Fish Passage Monitoring Methods

Prepared for the California Fish Passage Forum

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California Fish Passage Forum – Fish Passage Monitoring Methods

Executive Summary

The California Fish Passage Forum is a consortium of public, private and government organizations with a mission to protect and restore listed anadromous salmonid species, and other aquatic organisms, in California by promoting collaboration among public and private sectors for fish passage improvement projects and programs. The goal of the Forum is to restore connectivity of freshwater habitats throughout the historic range of anadromous fish. In 2015, the Forum's Science and Data Committee contracted with Ross Taylor and Associates to:

1. Summarize the Current Extent of Fish Passage Monitoring in California.
2. Investigate and summarize fish passage monitoring methodologies in use.
3. Develop or recommend methods for adoption by the Forum.
4. Complete a final report that includes the three previously mentioned tasks.

To determine the extent of fish passage monitoring in California as well as different methodologies and protocols being used, a questionnaire was developed and circulated to entities involved with implementing and/or funding of restoration projects. Information was generated for 36 completed fish passage projects that had some level of monitoring associated with them. Geographically, respondents were monitoring fish passage projects completed in Humboldt (4 projects), Trinity (1 project), Mendocino (9 projects), Marin (3 projects), Santa Cruz (9 projects), San Luis Obispo (1 project), and Santa Barbara (9 projects) counties. Pre-project and post-project monitoring was conducted for 28 of the 36 projects; for the remaining eight projects, only post-project monitoring was conducted. Respondents to the questionnaire employed a range of methods to conduct their fish passage monitoring, however several methods or protocols previously established by the California Department of Fish and Wildlife were cited frequently.

For the investigation of fish passage monitoring methods currently being used, a literature search was conducted to gather published fish passage monitoring methods and protocols. The literature review also focused on peer-reviewed journal articles regarding the monitoring of barrier removals, specifically the methods and results sections. Nine methodologies and 19 peer-reviewed journal articles were reviewed and summarized. Six of the methodologies were developed for monitoring fish passage projects in the western United States and were consistent in their step-by-step field methods to monitor changes in channel morphology and fish responses to fish passage projects.

The peer-reviewed papers addressed various types of migration barriers and target fish species, which in turn, influenced both the types of treatments and monitoring parameters. For example, East Coast and Northeast coast fish passage project monitoring was focused on the modification or removal of dams, and the fish species of interest included herring, alewife, American eel, Atlantic salmon and striped bass. Dam modifications were either engineered

fishways or natural-style fish passes. In contrast, Pacific Northwest projects were focused on anadromous salmonids with the treatment of road crossings more prominent. Also, many of the peer-reviewed papers were focused on fish passage successes, and documented failures were less common. However, several papers described failures as well as unintended consequences as a result of implementing fish passage projects.

Two tiers of monitoring methods were recommended by the Forum's Science and Data Committee. Tier 1 methods included the NOAA Restoration Center's Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet and CDFW's FRPG restoration project checklists. For Tier #1 monitoring, the Fish Passage Forum is recommending use of the NOAA worksheet. Tier 2 methods addressed more in-depth monitoring of: channel longitudinal profiles and cross-sections, fish passage performance of completed projects, juvenile fish abundance and distribution, and abundance and distribution of adult spawners.

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Introduction

The California Fish Passage Forum is a consortium of public, private and government organizations with a mission to protect and restore listed anadromous salmonid species, and other aquatic organisms, in California by promoting collaboration among public and private sectors for fish passage improvement projects and programs. The goal of the Forum is to restore connectivity of freshwater habitats throughout the historic range of anadromous fish.

The Forum's Science and Data Committee have supported the development of methodologies to standardize fish passage assessments and for project prioritization. The Forum was also instrumental in the development of the Passage Assessment Database (PAD), an ongoing map-based inventory of known and potential barriers to anadromous fish in California. In 2015, the Science and Data Committee contracted with Ross Taylor and Associates (RTA) to:

1. Summarize the Current Extent of Fish Passage Monitoring in California.
2. Investigate and summarize fish passage monitoring methodologies in use.
3. Develop or recommend methods for adoption by the Forum.
4. Complete a final report that includes the three previously mentioned tasks.

Fish passage barriers, such as culverts and dams, restrict the movement of adult and juvenile fish as well as degrade fish habitat by affecting transport of sediment, wood and other organic materials. The monitoring of fish passage projects has shown that if suitable habitat is present upstream of the barrier and/or fish have historically used upstream habitat, the likelihood of fish moving upstream and re-occupying that habitat after successful barrier removal is high (SRFB 2009). Because of this, when implemented properly, fish passage improvements are a very popular kind of habitat restoration project and have great potential to create dramatic improvements in fish production in a very short time (1–5 years) (SRFB 2009).

The monitoring of fish passage projects should address three basic questions posed by O'Neal and Scranton (2014):

1. Does the completed project reflect the design and requirements in the permit and/or funding application?

2. Has the engineered fish passage project continued to meet fish passage and design criteria post-project for at least five years?

3. Has the fish passage project demonstrated upstream presence of target species (by life stage) post-project within five years?

Summary of Current Extent of Fish Passage Monitoring in California

Several years after the Endangered Species Act (ESA) listing of coho salmon in 1996, numerous road managers in northern California completed comprehensive fish passage assessments. Progressively, these assessments have been conducted further south. By the early 2000s, several counties in northern California started implementing projects to restore fish passage at road crossings. Initial monitoring efforts were focused on validating that projects were constructed as designed as well as assessing the recolonization of newly available habitat by salmon, steelhead and other native fish species.

To determine the extent of fish passage monitoring in California as well as different methodologies and protocols used to monitor, a questionnaire was developed and circulated to entities involved with implementing and/or funding restoration projects. The questionnaire was created in an Adobe FormsCentral software program that was then accessible via an Internet address. The questionnaire requested the following information:

Section 1: Fish Passage Project Information

1. Project PAD ID#.
2. Project latitude and longitude in decimal degrees.
3. Project location – county, watershed, sub-watershed, stream name.
4. Project ownership.
5. Target fish species and life stages.
6. If applicable, watershed or recovery plan(s) that project addresses.
7. Type of fish passage project – stream crossing (retrofit, replacement with bridge, stream simulation, hydraulic design, or road removal); channel grade change (roughened riffle, weirs, or designed fishway); dam removal, or modification of natural barrier.
8. If a retrofit, describe type what was done.
9. Project contact – name, organization, phone number, and email address.
10. Completion date of fish passage project.

Section 2: Fish Passage Monitoring Information

1. Monitoring contact – name, organization, phone number and email address.
2. Funding source(s) to conduct project monitoring.
3. Location information (select one choice) – at project site only, within adjacent channel reach only, or at both project site and within adjacent channel.
4. Location information – in applicable, length of channel reach.
5. Location information – latitude and longitude in decimal degrees of the channel reach start and end points.
6. Was pre-project monitoring conducted – yes or no?
7. If “yes”, what types of pre-project monitoring were conducted? Select from: photo point documentation, channel survey (longitudinal profiles, cross sections, pebble counts); biological (juvenile distribution, presence/absence, out-migrant trapping, or adult spawner surveys); other (respondent could then describe “other”).

8. Describe types of post-project monitoring conducted – same choices as previously listed.
9. Status of project monitoring? Select from: completed, on-going, planned).
10. If completed, what were the start and end dates of monitoring?
11. What methods or protocols were used to conduct project monitoring?
12. Are monitoring results available? If "yes", please provide PDFs of results or Internet links.

The questionnaire was widely distributed to watershed restoration practitioners and grant managers throughout California. We allowed approximately five weeks for interested parties to respond. Information was generated for 36 completed fish passage projects that had some level of monitoring associated with them. Geographically, respondents were monitoring fish passage projects completed in Humboldt (4 projects), Trinity (1 project), Mendocino (9 projects), Marin (3 projects), Santa Cruz (9 projects), San Luis Obispo (1 project), and Santa Barbara (9 projects) counties.

Figure 1. Fish passage monitoring locations.

The fish species of concern were primarily the ESA-listed salmonids found in California, with steelhead most frequently selected, followed by coho salmon, resident trout, Chinook salmon, coastal cutthroat trout and Pacific lamprey (Figure 1). Most projects addressed the passage requirements of both adult and juvenile fish, 97% and 94% respectively.

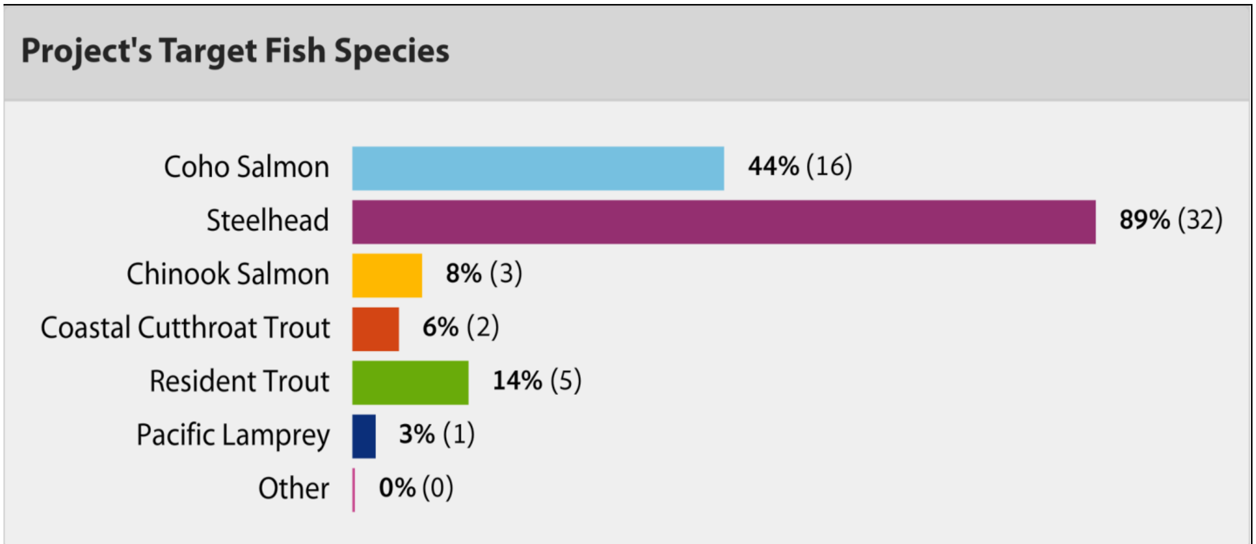

Figure 2. Target fish species of the 36 fish passage projects.

Most (33 or 92%) of the completed projects were identified in specific recovery or watershed plans and reports as priority restoration actions. These documents included:

1. Humboldt County Fish Passage Assessment – Final Report (RTA 2000).
2. Mendocino County Fish Passage Assessment – Final Report (RTA 2001).
3. Trinity County Fish Passage Assessment – Final Report (RTA 2002).
4. County of Marin Fish Passage Assessment – Final Report (RTA 2003).
5. County of Santa Cruz Fish Passage Assessment – Final Report (RTA 2004).
6. Corte Madera Creek Fish Passage Assessment – Final Report (RTA 2006).
7. California State Parks Mendocino District Fish Passage Assessment – Final Report (RTA 2007).
8. North Western Pacific Railroad Fish Passage Assessment – Final Report (RTA 2011).
9. Santa Ynez River Fish Management Plan (Entrix 2000).
10. Aptos Creek Watershed Assessment and Enhancement Plan (Conrad and Dvorsky 2003).
11. Southern California Steelhead Recovery Plan (NMFS 2012a).
12. Steelhead Restoration and Management Plan (CDFW 1996).
13. Recovery Strategy for California Coho Salmon (CDFG 2004).
14. Recovery Plan for Central California Coast coho salmon (NMFS 2012b).

The types of fish passage projects varied, with stream crossing replacement using a stream simulation design option being the most common, accounting for 10 of the 36 projects (Figure 2). Replacing culverts with bridges was the second most common project type, followed by retrofitting existing culverts. The two projects in the “other” category were modifications of a streamflow gauging station and removal of a sewer line and its concrete encasement (Figure 2).

The seven projects categorized as “retrofit of existing culvert” were located in Marin County (1), Santa Cruz County (3) and Santa Barbara County (3). Descriptions of the retrofits included:

1. Construction of vortex weirs within culvert and a fishway at the outlet (Marin Co.).
2. Modification of existing concrete weir and construction of four boulder weirs downstream (Santa Cruz Co.).
3. Construction of baffles within the culvert, a downstream grade control concrete wall and a downstream riffle ramp (Santa Cruz Co.).
4. Construction of baffles within culvert and downstream boulder weirs (Santa Cruz Co.).
5. Modification of concrete apron with step-pools (Santa Barbara Co.).
6. Modification of concrete apron with a designed fishway (two projects in Santa Barbara Co.).

Other types of fish passage projects selected included: one hydraulic design replacement, one crossing removal, one grade-change (roughened riffle), two grade-change (designed fishway), one dam removal, and two modifications of natural barriers (Figure 2).

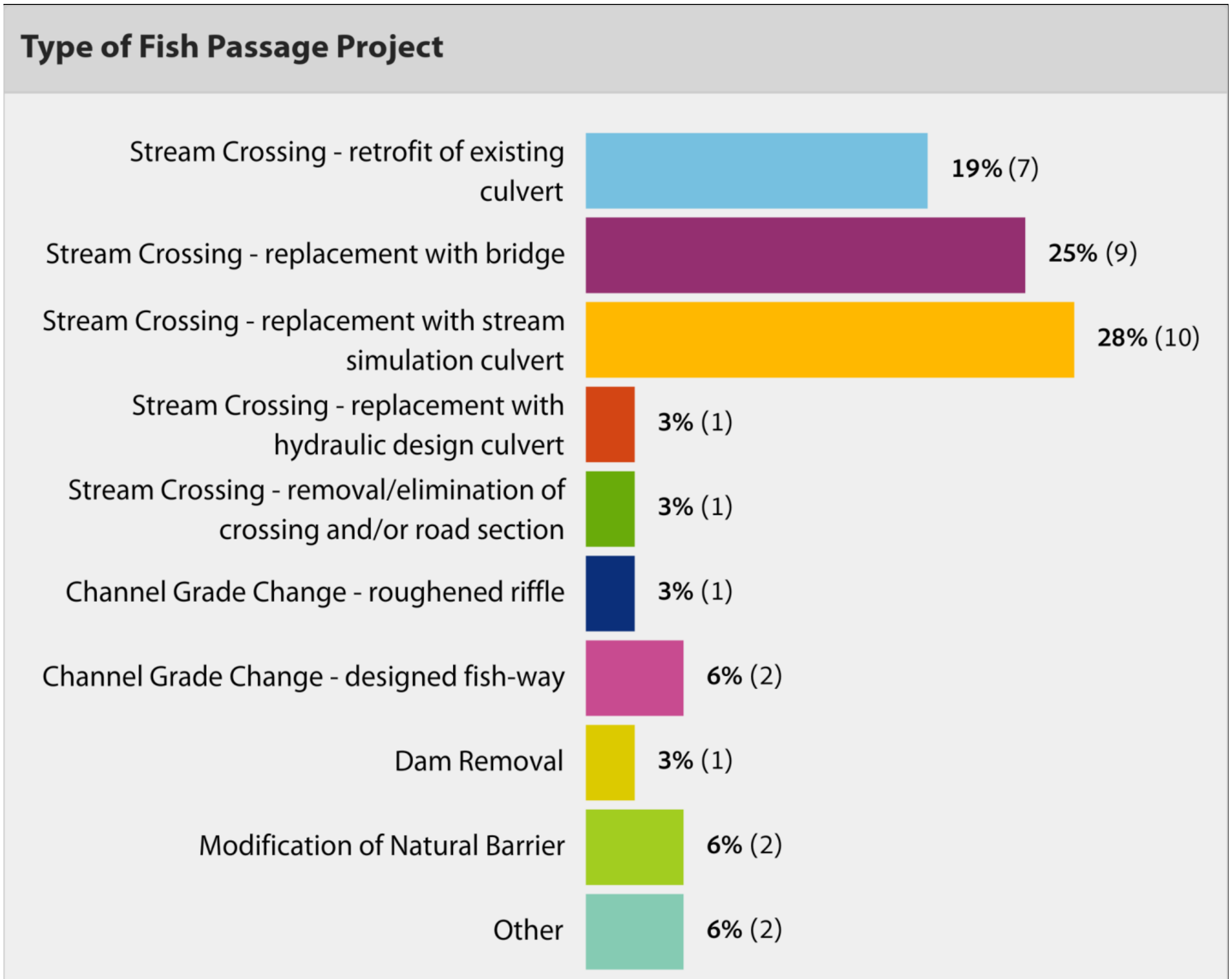

Figure 3. Types of completed fish passage projects.

Most (69% or 25 projects) monitoring occurred at the project location and within the adjacent stream channel. At the remaining 11 projects, monitoring occurred only at the fish passage project site.

Pre-project and post-project monitoring was conducted for 28 of the 36 projects; for the remaining eight projects, only post-project monitoring was conducted. Photo point documentation was the most common form of pre-project physical monitoring, and juvenile fish presence/absence was the most common form of pre-project biological monitoring (Figure 3). Pre-project channel longitudinal surveys were conducted at 17 projects, and at 10 of these sites, cross-sections were also established and surveyed (Figure 3). Pre-project pebble counts only occurred at two projects; one was associated with a small dam removal and the other was a culvert replacement with a bridge. After presence-absence sampling, juvenile fish distribution surveys were the second-most common form of pre-project biological monitoring (15 projects), followed by adult spawner surveys at seven projects (Figure 3). Pre-project out-migrant trapping was employed at one project (Figure 3). At one site, "other" pre-project monitoring included streamflow measurements and passage evaluation with hydraulic modeling software other than FishXing because the site was not a culvert (Figure 3).

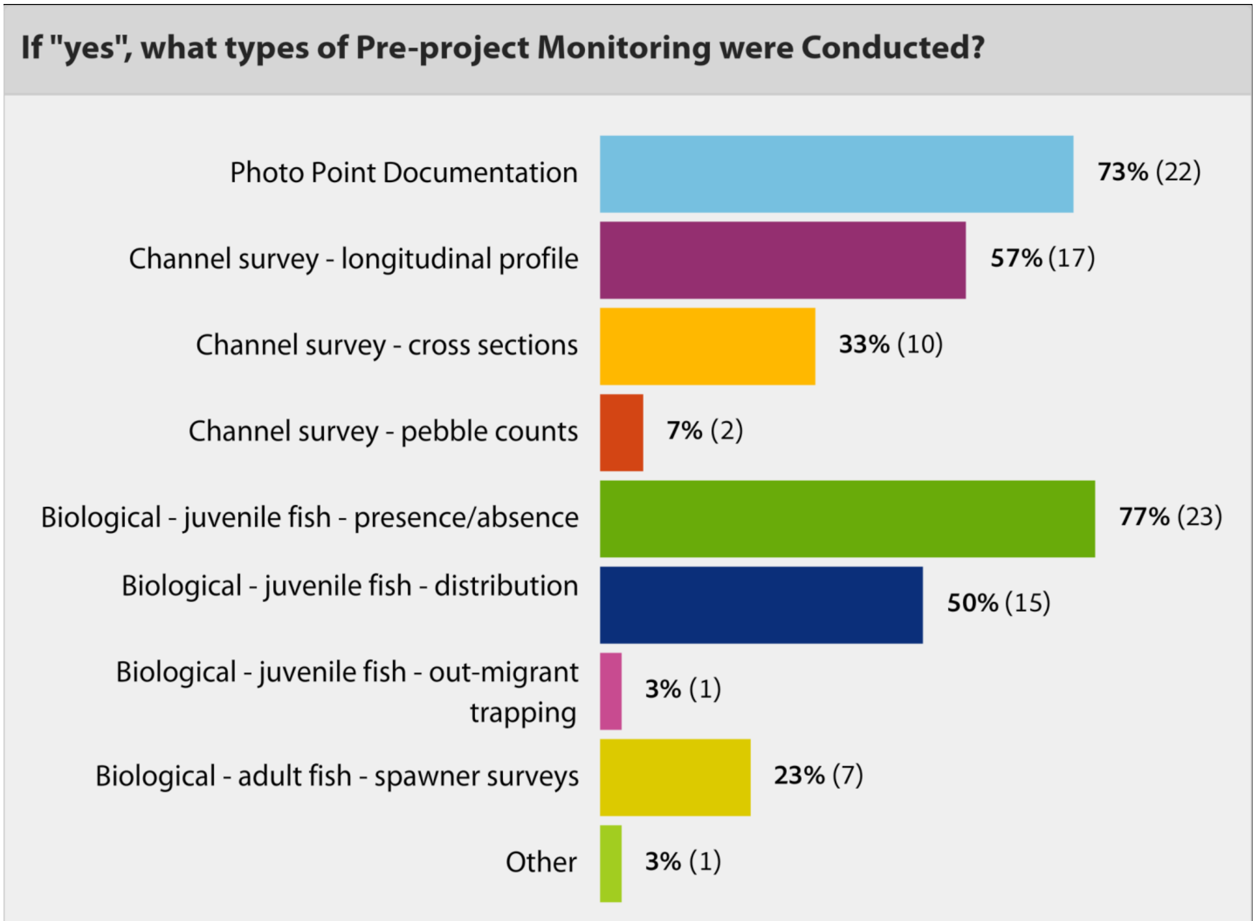

Figure 4. Types of pre-project monitoring conducted at 36 fish passage projects.

Photo point documentation was the most common form of post-project physical monitoring; however, fewer sites were photo documented post-project than pre-project (Figure 4). Juvenile fish presence/absence was the most common form of post-project biological monitoring (Figure 4). Santa Cruz County selected “other” for all nine of their projects, and further questioning revealed that they were conducting juvenile salmonid density estimates in stream reaches below and above completed fish passage projects (Figure 4). Post-project channel longitudinal surveys were conducted at 14 projects, three fewer sites than during pre-project monitoring (Figure 4). Post-project channel cross sections were monitored at the same 10 sites where pre-project data were collected (Figure 4). Post-project pebble counts only occurred at the small dam removal project located in Mendocino County. Post-project juvenile fish distribution surveys occurred at eight project sites, far less than the 15 reported during pre-project monitoring (Figure 4). This discrepancy was due to Santa Cruz County selecting “juvenile distribution” for pre-project and selecting “other” during the post-project sections of the online questionnaire. Pre-project out-migrant trapping was employed at one project (Figure 3). At one site, “other” pre-project monitoring included streamflow measurements and passage evaluation with hydraulic modeling software other than FishXing because the site was not a culvert (Figure 3).

