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MEMORANDUM

April 24, 2019

TO: Forest Practices Board

FROM: Howard Haemmerle, Adaptive Management Program Administrator

SUBJECT: Transmittal of the PHB Validation Study Design Report

The Forest Practices Board (Board) in August 2017 direct the AMPA to identify and work with a science panel with expertise in headwater stream systems to develop a study design to validate geomorphic potential habitat breaks (PHBs) proposed for use in the Fish Habitat Assessment Methodology (FHAM) for water typing. The purpose of this memo is to transmit the final study design to the Board.

Overview

The PHB validation study is to develop criteria for accurately identifying PHBs and to evaluate the utility of PHB criteria selected by the Board for use in the Fish Habitat Assessment methodology (FHAM). The PHB validation study seeks to determine which combination of gradient, channel width, and obstacles features would best be used within the context of the FHAM to locate regulatory division points between fish and non-fish stream segments. The specific geomorphic variables included in the study are those identified in the three alternatives by the Board at its February 13, 2018 meeting.

The approach of the study is to examine the relationship between end of fish points identified through the study and locations of selected nearby geomorphic features across forested EPA level III ecoregions in Washington and seek to identify which combination of geomorphic criteria would best be used in the FHAM. The study includes three years of sampling across three hydrologically and biologically important seasons (March-June, August-October, and November-January) at 35 sites in each of the ~~seven forested~~seven-forested ecoregions. The results of the study will inform the Board on PHB criteria that can be easily identified in the field (implementable), are objective measurements (repeatable), and are based upon empirical data (enforceable).

The proposed study design has been provided for review and comment to the stakeholder technical committee, CMER, CMER's Instream Scientific Advisory Group (ISAG), and to the managing editor of the AMP's independent scientific peer-review (ISPR) process. Comments were provided by each of these groups, considered by the authors of the study (Science Panel) and integrated into the final study design as deemed appropriate. The team prepared (and provided) response matrices for all comments received, noting how each comment was or was not incorporated into the study design.

<u>Project Schedule</u>

The following schedule approximates the overall implementation timing during fiscal years 2019-2023. It includes time for CMER reviews, ISPR, findings report, Policy recommendations, and delivery of recommendations to the Board in May of 2023 (Table 1).

The proposed implementation of this study would follow the recent CMER Protocols and Standards Manual guidelines (Chapter 7), with technical support from CMER likely occurring via ISAG. A project team would be formed with a DNR/AMP Project Manager assigned to oversee the work, followed by selection of a contractor to implement the study. The project team would provide regular updates to ISAG and CMER and, when products are available, they would be reviewed by ISAG and CMER. Annual project progress presentations would be given to Policy and the Board. Final reports would be developed following the Adaptive Management Process outlined in Board Manual Section 23.

Table 1. Proposed timeline of the PHB Validation Study. Assumption for fiscal year 2023 includes 2 months for CMER initial review, 5 months of ISPR process, 1 month of CMER findings report approval, 2 months at Policy for discussion before going to the Board in May of 2023.

Fiscal Year	**Implementation**			**Annual Update**		**Final Report**
	Mar - June	**Aug - October**	**November - January**	**CMER**	**Board**	**CMER/Policy/Board**
2019	***X***			***X***	***X***	
2020	***X***	***X***	***X***	***X***	***X***	
2021	***X***	***X***	***X***	***X***	***X***	
2022		***X***	***X***	***X***	***X***	
2023						***X***

Evaluation of physical features that define fish habitat in forested landscapes across Washington State

Study plan prepared for the Washington Forest Practices Board

March 20, 2019

Submitted by

PHB Science Panel

Phil Roni (Chair)
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Summary

Fish habitat in forested watersheds is influenced by many factors including gradient, channel condition, nutrients, flow, barriers to migration, history of anthropogenic and natural disturbance, and fish population size. The Washington Forest Practices Board has selected criteria to be used in determining potential habitat breaks (PHBs) between fish (Type F) and non-fish bearing waters (Type N) across the state. These criteria are based upon data collected during a single Washington Department of Natural Resources (DNR) protocol electrofishing survey and include gradient, bankfull width, and vertical and non-vertical barriers to migration. To evaluate which physical criteria best define the end of fish (EOF) habitat (the uppermost stream segments that actually or potentially are inhabited by fish at any time of the year), detailed information is needed on the uppermost fish location and associated habitat in small streams across Washington State. While some data on habitat conditions at last detected fish locations are available (e.g., from existing water type modification forms [WTMFs] submitted to DNR), these data were found to be insufficient to determine PHBs that defined last detected fish locations and associated habitat.

