Management System

In 2011, the CHaMP data management system consisted of five distinct tools: 1. Data Logger Application (field capture of auxiliary data); 2. CHaMP GIS Tools (process topographic points into polygons and TINs); 3. CHaMP-Monitoring.org (web-based application to view, edit, distribute data); 4. CHaMP Database (backend database for compilation and storage); 5. River Bathometry Toolbox (RBT).

In 2012, efforts to streamline the flow of over 177,000 files from over 400 sites spanning multiple states and organizations, and support and ensure stringent data quality throughout the entire data collection and management process via a wide array of field devices, continued. In 2012, efforts included development and installation of a laptop data broker application, changes to the handheld data logger auxiliary data collection software application; and enhancements that were made to the ChaMPMonitoring.org information system.

Laptop Data Broker

The laptop Data Broker software application was new in 2012. It was installed on all crew laptops used in the 2012 season to perform three main functions:

1. Send data from CHaMPMonitoring.org down to the logger
   - Crews retrieved hitch and site information from CHaMPMonitoring.org, then used the broker to send site information to the handheld logger.
2. Retrieve data from the logger
   - After field activities, crews used the broker to retrieve data from the logger and pull files from other field devices and put all data files into folders on the laptop.
3. Publish finished surveys as complete datasets for upload to CHaMPMonitoring.org.
   - The broker ensured crews that the set of files for a survey was complete, and helped them publish the dataset and upload all files to CHaMPMonitoring.org.

By introducing the Data Broker in 2012, many functions that were performed by the Cloud in 2011 were replaced. In addition, because it produced more immediate feedback to crews about data completeness, there was a significant decrease in the amount of time between data collection and posting of auxiliary data to CHaMPMonitoring.org. Use of the data broker also produced a notable decrease in the amount of effort required to complete QA review for auxiliary data.

Recommendations for 2013

The Data Broker enhancements recommended for the 2013 field season are:

- Provide the ability to indicate a method was not implemented
- Provide the ability to indicate a measurement was not implemented
- Automatically update broker software on the laptop
- Consider support for uploading discharge data from the Hach Data Logger as .csv file

Also for 2013, it is recommended that a crew folder be set up on the Cloud file server for each organization to use as a temporary workspace. The folder will allow crews to back up and share their topographic data files while they are in the post-processing phase, and provide the CHaMP topographic data processing lead with access to crew data to assist them with troubleshooting any issues that may arise.

Data Logger Application

The Allegro MX handheld data logger is an essential and integrated component of the data management system that plays a critical role in data capture, quality and flow. It lies at the interface between field observations and data entry and, as a result, lays the foundation for downstream data quality and metric generation capabilities. During 2012 the data logger application was enhanced to ensure quality control procedures are implemented at the time of data capture, to enhance usability, and to update data entry screen based on modifications to the 2011 protocol. Specifically, the following enhancements were planned and completed:

- Update data dictionary and data entry screens to reflect changes to the protocol
- Improve Quality Control - Enforce data dictionary rules
- Improve Data Flow /Efficiency
- Improve QA - Support "end of day" validation or "closeout" of a site
- Conduct usability/beta testing of new handheld software

Recommendations for 2013

The following enhancements to the Data Logger Application should be evaluated and prioritized with the protocol authors and crew supervisors between Jan and March 2013. The logger application should be updated to meet team priorities during April and May 2013.

- On any channel unit form, automatically move to current unit, and on any transect form, automatically move to current transect
- Add all channel unit elements to a single form, i.e., move LWD, Pool Tail Fines, Pebbles, Undercut Banks to Channel Unit form, and consolidate transect photos and riparian vegetation forms
- Create a new Channel Unit Layout form for entering Unit#, Tier1, Tier2, and Segment Number. Clicking on Unit# would jump to the detail form for that unit
- Support multiple side channel lengths and widths on the channel unit form, and set the default for side channel to "No"
- Only re-run the validation summary after button clicked, add the ability to jump from any form to validation summary form, and create a validation icon for "not required, but missing"
- Automatically create 10 discharge stations and allow three digits for negative velocity on discharge
- Support entering three depths for undercut banks and then display the average

CHaMPMonitoring.org

The CHaMPMonitoring.org information system is the central hub for all study design and monitoring data related to the CHaMP project. The website interface provides the beginning and end points for field implementation and data management activities. Study designs are loaded to the system and crews then evaluate their sites and organize field visits into distinct hitches (typically 4-8 days of field work). CHaMPMonitoring.org sends this hitch and site information to the data logger and tracks the progress of each site visit. As crews finish field surveys, they upload data files to CHaMPMonitoring.org and the measurements (including auxiliary measurements, site photos, topographic files, air temperature observations, stream temperature observations, and solar input estimates) are displayed on the website. Additionally, macroinvertebrate counts and biomass are uploaded from the processing laboratory.

As measurements stream into CHaMPMonitoring.org, three calculation engines (Auxiliary engine, RBT engine and AuxByRBT engine) are triggered to generate metrics for the visit. Both the measurements and calculated metrics are displayed in charts to support the quality assurance process. When measurements are updated, the associated metrics are automatically re-calculated. This integration makes the QA process more efficient. Once metrics pass QA guidelines, crews promote the data for each site visit. Promoting a visit enables metric sharing and distribution via CHaMPMonitoring.org. In addition, CHaMPMonitoring.org tracks the progress of visits and reports program-wide progress in the following stages – Planned, Data Collection, Post Processing, In QA, Data Approved, Data Released.

In 2012, CHaMPMonitoring.org was enhanced to:

- Support multiple sampling years, hitch planning, track the objective and purpose of visits, and allow more accurate and timely reporting of organizations' activities within watersheds.
- Send and receive data from the broker
- Support protocol changes, RBT enhancements, and update auxiliary metric procedures,
- Upload air, stream temperature and solar input files
- Incorporate QA review and edits
- Restrict viewing of private site location information
- Export spatial covariates with site metric download and export site evaluation data.

Recommendations for 2013

A number of enhancements to CHaMPMonitoring.org will be prioritized for 2013:

- Add new sites to watershed study design, as needed (support for opportunistic sampling—see Study Design and Sampling)
- QA review on temperature measurements, additional QA plots for data review, and display topo QA report
- Download topo files from watershed-scale
- Performance improvements for loading data; loading 2011 Solar Pathfinder data
- Additional help within application, training videos, and manuals on the website.

CHaMPMonitoring.org: Changes from 2011 to 2012

Enhancements to:

- Support multiple sampling years
- Support hitch planning and track the objective and purpose of visits
- Send and receive data from the Laptop Broker
- Allow planning, tracking and reporting of individual organizations activities within watersheds
- Support protocol changes
- Provide more accurate and timely visit progress reporting
- Upload air and stream temperature files
- Upload solar input files
- Incorporate QA review and edits
- Update auxiliary metric procedures
- Support enhancements to RBT
- Restrict viewing of private site location information
- Export spatial covariates with site metric download
- Export site evaluation data