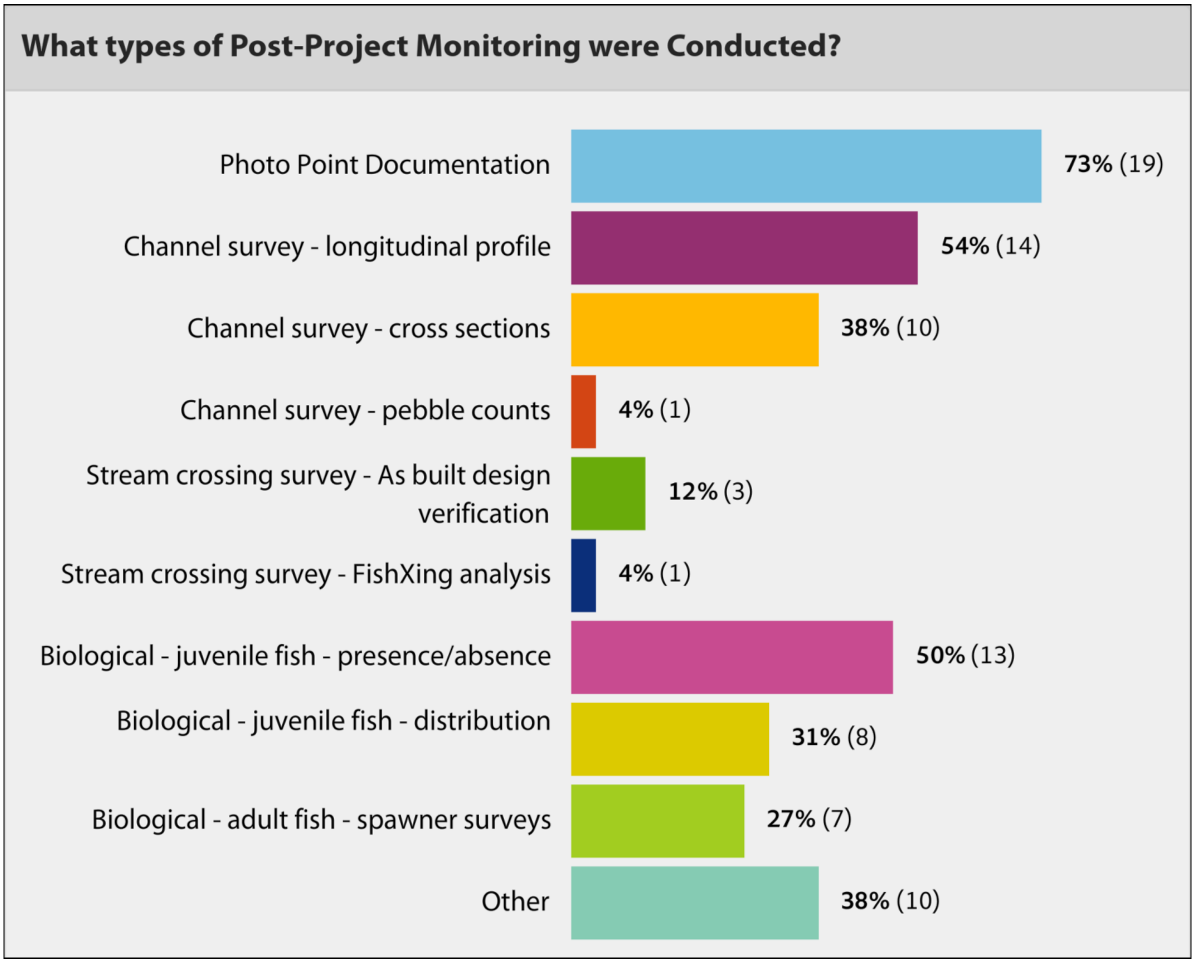

Figure 5. Types of post-project monitoring conducted at 36 fish passage projects.

Respondents to the questionnaire employed a range of methods to conduct their fish passage monitoring, with several methods or protocols cited frequently. The following bulleted list summarizes these commonly utilized methods or protocols.

<u>Channel/cross section surveys and pebble counts:</u>

- Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field techniques. USFS General Technical Report RM-245. 61 pp.

- Harris, R.R. 2005. Monitoring the effectiveness of culvert fish passage restoration. CDFG Salmon and Steelhead Restoration Account Agreement # P0210566: 28 pp.

- Kocher, S.D. and Harris, R.R. 2005. Qualitative monitoring of fisheries habitat restoration. University of California, Center for Forestry, Berkeley, CA. 166 pp.

Streamflow Measurements:

- Woodward, M.E. 2013. Standard operating procedure for discharge measurements in wadeable Streams in California, CDFW-IFP-002. 24 pp.

Adult Salmonid Spawner Surveys:

- Duffy, W.G. 2006. Protocols for monitoring the response of anadromous salmon and steelhead to watershed restoration in California. CDFG, Salmon and Steelhead Trout Restoration Account, Agreement #P0210565. 92 pp.

- Flosi, G., S. Downie, M. Bird, R. Coey and B. Collins. 2002. California salmonid stream habitat restoration manual, Volume II. Native Anadromous Fish and Watershed Branch, CDFG, Sacramento, California. Part IV: Fish Sampling Methods.

Juvenile Salmonid Surveys:

- Duffy, W.G. 2006. Protocols for monitoring the response of anadromous salmon and steelhead to watershed restoration in California. CDFG, Salmon and Steelhead Trout Restoration Account, Agreement #P0210565. 92 pp.

- Flosi, G., S. Downie, M. Bird, R. Coey and B. Collins. 2002. California salmonid stream habitat restoration manual, Volume II. Native Anadromous Fish and Watershed Branch, CDFG, Sacramento, California. Part IV: Fish Sampling Methods.

- Lockwood, R. N., and J. C. Schneider. 2000. Stream fish population estimates by mark-and-recapture and depletion methods. Chapter 7 *in* Schneider, James C. (ed.) 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

- Zippin, C. 1956. The removal method of population estimation. Journal of Wildlife Management 22:82–90.

Investigation of Fish Passage Monitoring Methods and Protocols

To complete this task, a literature search was conducted to gather published fish passage monitoring methods and protocols. The literature review also focused on peer-reviewed journal articles regarding the monitoring of barrier removals, specifically the methods and results sections.

Annotated Bibliography: Fish Passage Monitoring – Protocols and Methodologies

Allibone, R. 2000. Fish population and fish passage monitoring for Orokonui Creek, Otago. *Conservation Advisory Science Notes #304*, Department of Conservation, Wellington, New Zealand. 8 pp.

Allibone (2000) presented a proposed monitoring method to assess a gabion weir to be installed to block the migration of non-native brown trout into a small stream that supports native New Zealand fish species. The intention of the project was that fry of diadromous species would be able to migrate upstream through the interstitial spaces of the rocks within the gabion, but the gabion would block upstream movement of larger brown trout. Pre-project electrofishing was proposed to determine species composition above and below proposed gabion location and to remove brown trout from the stream. Post-project monitoring was to include electrofishing to mark downstream fry (with dye), assess movement of dyed fry upstream and to continue removal of upstream brown trout. This paper provided no results.

Armstrong, G.S., M.W. Aprahamian, G.A. Fewings, P.J. Gough, N.A. Reader and P.V. Varallo. 2010. Environment Agency fish pass manual: guidance on the legislation, selection and approval of fish passes in England and Wales. Almondsbury, Bristol, UK. 369 pp.

Armstrong et al (2010) is primarily a policy and design manual with 10 pages devoted to the monitoring of fish passage projects. The monitoring section provides a brief overview, not a set of methods that one could utilize and repeat. The general recommendations include (1) measuring depths and velocities within "fish passes" to compare with known fish swimming abilities and (2) a list of field methods for determining the efficiency of passage and acceptable duration of delayed passage. The monitoring section includes a graph that describes the cumulative effects of multiple, partial barriers within a watershed.

Two fish passage policies described in this manual are less rigorous than current California Department of Fish and Wildlife (CDFW), or NOAA guidelines.

"On an existing structure, the criteria to be fulfilled are lower than for new structures, as any improvement in potential access to the river upstream is desirable. As long as fish are witnessed to pass over or through the structure then it is evident that the fish pass has made a difference."

"The work on the Pau River showed that highly efficient passes in terms of both proportion of fish passing and short delay were associated with delay periods of less than two weeks."

Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton and D. Wells. 2007. Stream barrier removal monitoring guide. Gulf of Maine Council on the Marine Environment. 85 pp.

The Gulf of Maine Council on the Marine Environment (GOMC) River Restoration Monitoring Steering Committee developed the Stream Barrier Removal Monitoring Guide to improve the ability to (1) evaluate the performance of individual restoration projects, (2) assess the long-term ecological response of regional restoration efforts, (3) advance the understanding of restoration ecology and improve restoration techniques, (4) better anticipate the effects of future stream barrier removal projects, and (5) communicate project results to stakeholders and the public. Small, run-of-river, low-elevation dams (< 20 feet tall) are the primary focus of the Monitoring Guide because nearly 5,000 dams have been officially registered in the U.S. portion of the Gulf of Maine watershed (also includes portions of Nova Scotia, New Brunswick, and Quebec). Barriers at road culverts are mentioned secondarily throughout the document.

The Steering Committee convened a Stream Barrier Removal Monitoring Workshop to gather input on barrier removal monitoring from more than 70 natural resource scientists, managers and watershed restoration practitioners. Structured breakout and plenary sessions generated priority lists of monitoring parameters specific to stream barrier removal in the Gulf of Maine watershed. From the prioritized lists, the Steering Committee selected eight parameters that, when analyzed collectively, were expected to provide valuable data that would characterize adequately the physical, chemical and biological response of a given stream to a barrier removal project. These eight parameters, referred to as *critical monitoring parameters*, include (1) monumented cross-sections; (2) longitudinal stream profile; (3) stream bed sediment grain size distribution; (4) photo stations; (5) water quality; (6) riparian plant community structure; (7) macroinvertebrates; and (8) fish passage assessment (Figure 5). The Monitoring Guide presents detailed methods for each of the critical monitoring parameters except for macroinvertebrate and fish passage assessment. Because of the considerable variability associated with assessing these biological parameters, only general guidance was provided. For the first six parameters, the Monitoring Guide includes: a purpose statement, equipment list, step-by-step data collection methods, sampling frequency, site-specific considerations, and data management and analyses. In addition to the cross-section-based spatial and temporal monitoring framework, the Monitoring Guide employs a Before-After (BA) study design that requires an assessment of pre-project and post-project conditions (Kocher and Harris 2005).

For critical monitoring parameters #1 and #2, the basic channel survey methods reference Harrelson et al. (1994). Monumented cross-sections are distributed among three channel reaches: above the project area's influence, within the project area and downstream of the project area. Most of the remaining critical parameters are then measured at each cross-section. For example, pebble counts are made at each cross-section, not longitudinally as often performed. The upper channel reach is considered the "reference reach" and should be at least 10 channel widths in length. Riparian monitoring methods appear more relevant to dam removal projects in which vegetation communities adjacent to impounded water are expected to change post-removal. Fisheries monitoring section only lists general methods and citations.

Parameter	Variables	Description	Monitoring Design	Sampling Frequency
Monumented cross-sections	Elevations and distances	Cross-section geometry measured at permanently monumented transects. Horizontal distances recorded to tenths of feet (0.1 ft) and elevations to hundredths of feet (0.01 ft).	The number and location of cross-sections will depend on site-specific conditions. At a minimum, cross-sections should be established immediately upstream and downstream of the barrier, at bridges, in the impoundment, and upstream of the impoundment influence. Permanent geo-referenced monuments must be established at cross-section endpoints.	Monitoring should be conducted in the year preceding barrier removal. In the case of impoundments, pre-removal assessments should be coordinated with drawdown. Resurveys should occur annually or every other year for at least five years.
Longitudinal profile	Elevations and distances	Longitudinal profile measured in conjunction with monumented cross-sections. Horizontal distances recorded to the tenths of feet (0.1 ft) and elevations to hundredths of feet (0.01 ft).	Take elevation readings along the thalweg at important bed features, measuring distances using the baseline. In addition to distances and elevations, note details of features being measured and water-surface elevations at each bed-elevation measurement.	Longitudinal profiles should be resurveyed at the same frequency as the cross-section surveys.
Grain size distribution	Distributions of sediment size classes	Streambed surface grain size distributions characterized by collecting and analyzing sediment samples at monumented cross-sections.	In cross-sections dominated by fine sediments, each sample point should contain 1 liter of surface sediments for laboratory analysis. In cross-sections dominated by gravel, a pebble count should be performed.	Grain size sampling should be conducted at the same frequency as the cross-section surveys, during wading-depth stream conditions.
Photo stations	N/A	Repeat photographs capture a variety of ecosystem conditions and visually document stream response.	Photo stations should be described as distances or bearings from other known points such as cross-section endpoints or other permanent landmarks.	Photo-monitoring should include both leaf out and full vegetation in the year preceding restoration. Post-restoration photo monitoring is recommended for years 1, 2, and 5.
Water quality	Temperature	Precision: +/- 0.2°C. Accuracy: +/- 0.2°C	Select a minimum of three monumented cross-sections to evaluate water quality: upstream of the impoundment influence; deepest part of impoundment; and immediately downstream of the barrier. Properly record site information, including GPS coordinates, for purposes of resurveying. Prepare, test, and calibrate equipment. Collect and record water-quality data and site information.	Monitoring should occur one year prior to removal and annually thereafter for five years. All data should be collected weekly for eight weeks during August and September. If macroinvertebrate data are not being collected, water-quality data should be collected weekly from June through October or through continuous monitoring.
	Dissolved oxygen	Precision: +/- 2% or 0.2 mg/L, whichever is greater. Accuracy: +/- 2% of initial calibration saturation or 0.2 mg/L, whichever is greater		
	Conductivity	Precision: +/- 5%. Accuracy: +/- 5% against a standard solution		
Riparian plant community structure	Herbaceous layer	Using 1-m^2 (10.8 ft^2) quadrat, identify each species, record species percent cover and number of stems for all non-woody and all emergent species less than 3 ft (0.9 m) tall. Identify floating or submerged plants.	Monitor plant community at permanent sampling plots established within the restoration site and within an unaltered upstream reference site. Select three transects at each site, perpendicular to the streambank. Establish three permanent sampling plots along each transect according to vegetation types: herbaceous layer, shrub/sapling layer, and tree layer.	Vegetation monitoring is conducted best during the peak of the vascular plant growing season. In the northeastern U.S., this period is generally between July 15 and August 31. Vegetation monitoring should include a minimum of one year of pre-restoration and three years of post-restoration sampling. Preferably, post-restoration monitoring is conducted over a longer period, such as once every 3 to 5 years.
	Shrub and sapling layer	Within a 5-m (16.4 ft) radius, identify species and record percent cover of all woody stemmed plants with height 3–20 ft (0.9–6.1 m) and DBH 0.4–5.0 inches (1–12.7 cm). Note number of dead standing shrubs.		
	Tree layer	Within a 9-m (29.5 ft) radius, identify species and calculate basal area of each woody plant with height greater than 20 ft (6.1 m) and DBH greater than 5 inches (12.7 cm). Note number of dead standing trees.		
Macro-invertebrates	Recommend that project proponents work with regulatory jurisdictional authorities to develop a monitoring plan for macroinvertebrates. Please see Section IV.B.7 for additional guidance.			
Fish passage	Recommend that project proponents work with regulatory jurisdictional authorities to develop a monitoring plan for fish passage. Please see Section IV.B.8 for guidance.			

Table 1. Summary of the critical monitoring parameters (Figure 2 in the Stream Barrier Removal Monitoring Guide).

Crawford, B.A. 2011. Protocol for monitoring effectiveness of fish passage projects (culverts, bridges, fishways, log jams, dam removal, debris removal). Washington Salmon Recovery Funding Board, MC-1. 36 pp.

This protocol was developed to monitor the effectiveness of fish passage projects primarily in Washington and Oregon, with emphasis on culverts at road crossings. The protocol employs a before-and-after control impact (BACI) experimental design to test for changes associated with barrier removal (Stewart-Oaten et al. 1986). A BACI design samples the control and impact at both locations at designated times before and after the impact has occurred. For this type of restoration, barrier removal would be the impact, a location below the barrier would represent the control, and a location upstream of the barrier would represent the impact, that is, the location impacted by the project. Data are collected at year-0 (pre-project) and years-1, 2 and 5 (post-project). Data collection methods are presented for three "response indicators": evaluating barrier/passability of project structures, layout of control and impact channel reaches (above and below project structures) and monitoring of biological responses (juvenile electrofishing, juvenile snorkeling, and adult spawner surveys).

For fish abundance, the BACI design tests for changes upstream of the barrier removal *relative to* the abundance observed at the control reach downstream. This type of design is required when external factors (e.g., ocean conditions and harvesting) affect the population abundances at the control reach. The objective is to determine whether the difference between upstream and downstream abundances have changed as a result of the barrier removal project. A paired *t*-test will be used to test for differences between control (downstream) and impact (upstream) sites during the most recent impact year and Year 0. In other words, first compute the difference between the control and impact and use those values in a paired *t*-test. This test assumes that differences between the control and impact reaches are only affected by barrier removal and that external influences affect population abundance in the same way at both the control and impact reaches. To implement the design, at least 10 fish passage projects should be monitored. The number of projects proposed for monitoring in each category is based upon the calculated sample size needed to obtain statistically significant trend information in the shortest amount of time.

Decision criteria were developed by Crawford to determine "project success." Engineered design is considered effective if fish passage and design criteria are met for 80% of the structures on Year 5 (i.e., no statistical test). Effective means that the project must have a percent passability greater than 80% to be rated as "Yes." Fish passage is considered effective if a statistically significant change is detected for salmon abundance of either adults, redds, or juveniles between the calculated difference (Impact minus Control (current) as compared to Impact minus Control (baseline)) by Year 5 at the Alpha = 0.10 level for those targeted salmon and trout species present. Additionally, the actual amount of change is compared to the baseline value in the impact reach to determine if the change is biologically significant. Twenty percent change from the baseline was selected as a benchmark for biological significance.

The barrier evaluation uses a checklist that follows WA design guidelines (Bates and Whiley 2000, Bates et al. 2003). The checklist is "*Family Forest Fish Passage Program: Barrier Evaluation Forms*" (DNR 2005). The forms consist of measuring specific parameters based on engineering criteria, which assists in determining if the engineered solution is effective at providing fish passage. The layout of control (downstream) and impact (upstream) channel reaches is based on previously developed protocols (Kauffman et al. 1999, Peck et al. 2003, Mebane et al. 2003). One stream reach immediately upstream of the project in suitable spawning and rearing habitat is identified and sampled according to identified methods for each of the projects. The assumption is that fish colonizing new habitat will colonize the area nearest the barrier first. A paired control reach immediately downstream of each project site should be selected in the same manner as the impact reach for each of the projects. Control and impact reaches are 20 times the mean bankfull channel width (or at least 150 meters in length).

The monitoring of juvenile salmonid densities via electrofishing is based on Zippin (1956), Hankin (1984) and Hankin and Reeves (1988). The monitoring of juvenile salmonid densities via snorkel counts is based on Thurow (1994) and Rogers (2002). This protocol fails to recommend which juvenile sampling method is preferred, or when one should be selected.

The monitoring of adult spawner abundance is based on Jacobs and Nickelson (1999) and Hahn et al. (2001). It seems that these surveys are only conducted within the control and impact reaches. " . . . the estimates of adult spawner abundance and/or redd counts pre- and post-project will allow the investigator to determine whether there has been an increase in the abundance of spawners post treatment and to ascertain whether the project was effective in allowing more adult fish to spawn. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These impact reaches have been matched with control reaches of the same length and size on the same stream whenever possible in order to produce a BACI experimental design".

The Crawford (2011) protocol concludes with a section regarding summary statistics in which the following variables are to be reported: reach lengths, reach widths (average wetted width), GPS coordinates (at each cross-section along the control and impact reaches), sampling dates, juvenile fish densities (# of fish/m^2), spawner densities (# of fish/km), redd densities (# of redds/km) and fish passage design (reported as "yes" or "no"). This section also includes examples using hypothetical data sets.

<u>RTA Comments:</u>

This protocol's reach selection seems inappropriate for fisheries sampling by limiting sampling to two very short reaches. If a project is opening-up several thousand feet (or more) of spawning and rearing habitat, why would you limit sampling to no more than 300–500 feet of channel? The protocol assumes that there is suitable spawning habitat adjacent to project, but what if none exists? This protocol also cites numerous references that are missing in its References Cited section.

Duffy, W.G. 2006. Protocols for monitoring the response of anadromous salmon and steelhead to watershed restoration in California. CDFG, Salmon and Steelhead Trout Restoration Account, Agreement #P0210565. 92 pp.

This protocol is focused on validation monitoring to evaluate the biological response to watershed restoration projects. The introduction defines three types of monitoring: implementation, effectiveness and validation.

- Implementation monitoring is monitoring to document the fulfillment of contract obligations, or compliance with regulations or laws.
- Effectiveness monitoring is used to document trends in resource condition following a management action and is most often associated with physical or chemical processes and habitats.
- Validation monitoring is monitoring to document the response of biota to restoration actions and, ideally, establishes cause-and-effect relationships between restoration actions and biota (ONRC 2000).

The time required documenting pre-restoration condition, or change after restoration, varies with the species being monitored, the biological measure being used and number of replicate samples. In general terms, documenting pre-restoration condition for most fish response measures will require one or more years of sampling whereas documenting post-restoration change will require multiple years.

Duffy (2006) presents recommendations for validation monitoring protocols intended to detect responses of coho salmon and steelhead trout to watershed restoration actions. The question guiding selection of protocols was: what measurements are both practical and sensitive enough to detect a response by salmon and steelhead trout to restoration actions? The assumption inherent in this question is that salmon and steelhead trout will respond to watershed restoration actions. Protocols recommended in this report are not comprehensive. Rather, protocol selection was guided by the watershed restoration program goal of restoring salmon and steelhead trout, with consideration of the varied types of restoration actions.

The protocol presents methods for five categories of biological response monitoring: (1) juvenile salmonid abundance or population size, (2) relative weights of juvenile coho salmon and steelhead, (3) smolt production, (4) age distribution of steelhead, and (5) estimating escapement of adult salmon and steelhead. For each method, Duffy (2006) provides detailed information on: rationale, assumptions, limitations, sampling design, methods, data analysis, quality assurance and control, and personnel and equipment required.

Juvenile salmonid abundance is expressed as the number of fish per unit area (density), or number of fish caught per unit of effort (CPUE). Population size is an estimate of the number of fish present within a geographic area. Methods employed are electrofishing and snorkeling and are limited to use in small streams with adequate visibility. The design of a sampling program to estimate fish abundance incorporates random selection of sampling sites. The recommended design is systematic random sample selection, stratified by habitat type. Systematic random sample selection is relatively simple, as are the calculations required to estimate either abundance or population size. This sampling design may be applied to stream reaches, sub-watersheds, or smaller watersheds. Habitat units are classified as pools, deep pools (depth >1.1 meters), riffles, or runs/glides. For abundance estimates, the length and average wetted width is required for each habitat unit. Duffy (2006) provides methods for calibrating visual estimates of habitat area. The protocol recommends sample rates for juvenile coho salmon at 25% of all pools and runs/glides and 10% of the riffles and generally follows Hankin and Reeves (1988) visual snorkel counts calibrated with limited electrofishing (depletions). Duffy (2006) provides step-by-step examples of statistical analysis of data consistent with Hankin and Reeves (1988), data forms and NOAA (2001) guidelines for electrofishing listed salmonids.

The section on using the relative weight of juvenile salmonids to evaluate the biological response to habitat improvement seems more relevant to restoration projects intended to improve rearing habitat; not necessarily fish passage improvements. This method also requires anesthetizing and handling of sampled fish to collect accurate weight and length measurements.

The salmon and steelhead smolt production section describes methods for out-migrant trapping and estimating trapping efficiencies. Out-migrant trapping locations should be selected on the basis of answering a question. In the context of monitoring watershed restoration actions, a reasonable question might be; *Have restoration projects within a sub-watershed resulted in greater numbers of smolts migrating from the sub-watershed*? Locating a smolt trap as near as the sub-watershed outlet as is practical would provide the best opportunity to answer this question. Smolt trapping is labor intensive and annually requires operating a trap between late-February and mid-June to assess the period when smolts are migrating.