The purpose of this study is to develop criteria for accurately identifying PHBs and to evaluate the utility of PHB criteria selected by the Board for use in the Fish Habitat Assessment methodology (FHAM) as part of a water typing rule. The study is designed to 1) determine which combinations of gradient, channel width, barriers to migration, and other physical habitat and geomorphic conditions of the Board identified PHB criteria best identifies last detected fish location in an objective and repeatable manner[1] as applied in the FHAM and 2) evaluate if a set or combination of empirically derived criteria are better at identifying the starting point at which a protocol survey would begin. Additionally, this study is intended to provide insight into how last detected fish points, EOF habitat, and PHBs proposed by the Washington Forest Practice Board may vary across ecoregions, seasons, and years. Additionally, this study is intended to provide insight into how last detected fish points, EOF habitat, and PHBs proposed by the

[1] While the study will gather considerable information on fish distribution, it is not a long-term (>25 years) study on the upper limits of fish distribution per se.

Washington Forest Practice Board may vary across ecoregions, seasons, and years. We recommend the study be conducted across three years and three seasons (spring, summer, and fall) at 35 sites in each of seven forested EPA Level III ecoregions in Washington State. A total of 245 randomly selected sites from approved water type modification forms on the DNR hydro layer will be surveyed repeatedly every year for three years. Upstream fish distribution limits (i.e., last detected fish locations) will be determined during each season at each site following DNR protocols for electrofishing surveys. Once the uppermost fish is located during each sampling event, the last detected fish location will be flagged, GPS coordinates will be recorded, and a longitudinal profile habitat survey will be conducted to characterize habitat and geomorphic conditions 100 m downstream and 200 m upstream of the last detected fish location. During each of the three years, a random sample of one-third of all sites (82 sites) will be revisited seasonally and DNR protocol electrofishing surveys repeated to determine how much the last detected fish location changes intra- and inter-annually. If the last detected fish location changes during any subsequent survey, a longitudinal profile survey will be conducted to append upstream or downstream to ensure that there are habitat data 200 m above and 100 m below last detected fish locations for all seasons and years. Data will be analyzed to determine the combinations of gradient, channel width, and other geomorphic features that best define last detected fish locations, PHBs, EOF habitat, and whether these vary by ecoregion and season. The results of this study will be used to evaluate the effectiveness of PHB criteria in determining the regulatory break between fish (Type F) and non-fish bearing (Type N) waters.

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List of Acronyms

BFW	Bankfull Width
DNR	Department of Natural Resources
eDNA	Environmental DNA
EOF	End of Fish (Last detected fish following a Protocol Survey)
F/N Break	Regulatory break between fish and non-fish bearing waters
FHAM	Fish Habitat Assessment Method
GIS	Geographic Information System
PHB	Potential Habitat Break(s)
Type F	Fish Bearing Streams
Type N	Non-Fish Bearing Streams
WTM	Water Type Modification
WTMF	Water Type Modification Form

Introduction

Washington State forest practices are regulated by the Forest Practices Act established by the legislature, with rules established by the Washington Forest Practices Board (Board). The goals of the rules include protecting public resources (water quality, fish, and wildlife) and maintaining an economically viable timber industry. Rules pertaining to aquatic and riparian habitats are specifically included in the Forest Practices Habitat Conservation Plan, which provides coverage for approximately 9.3 million acres of forestland in Washington (6.1 million acres west of the Cascade Crest and 3.2 million acres in eastern Washington). Specific prescriptions (rules) are applied in waters containing fish to protect fish and their habitats.