The section on age distribution of juvenile steelhead is based on the rationale that using age as a measure for detecting a response to watershed restoration assumes that growth should be slower under poor habitat conditions than under good conditions. With slower growth, more time will be required to reach the critical size for smolting, resulting in fish being older at the time of smolting. Extending this assumption, growth would hasten as restoration actions improve habitat conditions until age at smolting is eventually reduced. This method may not be applicable for monitoring barrier removal projects because growth is more likely influenced by restoration projects that either reduce turbidity or summer water temperature regimes.

The adult salmon and steelhead section provides detailed methods consistent with CFDW. Duffy (2006) is based on surveyors walking stream channels counting live fish, carcasses and redds; carcasses and redds were marked or flagged. Depending on the length of channel to survey, either the entire reach is walked, or sub-sections are selected from a sampling framework based on the entire reach divided into strata.

Harris, R.R. 2005. Monitoring the effectiveness of culvert fish passage restoration. CDFG Salmon and Steelhead Restoration Account Agreement # P0210566: 28 pp.

This report, developed for CDFW, describes effectiveness monitoring methods focused on measurements of physical channel conditions above, below and through a stream crossing. The objective of monitoring fish passage restoration effectiveness is to determine whether and for how long the treatment has improved upstream and downstream habitat connectivity for targeted species of salmon and trout. This requires evaluating any structures as well as channel conditions above and below the project area. Harris (2005) recommends that pre-project, as built, and post-implementation project data should be available before effectiveness monitoring is initiated. The first step in effectiveness monitoring is to gather previously collected project data. This includes data on location, pre-project conditions, design specifications, as built conditions and implementation monitoring. This report also provides a concise summary table of monitoring questions, criteria, parameters and methods (Figure 6).

<u>Field Method #1 - Thalweg profiles</u>

The thalweg profile should be at least 20 active channel widths, upstream and downstream of crossing, measured with a total station to 0.01 foot accuracy. General survey methods cited as Harrelson et al. (1994). Establish benchmarks, capture all habitat breaks, such as pool tailwater controls and riffle crests. Also capture maximum depths of pools and runs. Record water depths at each survey point location. At stream crossing, survey points at inlet and outlet. Include elevations of any associated grade-control structures.

<u>Field Method #2 - Cross-sections</u>

At each stream crossing location, establish three cross-sections minimum: at inlet, outlet and tailwater control. Cross-sections at inlet and outlet will assess scour, deposition and bed stability. The tailwater cross-section can be used to assess stability (or changes) in the stream crossing's hydraulic control. General survey methods cited as Harrelson et al. (1994). This method recommends surveying elevations at the top of endpoint markers, the ground at endpoints, the tops of banks, breaks in slope, the toe of each bank, vegetation lines, the water edge, the thalweg elevation, the bed at structure inlets and outlet, and note when in line with the edges of structure inlets and outlets.

<u>Field Method #3 - Stream Velocity/Discharge Measurements</u>

The goal of this field method is to quantify an average velocity and high velocities through a passage area between resting habitats. These velocities would be compared with the swimming abilities of the targeted species and life stages. Velocity measurements should be taken during ordinary migration flows for the targeted population. Consult local fisheries biologists for migration flow information or for using annual exceedance flows to estimate migration flows. Critical measurements include just inside the inlet and outlet of the passageway. If the passage is large enough and wadeable, the number of cross-sections is determined by the culvert length.

One cross-section at the inlet, outlet and center of the passage is the minimum. The more readings taken along the length of the culvert, the more detailed will be the definition of the longitudinal variation in velocity. If the passage is not wadeable, take readings by extending the wading rod into the passage inlet and outlet. For each velocity cross-section, calculate the average velocity and note the high and low velocities (*Average Velocity = Sum of Each Cell Velocity ÷ Number of Cells*). Using longitudinal profile horizontal stationing, plot the high, low and average velocities. Display this data on a graph with the longitudinal profile. High, low and average velocities can then be compared to the swimming abilities of the targeted species and life stages to evaluate the passage restoration performance.

Field Method #4 - Habitat Typing

Habitat typing is used to characterize the quality of upstream habitat made accessible by the passage improvement. Sequential habitat typing may be used to determine if any changes have occurred due to the project e.g., upstream deposition or scouring. It should be done using the method provided in *Monitoring Effectiveness of Instream Habitat Restoration*.

MONITORING QUESTION	EFFECTIVENESS CRITERIA	PARAMETERS	FIELD METHODS
1. Is the project still functioning as designed?		Fish passage restoration project is within DFG passage guidelines.	
a. Is there still a sufficient jump pool depth for targeted species and life stages?	Residual pool depth at downstream outlet (if culvert outlet is perched or has entry leap).	If there is a jump, pool depth is appropriate for leap height. (Not required for no entry leap)	Field Method 1: Thalweg Profile Through Culverts plus water depths
b. Are leap heights still within jumping ability for targeted species and life stages?	Leap height (residual pool water surface elevation to passage outlet.)	Leap height is below critical heights for targeted species and life stage. (Not applicable for no entry leap.)	Field Method 1: Thalweg Profile Through Culverts.
c. Is stream velocity in critical flow areas still within the swimming ability of the target species and life stages?	Stream velocity	Stream velocity is equal to or less than swimming ability of target species and lifestage.	Field Method 3: Stream Velocity/Discharge Measurements[1]
d. Is upstream inlet of the passage area/ structure still at grade or below the channel bed?	Bed elevation at inlet and inlet elevation	Difference between natural channel bed and inlet is 0.	Field Method 1: Thalweg Profile Through Culverts
e. Is the passage area/ structure still at grade?	Slope	Passage structure is at specific designed slope or the slope relative to the natural channel.	Field Method 1: Thalweg Profile Through Culverts
f. Can sediment bed load still pass through the restored area?	Slope (top riffle to opening), active channel width, hydraulic capacity	Passage inlet shows no signs of clogging or deposition.	Field Method 1: Thalweg Profile Through Culverts, Field Method 2: Cross-section Surveys
g. Can the structure pass 100-year flows and debris?	Hydraulic capacity	Passage passes 100-year flows and watershed products.[2]	Field Method 2: Cross-section Surveys
h. Does the passage project shows signs of imminent failure?	Structural integrity	Structure shows no signs of collapsing.	Field Method 1: Thalweg Profile Through Culverts, Field Method 2: Cross-section Surveys
2. Have channel or bank adjustments impaired the function of the passageway?	Slope, head-cutting, sediment deposition	Channel adjustments have not impaired passage or habitat values.	Field Method 1: Thalweg Profile Through Culverts
3. Did the project have adverse effects on upstream or downstream habitat?	Bank erosion, channel incision / head-cutting, debris accumulation or sediment deposition.	Passage project has not adversely affected up and downstream habitat.	Field Method 1: Thalweg Profile Through Culverts. Field Method 2: Cross-section Surveys
4. Is upstream habitat still suitable for the targeted fish species and life stages?	Habitat types and quality in upstream reaches.	Area is still suitable for targeted species and life stages.	Habitat Monitoring *See Monitoring the Effectiveness of Instream Habitat Restoration*

Table 2. Monitoring questions, parameters, effectiveness criteria, and field methods (Harris 2005).

Kocher, S.D. and Harris, R.R. 2005. Qualitative monitoring of fisheries habitat restoration. University of California, Center for Forestry, Berkeley, CA. 166 pp.

These field methods were developed to provide a systematic approach for monitoring the implementation and effectiveness of Fisheries Restoration Grant Program (FRGP) projects. They include methods for collecting qualitative information to be used by CDFW for rating project performance. Information is collected prior to implementation (pre-treatment), after project completion (implementation) and at one or more future times (effectiveness). An assessment immediately after project completion permits evaluation of whether or not the project complied with design and contract specifications (implementation monitoring). Effectiveness monitoring is accomplished by comparisons of pre-treatment conditions to conditions after effects and performance have manifested. This approach consists of a series of pre-treatment, implementation and effectiveness checklists. The checklists are to be completed in the field, and based on systematic observations. Implementation monitoring is recommended for all projects. Pretreatment and effectiveness monitoring may be applied to approximately 10% percent of all completed projects using random sampling. The intent was for CDFW contract managers, dedicated FRGP staff, and/or professional consultants to conduct the monitoring.

The fish passage project field methods and checklists are located on pages 30–40 of Kocher and Harris (2005). Effectiveness of fish passage projects is judged based on their success at affecting habitat accessibility and the absence of unforeseen adverse effects on habitat, such as channel incision, instability, or excessive sedimentation caused by the project. Short-term effectiveness monitoring should occur during periods of fish migration, typically at highest flows, after at least one winter has passed. The pre-treatment monitoring checklist requires identification of the current passage problem and barrier category (temporal, partial, or complete) as well as the specific goals of the project including: facilitating/impeding fish passage, targeted fish species, targeted life stage, improving movement of watershed products and changing channel and bank conditions.

The implementation monitoring centers on the contract implementer's adherence to contract provisions. Checklist evaluation includes:

- Structure location, position, and alignment;
- Structure materials and condition
- Increased/decreased accessibility of habitat to fish;
- Length of habitat with affected accessibility; and
- Presence of any remaining passage barriers.

Effectiveness monitoring consists of evaluating whether the project reached the goals identified in the pre-treatment checklist. This is facilitated by collection of the same basic information about the site as collected during the pre-treatment phase. This allows evaluation of:

- Structure condition and position;
- Increased/decreased accessibility of habitat to fish of targeted species and age;
- Presence of any remaining passage barriers;

- Condition of banks and channels in the vicinity of the structure before and after implementation; and
- Improved movement of watershed products downstream through the project area.

Checklists also allow recording of fish observations during monitoring visits.

Note: CDFW's monitoring of projects completed with FRGP funding uses revised checklists, which have replaced the ones in Kocher and Harris (2005). The revised CDFW checklists are presented in Appendix B.

O'Neal, J., and R. Scranton. 2014. BPA-MBACI protocol for monitoring the effectiveness of partial barrier projects. Bonneville Power Administration. 54 pp.

This document details the monitoring design, procedures and quality assurance steps necessary to document and report the effectiveness of Partial Barrier Projects at the project site scale. This document supports the Bonneville Power Administration's (BPA) programmatic approach to project level Action Effectiveness Monitoring (AEM), as documented in "Action Effectiveness Monitoring of Tributary Habitat Improvement: A programmatic approach for the BPA Fish and Wildlife Program." This is based on the Washington Salmon Recovery Funding Board (SRFB) protocol, *Monitoring Effectiveness of Fish Passage Projects*, and the Columbia Habitat Monitoring Program.

This protocol details the monitoring procedures and methods necessary to document and report the reach-scale effectiveness of fish passage projects. Projects designed to restore fish passage that can be monitored using this protocol include actions, such as bridge projects, culvert improvements, dam removals, debris removals, diversion dam passage, fishway construction and weirs.

Questions to be answered:

- Does the project reflect the design and requirements in the permit and/or funding application?
- Has the engineered fish passage project continued to meet fish passage and design criteria post-project for at least five years?
- Has the fish passage project demonstrated upstream presence of target species (by life stage) post-project within five years?

Protocol Objectives are to determine whether:

- The design and information in the permit and/or funding application for fish passage are being met post-implementation (Years 1, 2 and 5).
- Both adult and juvenile salmonid densities in an impact reach upstream of the fish barrier are increasing relative to the densities in the downstream control reach (Year -1, 0, 1, 2 and 5).
- Fish passage design criteria are being met at each project monitored (Years 1, 2 and 5).

O’Neal and Scranton (2014) describe how this protocol uses a Multiple Before and After Control Impact (MBACI) experimental design to test for changes associated with restoring partial fish passage barriers. The MBACI design samples control and impact reaches simultaneously at designated times before and after treatments at several projects have occurred. For this type of restoration, improving or removing a partial fish passage barrier would be the treatment, that is, the location treated by the restoration action, and a location downstream of the project would represent the control. This type of design is required when external factors (e.g., local watershed characteristics) affect the fish returns at treatment sites. The object is to assess whether the difference between control and impact fish use has changed as a result of the restoration projects. Note that for this project category, the control is located downstream because the purpose of the project is to allow passage of fish upstream. Therefore, it is necessary to assess whether fish are accessing upstream habitat in the impact reach. For partial barriers, the MBACI design tests for changes in juvenile and adult fish use upstream of the barrier structure relative to fish densities in the control reach downstream.

O’Neal and Scranton (2014) then provide detailed, step-by-step, field methods on how to:

- Determine project reach lengths (20 times bankfull width).
- Determine the effectiveness of fish passage structures by re-surveying the new crossing to make sure it still meets passage criteria of focal species and age classes.
- Establishment and reoccupation of project photo points.
- Characterizing the stream morphology and habitat using a modified thalweg profile. This is based on Harrelson et al. (1994) survey methods.
- Estimating instream abundance of juvenile salmonids using snorkeling – methodology is adapted from O’Neal (2007).
- Estimating instream abundance of juvenile salmonids using electrofishing – based on multiple-pass removals and using Zippin (1956) to generate estimates.
- Estimating adult spawner abundance –adopted from Nickelson (1998); Hahn et al. (2001); Jacobs and Nickelson (1999).

O’Neal and Scranton (2014) also provide information regarding summary statistics, data analysis, metrics and indicators. What seems to be missing from this protocol is guidance on how to determine if, or when, significant changes are detected in the MBACI protocol. For example, the biological indicators are simply listed as:

- Changes in Fish Density - Fish - Density of Fish Species - Fish Life Stage: Juvenile Fish
- Changes in Fish Density - Fish - Density of Fish Species - Fish Life Stage: Adult Spawner
- Changes in Fish Density - Fish - Density of Fish Species - Fish Life Stage: Carcass
- Changes in Redd Density - Fish - Density of Fish Species - Redd

RTA Comments:

O'Neal and Scranton (2014) failed to provide the "how to" steps to interpret the before-and-after data to determine when these changes in fish or redd densities above and below a treated barrier constituted a significant response. How big a change is significant? In how many of the three post-project sample years does a change need to occur? Why would one not conduct annual spawner surveys for five straight seasons? It seems valuable spawner data might be missed in years 3 and 4, especially if these are good "water-years". Another reason to conduct annual spawner surveys is to better track project response for species such as coho salmon that have three distinct cohorts, and some California watersheds have cohorts of varying viability, or in several instances, missing cohorts.

Pess, G., J. Drake, P. Roni and T. Beechie. 2013. Characterizing stream morphology and habitat characteristics using a modified thalweg profile for full barrier removal projects. NOAA Fisheries, Northwest Fisheries Science Center. 8 pp.

This brief paper describes the methods required to conduct a longitudinal survey of a channel's thalweg through a barrier removal project area. As with several of the previously reviewed methods and protocols, Pess et al. (2013) defaults back to Harrelson et al. (1994) when describing basic channel surveying techniques.

The paper provides step-by-step directions in completing a thalweg profile survey. Treatment reaches will be upstream of the former full barrier, whereas control reaches will be downstream of the former full barrier. Both reaches should be of equal length, 10–20 times the average bankfull width, but at least 50 meters in length.

Pess et al. (2013) list the following metrics that can be calculated from the longitudinal profiles:

1) the total number of pools
2) the proportion in residual pool (Madej 1999; Mossop and Bradford 2006)
3) the maximum residual pool depth
4) the average maximum residual pool depth
5) the variance in maximum residual pool depth
6) longitudinal "mean square error," and
7) the frequency of pools in the form of the number of channel widths per pool (Montgomery et al. 1995)

"Total Number of pools" is defined as the number of depressions in the thalweg profile that have a control both at the head and tail and include a maximum depth greater than the head and tail. "Residual pool depth" represents the depth of a pool that would theoretically remain if there were no flow in the stream (Lisle 1987). As a survey precaution, one should apply a minimum residual depth criterion of ≥0.1 m to the total number of pools and the proportion in residual pool to ensure that residual depths reflect major morphological features and not small irregular features in the streambed. Further, it is assumed that juvenile salmonids in the sampled reaches will be most abundant in habitat units >0.25 m deep (Mossop and Bradford 2006), which will be equivalent to pools and glides with residual depths greater than ~0.1 m.

“Proportion in residual pool” (Lisle 1987) is expressed as the proportion of the reach length in residual pools, calculated as the total length of the entire reach in residual pools divided by the surveyed reach length. This is equivalent to “percent pool” calculated with other methods (Montgomery et al. 1995). “Average maximum residual pool depth” is an index of pool quality, as the average of the maximum residual pool depths in a reach. “Variance in maximum residual pool depth” is a variation index (Madej 1999), which serves as an index of variation within pools that is calculated as the standard deviation of the population of residual depths in a reach. Higher variation index values will indicate more variable morphology within residual pools. “Number of channels widths per pool” is a measure of pool frequency that has been associated with both juvenile and adult fish use (Montgomery et al. 1999; Pess et al. 2011).

Annotated Bibliography: Fish Passage Monitoring – Peer Reviewed Research

Burroughs, B.A., D.B. Hayes, K.D. Klomp, J.F. Hassen and J. Mistak. 2010. The effects of Stronach Dam removal on fish in the Pine River, Manistee County, Michigan. Transactions of the American Fisheries Society 139:1595–1613.

Burroughs et al. (2010) documented the response of the fish community in Pine Creek, Michigan to the gradual removal of Stronach Dam. Ten sites were sampled during the course of dam removal (1997–2003) and for four years following removal (2004–2007). Pine Creek has a drainage area of 265 square miles and is a tributary of the Manistee River. Stronach Dam, built in 1911–12, was located 3.3 miles upstream of the Manistee confluence and had no fish passage facilities. Sediment filled the upstream reservoir, and in 1953, the dam was decommissioned for power generation. A staged removal was selected to meter accumulated sediment to the downstream channel; this process encompassed a seven-year period. Fish sampling was conducted with boat electrofishing equipment at 10 sites (four upstream of impoundment, four within impounded reach and two downstream of the dam). Sites were blocked with nets and multiple-pass depletions were conducted to generate population estimates for five species of fish. Indices of relative abundance were generated for other fish species. Pre-project, 11 species were found only downstream of the dam, one species only upstream of the dam and 19 species were captured both above and below the dam. Post-removal, eight species formerly found only below the dam were captured in the upstream reaches. Most fish species (18 of 25 species) showed increases in abundance following dam removal, strongly supporting the idea that dam removal reduces multiple factors limiting riverine fishes beyond passage.

Duck Creek Associates. 2009. Evaluation of fish passage improvement projects in the South Coast and Rogue River basins. Oregon Watershed Enhancement Board. 326 pp.

In 2009, Duck Creek Associates was contracted by the Oregon Watershed Enhancement Board (OWEB) to evaluate various fish passage enhancement projects carried out from 1992 to 2001 in the Southwest Region of Oregon. Duck Creek conducted field assessments at 64 of these project sites. The two primary objectives of this study were to determine if fish passage improvement projects provide adequate passage for salmonids and if juvenile salmonids utilize the habitat above the passage improvement projects. Snorkeling was conducted in the first 330 meters upstream of each culvert to determine juvenile fish presence. FishXing was used to evaluate the crossings to determine if passage criteria were being met at each project site that had a culvert. Snorkel results found juvenile salmonids upstream of most of the sites, and reaches with no fish were generally considered to be poor habitat (too steep or dry). FishXing results indicated that 16 of 42 culverts (or 38%) were 100% impassable by juveniles. Of the 16 rated as impassable, all were velocity barriers, three were combined velocity/outlet drop barriers, and three were rated as velocity/depth barriers. The remaining 26 culverts were considered to be passable through varying percentages of modeled flows.

Franklin, A.E., A. Haro, T. Castro-Santos and J. Noreika. 2012. Evaluation of nature-like and technical fishways for the passage of alewives at two coastal streams in New England. Transactions of the American Fisheries Society 141:624–637.

Franklin et al. (2012) compared and evaluated passage of adult alewives through two nature-like and three technical fishways in various rivers in New England using Passive Integrative Transponder (PIT) tag telemetry. A perturbation boulder rock ramp (32 m long; 4.2% slope) constructed in Town Brook (Plymouth, Massachusetts) passed 94% of the fish that made passage attempts, with most fish ascending the ramp in less than 22 minutes. In the East River (Guilford, Connecticut), a step-pool bypass design (48 m long; 7.1% slope) passed only 40% of attempting fish, with a median transit time of 75 minutes. In Town Brook, a technical pool-and-weir fishway (14 m long; 14.3% slope) exhibited poor entry and poor passage for the fish. In contrast, in the East River, two technical steep-pass fishways (3 m long; 29.6% and 9.6% slopes) passed the majority of available fish, although one of these steep-pass fishways may have lacked sufficient flow to attract fish to the entrance. In both Town Brook and the East River, tagged fish passed rapidly downstream through all fishways after spawning. In the East River, the amount of time fish spent in the spawning habitat before migrating downstream ranged from 1 to 41 days. These studies demonstrate that some nature-like and technical fishway designs can effectively facilitate passage of alewives, but a fishway's location in relation to a spillway is important, and further evaluations are required to more precisely identify the influence of the vertical drop per pool and the specific local hydraulics on alewife behaviors and passage performance.

Grote, A.B., M.M. Bailey and J.D. Zydlewski. 2014. Movements and demography of spawning American shad in the Penobscot River, Maine, prior to dam removal. Transactions of the American Fisheries Society 143:552–563.

Grote et al. (2014) conducted a baseline study to better understand the migratory movements, age and spawning histories of American shad in the Penobscot River prior to a major dam removal project. The study's four objectives were to:

(1) Describe American shad movements and use of accessible freshwater habitat;
(2) Determine the frequency and duration of approaches to lowermost dam (Veazie Dam);
(3) Characterize age and spawning histories; and
(4) investigate post-spawning behavior and survival during seaward migration.

Radio telemetry (70 fish) and acoustic telemetry (14 fish) were used to investigate movement of shad during two years, 2010 and 2011. Scale analysis was used to determine age and spawning history. Fish were tagged 1–5 km below Veazie Dam, and less than 10% of the tagged fish were detected at the dam. Between 85–90% of study fish initially moved downstream after tagging. Freshwater residency averaged nine days post-tagging and survival rates back to were high (>70%), suggesting a high rate of repeat spawners. Age-class structure was consistent to previous work in other Northeast rivers.

Haro, A. and B. Kynard. 1997. Video evaluation of passage efficiency of American shad and sea lamprey in a modified Ice Harbor fishway. North American Journal of Fisheries Management 17: 981–987.

Haro and Kynard (1997) monitored the movement and behavior of American shad and sea lamprey via closed-circuit video at several locations within a modified Ice Harbor fishway associated with the Cabot Fishway on the Connecticut River (at Turner Falls at river km 198). The fishway was modified in 1982 because the original fishway had a poor passage efficiency of American shad. The modifications included blocking alternate weirs and partially blocking orifices to reduce pool turbulence and improve flow characteristics over surface weirs. The study's objectives included: (1) identify primary routes of passage (surface weirs or submerged orifices); (2) characterize diel patterns of movement; and (3) compare efficiency of movement at two points in the Cabot fishway. American shad were observed only using the weirs, never the submerged orifices. There was no significant difference between the rate of upstream movement of sea lampreys through the surface weirs or submerged orifices. Upstream movement of American shad was greater during day than night, and lampreys moved more frequently at night. Passage efficiencies were still very low through the modified fishway due to excessive velocities, turbulence and air entrainment.

Hitt, N.P., S. Eyler and J.E.B. Wofford. 2012. Dam removal increases American eel abundance in distant headwater streams. Transactions of the American Fisheries Society 141:1171–1179.