The Board is responsible for rule-making and overseeing the implementation of forest practice rules. The evaluation of the effectiveness of these rules is directed by the Adaptive Management Program of the Washington Department of Natural Resources. Water typing is an important part of applying contemporary forest practice rules since prescriptions in riparian areas are based in part on whether streams are or potentially could be used by fish. Streams identified as having fish habitat are classified as Type F waters, defined in the interim water typing rule WAC 222-16-031, and have specific riparian buffer prescriptions and fish passage requirements. Fish habitat is defined in WAC 222-16-010 as "…habitat, which is used by fish at any life stage at any time of the year including potential habitat likely to be used by fish, which could be recovered by restoration or management and includes off-channel habitat." Currently, an interim rule delineates Type F waters through the use of either default physical criteria (e.g., 2 feet defined channel within the bankfull width and greater than 20 percent slope) or protocol surveys (e.g., electrofishing). DNR provides a map showing where a model has determined fish bearing stream segments. The Forest Practice Rules require forest land owners to determine, in the field, the type of any regulated waters as identified within proposed harvest areas prior to submitting a forest practices application/notification. Landowners may use the physical criteria or the results from protocol survey electrofishing to identify the regulatory F/N break. Landowners are encouraged to submit a Water Type Modification Form (WTMF) to the DNR to make permanent changes to the water type maps. Thousands of WTMF have been submitted to DNR to modify water body types and modify the location of the break between Type F and Type N waters. The process for submitting and getting water type approved is outlined includes the following steps:

1. Proponent conducts a "protocol electrofishing survey"
2. Proponent submits a WTMF
3. DNR and reviewers concur/don't concur
    a. If DNR and reviewers concur, the water type modification is approved
    b. If DNR and reviewers don't concur, a site visit is organized to adjust and determine the F/N break

The Board is currently in the process of establishing a permanent water typing rule. Ultimately, the rule must be implementable, repeatable, and enforceable by practitioners and regulators involved in the water typing system. An important part of the permanent rule will be guidance on a specific protocol to determine the regulatory break between Type F and Type N waters. The Board is considering the use of a fish habitat assessment method that incorporates known fish use with potential habitat breaks (PHBs) to identify features that can be used to locate the starting location for a survey of fish use and the end point of waters to be protected for fish habitat. These PHBs are based upon changes in gradient, stream size, and the presence of vertical and non-vertical barriers to migration (e.g., obstacles).

Over the past 20 years, protocol electrofishing surveys have been conducted under WAC 222-16-031 with guidance provided by Board Manual Section 13 to determine the upper extent of Type F waters. These fish presence surveys have incorporated additional stream length (defined in WAC 222-16-010) to capture habitat that was "likely to be used by fish" upstream of the detected uppermost fish during a protocol survey. Throughout Washington, the uppermost-fish detected is most often a salmonid. In over 90% of cases the uppermost fish is a cutthroat trout *Oncorhynchus clarki* (D. Collins, Washington Department of Natural Resources, unpublished data). Other salmonid species that have been recorded at uppermost fish locations across Washington include rainbow trout *O. mykiss*, brook trout *Salvelinus fontinalis* (an introduced non-native that has become established in many Washington streams), and (rarely) bull trout *S. confluentus*. In headwater reaches that are accessible to anadromous fishes, coho salmon *O.*

kisutch juveniles have been reported on occasion as the uppermost fish during protocol survey seasons (March 1st through July 15th). Of the non-salmonid species recorded at uppermost fish sites in western Washington, sculpins *Cottus* spp. were most prevalent, followed by brook lamprey *Lampetra* spp., and less commonly dace *Rhinichthys* spp., three-spine stickleback *Gasterosteus aculeatus*, and Olympic mudminnow *Novumbra hubbsi*. The only uppermost non-salmonid fish species recorded in east-side Washington streams were sculpins.

Many factors determine the limits of distribution of fishes, including barriers to migration, stream gradient, flow/channel size, and food resources. Understanding the current science on these four factors is important prior to discussing how they can be used to most accurately define the upstream limits of fish distribution in forested streams of Washington State.

Barriers to Migration

Natural stream habitat breaks that might obstruct or completely block upstream fish movement to apparently suitable habitat include: vertical drops, steep cascades, bedrock sheets, and trench/chutes (Hawkins et al. 1993; Figure 1).