Hitt et al. (2012) evaluated American eel abundance in headwater streams of Shenandoah National Park, Virginia, by comparing sites before and after removal of a large downstream dam (Embrey Dam) on the Rappahannock River. The authors used a 15-year data set to evaluate temporal trends in eel abundance, biomass and body size in tributaries located 118 to 150 km upstream of the dam removal location. Depending on sample site location, these data sets included between five and eight years of pre-project data. Three-pass electrofishing depletions within 100 m reaches were used to evaluate fish communities. Pooled weights and total lengths were recorded for captured American eels. Effects of dam removal were evaluated with time-series analysis, non-parametric and parametric statistical tests. Results showed mean eel abundances increased from 1.6 to 3.9 eels/100 m post-dam removal, and these increases exceeded modeled predictions. The time-series analysis observed a four-year lag time in increased abundance within the tributaries upstream of Embrey Dam. The average minimum lengths of eels decreased from 545 mm to 368 mm, and numerous eels <300 mm were present after dam removal, suggesting that Embrey Dam had blocked passage of smaller bodied individuals. This study demonstrated that dams can influence American eel abundance in distant headwater streams.

Hogg, R., S.M. Coghlan and J. Zydlewski. 2013. Anadromous sea lampreys recolonize a Maine coastal river tributary after dam removal. Transactions of the American Fisheries Society 142:1381–1394.

Hogg et al. (2013) used PIT technology to monitor the recolonization of habitat by sea lampreys in the Sedgeunkedunk Stream, a third-order tributary to the Penobscot River in Maine. During spawning runs of 2008–2011 (before and after dam removal), individuals were marked with PIT tags, and their activity was tracked with daily recapture surveys. Open-population mark recapture models indicated a four-fold increase in the annual abundance of spawning-phase sea Lampreys, with estimates rising from 59±4 (_*N*± SE) before dam removal (2008) to 223±18 and 242±16 after dam removal (2010 and 2011, respectively). Accompanying the marked increase in annual abundance was a greater than four-fold increase in nesting sites: the number of nests increased from 31 in 2008 to 128 and 131 in 2010 and 2011, respectively. During the initial recolonization event (i.e., in 2010), sea Lampreys took six days to move past the former dam site and nine days to expand into the furthest upstream reaches. Conversely, during the 2011 spawning run, sea Lampreys took only three days to penetrate into the upstream reaches, thus suggesting a potential positive feedback in which larval recruitment into the system may have attracted adult spawners via conspecific pheromone cues. Although more research is needed to verify the migratory pheromone hypothesis, our study clearly demonstrates that small-stream dam removal in coastal river systems has the potential to enhance recovery of declining anadromous fish populations.

Hogg, R., S.M. Coghlan, J. Zydlewski and C. Gardner. 2015. Fish community response to a small-stream dam removal in a Maine coastal river tributary. Transactions of the American Fisheries Society 144:467–479.

Hogg et al. (2015) used a modified bBACI study to monitor the recolonization of native fishes after the removal of the Mill Dam of Sedgeunkedunk Stream in 2009. Electrofishing at fixed treatment and reference sites was started in 2007 and was conducted twice yearly. Results indicated that density, biomass and diversity of the fish assemblage increased at all treatment sites upstream of the 2009 dam removal. No distinct changes in these metrics occurred at reference sites. The biological monitoring documented recolonization and successful reproduction of Atlantic salmon, alewife and sea lamprey in previously inaccessible upstream reaches. These results clearly demonstrated that dam removal enhanced the fish assemblage by providing an undisrupted stream gradient linking a small headwater lake and tributary with a large coastal river, its estuary, and the Atlantic Ocean.

Kiraly, I.A, S.M. Coghlan, J. Zydlewski and D. Hayes. 2014. Comparison of two sampling designs for fish assemblage assessment in a large river. Transactions of the American Fisheries Society 143:508–518.

Kiraly et al. (2014) compared the efficiency of stratified random and fixed-station sampling designs to characterize fish assemblages in anticipation of dam removal on the Penobscot River, the largest river in Maine. Boat electrofishing methods were used in both sampling designs. Multiple 500-m transects were selected randomly and electrofished in each of nine strata within the stratified random sampling design. Within the fixed-station design, up to 11 transects (1,000 m in length) were electrofished, all of which had been sampled previously. In total, 88 km of shoreline were electrofished during summer and fall in 2010 and 2011, and 45,874 individuals of 34 fish species were captured. Species accumulation and dissimilarity curve analyses indicated that all sampling effort, other than fall 2011 under the fixed-station design, provided repeatable estimates of total species richness and proportional abundances. Overall, the two sampling designs were similar in precision and efficiency for sampling fish assemblages. Given the results from sampling in the Penobscot River, Kiraly et al. (2014) concluded that the stratified random design was preferable to the fixed-station design due to less potential for bias caused by varying sampling effort, such as what occurred in the fall 2011 fixed-station sample or due to purposeful site selection.

Martens, K.D., and P.J. Connolly. 2010. Effectiveness of a redesigned water diversion using rock vortex weirs to enhance longitudinal connectivity for small salmonids. North American Journal of Fisheries Management 30:1544–1552.

Martens and Connolly (2010) evaluated the passage of juvenile steelhead (85 mm to 240 mm in length) over rock vortex weirs in Beaver Creek, a tributary to the lower Methow River in Washington. At four locations, dam-style diversions were replaced with a series of rock vortex weirs designed to allow fish passage, but still maintain ability to divert water into diversion canals. The four dams were replaced with weirs between 2000 and 2004, and passage evaluations occurred between 2004 and 2007. Passage was evaluated with the use of PIT tags and antenna arrays. Passage time through the series of vortex weirs was compared to a nearby control reach of natural channel. Pre-project electrofishing also evaluated species diversity above and below the diversions. In addition to documenting successful juvenile steelhead passage, three new fish species (Chinook salmon, juvenile coho salmon and mountain whitefish) were observed in upstream reaches during post-project sampling, indicating successful restoration of longitudinal connectivity. Passage delays (weirs versus control reach) were only detected at very low flows.

McLaughlin, R.L., E.R. Smyth, T. Castro-Santos, M.L. Jones, M.A. Koops, T.C. Pratt, and L.A. Velez-Espino. 2012. Unintended consequences and trade-offs of fish passage. Fish and Fisheries 13:1–25.

McLaughlin et al. (2012) synthesized evidence for the unintended consequences and trade-offs associated with the passage of fishes, primarily at fishways at dams and dam removals. The synthesis consisted of three parts. The first part examined the unintended effects associated with fishways and dam removal, the literature evidence for them and areas where additional research is needed. The second part demonstrated how these unintended effects can create trade-offs for fishery managers, between different environmental concerns and between different species of conservation concern or recreational or commercial value, with significant environmental and economic consequences. The third part briefly introduced structured approaches that can be used to explicitly evaluate the benefits and costs, and corresponding trade-offs, associated with fish passage and dam removal decisions. Unintended consequences included: passage delays, fallback, ecological traps, selective passage, species interactions at dam site or fishway entrance, unwanted introductions above the dam site, and incomplete or unintended restoration outcomes. A recent appeal to remove the dam on the Black Sturgeon River on the Canadian (north) shore of Lake Superior was provided as an example of unwanted effects and trade-offs from fish passage and dam removal, which can create difficult challenges for resource managers. This example involves sea lamprey, a parasitic invader in the Great Lakes, walleye, a species of interest to commercial and recreational fishers, and lake sturgeon and northern brook lamprey (species recommended for listing as threatened and special concern). McLaughlin et al. (2012) concluded that for some river systems, decisions about how to manage fish passage involve substantial risks. As a result, the use of a formal, structured process could inform a transparent, objective and, where possible, quantitative evaluation of these risks. Such a process can also facilitate the design of an adaptive framework that provides valuable insights into future decisions.

Negrea, C., D.E. Thompson, S.D. Juhnke, D.S. Fryer and F.J. Loge. 2014. Automated detection and tracking of adult Pacific lampreys in underwater video collected at Snake and Columbia River fishways. North American Journal of Fisheries Management 34: 111–118.

Negrea et al. (2014) designed, implemented and tested a computerized system for processing underwater video clips captured by static cameras and removing “quiet” frames in which no activity is detected. When the system detected activity, it tracked and counted the moving object. The implementation used an adaptive background-subtraction algorithm for detection and motion prediction for tracking. The system was developed to reduce the amount of video that must be reviewed by personnel, and to produce total fish passage counts through the monitored area. The automated system reduced the total number of video hours requiring review by an average of 87.5% for count window videos and 83.5% for videos of picketed leads and lamprey passage orifices. The software detected 98.6% of the 144 Pacific lampreys that were observed in 185 hours of raw video. Because the system was fully automated, monitoring requirements were negligible, and the cost reduction for fish monitoring was proportional to the number of quiet frames removed.

Noonan, M.J., J.W. Grant, and C.D. Jackson. 2012. A quantitative assessment of fish passage efficiency. Fish and Fisheries 13: 450–464.

Noonan et al. (2012) reviewed 65 articles written between 1960 and 2011 that addressed fish passage efficiency of various species of fish, mostly within fishways constructed at dams. On average, downstream passage efficiency was 68%, higher than upstream passage efficiency of 42%, and efficiency did not differ across the geographical regions of study. Salmonids were more successful than non-salmonids in passing upstream (62% vs. 21%) and downstream (75% vs. 40%) through fish passage facilities. Passage efficiency differed significantly between types of fishways; pool and weir, pool and slot and natural fishways had the highest efficiencies, whereas Denil and fish locks/elevators had the lowest. Upstream passage efficiency decreased significantly with fishway slope, but increased with fishway length and water velocity. The overall conclusion was that the low efficiency of passage facilities indicated that most need to be improved to sufficiently mitigate habitat fragmentation for the complete fish community across a range of environmental conditions.

Price, D.M., T. Quinn and R.J. Barnard. 2010. Fish passage effectiveness of recently constructed road crossing culverts in the Puget Sound region of Washington State. North American Journal of Fisheries Management 30: 1110–1125.

Price et al. (2010) evaluated passage conditions at 110 sites that had been permitted under Washington's hydraulic project approval (HPA) process required for construction of new culverts at road crossings. They used a stratified random sampling design to select 30–50 HPA permits issued in 1998, 2003 and 2007. The field evaluations at the 110 sites were conducted by a geomorphologist and two biologists. Each site was evaluated using the Washington Department of Fish and Wildlife (WDFW) fish passage assessment methodology and barrier standard, the legal standard for the state since 1994. The barrier standard is based on the swimming and leaping capabilities of six-inch long trout, thus a culvert designated as a "barrier" may not block all fish attempting to pass a particular site. Results of the evaluations determined that 30% of the new culvert installations were still barriers, as legally defined by the 1994 barrier standard. Although not statistically different, the older installations tended to have slightly higher barrier proportions than the newer culverts installations. The "no-slope" design had the greatest percentage of failure (45%) to meet the barrier standard. Most failures were attributed to noncompliance with permit provisions, particularly culvert slope, and a lack of critical evaluation of proposed plans in the context of site-specific conditions by permitting biologists.

Raabe, J.K., and J.E. Hightower. 2014. Assessing distribution of migratory fishes and connectivity following complete and partial dam removals in a North Carolina river. North American Journal of Fisheries Management 34: 955–969.

Raabe and Hightower (2014) assessed the movement of migratory fishes between 2008 and 2010 and surveyed available habitat in the Little River, North Carolina, a tributary to the Neuse River, after three complete dam removals and one partial (notched) dam removal. Migratory fishes were tagged with PIT tags at a resistance-board weir located at a dam removal site (river kilometer 3.7) and their movements were followed with an array of PIT antennas. The river-wide distribution of fishes following the dam removals varied by species. For example, 24–31% of anadromous American shad, 45–49% of resident gizzard shad and 4–11% of nonnative flathead Catfish passed the dam removal site at river kilometer 56 in 2009 and 2010. No pre-removal data were available for comparison, but reach connectivity seemed to increase as tagged individuals passed former dam sites and certain individuals moved extensively in both directions (upstream and downstream). Gizzard shad required the deepest water to pass this notched structure, followed by American shad, and then flathead catfish. Fish that passed the notched dam accessed more complex habitat (e.g., available substrate size-classes) in the middle and upper reaches of Little River. Apparent migratory impediments and delays at the notched dam suggested that partial removal was less effective than the complete dam removals. The results provide strong support for efforts to restore currently inaccessible habitat through complete removal of derelict dams.

Roegner, G.C., E.W. Dawley, M. Russell, A. Whiting and D.J. Teel. 2010. Juvenile salmonid use of reconnected tidal freshwater wetlands in Grays River, lower Columbia River basin. Transactions of the American Fisheries Society 139:1211–1232.

Roegner et al. (2010) measured hydrologic changes that resulted from the removal of tide gates from diked pastureland and determined the subsequent time series of salmonid abundance and size frequency in the restoring marshes located in the Grays River, a tributary to the lower Columbia River. Dike breaching caused an immediate return of full semidiurnal tidal fluctuations to the pasturelands. Seine nets and fyke nets were used for sampling juvenile salmonids. Juvenile Pacific salmonids quickly expanded into this newly available habitat and used prey items that were presumably produced within the marshes. Threespine sticklebacks dominated the fish sampling and accounted for nearly 94% of the captured fish. The authors concluded that full restoration of sites like Kandoll Farm and Johnson Farm from cattle pastures to tidal swamps will take decades at a minimum. However, reconnection of these sites to tidal inundation allowed an immediate increase in the opportunity for juvenile salmonids of several species and life history types to access productive wetland habitat.

Sheppard, J. and S. Block. 2013. Monitoring response of diadromous populations to fish passage improvements on a Massachusetts coastal stream. Journal of Environmental Science and Engineering A-2:71–79.

Sheppard and Block (2013) assessed fish passage over one technical fishway and two nature-like fishways on the Acushnet River in Massachusetts. The fish species of interest were river herring (alewife and blueback herring) and juvenile American eel (elvers). The Acushnet River has a drainage area of 18.8 square miles and approximately 42 miles of total stream length. Fisheries monitoring occurred between 2005 and 2011 (seven years). Two years of baseline (pre-construction) data were collected in 2005–2007, which included a passive video recording weir for river herring at the upper end of tidal influence (below the three barriers). Catch per unit effort (CPUE) scores were generated for the trapping of elves. Post-construction trapping monitored river herring and elver returns during April–June for five years. Results documented improved passage at all three fishways and during the 4th post-construction season, river herring counts had increased more than tenfold pre-construction baseline counts. This data indicated that higher numbers of age-0 elvers were present in the upper watershed post-construction.

Weigel, D.E., P.J Connolly, K.D. Martens and M.S. Powell. 2013. Colonization of steelhead in a natal stream after barrier removal. Transactions of the American Fisheries Society 142:920–930.

Weigel et al. (2013) used a before-after experimental design to follow the process of colonization of steelhead and fluvial rainbow trout in Beaver Creek, a tributary to the lower Methow River in Washington. Juvenile fish were collected by electrofishing and PIT tagged at six monitoring sites (below, within and above six barriers). Adult steelhead and fluvial rainbow trout were captured at a picket weir trap for tagging. Three PIT tag antenna detection stations were established. The monitoring program operated for five years, with one-year of pre-treatment data collection. Adult steelhead entered Beaver Creek during the first spawning season post-barrier removal, and parr from the initial brood years also returned to Beaver Creek, indicating that a complete life cycle of steelhead was established. By third and fourth year post treatment, steelhead were in the upper watershed. Pre-treatment PIT tagging also confirmed that resident trout progeny were expressing anadromy.

Welsh, S.A., and J.L. Aldinger. 2014. A semi-automated method for monitoring dam passage of upstream migrant yellow-phase American eels. North American Journal of Fisheries Management 34: 702–709.

Welsh and Aldinger (2014) tested a motion-activated eel ladder camera (ELC) on an eel ladder at Millville Dam on the lower Shenandoah River in West Virginia. Digital images with date and time stamps of each American eel that passed allowed for daily total counts and total length (TL) measurements using photogrammetric methods with digital imaging software. ELC counts and TL measurements were compared with physical trapping counts and measuring board lengths. Results showed ELC counts and TL measurements were consistent with physical collection data. The use of ELC resulted in significant sampling costs, and time-stamped photos allowed for accurate documentation of actual passage time. Other advantages of the ELC included less review time of still photos versus time-lapse video and no loss of count data during turbid conditions because migrating eels were ramped up onto a meshed platform and were photographed above the water level.

Development of Fish Passage Forum Monitoring Methodologies

The California Fish Passage Forum Science and Data Committee requested development of a tiered monitoring approach so that depending on a host of factors (such as available funding or expertise), some level of project monitoring could occur.

Conclusions from the investigation of recently implemented fish passage monitoring included:

- Fish passage project monitoring is important to the success of future projects. Pre-project information was also widely acknowledged as imperative to a comprehensive monitoring program.

- The various types of migration barriers and target fish species influence both treatments and monitoring parameters. For example, East Coast and Northeast coast fish passage project monitoring was focused on the modification or removal of dams, and the fish species of interest included herring, alewife, American eel, Atlantic salmon and striped bass. Dam modifications were either engineered fishways or natural-style fish passes. In contrast, Pacific Northwest projects were focused on salmonids with the treatment of road crossings more prominent.

- Many of the peer-reviewed papers were focused on fish passage successes, and documented failures were less common. However, several papers described failures as well as unintended consequences as a result of implementing fish passage projects. Case studies, such as those presented on the FishXing website, that include “lessons learned” sections, are valuable in presenting project challenges and failures.

- Most of the existing fish passage monitoring methods had overlaps and similarities in their approaches to the monitoring performance of fish passage projects. For example, nearly all of the approaches to measuring channel thalweg profiles defaulted back to Harrelson et al. (1994). In California, most respondents to our questionnaire were using methods consistent with CDFW’s methods for conducting spawner surveys and juvenile fish sampling.

- Advances in tagging and video technology have been widely incorporated into monitoring the biological response to fish passage projects. PIT tags and fixed antenna arrays were widely used to track the recolonization of newly accessible habitat as well as determine migration rates through fish passage projects, such as roughened ramps or fishways. Digital videography has allowed for improved fish counts past fixed locations as well as more detailed evaluation of fish behavior in response to various types of submerged weirs, baffles or orifices.

Recommendations: Tier #1 Monitoring Methods

Tier #1 methods should use checklists and photo points to quickly and inexpensively monitor the status of recently completed fish passage projects. The Fish Passage Forum recommends using the NOAA Restoration Center's Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet. This worksheet was developed to collect both pre-implementation and post-implementation information to assess progress towards meeting the Restoration Center's program goals. The checklist is appropriate to be used on a variety of project types, in which the primary goal is to restore natural stream conditions and unrestricted migratory fish passage to upstream habitat. A particular strength of the NOAA worksheet is a basic comparison of the completed "as-built" project to pre-project design specifications and passage criteria. In addition to the "as built" monitoring found in this form, the NOAA Restoration Center also recommends collecting biological data on presence/absence both above and below the barrier and before and after the project. This can be accomplished using spawner surveys or juvenile surveys as described in the Tier II monitoring section below and should occur at least one year prior to the project's implementation and one to three years post project implementation depending on the available monitoring funding.

The NOAA Restoration Center's monitoring worksheet is available online at:
http://www.habitat.noaa.gov/toolkits/restoration_center_toolkits/forms_and_guidance_documents/ori_monitoring_sheet_w_guidance.pdf

When downloaded, the NOAA's Center's Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet contain fields that may be filled-in electronically. However, a copy of the worksheet and guidance materials is also located in Appendix A.

If additional funding is available and additional metrics are desired, CDFW's FRGP has project checklists for the following types of fish passage projects:

- Site Summary – Instream/Fish Passage Implementation Monitoring
- Fish Passage at Stream Crossings – Pre-treatment
- Fish Passage at Stream Crossings – Implementation
- Fish Passage at Stream Crossings – Post-treatment
- Fish Passage at Barriers – Pre-treatment
- Fish Passage at Barriers – Implementation
- Fish Passage at Barriers – Post-treatment
- Stream Crossing Upgrading – Pre-treatment
- Stream Crossing Upgrading – Post-treatment
- Pre-treatment Effectiveness Monitoring Summary
- Post-treatment Effectiveness Monitoring Summary
- Photographic Monitoring Guidelines

When downloaded from CDFW's website, most of the FRGP checklists' data fields may be entered electronically. However, hardcopies of CDFW's checklists are also provided in Appendix B.

Recommendations: Tier #2 Monitoring Methods

Tier #2 methods require resources and expertise beyond the Tier #1 checklists. These methods should allow for the evaluation of the project, the adjacent stream channel and the biological response of target fish species and age classes. Because funding often dictates the extent of a fish passage project's monitoring program, tier #2 methods may have to be prioritized. The Fish Passage Forum recommends that all tier #2 monitoring programs include measurements of the channel profile and cross sections. These measurements allow evaluation of channel adjustments as influenced by the project, as well as provide the measurements needed to assess project performance in meeting passage criteria of target fish species and age classes. If funding is limited, the Forum recommends that monitoring the biological response of completed projects is limited to sites that are confirmed during pre-project assessments as complete migration barriers. The Forum also recommends focusing Tier II efforts on complete/total barriers rather than temporal/partial barriers because fish are often found both below and above partial barriers due to brief flow regimes that provide temporary passage for aquatic organisms. Observing fish above a partial barrier pre project makes it extremely difficult to quantify the effectiveness of barrier removal using these methods, hence the recommendation for Tier II monitoring for only complete/total barriers.

The Fish Passage Forum recommends the use the following methods, which were selected and/or adopted from methods presented earlier in this report.

Channel Profile and Cross Sections

Recommended methods for monitoring channel longitudinal profiles and cross sections associated with fish passage projects draw heavily from previously cited and described methods (Harris 2005, Collins et al. 2007, Pess et al. 2013, O'Neal and Scranton 2014). For basic survey techniques, Harrelson et al. (1994) should be referenced. This method for quantifying stream morphology and habitat characteristics consists of surveying the streambed elevation along the deepest portion of the stream (the thalweg), which yields a two-dimensional, longitudinal profile of streambed elevations (Mossop and Bradford 2006). Depressions in the longitudinal profile represent pools, or deeper habitats, often with low velocities during low flow periods, whereas crests in the longitudinal profile represent riffles (Mossop and Bradford 2006). Thalweg profiles are a useful tool to assess and monitor fish habitat in wadable streams, in part because surveyed thalweg profiles improve the accuracy and precision of channel and pool measurements (Bauer and Ralph 2001, Mossop and Bradford 2006). Thalweg profiles provide quantitative measures of stream channel morphology (i.e., stream channel gradient) and fish habitat (i.e., variation in pool depth), while remaining independent of flow conditions (Lisle 1987, May and Lee 2004, Mossop and Bradford 2006). Longitudinal profiles associated with barrier removal projects accurately quantify changes in channel grade due to head-cutting or aggradation, especially when a perched culvert or low-elevation dam is removed and/or sediment transport processes are restored to the downstream channel reach. A series of post-project channel profiles is also useful for evaluating the stability and longevity of grade control features.

For a given fish passage project, the Forum recommends that channel longitudinal profile and cross-section surveys are performed at these specific intervals:

Pre-project – During the spring or summer prior to implementation of the fish passage project. This survey provides the baseline profile of the stream channel above, below and through the existing barrier as well as baseline cross-sections at key locations.

Post-project – After construction, but prior to the onset of winter rains and elevated streamflows. This “record” survey allows a comparison of the constructed project to the design specifications and fulfills the requirements of implementation monitoring.

Post-project – In subsequent summers after elevated winter flows have passed through the project site and channel adjustments have occurred. Recommend at least two surveys after the first and second winters, but additional surveys should be considered at year-5 or after the project has been subjected to large flow events (peak discharges ≥10-year recurrence intervals).

Channel Profile - Step-by-step Procedures

1. Establish benchmarks that can be re-occupied on subsequent surveys. Use four-foot lengths of rebar driven (at least two feet deep) into stable areas. For each project area, consider establishing at least two benchmarks, one at either end of the monitoring reach. Benchmarks should be established in locations that will not be disturbed during project construction. Cap each rebar and flag locations with surveyor’s tape. Record detailed notes regarding each benchmark’s location. Take photographs of benchmarks.

2. The channel profile should extend for at least 10 to 20 bankfull channel widths, both upstream (treatment reach) and downstream (control reach) of the crossing/project area. Each reach should be at least 50 m (≈165 feet) in length. Depending on project-specific objectives, the channel profile monitoring reach may exceed 20 bankfull channel widths. To determine an average bankfull width, at least five bankfull widths should be measured at stable locations within the vicinity of the project area; however, avoid unnaturally wide areas typically found just upstream of undersized culverts. The bankfull width is the location along the stream banks where the streamflow fills the channel to the top of the banks and water begins to overflow onto the floodplain. If it is difficult to identify the bankfull elevation, refer to Harrelson et al. (1994) or CHaMP (2013) for details. CHaMP section #4 (Locating new sites) includes a table of useful indicators.

3. Once the upper end of the treatment reach and the lower end of the control are identified, mark these locations with surveyor’s flagging and then measure/record each location’s Global Positioning System (GPS) coordinates.

4. A channel profile survey may be conducted with one of the following: (1) total station and prism rod; (2) auto-level, tapes, and stadia rod; or (3) range finder mounted on a mono pod and a target also mounted on a monopod. Refer to general survey methods cited as Harrelson et al. (1994). Pess et al (2013) provides step-by-step instructions for completing the survey with a range finder. Vertical elevations are measured to 0.01 foot accuracy and horizontal distances measured to 0.1 foot accuracy. A two-person crew is typically required to complete a channel profile survey: one operates the total station or scope, and the other handles the prism or stadia rod. The person on the scope or total station also records data or field notes. The rod person determines the channel thalweg points to capture, measures and calls out water depths, and provides information regarding each survey point (such as, “max pool depth”, “tailwater control”, or “culvert inlet invert”).

5. Start and end the longitudinal survey at distinct habitat breaks, such as the downstream end of a riffle, or at the tailwater control of a pool, or a run. Capture all habitat breaks, such as pool tailwater controls and riffle crests. At each point, an elevation of the channel thalweg is measured - the thalweg defined as the flow path of the deepest water in a stream channel. The survey should also capture maximum depths of all pools and runs. If surface flow is present, record water depths at each survey point location. Most channel profile surveys for fish passage monitoring capture elevations for 40 to 100 locations.

6. At the stream crossing, survey elevations at inlet and outlet invert (lowest point). Also include thalweg elevations of any associated grade-control structures located upstream and/or downstream of the crossing. Maximum pool depths in-between grade control structures should also be surveyed.

7. At each project location, at least three cross-sections should be surveyed at the crossing inlet, outlet and downstream tailwater control. Cross-sections at inlet and outlet will assess scour, deposition and bed stability. The tailwater cross-section can be used to assess stability (or changes) in the stream crossing’s hydraulic control. Additional cross-sections may be established throughout the treatment and control reaches.

8. Each cross-section should be monumented with capped and flagged rebar stakes located at the outer edges of the bankfull channel, on both the left-bank and right-bank. This method recommends surveying elevations at the top of endpoint markers, the ground at endpoints, the tops of banks, breaks in slope, the toe of each bank, vegetation lines, the water edge, the thalweg elevation, the bed at structure inlets and outlet, and note when in line with the edges of structure inlets and outlets.

Channel Profile – Data Analysis and Interpretation

Pess et al. (2013) described the following several metrics that can be calculated from the longitudinal profiles: 1) the total number of pools; 2) the proportion in residual pool (Madej 1999; Mossop and Bradford 2006); 3) the maximum residual pool depth; 4) the average maximum residual pool depth; 5) the variance in maximum residual pool depth; 6) longitudinal "mean square error"; and 7) the frequency of pools in the form of the number of channel widths per pool (Montgomery et al. 1995).

"Total Number of pools" is defined as the number of depressions in the thalweg profile that have a control both at the head and tail and include a maximum depth greater than the head and tail. "Residual pool depth" represents the depth of a pool that would theoretically remain if there were no flow in the stream (Lisle 1987). As a survey precaution, one should apply a minimum residual depth criterion of ≥0.1 m to the total number of pools and the proportion in residual pool to ensure that residual depths reflect major morphological features and not small irregular features in the streambed. Further, we suspect that juvenile salmonids in the sampled reaches will be most abundant in habitat units >0.25 m deep (Bradford et al. 2001), which will be equivalent to pools and glides with residual depths greater than ~0.1 m.

"Proportion in residual pool" (Lisle 1987) is expressed as the proportion of the reach length in residual pools, calculated as the total length of the entire reach in residual pools divided by the surveyed reach length. This is equivalent to "percent pool" calculated with other methods (Montgomery et al. 1995). "Average maximum residual pool depth" is an index of pool quality, as the average of the maximum residual pool depths in a reach. "Variance in maximum residual pool depth" is a variation index (Madej 1999), which serves as an index of variation within pools that is calculated as the standard deviation of the population of residual depths in a reach. Higher variation index values will indicate more variable morphology within residual pools. "Number of channels widths per pool" is a measure of pool frequency that has been associated with both juvenile and adult fish use (Montgomery et al. 1999; Pess et al. 2011).

Changes in channel profile between pre-project, record and post-project surveys can be graphically displayed by over-laying the longitudinal profiles on a single graph (Figure 5). These types of overlays allow one to visually inspect extent and magnitude of channel incision as well as determine how quickly it takes the affected channel to achieve a new equilibrium in regards to a stable channel slope and elevation. For example, one of the objectives of the Glenbrook Gulch dam removal project was to have the sediment stored behind the dam redistributed to the downstream reach. Thus, the sediment left behind is depicted by the gray line in Figure 5, and then the three post-project surveys quantify the channel incision through the sediment (Figure 5). Pre-project, the upper limit of the channel incision was predicted to be a large pool upstream of the pond that was formed by a fully-spanning redwood log; again the overlay of the five channel profiles confirmed the extent of the channel incision (Figure 5).

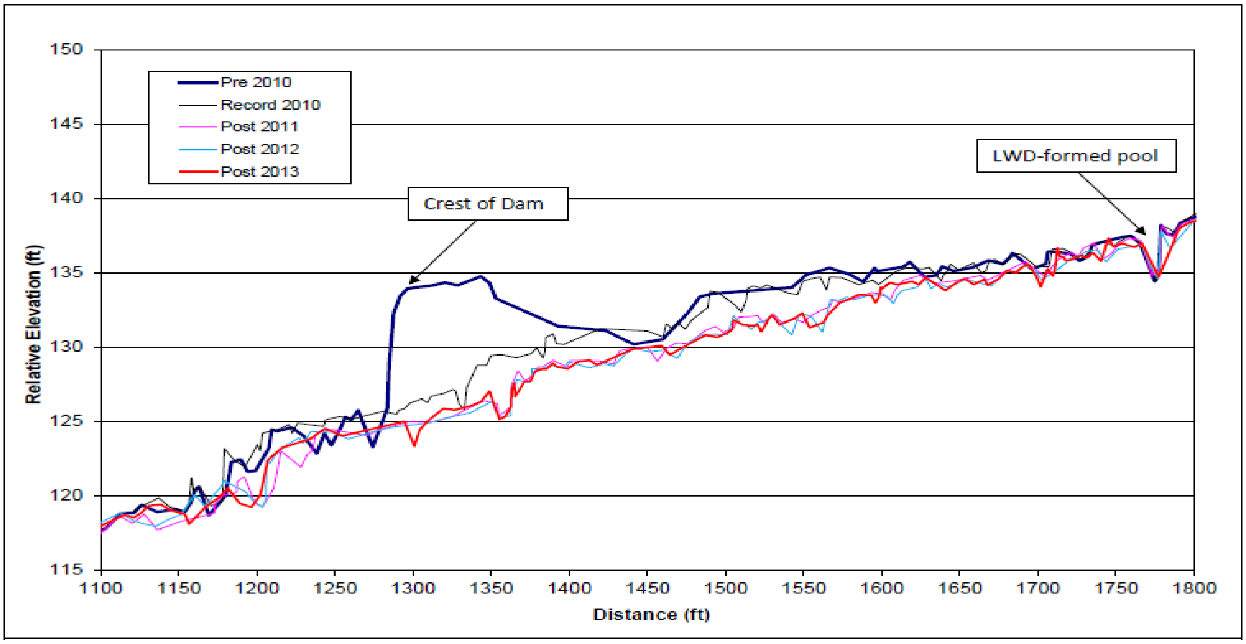

Figure 5. Example of an overlay of five longitudinal channel profiles, Glenbrook Gulch dam removal project in Mendocino County.

Performance of New Crossing

Methods for monitoring the performance of a new stream crossing should focus on whether or not the new structure meets the passage criteria of target fish species and age classes in terms of depths, velocities and leap heights during migration-level streamflows. In California, new stream crossing structures and restoration of fish passage at identified barriers should use design criteria provided in Part XII of the CDFW Restoration Manual (Love and Bates 2009). These designs were recommended by CDFW based on meeting state and federal guidelines for fish passage criteria (CDFG 2003; NOAA 2001).

Projects designed and constructed to criteria in the above-referenced guidance documents are presumed to provide fish passage. Therefore, monitoring of project design upon completion of construction and over time constitutes the most appropriate and measurable effectiveness monitoring. Although detection of fish presence upstream of a project is an indicator that the project is not a barrier to all fish, meeting and maintaining design criteria provides a more stringent requirement for fish passage.

Depending on the project design, methods for monitoring the structure's performance may vary. For example, new installations based on CDFW's hydraulic design option can be resurveyed and evaluated with FishXing to confirm that passage criteria of target fish species and age classes are being met. Embedded culverts and open-bottom arch culverts based on CDFW's stream simulation design option can be evaluated with FishXing, or by comparing slopes, depths and velocities through the new crossing with slopes, depths and velocities within the natural channel.

The following step-by-step instructions include methods adopted and/or modified from Harris (2005), Crawford (2011) and O'Neal and Scranton (2014).

FishXing Performance Monitoring - Step-by-step Procedures

Resurvey the new installation following methods presented in Part IX of CDFW's Restoration Manual. The elevations required to perform a FishXing analysis may also be obtained from the monitoring program's channel longitudinal profile, as long as a tailwater control cross-section was also surveyed.

Using the post-project survey elevations and the new crossing's specifications, evaluate passage of the target fish species and age classes used during the project's design phase. Use the same hydrologic information and passage criteria that were used when the original crossing was evaluated for fish passage. Procedures for using FishXing are provided in Part IX of the CDFW Restoration Manual as well as at the FishXing website in the help files: http://www.fsl.orst.edu/geowater/FX3/help/FX3_Help.html.

An initial evaluation of fish passage criteria should be performed immediately after project completion and prior to the onset of winter rains. This initial evaluation will determine if the project was built as intended. Additional passage criteria evaluations should occur one, two and five years post-project, or after the project has been subjected to large flow events (peak discharges ≥10-year recurrence intervals).

If the completed project meets fish passage criteria for ≥80% of the range of estimated fish passage flows, the project should be considered "in compliance" with providing sufficient passage.

Stream Simulation Performance Monitoring - Step-by-step Procedures

The objective of the stream-simulation design option is to construct a stream crossing that has channel conditions through it that are similar to those that a migrating fish would encounter within the natural channel. Within the natural channel, riffles are often the shallowest and swiftest flowing areas that a migrating fish encounters; thus the comparison of depths and velocities within a stream-simulation designed crossing to depths and velocities within adjacent riffles is an appropriate monitoring tool. Measuring water depths and velocities during migration-level flows should only be conducted when wading conditions are safe – this method should be limited to projects on streams with small drainage areas and relatively low migration flows (for example, Morrison Gulch in Humboldt County, DA = 0.99mi^2 and adult passage flows = 3-48 cfs).

Conduct a site visit to the project area during a suspected migration-level streamflow. Using a flow meter, measure and record the stream discharge.

Within the channel monitoring reaches (the upstream treatment reach and downstream control reach), identify the riffle areas.

Measure the linear lengths of the riffles. Within the riffles, determine the flow path of the thalweg. Following this flow path, measure and record the water depth at 10 locations per riffle. Within the stream-simulation crossing, also determine the flow path of the thalweg and measure/record depths at a minimum of 10 locations. Depending on if English or metric units are used, measure depths in feet to 0.1 foot or to nearest cm.

Compute average riffle depths within natural channel and within the stream crossing. Compare averages using a two-sample t-test.

With the flow meter, measure and record water velocities within the thalweg flow path of the riffles identified within the channel monitoring reaches. Within each riffle, measure the velocity at 10 locations. Velocities should be measured within 0.25 feet of the channel bottom. Within the stream-simulation crossing, also determine the flow path of the thalweg and measure/record velocities at a minimum of 10 locations.

Compute average velocities within natural channel and within the stream crossing. Compare averages using a two-sample t-test.

<u>Biological – Juvenile Fish Abundance</u>

Adopt the juvenile fish abundance methods developed by Duffy (2006) for monitoring the response of anadromous salmon and steelhead to watershed restoration in California. The basic field methods described by Duffy (2006) are similar to those proposed by Crawford (2011) and O'Neal and Scranton (2014); however, these other methods limit the sampling to only the project channel monitoring reaches and/or recommend only sampling juvenile salmonids in post-project years 1, 2 and 5. The Forum recommends sampling at least the minimum number of cohorts associated with the target species. For example, coho typically have a 3 year lifecycle, so we would recommend surveying for juveniles for at least 3 years to avoid missing a potentially extirpated cohort and biasing the results toward species absence. The amount of channel to sample will most likely be dictated by budgetary constraints and access permission if the stream channel is located on private property. The duration of juvenile abundance sampling is usually dictated by budget. Duffy (2006) sets the stage for the step-by-step instructions:

<u>*Rational*</u>

Abundance and population size are terms used, in fisheries biology, to express two similar but different measures. Abundance refers to the number of fish sampled in an area. When expressed as the number of fish observed or captured per unit area, abundance may also be referred to as density. Abundance is also expressed as CPUE, for example, the catch per hour of electrofishing. Population size refers to the number of fish of a particular species occupying a geographic area. The geographic area occupied by a population is usually an entire stream or watershed, although large watersheds may have more than one population. Estimates of population size could be obtained from sampling the entire area of interest, but this is not practical. Population size is instead estimated by sampling a statistically selected subsample from those habitats available, then extrapolating density to the total area of habitat.

The number of juvenile salmon or steelhead present in a stream or stream reach often requires less effort than estimating abundance of other life history stages, such as adults, smolts, or eggs. For example, all field sampling to estimate juvenile coho salmon population size in a 6 km reach of Prairie Creek in Humboldt County required about 530 person hours, whereas weekly sampling to estimate adult escapement required about 900 person hours and daily smolt trapping during February to June required about 8,400 person hours. Measurements of the number of juvenile salmon or steelhead present in a stream also provides several types of information useful to monitoring:

- When measured over multiple years, trends in juvenile salmon or steelhead abundance may provide information on the response of juvenile salmonids to habitat change and environmental conditions. However, other factors such as ocean conditions, ocean survival rates, water-year types and diseases often influence juvenile salmonid productivity and are extremely difficult to detect and quantify.
- When combined with estimates of the number of adults spawning the previous season, abundance of juvenile salmon and steelhead can provide information on survival from the egg to juvenile period.
- When combined with estimates of the number of smolts migrating from a stream, data on abundance of juvenile salmon and steelhead can provide information on survival during the entire juvenile period.

Methods described here are intended to provide information on juvenile coho salmon or steelhead abundance within streams or stream reaches. These abundance estimates can be expanded to the watershed scale to provide population estimates. Most Chinook salmon in California streams migrate to the estuary soon after hatching and do not occupy stream habitats for an extended period. Abundance estimates require less rigorous sampling and are usually better suited to monitoring population trends or the response of a watershed to management actions, such as measuring change in the abundance of juvenile salmonids over time. More rigorous sampling for population estimates is required when comparisons of survival at distinct life stages is desirable.

Assumptions

The method described here employs both diver observation and electrofishing techniques. The primary assumption inherent in this method is that fish are susceptible to the gear. For divers, susceptibility means that fish are visible to divers and that divers can accurately identify and count species. In electrofishing, susceptibility means both that the gear is efficient in temporarily stunning fish and that field personnel are efficient in capturing fish stunned by electrical current. Furthermore, the method assumes that diver observations and electrofishing estimates are correlated. These assumptions are not always met (Peterson et al. 2004). Environmental conditions, such as turbidity, specific conduction, water temperature, complexity of the habitat, light and other factors can influence efficiency of both diver observations and electrofishing capture.

Limitations

Methods described here are intended for small–medium size streams in which most pools (>75%) are <1.1 m in deep and the stream has a wetted perimeter of < 10 m. Water in streams must also allow divers to see fish clearly at 3–5 m if visual counts of juvenile salmonids are to be considered reliable. These conditions are necessary for two divers to effectively sample a stream. Streams that are too large to be sampled with snorkeling should be sampled with electrofishing equipment. Similarly, streams too small to dive, or in which the visibility is limited, should be sampled with electrofishing equipment. Sampling is recommended during August–October. Sampling during late summer through early fall will increase the likelihood that assumptions and limitations involved with methods are met. During late summer–early fall, water clarity in California streams is greatest, and juvenile coho salmon and steelhead are large enough to be visually located and distinguished.

Sampling Design

The design of a sampling program to estimate fish abundance should incorporate random selection of sampling sites. The design recommended here incorporates systematic random sample selection stratified by habitat type. Systematic random sample selection is relatively simple, and the calculations required to estimate either abundance or population size are not cumbersome. This sampling design may be applied to stream reaches, sub-watersheds or smaller watersheds. Sampling designs for large watershed, regional or statewide monitoring programs often employ techniques other than systematic random sampling for selecting a statistically valid random sample. The chief reason for these more elegant approaches is that, in sampling over large areas, it is impractical to define all the possible habitat units that could be sampled. Instead, these techniques are usually designed to randomly select sampling points from information in geographic information databases.

Refer to Duffy (2006) for the step-by-step field methods as well as statistical analyses.

Biological – Juvenile Fish Distribution

Because estimating juvenile salmonid abundance is relatively time intensive, an alternate means to determine if a fish passage project is providing access is to conduct juvenile distribution surveys above and below the project site. This type of monitoring should also be conducted pre-project and post-project, and is most appropriate if used when the barrier is determined to be a complete barrier to anadromous species. Before-and-after distribution surveys are also a suitable means to evaluate the effects of a barrier removal on the entire fish community, not just salmonids. For example, on Ryan Creek in Mendocino County, pre-project fish distribution surveys only detected juvenile coastal rainbow trout upstream of Ryan Creek Road. Downstream of the barrier, the fish community also included juvenile coho salmon, Pacific lamprey and sculpins. Post-project surveys then documented the presence of all four species upstream of the open-bottom arch culvert.

Duck Creek Associates (2009) used snorkeling to determine juvenile presence upstream of treated stream crossings, sampling up to 330 meters of stream channel. Juvenile fish were identified to species and enumerated. This sampling was only conducted post-project and only in the channel upstream of the treated crossing. This method would be acceptable to determine differences in a stream's fish community diversity above and below a barrier (pre-project) and then to evaluate changes in diversity after the barrier was treated (post-project).

When monitoring fish passage projects where coho salmon are the target species, the Fish Passage Forum recommends using a recently completed juvenile coho salmon spatial structure monitoring protocol developed by CDFW (Garwood and Ricker 2015). This juvenile coho salmon spatial structure monitoring protocol uses the design based sampling of the Coastal California Salmonid Monitoring Plan (CMP) to measure occupancy patterns of juvenile salmonids during the summer juvenile rearing period. The spatial structure of rearing coho salmon addresses one of the four viable salmon population (VSP) parameters developed by NOAA Fisheries to determine a population's risk of extinction. These parameters include abundance, productivity (population growth rate), spatial structure, and diversity (McElhany et al. 2000). Although Garwood and Ricker (2015) uses a generalized random tessellation stratified (GRTS) spatial sampling design for reach selections on a larger watershed scale, the basic procedures for conducting the "small stream" single reach dive counts are appropriate for assessing changes in spatial distribution before and after implementing a fish passage project. Pre-project and post-project dive counts would be made in the stream reaches downstream and upstream of the project location; following the procedures described by Garwood and Ricker (2015).

The methods document produced by Garwood and Ricker (2015) is presented in Appendix C.

<u>Biological – Adult Spawner Abundance and Distribution</u>

Adopt the adult salmon and steelhead escapement methods developed by Duffy (2006) for monitoring the response of anadromous salmon and steelhead to watershed restoration in California. The basic field methods described by Duffy (2006) are similar to those proposed by Crawford (2011) and O'Neal and Scranton (2014); however, these other methods limit the sampling to only the project channel monitoring reaches and/or recommend only conducting spawner surveys in post-project years 1, 2 and 5. . The Forum recommends sampling at least the minimum number of cohorts associated with the target species. For example, coho typically have a 3 year lifecycle, so we would recommend surveying for juveniles for at least 3 years to avoid missing a potentially extirpated cohort and biasing the results toward species absence. The amount of channel to sample will most likely be dictated by budgetary constraints and access permission if the stream channel is located on private property, but we recommend surveying until the end of anadromy to avoid missing fish that have passed through the former barrier location. The duration of adult escapement sampling is usually dictated by budget. Duffy (2006) sets the stage for the step-by-step instructions:

Rational

The number of adult salmon or steelhead returning to a stream to spawn is defined as "escapement", meaning those adults that have escaped the fishery to reproduce. Estimates of escapement provide essential information on the size of populations. The number of adults escaping to spawn is influenced by mortality at all younger life history stages. Because habitat conditions in freshwater and the ocean influence survival, estimates of escapement are the often considered the ultimate measure of population response. These estimates of escapement are frequently used as an indicator of production for future generations of fish. Escapement has been estimated using a variety of techniques. In larger rivers, aerial surveys, or counts at dams, sometimes used estimate escapement. In smaller rivers and streams, carcass mark-recapture techniques, visual counts of live fish, and counts of redds constructed have all been used to estimate escapement, or provide an index of the number of spawners. In addition to these methods, technological improvements in underwater video and hydro-acoustic equipment are now being applied to estimating salmon escapement. These latter techniques offer promise, but their costs are currently beyond the scope considered for widespread use.

Assumptions

Here we describe methods for obtaining escapement estimates using carcass mark-recapture techniques, visual counts of live fish, and counts of redds constructed. Certain assumptions are inherent in each method. The assumptions inherent in carcass mark-recapture techniques include:

1. The population is closed and carcasses are not immigrating into the area (drifting in from upstream);
2. Carcasses do not lose their marks between the time of release and recapture;
3. Marking carcasses does not affect the probability of their being re-sighted;
4. All marked and unmarked carcasses have an equal probability of emigrating, i.e., drifting out of the survey area, or being removed by animals;
5. All marked and unmarked carcasses have an equal probability of being re-sighted;
6. Carcass surveys represent a random sample, in which each of the possible combinations of marked and unmarked carcasses has an equal probability of occurring;
7. All marked carcasses re-sighted are identified and reported;

Assumptions in the technique using visual counts of live fish include:

1. Surveys begin before live fish enter the survey reach;
2. Surveys continue until live fish are no longer present in the survey reach;
3. Live fish in the survey reach are visible to observers;
4. Species of live fish can be distinguished by observers; and
5. Observer efficiency can be defined.