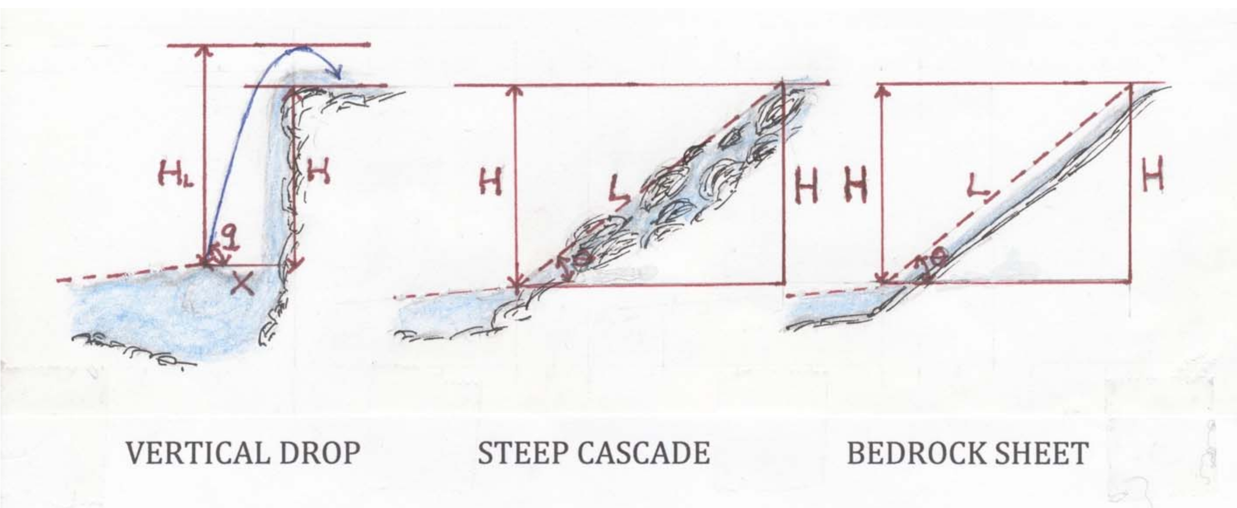

Figure 1. Three types of habitat that could pose obstacles or barriers to upstream movement of headwater fishes.

The ability of fishes to pass such obstacles is associated with their swimming and leaping abilities. The swimming ability of fishes is typically described in terms of cruising, prolonged, and burst speed, which are measured in units of body lengths per second (Watts 1974; Beamish 1978; Webb 1984; Bell 1991; Hammer 1995). Cruising speed is the speed a fish can sustain essentially indefinitely without fatigue or stress, usually 2–4 body lengths per second. Cruising speed is used during normal migration or movements through gentle currents or low gradient reaches. Prolonged speed (also called sustained speed) is the speed a fish can maintain for a period of several minutes to less than an hour before fatiguing; typically 4–7 body lengths per second. Prolonged swimming speed is used when a fish is confronted with more robust currents or moderate gradients. Burst speed is the speed a fish can maintain for only a few seconds without fatigue, typically 8–12 body lengths per second. Fish typically accelerate to burst speed when necessary to ascend the short, swiftest, steepest sections of a stream, to leap obstacles, or avoid predators.

Swimming ability is influenced by environmental factors such as temperature, ontogeny, and condition. Body form can also affect swimming ability, with more fusiform body shapes being advantageous for stronger burst speeds in fishes such as cutthroat and rainbow trout (Bisson et al. 1988; Hawkins and Quinn 1996) rather than other fishes.

When leaping obstacles, fish come out of the water at burst velocity and move in a parabolic trajectory (Powers and Orsborn 1985). Relationships for the height attained in the leap, and the horizontal distance traversed to the point of maximum height are often used to assess barriers. Depth at the point of takeoff is important for enabling fish to reach burst velocity. Stuart (1962) found water depth of at least 1.25 times the height of an obstacle to be required for successful upstream barrier passage. More recently, however, Kondratieff and Myrick (2006) reported that small brook trout (size range 100-150 mm) could jump vertical waterfalls as high as 4.7 times their body length from plunge pools only 0.78 times the obstacle height, and larger brook trout (size ranges 150-200 mm and 200 mm+) could jump waterfalls with heights 3 to 4 times their body length if the plunge pool depth was at least 0.54 times the obstacle height.