Assumptions in the technique using visual counts of redds are similar to those for live fish and include:

1. Surveys begin before fish construct redds in the survey reach;
2. Surveys continue until redds are no longer being constructed in the survey reach;
3. Redds in the survey reach are visible to observers;
4. Redds can be associated with the species constructing them; and
5. Observer efficiency in seeing redds can be defined.

Limitations

Estimating numbers of salmon or steelhead escaping may not be possible, or may be difficult, in some streams during some years. In streams with very small populations, estimating escapement using carcass mark-recapture methods may present statistical challenges if the number of re-sighted marked carcasses is small. Analysis of data from small populations may require consultation with a statistician familiar with mark-recapture experiments. Methods relying on visual observation of either live fish or redds may also be limited in streams that remain turbid for a substantial proportion of the spawning period. Finally, both carcass mark-recapture and visual observation methods require observers to regularly census survey reaches. This requires considerable labor and may not be possible during periods of high water.

Sampling Design

The objective for estimating escapement is often to estimate the number of adult fish returning to spawn in a tributary stream or some reach of importance. Sampling designs for reaches of streams that are not exceptionally long are typically to survey the entire reach. For visual observation methods, random subsampling can be employed if the objective is to estimate escapement for a steam or entire watershed that cannot be reasonably surveyed in its entirety. In the latter case, the entire habitat in the survey area is first defined. Second, the survey area is divided into strata of similar size having similar physical attributes. Third, random reaches within each stratum are selected to survey. Permission to access property may not be granted to some reaches. Because of this, it is advisable to select 20–30% more reaches than will be sampled. Having randomly selected a number of reaches in excess of the number desired will provide a valid process for selecting alternate reaches.

Sampling designs for larger rivers or watersheds can incorporate quantitative methods, or a combination of quantitative methods and index sampling. Quantitative methods typically consist of intensive escapement estimates along survey reaches selected randomly from within the watershed. Alternatively, intensive surveys of selected reaches are sometimes combined with qualitative indices, such as single surveys during peak spawning activity, to provide information from a larger area.

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APPENDIX A:

NOAA RESTORATION CENTER'S WORKSHEET AND GUIDANCE MATERIALS FOR TIER #1 MONITORING

NOAA Restoration Center

Page 1 of 3

Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet

A General Info

Once complete, please remember to submit this form via e-mail to your local NOAA Restoration Center project technical monitor.

Project Name		
Funding Mechanism		*Award Date*
Performance Measures / Monitoring Contact (person filling this form)	*Phone*	*Email*

	PRE-IMPLEMENTATION	POST-IMPLEMENTATION
B Project Timing	*Anticipated Start Date* / *Anticipated End Date*	*Actual Start Date* / *Actual End Date*
C Available Habitat	*What is the anticipated number of stream miles to be made accessible upstream of the project site?* miles	*What is the actual number of stream miles made accessible upstream of the project site?* miles *Verification methods*
D Site "Passability"	*Describe the following physical parameters of the project design.*	*Describe the as-built parameters at the site.*
	Channel Width in Project Area:	**Channel Width in Project Area:**
	Baseline .... ft.	As-Built Condition .... ft.
	Target Range .... to ft.	
	Channel Slope / Gradient in Project Area:	**Channel Slope / Gradient in Project Area:**
	Baseline .... %	As-Built Overall Slope .... %
	Target Range .... to %	As-Built Maximum Channel Slope ..... %
	Maximum Channel Slope............. %	
	Maximum Jump Height:	**Maximum Jump Height:**
	Baseline .... in.	As-Built Condition .... in.
	Target Range .... to in.	
	Does the project design meet regionally appropriate fish passage criteria? ☐ Yes ☐ No	**Does the as-built conditions fall within the target ranges listed at left?** ☐ Yes ☐ No
	Provide reference sources used to develop target ranges.	*Comments*

NOAA/FISHERIES/RC/ORI Tier 1 Monitoring Worksheet Updated 04/10

NOAA Restoration Center

Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet

	PRE-IMPLEMENTATION	POST-IMPLEMENTATION
E Presence of Target Fish Species	*Identify ONE target diadromous fish species:* *What is the upstream status of the target diadromous fish species?* ☐ Present ☐ Absent *For which life stages is passage limited?* ☐ Adult ☐ Juvenile *List other fish species that will benefit and their pre-project status:* *Species:* ☐ Present ☐ Absent ☐ Present ☐ Absent *Describe the methodology used to determine presence/absence of the target species.*	*What is the upstream status of the target diadromous fish species? (This may be reported annually from 1-5 years post-implementation.)* ☐ Present ☐ Absent *Which life stages, if any, have been observed upstream?* ☐ Adult ☐ Juvenile *List other fish species and their post-project status:* *Species:* ☐ Present ☐ Absent ☐ Present ☐ Absent *Describe the methodology used to determine presence/absence of the target species.*
F Community Participation	*What is the anticipated number of volunteers and volunteer hours to be associated with the project?* Estimated Number of Volunteers.......... Estimated Volunteer Hours................	*What were the actual number of volunteers and volunteer hours associated with the project?* Actual Number of Volunteers............. Actual Volunteer Hours.................. *Verification methods*
G Community Enhancement	*Will there be a civic project (e.g. park development, recreation enhancement, etc.) associated with the barrier removal anticipated?* ☐ **Yes** ☐ **No** *If yes, please describe.*	*Was the anticipated civic project associated with the barrier removal carried out?* ☐ **Yes** ☐ **No** *Comments*

NOAA/FISHERIES/RC/ORI Tier 1 Monitoring Worksheet Updated 04/10

NOAA Restoration Center

Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet

	PRE-IMPLEMENTATION	POST-IMPLEMENTATION
H Operating and Maintenance Costs	*Will the barrier removal result in reduced annual operating, maintenance and / or liability costs at the site?* ☐ Yes ☐ No *What is the estimated average **annual** operating, maintenance, and/or liability cost over the next five-year period if the barrier were to remain in place?* /year	*What is the estimated average **annual** operating, maintenance, and / or liability cost over the next five-year period without the barrier in place?* /year *What is the **annual** average change in cost? (This will auto-fill)* /year
I Public Safety	*Will the barrier removal eliminate or diminish a documented safety hazard?* ☐ Yes ☐ No *If yes, please describe.*	*Did the barrier removal eliminate or diminish a documented safety hazard?* ☐ Yes ☐ No
J Additional Project Monitoring (if applicable)	*Please indicate if any additional monitoring activities will be conducted at the project site.* ☐ No additional monitoring ☐ Juvenile surveys ☐ Outmigrant trapping ☐ Spawner surveys ☐ Topographic channel surveys ☐ Habitat evaluation ☐ Photo points ☐ Other *If yes, please describe. Wherever possible, please include information on methodology used, as well as baseline and target conditions.*	*If additional monitoring studies were completed, please describe post-implementation conditions.*

Once complete, please remember to save this form, then submit it via email to your local NOAA Restoration Center project technical monitor.

NOAA/FISHERIES/RC/ORI Tier 1 Monitoring Worksheet Updated 04/10

GUIDANCE MATERIALS

NOAA Restoration Center Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet

I. Background

In order to assess progress towards program goals, the NOAA Restoration Center is collecting pre and post implementation data for a variety of parameters for stream barrier removal projects. This may include dam removal, culvert removal, and culvert replacement projects where the primary goal is to restore natural stream conditions and unrestricted migratory fish passage to upstream habitat.

II. General Guidance

Award period.

- ☑ NOAA can only require monitoring within the duration of the award period. Award periods may be established to allow for post-implementation monitoring. Any data gained beyond the award period may be useful to further inform post-implementation results and would be welcomed.

Worksheet Data Collection.

- ☑ The Stream Barrier Removal Performance Measures and Project Monitoring Worksheet is designed be to completed by the grantee at the beginning and end of a stream barrier removal project funded through the NOAA Restoration Center, with the assistance of local NOAA Restoration Center technical monitors and/or representatives from partner organizations.
- ☑ The pre-implementation portions of the worksheet should be completed prior to project implementation. The post-implementation portions of the worksheet should be filled out at the close of the award period. For some parameters, data collected after the award period would be useful to further inform post-implementation results.

Project Monitoring Parameters.

- ☑ Parameters included in the worksheet were not developed to be an exhaustive set of parameters that could be measured, but rather to contribute to a specific set of program level performance measures that assess progress towards NOAA Restoration Center program goals.
- ☑ Projects are welcome to monitor projects beyond the parameters outlined within the worksheet to assess their projects.

III. Worksheet Protocols

A ***GENERAL INFORMATION***

- ☑ Please provide the official ***project name*** from your award materials.
- ☑ The ***funding mechanism*** is the specific grant program through which your project was funded (e.g. NOAA Open Rivers Initiative, American Rivers, FishAmerica Foundation, etc.).
- ☑ Enter the official ***award start date*** found on your award materials.
- ☑ Enter in the ***contact information*** (full name, phone number, and email address) for the designated person who will complete the monitoring worksheet.

B ***PROJECT TIMING***

- ☑ **Pre-implementation.** Indicate the dates on which the implementation is intended to begin and end. These dates should reflect the duration of all activities funded through the award.
- ☑ **Post-implementation** In some cases, delays may change the start or end dates for a project. Indicate the actual starting and ending dates for project implementation.

C ***AVAILABLE HABITAT***

The number of stream miles made accessible upstream of the project site as a result of barrier removal.

- ☑ **Pre-implementation.** Project grantees can use a combination of the following data sources to estimate the number of upstream stream miles to be made accessible as a result of the project. Stream miles should be calculated from project site to next upstream fish passage barrier or extent of anadromy.
  - Existing aerial photos and maps of the project watershed (used to locate additional unreported barriers or a significant increase in stream slope that would influence habitat use).
  - Local or regional barrier databases.
  - Existing staff or local expert knowledge of the project watershed.
  - Field verification (in cases where there is permission to access the stream).
- ☑ **Post-implementation.** Grantees can use a combination of the following sources to verify the number of upstream miles made accessible as a result of the project.
  - Existing aerial photos and maps of the project watershed (used to locate additional unreported barriers or a significant increase in stream slope that would influence habitat use).
  - Local or regional barrier databases.
  - Existing staff or local expert knowledge of the project watershed.

1 NOAA/FISHERIES/RC/ORI Tier 1 Monitoring Worksheet Updated 04/10

- Field verification (in cases where there is permission to access the stream).

On the worksheet, in addition to describing the verification methods used, also describe any uncertainties that may have affected the calculation.

☑ **Frequency / Duration of Sampling.**

- The number of stream miles opened by each project should be estimated pre-implementation and verified after project completion.
- A small number of barrier removal projects may require stream channel adjustment before passage through the site has been fully restored. Even in these cases, number of stream miles made accessible will be reported immediately after barrier removal implementation.

D *SITE "PASSABILITY"*

Improved "passability" for target species as a result of barrier removal based on measureable physical conditions within the stream channel at the site.

☑ **Pre-implementation.**

- The project grantee is requested to provide project designs to NOAA technical monitors prior to implementation. Projects should be designed to meet regionally appropriate fish passage criteria (see below).
- Specific baseline and target range information should be provided in the worksheet for channel width, channel slope and maximum jump height within the project area.
- The **baseline** should reflect the actual conditions before the project, and the target ranges should be based on regionally appropriate fish passage criteria and should reflect project design plans (see below).
- **Channel width** should be determined by taking three measurements of the active channel width immediately within the barrier removal site (for culverts, just under the crossing and for dams, at the dam and immediately upstream and downstream). Take the average of these three measurements to determine channel width.
- **Channel slope** should be determined by taking a longitudinal profile throughout the project reach upstream and downstream to the extent of barrier influence on the channel slope. Determine the **overall channel slope** from just upstream of the influence of the barrier to just downstream of its influence. Determine the **maximum channel slope** through the site before and after the project using the pre-project and as-built longitudinal profiles.
- Using the pre-project and/or as-built longitudinal profile, determine the **maximum height** a fish would have to jump to migrate through the site.

☑ **Regionally Appropriate Fish Passage Criteria.**

- **California.** All projects should be designed to meet appropriate criteria as described in NMFS Southwest Fish Passage Guidelines.
- **Oregon and Washington.** All projects should be designed to meet appropriate criteria defined in NMFS Northwest Fish Passage Guidelines.
- **Northeast.** Although there is not a single standard in the Northeast, grantees must describe and document how their design criteria for the chosen target species were established and how their design meets these criteria. Design criteria should include flow velocities as they relate to swimming abilities of the target species (including burst and sustained swimming speeds), jump heights, flow depths, channel width and gradient. If necessary, hydraulic modeling should be used to verify whether the design will meet these criteria.
- **Southeast.** Although there is not a single standard in the Southeast, project grantees must describe and document how their design criteria for the target species were established and how their design meets these criteria. Design criteria should include flow velocities as they relate to the swimming abilities of the target species (including burst and sustained swimming speeds), jump heights, flow depths, channel width and gradient. If necessary, hydraulic modeling should be used to verify whether the design will meet these criteria.

☑ **Post-implementation.**

- Based on a post-implementation survey, the grantee should provide as-built conditions for channel width, channel slope, and maximum jump height (see instructions above in pre-implementation section).
- Site "passability" is determined by comparing the as-built conditions to the target ranges determined during project design.

- It is possible that project grantees could encounter unexpected conditions at the site, such as a natural rock ledge or water fall, that prevent the contractors from implementing the plans as designed. In these cases, a barrier could still exist at the project site even if the project is built as designed. Any such unexpected conditions should be described.

☑ **Frequency / Duration of Sampling.**

- A pre-implementation survey should be conducted at the site to document baseline conditions prior to barrier removal.
- The post-implementation survey should be conducted immediately after project implementation and document as-built conditions.

☑ **Optional Monitoring.**

- Measure the channel conditions over several years after project implementation to observe channel adjustment over time.
- Flow velocities (via a flow meter) and depths in the barrier reach post-project could be measured. This would verify passable conditions in a direct way and would evaluate how successful the design process was at estimating the necessary channel geometries for fish passable conditions.

E ***PRESENCE OF TARGET FISH SPECIES***
Change in presence of target diadromous species upstream of the project site.

☑ **Pre-implementation.**

- Identify *one* target diadromous species and its life stage (juvenile or adult) that, if able to pass through the site, would represent adequate passage for all other species in the area. For example, if two diadromous species are likely to use the site, choose the species and life stage with the least swimming or jumping abilities. Use one of the following survey techniques[1] to identify and report presence/absence for either adults or juveniles of the target species upstream of the project site:

  Adults. Upstream weirs, mark-recapture, spawner surveys, videography at barrier location, snorkel counts.

  Juveniles. Mark-recapture, migrant traps, snorkel counts, electroshocking, videography.

- Describe the survey techniques used to determine the presence/absence status of the target diadromous fish species.
- If a pre-implementation survey is not possible, report whether the barrier is a known full barrier or partial barrier for the target diadromous fish species. Describe any pre-project data that is available. If no recent biological information is available, include surrogate information (e.g. last time the target species was seen above the barrier, a description of "completeness" of barrier, etc.).

☑ **Post-implementation.**

- If the pre-implementation status was determined to be ***absent***, use one of the survey techniques to identify and report presence/absence following implementation.
- If pre-project upstream status was determined to be ***present*** (e.g. partial barriers), report any change in presence/absence following implementation. In this case, the post-implementation result may be continued "presence".
- Describe the methodology used to determine presence/absence status of the target diadromous fish species.

☑ **Frequency / Duration of Sampling.**

- The timing and frequency should correlate with the life history of the target species. At a minimum, this parameter should be monitored once post-implementation, and at a maximum it could be monitored on an annual or seasonal basis.
- Monitoring for this measure is likely to yield meaningful results in the first 3 years after project implementation, although in some situations it may be valuable to monitor for the first 5 years.
- Once target fish presence is detected upstream of the project site post-implementation, monitoring for this measure is complete.

☑ **Optional Monitoring.**

- For partial barriers or projects where the pre-implementation status was identified as ***present***, the proportional change in the number of adults or juveniles may be measured.

F ***COMMUNITY INVOLVEMENT***
Number of volunteers associated with the project and the number of volunteer hours contributed, if applicable.

1 Use regional or state protocol for fish surveys. If unknown then refer to the following document: Roni, P. (Editor) 2005. Monitoring stream and watershed restoration. *American Fisheries Society*, Bethesda, Maryland, 350 p.

GUIDANCE MATERIALS *(continued)*

NOAA Restoration Center Fish Passage Barrier Removal Performance Measures and Monitoring Worksheet

☑ **Pre-implementation.**

- Estimate the number of volunteers that may participate in the project and the number of volunteer hours that may be contributed.
- Volunteers may include youth crew members (e.g. California Conservation Corps) or other in-kind services enabling project implementation.

☑ **Post-implementation.**

- Calculate the cumulative number of volunteers associated with the project and the number of volunteer hours contributed.
- Describe the methods used to calculate the number of volunteers and volunteer hours in the worksheet.

☑ **Frequency / Duration of Sampling.**

- Data can be collected throughout the award period and reported as cumulative numbers at the end of the award.

G ***COMMUNITY ENHANCEMENT***
Local civic enhancement projects associated with the barrier removal.

☑ **Pre-implementation.**

- Determine whether or not there will be a local community, civic enhancement project associated with the barrier removal project.
- Local civic enhancement projects may include but are not limited to adjacent recreation enhancement, park development, and/or riverfront revitalization.
- Describe the local civic enhancement project(s) associated with the barrier removal.

☑ **Post-implementation.**

- Confirm whether or not the local civic enhancement project(s) associated with the project was carried out.

H ***OPERATING AND MAINTENANCE COSTS***
Change in operations, maintenance and/or liability costs associated with the barrier removal.

☑ **Pre-implementation.**

- Determine the expected operations, maintenance and/or liability costs over the next 5 years if the barrier were to remain in place
- Periodic or less frequent costs that may occur during this period (e.g. structural upgrades to meet safety or regulatory requirements) may be incorporated into the estimate.
- Divide this number by 5 to determine the average annual operations and maintenance costs associated with the barrier.

☑ **Post-implementation.**

- Determine the expected operations, maintenance and/or liability costs of the site over the next 5 years once the barrier has been removed.
- Divide this number by 5 to determine the average annual Operations and Maintenance costs associated with the barrier.
- The post implementation average cost will automatically be substracted from the pre-implementation average cost to determine the average annual change in operations and maintenance costs.

☑ **Frequency / Duration of Sampling.**

- Estimated costs should be calculated prior to implementation and following project implementation.

☑ **Optional Monitoring.**

- Track actual expenses for 5 years post-implementation to verify estimated change in operating costs.

I ***PUBLIC SAFETY***
Improved public safety associated with the barrier removal, if applicable.

☑ **Pre-implementation.**

- Describe whether or not barrier removal will eliminate or diminish a public safety hazard.
- Safety hazards may include barriers that serve as attractive nuisances and present swimming and boating dangers. Also, barriers that are structurally deficient, in danger of failure, or cause flooding may be considered public safety hazards.
- Describe the safety hazards caused by the barrier and how they will be eliminated or diminished through removal.

☑ **Post-implementation.**

- After implementation, confirm that the public safety hazard has been eliminated or diminished.

J ***ADDITIONAL PROJECT MONITORING***
Describe additional project monitoring, such as pre-and post project spawner or juvenile surveys, outmigrant trapping, topographic data collection, geomorphic monitoring, photo documentation or other monitoring activities associated with the project but not described in the form.

APPENDIX B:
CDFW CHECKLISTS FOR TIER #1 MONITORING

SITE SUMMARY - Instream/Fish Passage Implementation Monitoring

Site Name: **Site ID:**

Grant #: **Project title:**

Year: **Evaluator:** **Checklists** (circle types attached): **CB FB FC FS IN SF**

Summary of Performance Measures by Site

DFG project type	Metric name as it appears in the CHRPD	Conversion	Reporting Metric	Reporting Unit
HI	Length of instream habitat treated - except for bank stabilization (sum of individual feature lengths)	ft /5280 ft =		miles
HS	Length of streambank stabilized (count both sides of stream where applicable)	ft /5280 ft =		miles
HI	Length of stream treated for channel reconfiguration/connectivity	ft /5280 ft =		miles
HI	Length of off-channel stream created	ft /5280 ft =		miles
HI	Length of stream treated for channel structure placement (sum of individual channel structure lengths, for feature types 301-303 and 310-344)	ft /5280 ft =		miles
HI	Length of stream treated with spawning gravel placement	ft /5280 ft =		miles
HI	Gravel volume added to stream →			cubic yards
HI	Instream features installed/modified →			number
HI	Instream pools created/added →			number
HI	Type of instream habitat or streambank stabilization treatment (list 3-digit numeric type codes):			list codes
HI	Amount of wetland area treated	ft^2/43,560 ft^2 =		acres
HI	Amount of artificial wetland area created	ft^2/43,560 ft^2 =		acres
HI	Amount of estuarine area treated	ft^2/43,560 ft^2 =		acres
HI	Amount of estuarine area created	ft^2/43,560 ft^2 =		acres
FP	Stream crossings treated to improve fish passage →			number
FP	Stream length opened for fish passage by improving stream	ft /5280 ft =		miles
HU	Sediment volume prevented from entering stream (if applicable) →			cubic yards
HB	Barriers other than stream crossings removed/modified →			number
HB	Stream length opened for fish passage - barriers other than stream crossings	ft /5280 ft =		miles
SC	Fish screens installed →			number
SC	Fish screens replaced/maintained →			number
SC	Flow rate at screened diversion from the water right →			cfs
SC	Quantity of water protected by screens as stated in the water right →			acre-feet/yr
SC,WD	Water flow gauges installed →			number
WC,WP	Amount of water returned to the stream (not including water maintained in stream)			cfs
WP	Volume of water leased or purchased →			acre-feet/yr

REQUIRED *for all implementation projects or see Site Summary page____ of____. Total for the site, for the calendar year.*

ALL	Overall stream length treated (one side of stream only)*	ft /5280 ft =		miles
ALL	Length of aquatic habitat disturbed →			feet
ALL	Area (footprint) of instream features installed within bankfull channel →			$feet^2$

Field Verification of Site Location: ☐ The site is digitized correctly or ☐ pdated site information has been submitted

*Enter "All" metrics into CHRPD even when they are 0. *Length of entire reach where work occurred.*

☐ Comment on back CRMEP 06/01/11 Draft Page_____ of _____

FC - FISH PASSAGE at STREAM CROSSINGS

PRE-TREATMENT

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

			Comments
	Project Feature Number		
	Feature Type Code		
Crossing	1. Is upgrading, removing, or retrofitting the existing crossing to improve fish passage an objective?		
	a. Structural condition: Excl, Good, Fair, Poor, Fail		
	b. Problems: ALN, APP, COR, CRS, DIV, NTG, OVT, PIP, PLG, UND, UNS, WSH, NON, OTH		
	2. Percent slope through the crossing (water surface elevation): (%)		
Fish	3. If applicable, fish passage evaluation filter: GRN, GRY, RED		
	4. Is increasing adult fish passage an objective of the feature?		
	a. Targeted adult fish species: CHI, COH, CTT, SHT, etc.		
	5. Is there currently a barrier to adult fish of the targeted species?		
	a. Current barrier category: PAR, TEM, TOT, OTH		
	b. Target barrier category: PAR, TEM, NON, OTH		
	c. Types of passage problems: CGA, FJH, NRP, WTD, WTV, OTH		
	d. Targeted improvements: CGA, FJH, NRP, WTD, WTV, OTH		
	6. Is increasing juvenile fish passage an objective of the feature?		
	a. Targeted juvenile fish species: CHI, COH, CTT, SHT, etc.		
	7. Is there currently a barrier to juvenile fish of the targeted species?		
	a. Current barrier category: PAR, TEM, TOT, OTH		
	b. Target barrier category: PAR, TEM, NON, OTH		
	c. Types of passage problems: CGA, FJH, NRP, WTD, WTV, OTH		
	d. Targeted improvements: CGA, FJH, NRP, WTD, WTV, OTH		
	8. Is improving fish jump height an objective?		
	a. Minimum fish jump height at crossing: (ft.)		
Sediment Delivery	9. Is there evidence of previous sediment delivery from the crossing?		
	a. Sediment sources: SFE, FLS, LAN, CUT, SBL, NRL, EFL, SCW, DIV, RRG, NRG, SBE, OTH		
	10. Is there potential for sediment delivery from the crossing?		
	a. Delivery potential: LOW, MOD/LOW, MOD, MOD/HIG, or HIG		
	11. Is decreasing potential for future sediment delivery an objective?		
Channel	12. Is there localized channel aggradation upstream of the crossing?		
	13. Is there localized channel incision or scour downstream of the crossing?		
	14. Are there other channel problems in the vicinity of the crossing?		
	15. Is correcting or stabilizing localized channel problems an objective?		
Banks	16. Is there streambank erosion or instability in the vicinity of the crossing?		
	a. Locations: UPS, DNS, WIN and LBK, RBK		
	b. Apparent causes: BAR, CNR, EMG, GRZ, HYD, UND, USG, OTH		
	17. Is stabilizing the streambank and/or reducing bank erosion an objective?		
Products	18. Is downstream movement of watershed products impaired at the barrier?		
	a. Movement currently impaired: DBR, SUB, WTR, OTH		
	19. Is improving downstream movement of watershed products an objective?		
Comments			

Y=Yes, N=No, P=Partially, D=Don't know, A=Not Applicable. CRMEP 06/01/11 Draft

FC - FISH PASSAGE at STREAM CROSSINGS

IMPLEMENTATION

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

			Comments
	Project Feature Number		
	Feature Type Code		
Stream Crossing	1. Was the new or upgraded crossing installed as approved?		
	a. Materials: CON, MTL, NTR, OFR, PLA, WOO, OTH		
	b. Structural condition: Excl, Good, Fair, Poor, Fail		
	c. Problems: ALN, APP, CRS, NTG, UNS, NON, OTH		
	d. Estimated sediment volume prevented from entering a stream: (cy/10 yr)		
	2. Does the crossing structure meet CDFG fish passage criteria?		
	3. Does fish passage rely on a correctly functioning back flooding weir(s)?*		
	4. Were the fill or side slopes constructed at stable angles?		
	5. Were the fill or side slopes treated to prevent erosion as approved?		
	*a. Methods: ARM, BNC, COM, NTM, PLN**, SEE, SLF, STM, OTH*		
	6. Were treatments to prevent plugging & inlet erosion installed as approved?		
	a. Installed at inlet: ARM, DBB, FLA, GRC, MIT, WGW, OTH		
	7. Were treatments to protect the outlet from erosion installed as approved?		
	a. Installed at outlet: ARM, DSP, GRC, OTH		
	8. If a bridge, were bridge abutments constructed as approved?		
	9. Was road surface/ditch runoff disconnected from streams as approved?		
	10. Percent slope through the crossing (water surface elevation): (%)		
Channel	11. Did channel conditions at the crossing require grade control weirs/structures?*		
	12. Was the channel adjacent to the crossing excavated to a stable shape?		
	a. Location of excavation relative to crossing: DNS, UCR, UPS, OTH		
	13. Was all fill and trapped sediment in the channel removed or stabilized?		
	a. If not, were measures to control sediment release applied as approved?		
Spoils	14. Were spoils placed where they cannot deliver sediment, as approved?		
	a. Spoils volume estimate: (cy)		
Metrics	15. Length of habitat made accessible by the feature: (mi)		
	16. Length of aquatic habitat disturbed at the feature: (ft)		
	17. Area of the feature installed within bankfull channel: (ft^2)		
Implementation	18. Does the feature meet design, contract & permit specifications?		
	a. If not, were modifications beneficial to performance?		
	b. Is non-compliance significant enough to jeopardize performance?		
	c. Are corrections needed?		
	19. Would a different treatment or design have been preferable? If Y, comment.		
	20. **Feature Implementation Rating: Excl, Good, Fair, Poor, Fail**		
Comments			

* Weirs are separate features, use FB checklist. **Y**=Yes, **N**=No, **P**=Partially, **D**=Don't know, **A**=Not Applicable. CRMEP 06/01/11 Draft

FC - FISH PASSAGE at STREAM CROSSINGS **POST-TREATMENT**

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

		Project Feature Number		**Comments**
		Feature Type Code		
Crossing	1.	Is the upgraded, removed, or retrofitted crossing performing as designed?		
		a. Structural condition: Excl, Good, Fair, Poor, Fail		
		b. Problems: ALN, APP, COR, CRS, DIV, NTG, OVT, PIP, PLG, UND, UNS, WSH, NON, OTH		
	2.	If applicable, are back flooding weirs functioning as designed?*		
	3.	Percent slope through the crossing (water surface elevation): (%)		
Fish	4.	If applicable, fish passage evaluation filter: GRN, GRY, RED		
	5.	If an objective, did the feature increase adult fish passage?		
		a. If yes, for which targeted species: CHI, COH, CTT, SHT, etc.		
	6.	Does any barrier to targeted adult species remain at the feature?		
		a. Current barrier category: PAR, TEM, TOT, NON, OTH		
		b. Remaining passage problems: CGA, FJH, NRP, WTD, WTV, NON, OTH		
	7.	If an objective, did the feature increase juvenile fish passage?		
		a. If yes, for which targeted species: CHI, COH, CTT, SHT, etc		
	8.	Does any barrier to targeted juvenile species remain at the feature?		
		a. Current barrier category: PAR, TEM, TOT, NON, OTH		
		b. Remaining passage problems: CGA, FJH, NRP, WTD, WTV, NON, OTH		
	9.	If an objective, was fish jump height improved?		
		a. Minimum fish jump height at crossing: (ft.)		
Sediment Delivery	10.	Has there been sediment delivery from the crossing since implementation?		
		a. Sediment sources: SFE, FLS, LAN, CUT, SBL, NRL, EFL, SCW, DIV, RRG, NRG, SBE, OTH		
		b. Estimate delivery since implementation (cy):		
	11.	Is there still potential for sediment delivery from the crossing?		
		a. Delivery potential: LOW, MOD/LOW, MOD, MOD/HIG, or HIG		
	12.	If an objective, was potential for future sediment delivery reduced?		
Channel	13.	If applicable, are assoicated grade control structures functioning as designed?*		
	14.	If sediment had aggraded upstream of the crossing, does any remain?		
	15.	If there was channel incision/scour downstream of the crossing, has it stabilized?		
	16.	Are there other channel problems in the vicinity of the crossing?		
	17.	If an objective, were localized channel problems corrected or stabilized?		
	18.	Were there unintended effects on the channel? If Y, comment.		
Banks	19.	Is there bank erosion or instability in the vicinity of the crossing?		
		a. Locations: UPS, DNS, WIN and LBK, RBK		
		b. Apparent causes: BAR, CNR, EMG, GRZ, HYD, UND, USG, OTH		
	20.	If an objective, was streambank instability and/or bank erosion reduced?		
	21.	Were there unintended effects on banks? If Y, comment.		
Products	22.	Is downstream movement of watershed products impaired at the crossing?		
		a. Movement currently impaired: DBR, SUB, WTR, OTH		
	23.	If an objective, did the feature improve watershed product movement?		
Rating	24.	**Feature Effectiveness Rating: Excl, Good, Fair, Poor, Fail**		
	25.	Does this feature need: DEC, ENH, MNT, REP, NON, OTH		
	26.	Are additional restoration treatments recommended at this location?		

* Weirs are separate features, use FB checklist. Y=Yes, N=No, P=Partially, D=Don't know, A=Not Applicable. CRMEP 06/01/11 Draft

FB - FISH PASSAGE at BARRIERS

PRE-TREATMENT

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

				Comments
		Project Feature Number		
		Feature Type Code		
Fish	1.	Is providing adult fish passage an objective of the feature?		
		a. Targeted adult fish species: CHI, COH, CTT, SHT, etc.		
	2.	Is there currently a barrier to adult fish of the targeted species?		
		a. Current barrier category: PAR, TEM, TOT, OTH		
		b. Target barrier category: PAR, TEM, NON, OTH		
		c. Types of passage problems: FJH, NRP, WTD, WTV, OTH		
		d. Targeted improvements: FJH, NRP, WTD, WTV, OTH		
	3.	Is providing juvenile fish passage an objective of the feature?		
		a. Targeted juvenile fish species: CHI, COH, CTT, SHT, OTH		
	4.	Is there currently a barrier to juvenile fish of the targeted species?		
		a. Current barrier category: PAR, TEM, TOT, OTH		
		b. Target barrier category: PAR, TEM, NON, OTH		
		c. Types of passage problems: FJH, WTD, WTV, OTH		
		d. Targeted improvements: FJH, WTD, WTV, OTH		
Channel	5.	Is there localized stream channel aggradation upstream of the barrier?		
	6.	Is there localized channel incision or scour downstream of the barrier?		
	7.	Are there other stream channel problems in the vicinity of the barrier?		
	8.	Is correcting or stabilizing localized channel problems an objective?		
Banks	9.	Is there streambank erosion or instability in the vicinity of the barrier?		
		a. Locations: DNS, UPS, WIN and LBK, RBK		
		b. Apparent causes: BAR, CNR, EMG, GRZ, HYD, UND, USG, OTH		
	10.	Is stabilizing the streambank and/or reducing bank erosion an objective?		
Products	11.	Is downstream movement of watershed products impaired at the barrier?		
		a. Movement currently impaired: DBR, SUB, WTR, OTH		
	12.	Is improving downstream movement of watershed products an objective?		
Comments				

Y=Yes, **N**=No, **P**=Partially, **D**=Don't know, **A**=Not Applicable. CRMEP 06/01/11 Draft

FB - FISH PASSAGE at BARRIERS **IMPLEMENTATION**

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

			Comments
	Project Feature Number		
	Feature Type Code		
Structure Installation	1. Does the structure meet design specifications?		
	a. Structural condition: Excl, Good, Fair, Poor, Fail		
	b. Problems: ANC, BBB, CRF, MAT, SHF, STR, SWA, UND, UNS, WSH, NON, OTH		
	2. Was the structure installed in the approved location and position?		
	3. Were approved materials used for the structure?		
	a. Materials: CON, LWD, MTL, NTR, OFR, PLA, RTW, WOO, OTH		
	4. Were the approved sizes of materials used for the structure?		
	5. Was the structure secured or anchored as approved?		
	a. Methods: BUR, CBL, REB, STK, TIE, UNA, WDG, OTH		
	6. Does fish passage rely on a functioning back flooding weir(s)?*		
Barrier	7. Was the barrier removed as approved?		
	8. Was the barrier modified as approved?		
	a. Are there problems visible with the modified barrier? If Y, comment.		
Channel	9. Was the channel adjacent to the barrier excavated to a stable shape?		
	a. Location of excavation relative to barrier: DNS, UPS, WIN, OTH		
	10. Was all fill and trapped sediment in the channel removed or stabilized?		
	a. If not, were measures to control sediment release applied as approved?		
	11. Did channel conditions at the barrier require grade control weirs/structures?*		
Metrics	12. Length of habitat made accessible: (mi)		
	13. Length of aquatic habitat disturbed at the feature: (ft)		
	14. Area of feature installed within bankfull channel: (ft^2)		
Implementation	15. Does the feature meet design, contract & permit specifications?		
	a. If not, were modifications beneficial to performance?		
	b. Is non-compliance significant enough to jeopardize performance?		
	c. Are corrections needed?		
	16. Would a different treatment or design have been preferable? If Y, comment.		
	17. **Feature Implementation Rating: Excl, Good, Fair, Poor, Fail**		
Comments			

* If applicable, consider it a separate FB feature. **Y**=Yes, **N**=No, **P**=Partially, **D**=Don't know, **A**=Not Applicable. CRMEP 06/01/11 Draft

FB - FISH PASSAGE at BARRIERS

POST-TREATMENT

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

			Comments
	Project Feature Number		
	Feature Type Code		
Structure	1. Is the structure functioning as designed?		
	a. Structural condition: Excl, Good, Fair, Poor, Fail		
	b. Problems: ANC, BBB, CRF, MAT, SHF, STR, SWA, UND, UNS, WSH, NON, OTH		
	2. Is the structure still in its original location and position?		
	3. If applicable, are back flooding weirs functioning as designed?*		
Barrier	4. Has a new barrier accumulated at the site of the removed barrier?		
	5. Has the modified barrier remained in the as-built configuration?		
	a. Are there problems visible with the modified barrier? If Y, comment.		
Fish	6. If an objective, does the feature provide adult fish passage?		
	a. If yes, for which targeted species: CHI, COH, CTT, SHT, etc.		
	7. Does any barrier to targeted adult species remain at the feature?		
	a. Current barrier catagory: PAR, TEM, TOT, OTH		
	b. Remaining passage problems: FJH, NRP, WTD, WTV, OTH		
	8. If an objective, does the feature provide juvenile fish passage?		
	a. If yes, for which fish species: CHI, COH, CTT, SHT, etc.		
	9. Does any barrier to targeted juvenile species remain at the feature?		
	a. Current barrier category: PAR, TEM, TOT, OTH		
	b. Remaining passage problems: FJH, NRP, WTD, WTV, OTH		
Channel	10. Are grade control weirs/structures functioning as designed?*		
	11. If sediment had aggraded upstream of the barrier, does any remain?		
	12. If there was incision/scour downstream of the barrier, has it stabilized?		
	13. Are there other channel problems in the vicinity of the feature?		
	14. If an objective, were localized channel problems corrected or stabilized?		
	15. Were there unintended effects on the stream channel? If Y, comment.		
Banks	16. Is there bank erosion or instability in the vicinity of the feature?		
	a. Locations: DNS, UPS, WIN and LBK, RBK		
	b. Apparent causes: BAR, CNR, EMG, GRZ, HYD, UND, USG, OTH		
	17. If an objective, was streambank instability and/or bank erosion reduced?		
	18. Were there unintended effects on streambanks? If Y, comment.		
Products	19. Is downstream movement of watershed products impaired at the feature?		
	a. Movement currently impaired: DBR, SUB, WTR, OTH		
	20. If an objective, did the feature improve watershed product movement?		
Rating	21. **Feature Effectiveness Rating: Excl, Good, Fair, Poor, Fail**		
	22. Does this feature need: DEC, ENH, MNT, REP, NON, OTH		
	23. Are additional restoration treatments recommended at this location?		
Comments			

* If applicable, consider it a separate FB feature. Y=Yes, N=No, P=Partially, D=Don't know, A=Not Applicable. CRMEP 06/01/11 Draft

CU - STREAM CROSSING UPGRADING **PRE-TREATMENT**

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

	Project Feature Number			
	Feature Type Code			
Stream Crossing	1. Is replacing or upgrading an existing crossing an objective?			
	2. Crossing type: AFD, AFW, ARZ, BAC, BRI, CUL, HUM, UAF, OTH			
	3. Structure condition: Excl, Good, Fair, Poor, Fail			
	4. Problems: ALN, APP, COR, CRS, INL, LNG, OTL, OVT, PIP, PLG, NTG, SLA, UNS, WSH, NON, OTH			
	5. Is "storm-proofing" the crossing an objective of the upgrade?			
	6. Is the crossing "storm-proofed" according to CDFG standards?			
	a. Is the crossing designed to pass at least a 100-yr flow?			
	b. If an undersized culvert in deep fill, is there an overflow culvert?			
	c. Is the crossing constructed or treated to eliminate diversion potential?			
	d. Does the crossing inlet have a low plug potential?			
	e. Is the crossing outlet protected from erosion?			
	f. Are the culvert inlet, outlet, and bottom open and in sound condition?			
	g. If a bridge, are bridge abutments stable and not restricting flow?			
	h. Is the crossing fill stable?			
	i. Are road surfaces/ditches disconnected to the greatest extent possible?			
	j. Length of road surface or ditch draining to this crossing: (ft)			
	*k. If a Class I stream, does crossing meet CDFG fish passage criteria?**			
Sed. Delivery	7. Is there evidence of previous sediment delivery from the crossing?			
	a. Sediment sources: SFE, FSL, LAN, CUT, SBL, NRL, EFL, SCW, DIV, RRG, NRG, SBE, OTH			
	8. Proposed sediment volume prevented from entering stream or "sediment savings": (cy)			
Channel	9. Is there localized stream channel aggradation or a sediment fan upstream of the crossing?			
	10. Is there channel incision or localized scour downstream of the crossing?			
	11. Are there other stream channel problems in the vicinity of the crossing?			
	a. Stream channel problems: AGG, BRD, FLO, GRC, HDC, INC, NAR, SCU, STT, WID, NON, OTH			
	12. Is correcting or stabilizing localized stream channel problems an objective?			
	13. Gradient of stream channel through existing crossing: (%)			
Banks	14. Is there streambank erosion or instability in the vicinity of the crossing?			
	a. Locations: UPS, DNS, WIN and LBK, RBK			
	b. Apparent cause: BAR, CNR, EMG, GRZ, HYD, UND, USG, OTH			
	15. Is stabilizing the streambank and/or reducing bank erosion an objective?			

Comments	Feature #:	Feature #:	Feature #:

* If primarily for fish passage, use FC. **Y**=Yes, **N**=No, **P**=Partially, **D**=Don't know, **A**=Not Applicable. CRMEP 06/01/11 Draft

CU - STREAM CROSSING UPGRADING

POST-TREATMENT

Grant #: **Project title:**

Site ID: **Site Name:**

Date : **Evaluator:** page ___ of ___

	Project Feature Number			
	Feature Type Code			
Stream Crossing	1. Is the new or upgraded crossing structure performing as designed?			
	a. Structure condition: Excl, Good, Fair, Poor, Fail			
	b. Problems: ALN, APP, COR, CRS, INL, LNG, OTL, OVT, PIP, PLG, NTG, SLA, UNS, WSH, NON, OTH			
	2. If an objective, was the stream crossing "storm-proofed"?			
	a. Is the crossing designed to pass at least a 100-yr flow?			
	b. If an undersized culvert in deep fill, is there an overflow culvert?			
	c. Is the crossing constructed or treated to eliminate diversion potential?			
	d. Does the crossing inlet have a low plug potential?			
	e. Is the crossing outlet protected from erosion?			
	f. Are the culvert inlet, outlet and bottom open and in sound condition?			
	g. If a bridge, are bridge abutments stable and not restricting flow?			
	h. Is the crossing fill stable?			
	i. Are road surfaces/ditches disconnected to the greatest extent possible?			
	j. Length of road surface or ditch draining to this crossing: (ft)			
	*k. If a Class I stream, does crossing meet CDFG fish passage criteria?**			
Sediment Delivery	3. Has there been sediment delivery from the crossing since implementation?			
	a. Sediment sources: SFE, FLS, LAN, CUT, SBL, NRL, EFL, SCW, DIV, RRG, NRG, SBE, OTH			
	b. Estimate delivery since implementation: (cy)			
	4. Adjusted sediment savings estimate: (cy)			
	5. Have spoils delivered sediment to streams?			
	a. Estimated delivery from spoils since implementation: (cy)			
Channel	6. Does any aggraded sediment upstream of the crossing remain?			
	7. Has stream channel incision/scour downstream of the crossing stabilized?			
	8. Are there other stream channel problems in the vicinity of the crossing?			
	a. Stream channel problems: AGG, BRD, FLO, GRC, HDC, INC, NAR, SCU, STT, WID, NON, OTH			
	9. If an objective, were localized channel problems corrected or stabilized?			
Banks	10. Is there streambank erosion or instability in the vicinity of the crossing?			
	a. Locations: UPS, DNS, WIN and LBK, RBK			
	b. Apparent cause: BAR, CNR, EMG, GRZ, HYD, UND, USG, OTH			
	11. If an objective, was streambank instability and/or bank erosion reduced?			
	12. Were there unintended effects on streambanks? If Y, comment.			
Rating	13. **Feature Effectiveness Rating: Excl, Good, Fair, Poor, Fail**			
	14. Does this feature need: DEC, ENH, MNT, REP, NON, OTH			
	15. Are additional restoration treatments recommended at this location?			
Comments				

□ **Comment on back.** * If primarily for fish passage, use FC. **Y**=Yes, **N**=No, **P**=Partially, **D**=Don't know, **A**=Not Applicable. CRMEP 06/01/11 Draft

PRE-TREATMENT EFFECTIVENESS MONITORING SUMMARY

Grant #: **Project title:**

Evaluator: **Reporting Date (mm/dd/yy):**

Is this Project Maintenance (PM)? □Yes □ No If yes, original contract or grant #:

Checklist Name		# Project Features	# Features Monitored
CB	Channel Reconstruction & Bank Stabilization		
CD	Stream Crossing Decommissioning		
CU	Stream Crossing Upgrading		
FB	Fish Passage at Barriers		
FC	Fish Passage at Stream Crossings		
FS	Fish Screening of Diversions		
IN	Instream Habitat & Bank Restoration		
LU	Land Use Treatments and Exclusion Fencing		
RD	Road Segment Decommissioning		
RT	Revegetation Treatments		
RU	Road Segment Upgrading		
SF	Streamflow Treatments		
US	Upslope Stabilization & Delivery Prevention		
VC	Vegetation Control & Removal		

Monitoring Summary/Notes:

continued on back ☐

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POST-TREATMENT EFFECTIVENESS MONITORING SUMMARY

Grant #: **Project title:**

Evaluator: **Reporting Date (mm/dd/yy):**

Is this Project Maintenance (PM)? □Yes □ No If yes, original contract or grant #:									
Checklist Name		# Project Features	# Features Monitored	# EXCELLENT	# GOOD	# FAIR	# POOR	# FAILED
CB	Channel Reconstruction & Bank Stabilization							
CD	Stream Crossing Decommissioning							
CU	Stream Crossing Upgrading							
FB	Fish Passage at Barriers							
FC	Fish Passage at Stream Crossings							
FS	Fish Screening of Diversions							
IN	Instream Habitat & Bank Restoration							
LU	Land Use Treatments and Exclusion Fencing							
RD	Road Segment Decommissioning							
RT	Revegetation Treatments							
RU	Road Segment Upgrading							
SF	Streamflow Treatments							
US	Upslope Stabilization & Delivery Prevention							
VC	Vegetation Control & Removal							

Overall Effectiveness Rating (circle one): **EXCELLENT** **GOOD** **FAIR** **POOR** **FAILED**

Rational/Recommendations

continued on back □

Long-term post-treatment monitoring recommended □ **No** □ **Yes - Year of next monitoring visit:**___________

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Photographic Monitoring Guidelines

Taking Photographs

All photographs should be taken standing up with the camera at eye height. If this position is not used, it should be noted on the Photograph Description Form. Photographs should be framed to encompass the expected "area of influence" and not just the project component expected to cause changes. For example, projects involving large excavations of soil for a decommissioned stream crossing require a view of the entire excavation area. Photographs of in-stream structures designed to develop pools should include the area expected to scour and the resulting gravel bar immediately downstream. Fixed landscape features such as large or unique trees or stumps, boulders, fences, buildings, road intersections, and the horizon should be included. Each photograph should contain a scale element such as a vehicle, person, survey rod, meter board, or white board (Lewis et al. 2000).