To successfully ascend 4.7 body lengths in height, a back-calculation from the Powers and Orsborn (1985) trajectory equation yields a burst speed of 22 body lengths per second (11.7 feet per second) for the 100-150 mm body-length brook trout reported by Kondratieff and Myrick (2006). If it is assumed that other salmonids (e.g., cutthroat, rainbow trout or coho salmon) could perform as well as brook trout in the size range typically found at uppermost fish locations in Washington (Sedell et al. 1982; Fransen et al. 1998; Liquori 2000; Latterell et al. 2003; Peterson et al. 2013), then a burst speed of 22 body lengths per second (11.7 feet per second) would allow the largest fishes in the size range typical of headwater-dwelling salmonids (160 mm) to leap a vertical obstacle 2.6 feet high, whereas a vertical obstacle of 3 feet high would be impassable.

When leaping is not required, fishes may ascend steep cascades and other high-velocity habitat units (Hawkins et al. 1993) by seeking pockets of slow water interspersed in areas with turbulent flow (e.g., boundary layers near rocks or logs). The average water velocity measured in cascade habitat units in small western Washington streams by Bisson et al. (1988) was only 24.8 ± 3.2 cm/s, or about 0.8 ft/s. Average water depth in these same cascades was 10.0 ± 1.4 cm, or about 4 inches. It is possible that fish may ascend streams during periods of elevated flow by moving along the channel margins where water velocities are reduced relative to mid-stream and small falls and boulder cascades are partially or completely submerged.

Although studies examining fish migration through potential non-vertical obstacles are rare, a small number of studies have examined brook trout movement through steep cascades and reported fish ascending cascades of more than 20% gradient (Moore et al. 1985; Adams et al. 2000; Björkelid 2005). For example, Adams et al. (2000) reported that adult brook trout ascended cascades with slopes of 13% that extended for more than 67 m, and 22% for more than 14 m as well as adult brook trout ascending a waterfall 1.2m high. Similarly, Björkelid (2005) reported invasive brook trout colonizing 18 headwater streams in Sweden and found they ascended stream segments of 22% measured with a clinometer and 31% measured with GIS.

Gradient

In Washington streams, fish (not necessarily the uppermost fish) have been observed in headwater segments with overall slopes as steep as 31% (S. Conroy, formerly Washington Trout [now Wild Fish Conservancy], unpublished data), 35% (J. Silver, Hoh Indian Tribe, unpublished data; D. Collins, Washington Department of Natural Resources, unpublished data), and in reach gradients of 25% and steeper in Oregon streams (C. Andrus, Oregon Department of Forestry, unpublished data; Connolly and Hall 1999). This range of channel steepness is consistent with other observations in western North America (e.g., Fausch 1989; Ziller 1992; Kruse et al. 1997; Watson and Hillman 1997; Dunham et al. 1999; Hastings et al. 2005; Bryant et al. 2004, 2007) and Europe (Huet 1959). In the “trout zones” of European rivers (headwaters), brown trout *Salmo trutta* predominate and reach gradients may be 10 to 25% or steeper (Huet 1959; Watson 1993). In Washington, it is important to note that fish presence in streams steeper than 15% accounted for only 10% of reported occurrences in forested streams (Cole et al. 2006; J. T. Light, Plum Creek Timber, unpublished data). However, these observations clearly establish that fish habitat in headwater streams extends into steep step-pool and cascade reach types (Montgomery and Buffington 1993).

In steep step-pool and cascade reaches, habitat use by fishes may be different from the pool-riffle reaches further downstream. For example, in streams of low to moderate gradient and well-developed pool-riffle sequences (Montgomery and Buffington 1993; 1997), gravels are usually relatively abundant. In steep, typically boulder-bed reaches where the uppermost fish are often found, pool-riffle sequences are generally absent, gravels are less abundant, and gravels that are present are confined to small patches around wood or rock; these patterns are distinctly different from lower gradient streams (Heede 1972; Kondolf et al. 1991). Often the water surface slopes where fish occur in step-pool habitats have much lower local gradients than the overall reach gradient and may range from only 0.4 to 4%, even where overall reach gradients may be as high as 35% (Kondolf et al. 1991; Figure 2).