Vehicles and stadia rods make handy scale elements for large road projects. Meter boards are preferable for projects in low vegetation such as herbaceous or meadow vegetation. For stream related projects, a six-foot long stadia rod or other measuring item can be used. For projects that are not focused on improving vegetation, a lopper or a machete should be used to cut back vegetation and improve the photo.

Timing

Sequential photographs must be taken over time in order to show changes in site conditions. The timing and number of photos needed for an effective photo sequence depends on the project type. At minimum, photos should be taken at three different times, before project implementation, directly after project implementation, and again at a later date appropriate to the particular project. This later date for photographing effects depend on the project type and goals.

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Field Sampling

For projects with many project features, such as a road improvement or decommissioning projects with multiple stream crossings, rolling dips and areas of regrading, or extensive projects such as riparian plantings, it may not be necessary to establish photo points at each project feature. In this case, **photo sampling** may be necessary and both representative and unique project sites can be selected for monitoring. Some sites may not be "photogenic" and monitoring efforts should be focused on sites where views are both representative and interesting.

For **linear riparian projects,** a minimum of 25 photos along a photo transect is suggested. Photos taken every 100 feet along the channel will amount to about 25 photos per half mile of stream. A transect should be established from project start to end point along which photos are taken from mid-channel if possible. Photos may need to be taken from banks opposite to project work in very narrow channels. Photo points should be monumented with permanent markers if possible. If this is not feasible, distance along the transect relative to an established starting point should be recorded using a string box or tape. For projects larger than a half mile in length, a minimum of 25 photos should be distributed throughout the project reach. These can be located at intervals longer than 100 feet or at strategic project locations. Strategic locations include areas with good views, such as from the top of a large boulder. For more in-depth guidance on effective photography of vegetation see Hall (2002). For long extensive **road projects**, photo points should be established at a minimum of 30 percent of treated sites. Larger features where changes are more readily detected are recommended for photo documentation.

Sampling is *not* recommended for **in-stream** projects. Instead, photos of every in-stream structure should be taken. For additional guidance on effective photography of sediment and erosion control projects see Lewis et al (nd).

Table 1. Photograph Recommendations for Fish Passage Projects.

Project Goal: Improve fish passage by modifying or removing barriers

Projects: Fish ladders, channel modification, barrier removal, barrier modification, etc.

Effectiveness Photo Timing: Periods of adult fish migration, typically at highest flows and periods of juvenile fish migration, typically at lower flows.

Photographic Monitoring Guidelines

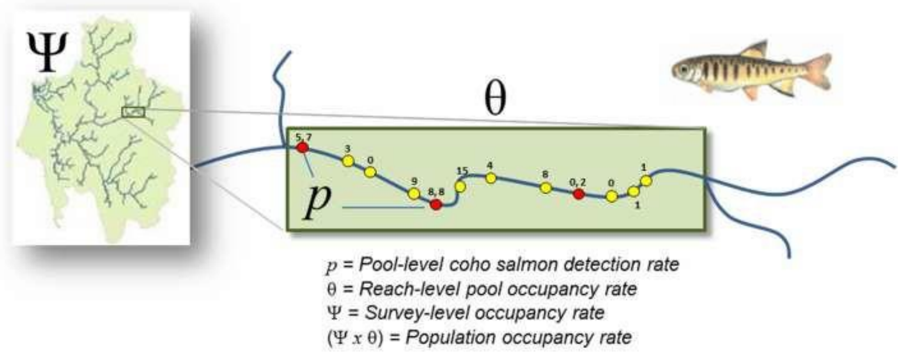
Implementation/ Effectiveness Criteria for FP	***Pre-project photographs***	***Post project photographs***
Properly installed inlets and outlets	Photographs taken from directly downstream and directly upstream of future passage structure at elevation of structure	Photographs taken from directly downstream and directly upstream of passage structure looking through it
Proper culvert/bridge alignment	Photographs taken from above and from side looking at location where new structure will be installed	Photographs taken from above and from side of culvert/bridge slope. Culvert photographs should show culvert inlets and outlets relative to the vertical and horizontal distance from the channel bottom. Photograph of habitat unit at inlet and outlet of structure.
Area of habitat made accessible	Photograph of conditions causing fish barrier Photograph of habitat above barrier	Photograph of location of former barrier Photograph of habitat above former barrier
No unforeseen adverse effects on habitat such as incision, instability or sedimentation	Photographs of channel conditions taken from mid-channel upstream of barrier, downstream, and at barrier	Photographs taken from mid-channel of channel upstream and downstream of former, and at former barrier
Increased attraction flows during migration periods (for barrier modifications)	Photograph of attraction flow at barrier during migration	Photograph of attraction flow at former barrier during migration

APPENDIX C:

GARWOOD AND RICKER (2015): JUVENILE COHO SPATIAL STRUCTURE MONITORING PROTOCOL: SUMMER SURVEY METHODS

2015 Juvenile Coho Salmon Spatial Structure Monitoring Protocol: Summer Survey Methods

California Department of Fish and Wildlife



Contacts: Justin.Garwood@wildlife.ca.gov, Seth.Ricker@wildlife.ca.gov, California Department of Fish and Wildlife, 5341 Ericson Way, Arcata, CA 95521

INTRODUCTION

NOAA established four viable salmon population (VSP) parameters to determine a population's risk of extinction. These parameters include: abundance, productivity (population growth rate), spatial structure, and diversity (McElhany et al. 2000). Trend monitoring for these VSP parameters is the measure by which extinction risk and recovery status of an ESU is evaluated. NOAA's framework for assessing the viability of SONCC and CCC coho salmon includes several criteria. The first set of criteria dictates that all diversity strata within and ESU need to be represented by multiple viable populations. These criteria establish abundance targets for functionally independent populations within the ESU. The second set of criteria seek to ensure that populations, both viable and nonviable, are distributed in a manner that maintains connectivity among populations throughout an ESU. In particular, the criteria specify that both dependent and non-core independent populations exhibit occupancy patterns that indicate significant immigration is occurring from the 'core populations' (Williams et al. 2008, Spence et al. 2008). To address data needs for viability assessment, the California Department of Fish and Wildlife and the NOAA cooperatively developed the Coastal California Salmonid Monitoring Plan (CMP). Adams et al. (2011) describes the strategy, design, and methods that are used in CMP monitoring. This juvenile coho salmon spatial structure monitoring protocol uses the design based sampling of the CMP to measure occupancy patterns of juvenile salmonids during the summer juvenile rearing period.

SURVEY DESIGN

The juvenile monitoring protocol presented here is designed to allow estimation of coho salmon occupancy rates during the summer (June-September) based on detection-non- detection data collected from rapid visual encounter surveys. Models developed by Mackenzie et al. (2002) and modified by Nichols et al. (2008) allow occupancy to be estimated at two spatial scales: the sample reach (i.e., the proportion of habitat units---pools in this case--- occupied by at least one fish in a sample reach) and the population (i.e., the proportion of reaches occupied within the sample frame) while accounting for imperfect detection at the both the sample reach and habitat unit. Both habitat unit (pool) and reach covariates (e.g. observer, habitat complexity, etc.) will be used assess their influence on local coho salmon detection rates and overall annual coho salmon occupancy patterns across the landscape. Ultimately, occupancy estimates obtained from this survey can be used to assess trends in coho salmon spatial structure for a given area as well as the habitat factors that best explain occupancy.

POOL UNIT SELECTION AND SAMPLING APPROACH

1) Pools are defined as typically having the following characteristics:

- Geomorphic depression in the channel (laterally concave)
- Impoundment or obstruction damming water
- Control structure, such as bedrock or log, forming a scour line
- Slow water velocities (except at the head of the pool)
- Lack of surface turbulence
- Wetted width typically greater than adjacent riffles or runs

Small Streams

2) Every second pool having specific minimum depth (see #3) and area (see #4) criteria will be sampled, along the entire length of each GRTS selected survey reach. To account for detection probabilities of individual divers and species, every 4th survey pool will be sampled with two independent passes (i.e. 2-1-1-1-2-1-1-1-2). The first pool will be selected at random by a coin toss and the survey will move from downstream to upstream. The first survey pool will be surveyed with two independent passes. Each 4th survey pool will be determined and flagged by the primary observer so the secondary observer will clearly identify the same individual habitat unit number and its specific boundaries. To minimize biases around species and count observations, all observations made by observers will remain confidential at the habitat unit level (i.e. counts of observer 2 are 'blind' to what observer 1 obtained until after both passes are completed and data is entered).

3) For a pool to be included as a potential sample unit, it must meet maximum pool depth categories that are defined for each reach in advance using GIS and the NOAA IP model based on the size of a given stream derived from the Mean annual flow parameter (cubic meters/ second):

< 0.1 CMS = 25 cm
0.1 – 1.0 CMS = 30 cm
1.0 – 1.5 CMS = 40 cm
> 1.5 CMS = 50 cm

These criteria are used to avoid excessive sampling in marginal quality habitats in larger streams.

4) For a pool to be included as a potential sample unit, it must have a minimum surface area of **3 m²** for streams with wetted channel width **<3 m** AND a width of **at least one-half** the wetted channel width. For streams with wetted widths > 3 m, a pool must have a minimum surface area of 6 m² AND a width of at least one-half the wetted channel width. Backwater pools **do not** need to equal at least one-half the channel width and must have a minimum surface area of at least 3 m².

5) Smaller side-channels will be included in the survey sequentially after the primary channel has been completed up to where it rejoins the side-channel (**See BOX 3 for details**). Units need a minimum depth of **30 cm**, surface areas of **3 m²** in side-channels <3 m wide and **6 m²** in side- channels >3 m wide, and a width of **at least one-half** the wetted channel to be selected. All side- channel pool habitats need to have depths ≥30 cm.

6) Pools having complex habitat features and exceeding five meters in average width will be surveyed by two divers using lanes. After the first pass, individual divers will switch sides for the second pass keeping observations confidential until data are recorded.

7) In general, pool boundaries should be defined based on hydrologic and geomorphic breaks or obstructions that would impede fish from passing from one unit to the next between dive passes. Attempt to break units based on shallow areas occurring between deeper habitats and/ or channel obstructions present. However, in some cases distinct breaks will not be present and breaking the unit becomes subjective. When clear breaks cannot be defined, attempt to keep fish from escaping the defined area with a careful primary dive approach.

8) Reaches that exhibit sustained water quality after the first dive pass (e.g. little/no siltation of the pool due to diver disturbance) will be sampled with two independent dive passes spaced five minutes apart or when conditions of the unit have returned to their normal state. Many coastal streams in California have excessive amounts of silt resulting in the first dive pass suspending sediments and compromising the ability to conduct a secondary pass in a reasonable timeframe. These streams should have secondary passes completed the following day. In this two day sampling, it is imperative that unit flagging tape include unit # and primary diver initials. Flagging needs to be secured such that it will be available the next day to identify the pool unit number.

9) In general, snorkel surveys should be **discontinued** if underwater visibility gets poor (Secchi Disk transparency of **1.25 m or less**) prior to surveying a unit. However, if conditions improve after a few units, continue with the first unit in succession with reasonable visibility.

Large Rivers

Large river sections require different sampling unit selection criteria than small streams based on different stream channel morphology and most juvenile coho salmon rearing habitat being limited to features proximal to the main channel. **All identified habitat features** will be surveyed in large river reaches since available sampling units are expected to occur much less frequently per unit distance. Reaches within large river sections will be defined prior to field sampling so crews follow the correct unit selection criteria and sampling protocol. In the Smith River, we defined a large river using an estimated mean annual discharge parameter of >10 cms from the NOAA IP model in a GIS.

10) Sampling will be limited to areas containing off-channel pools, backwaters, side channels, alcoves, thermal refuge, and river bank edge features (e.g. dense riparian vegetation, beaver created structures, log jams). For bank edge features and connected backwaters/ alcoves, each unit must have depth of at least **50 cm** AND a minimum surface area of **6 m^2** AND a water temperature **<22° Celsius** at the time of inspection. For all off-channel and side-channel features, each unit must have a depth of **30 cm** and a surface area of **3m^2**.

11) All identified off-channel and proximal channel habitats will be surveyed with two independent dive passes. Many large stream units occurring on the edge of the main channel will have no defined boundaries in the pelagic region opposite of the bank. Prior to the survey, both observers need to define the area to be searched so equal effort is applied. The survey area is confined to existing cover features characterizing the defined unit.

12) If large river units need to be surveyed by two divers using lanes (see #6)

VARIABLE DEFINITIONS

These definitions define how each variable is collected within the three survey components: Survey Header, Habitat, and Observations. More specific variable definitions are also provided in

Survey Reach Header:

Date: Record the date of the survey (MM/DD/YYYY). Fill out a new header each day if a given reach takes multiple days to complete.

GeoArea: Record the geographic area of the given survey (e.g. Smith River, Mattole River).

LocationCode: Record the GRTS reach number you are surveying.

Survey: Record **GRTS** for GRTS selected survey reach or **INCIDENTAL** for an incidental reach survey.

Total Dry Channel: Record the sum of linear dry channel (meters) throughout each reach.

Comments: Used to record any notes associated with the reach survey.

Pool Habitat Data:

To minimize disturbing fish and the unit's water clarity, pool measurements and cover estimates will be recorded by the secondary diver after they have completed their biological survey. However, these metrics will be recorded by both observers independently for every 10th unit to explore variation in data collection.

UnitNumber: Record the pool unit number starting the reach with unit #1, then #2, etc. Record 999 if unit is not part of regular survey (i.e. exploratory survey in an unselected unit).

Water Temp: Record the water temperature in degrees Celsius. Record all pool temperatures in Large River reaches and at least three pool temperatures throughout Small Stream reaches (i.e bottom, middle, top).

Secchi (m): Record the Secchi Disk distance to the nearest 0.1 meters in three units spread throughout a given reach (Beginning, middle, end). Be careful not to disturb sediment on the stream bottom when recording the Secchi distance. If the Secchi Disk distance is less than 1.2m terminate the survey (see #9 in previous section). If the distance exceeds the length of the unit record 999.

UTME: Record UTM Easting coordinates from GPS.

UTMN: Record UTM Northing coordinates from GPS.

GPS coordinates (UTM Datum: NAD83 Zone 10N) will be collected near the bottom of each pool through point averaging recorded during habitat measurements.

Pool Type: See BOX 1. Record the type that best represents the characteristics of a given pool: MCP (Main channel pool), SP (Scour pool), BP (Backwater pool), FL (Flatwater).

Max Pool Length: Record the maximum defined pool length to the nearest 0.1 meters.

Ave Pool Width: Record the pool width to the nearest 0.1 meters that best represents the average width that will be used to calculate the pool surface area.

Residual Pool Depth (Streams all off channel units): Record the residual pool depth to the nearest centimeter by subtracting the maximum depth of the riffle crest exiting the pool from the maximum pool depth.

Maximum Depth (Large Rivers only): Record the maximum Depth of the survey area to the nearest centimeter. **Record Residual depths at all off-channel and side-channel sites on large river reaches.

Cover Rating: See BOX 2. Record the overall rating of the pools available fish cover (1-5).

Cover Area: See BOX 2. Record the area of the pool unit occupied by fish cover in meters squared.

LWD Count: See BOX 2. Record the number of large logs occurring in or suspended above the wetted portion of a unit at the time of the survey.

Notes: Record any comments related to the pool unit.

Biological Observations:

Diver Initials: Record the diver's initials.

Dive Pass: Circle the number indicating if this is the first (1°) or second (2°) dive pass. If a single dive unit then circle both (1°and 2°) to indicate a single pass.

Common Name: Select the species of a given observation.

Count: Record the number of individuals observed.

Stage: Record the life stage of a given observation (See **Table 1** for specifics).

Age Class: Select the age category of organism (See **Table 1** for specifics).

Notes: Record any applicable notes.

BOX 1. Expanded Pool Habitat Type Definitions

Main Channel Pools: These pools encompass majority of wetted stream width (>60%).

Trench Pool: Canyon-like pool, generally U-shaped and often flanked by bedrock walls.

Mid-Channel Pool: Large pool formed by mid-channel scour with scour hole covering >60% wetted channel.

Confluence Pool: Large pool formed at or below the confluence of two or more channels.

Step Pool: A series of small pools separated by short cascades usually found in upper reaches with high gradients.

Scour Pools: These pools often contain scour holes less than 60% of wetted stream width.

Corner Pool: Lateral scour on bank forming pool at channel bend, usually found in lower reaches full of alluvium.

Log Scour Pool: Flow impinges on obstruction consisting of woody debris, usually <60% of wetted channel width.

Root Wad Scour Pool: Flow impinges on obstruction consisting of tree root mass, usually <60% of wetted channel.

Boulder Scour Pool: Flow impinges on obstruction consisting of one or more boulders, usually <60% channel.

Bedrock Scour Pool: Flow impinges against bedrock stream bank, usually <60% of wetted channel width.

Plunge Pool: Flow passes over complete channel obstruction such as a log and drops steeply creating scour pool.

Backwater Pools: These pools form apart or mostly apart from main channel.

Side Channel Pool: Pool formed outside the main channel, often dry or unconnected during summer.

Backwater Obstruction Pool: Pool formed in channel margin by eddies around boulder, log or root wad.

Dammed Pool: Formed upstream of a complete or nearly complete channel blockage (i.e. log jam, beaver dam, etc.)

Flatwater: Glides and Runs which fall into our unit selection parameters are recorded as flatwater.

Glide: Unit characterized by low flow and uniform channel bottom usually consisting of mud, sand or gravel.

Run: Unit generally faster flowing than glides, and has uniform channel bottom of gravel, cobble, and boulder.

Edgewater: We will encounter these usually on large (Mainstem Smith) channels in the stream margins. Diving the entire pool in these cases likely is not feasible. Water velocity is low and units mostly shallow, often associated with riffles.

BOX 2. Determining Habitat Unit Cover Quality

Cover Rating: is defined as an ocular three dimensional ranking of all cover available to salmonids in relation to the total pool volume at the time of survey. Cover includes any features within the pool (or suspended less than 1 meter above the pool) that are available refugia for juvenile salmonids including: undercut banks and boulders, woody debris, overhanging vegetation, bubble curtains, aquatic vegetation, etc. This rating is defined within five broad classes:

(1) None: Unit is void of fish cover.

(2) Poor: Unit is lacking significant fish cover and complexity. Unit contains at least one of the following features in limited availability: LWD, SWD, Boulders, root masses, undercut bank, submerged vegetation, overhanging vegetation, bubble curtain.

(3) Average: Unit generally provides fish cover, but lacks complexity, containing at least two of the following features in moderate availability: LWD, SWD, Boulders, root masses, undercut bank, submerged vegetation, overhanging vegetation, bubble curtain.

(4) Good: Unit provides extensive quality fish cover for up to 50% of the area from at least three of the following complex features: >1 LWD, > 2 SWD, deep undercut bank, large root mass, extensive aquatic vegetation/ submerged branches, >4 undercut boulders, dense submerged overhanging vegetation.

(5) Excellent: Unit has excellent fish cover usually dominating >40% of the pool area with at least four complex cover features (each available in extensive amounts). Unit must include >2 LWD and numerous SWD. Unit is difficult to navigate and survey.

Cover Area: A measure of the area of the unit occupied by fish cover. The area is estimated from an overhead view and is recorded in meters squared. Cover includes both small and large woody debris, undercut banks, undercut boulders, roots and rood wads, overhanging vegetation, and aquatic vegetation. Features must be >0.25 m^2 each, within the wetted portion of the unit and/ or suspended ≤ 1 meter directly above the wetter portion of the unit.

LWD Count: The number of logs greater than 30cm in diameter *and* greater than 2m in length occurring in (or suspended ≤ 1 meter directly above) the wetted area of the sampling unit. Log diameter must be 30 cm within the habitat zone to be included as LWD. Multi-stemmed logs are counted as one LWD.

BOX 3. Sampling Side Channels, Alcoves and Backwaters

Side Channels: Side-channels are a subchannel of the main-channel; water either flowing or standing; may be disconnected at low flows; source of the water is the main channel. Side-channels are also separated from the main channel based on juvenile salmonids not having the ability to migrate between two adjacent habitats in the two adjacent channels. Pool unit selection rules in side channels are the same as main channel pools based on the average side channel width (Small Streams: <3 meters average width, Large Streams: >3 meters average width). Once the channel width is defined then units are defined based on pool type, pool surface area, the pool being >50% of the side-channel width, and having a temperature < 22°C. All side channel units need to have maximum depths ≥30 cm regardless of the defined depth criteria in the main-channel. Every second pool in side-channels will be sampled along the entire length of each side-channel in small and large streams. Every 4th survey pool will be sampled with two independent passes (i.e. 2-1-1-1-2). Work up the main-channel first to where the side- channel reconnects to the main-channel, and continue pool selection systematically through the side-channel. In Large River reaches, census all pool habitats in side-channels having less than a total of four units. Survey every second pool in Large River side-channels having greater than three available pools.

Backwaters/ Alcoves: These are single pools that are isolated from the main-channel (connected or disconnected). If the feature is connected to the main-channel then the survey area does not include the main-channel, only the habitat proximal to the main-channel. Delineate the edge of the unit based on the river bank location both upstream and downstream. The minimum surface area criteria equal that of the channel it's connected to. The minimum depth for all these units is ≥ 30 cm. Every second pool will be sampled in Small and Large Streams and all backwater/ alcove habitats will be censused in Large Rivers. Unlike the Large River edge habitats, backwaters and alcoves in Large Rivers do not need to contain habitat complexity features or cold water refugia to define the unit, though it must be < 22°C.

Table 1. Age class and stage categories used for recording specific salmonid life stage observations.

Species	Age: 0+[1]	Stage	Age: 1+[1]	Stage	Age: Adult	Stage
Coho Salmon	Yes	Parr	Yes	Parr	No	NA
Chinook Salmon	Yes	Parr	Yes	Parr	No	NA
Trout spp.	Yes	Parr	Yes	Parr	No	NA
Cutthroat Trout	No	NA	No	NA	~ >150mm[2]	Adult
Rainbow Trout	No	NA	No	NA	~ >150mm[3]	Adult
Steelhead Trout	No	NA	No	NA	Yes, Sea run	Adult

[1]Size can vary by stream and/ or date of survey. Age classes need to be determined underwater by observers prior to a reach survey by defining specific size cutoffs of salmonids present in (or directly below) the reach.

[2]Individual has heavy black spotting especially below the lateral line and generally lacks parr marks, size may vary by stream.

[3]Resident: Individual lacks parr marks, usually darker in color overall compared to anadromous forms, white belly, may have reddish color along lateral line and cheeks, and usually occurs in headwater areas, size may vary by stream.

Core Sampling Equipment List for Summer Juvenile Coho Salmon Surveys

Personal Equipment
Dive duffle to hold all gear Field backpack
Waterproof flashlight
Batteries (enough for entire season)
Neoprene dive gloves with kevlar® (seal stitch seams with aquaseal®) Neoprene dive hood
Neoprene surf wetsuit 8-7mm with hood) Neoprene bootees
Laced wading boots
Neoprene gravel guards for boots
Skateboarding knee pads with hard plastic knee cap protection
Dive mask, snorkel

Survey Equipment
Protocols/ species keys
Data sheets and/ or PDA
Tadum
GPS
waterproof camera
50 meter metric roll tape for large streams
15 meter metric roll tape for small streams
Secchi Disk for recording underwater visibility
Thermometer (should also consider thermographs over the season)
Stadia rod (with cm units)
Coin (flip for determining start pool)
Pencils
Flagging/ Sharpies (for defining individual survey units)
Handheld tally counters (Up to 2 per diver)
Dive slate with pencil (optional-good for large survey units)

Safety Equipment
SPOT® safety device First aid kit
Emergency phone number contact sheet
Reach reconnaissance fact sheet with map and directions