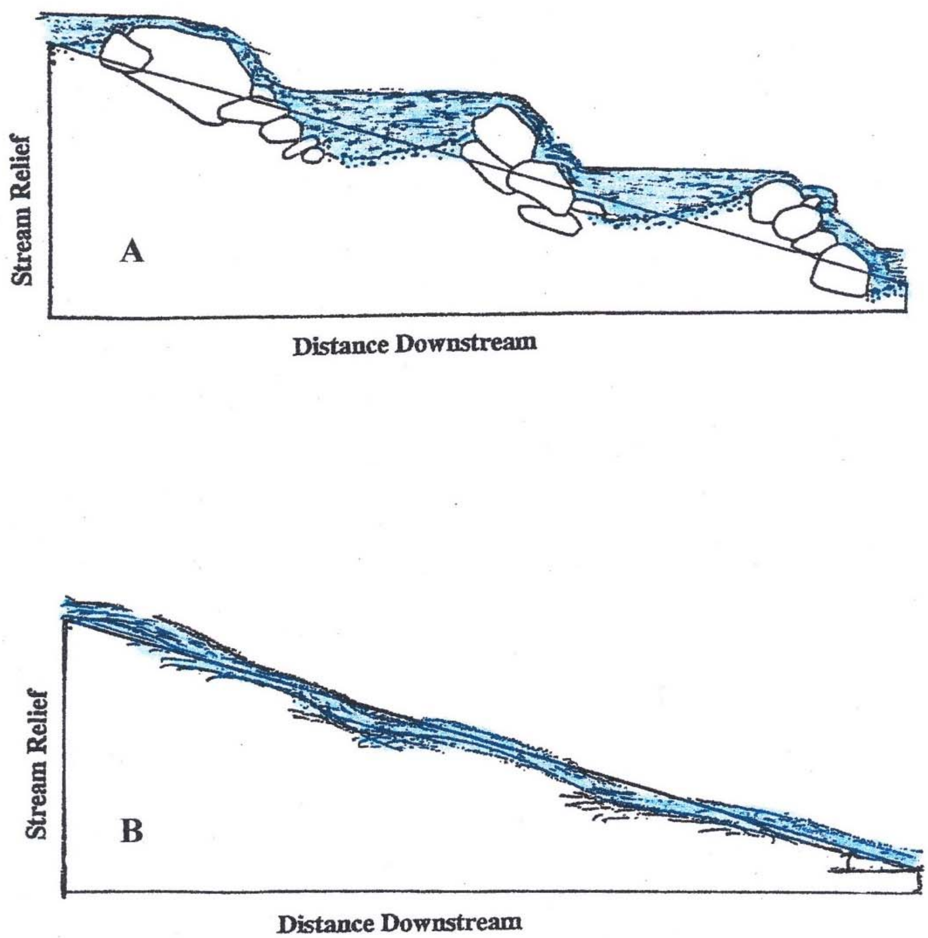

Figure 2. Two very different profiles of a headwater reach with the same overall reach gradient. Illustration (A) demonstrates how roughening elements create local gradients that are lower than the overall reach gradient, while reaches without such features (B) do not.

Flow and Channel Size

Bankfull width (BFW) is used to define the stage of discharge at which a stream does its habitat-building work (Andrews 1980; Leopold 1994; Rosgen 1996). Often BFW is used as a surrogate for stream discharge (area, depth, and velocity), which is important for determining the uppermost fish and extent of fish habitat (Harvey 1993). Fransen et al. (1998) estimated mean annual flow rates at the upstream extent of fish distribution for 79 streams in the western Cascade foothills and Willapa Hills in Washington and found that 90% of these streams had mean annual flows of 3.5 cfs (±0.1 m^3/s) or less at the upper boundary of fish presence; 80% had mean annual flows of 2 cfs (±0.06 m^3/s) or less at the upper boundary; 65% had mean annual flows of 1 cfs (±0.03 m^3/s) or less at the upper boundary; and approximately 25% of the sites had mean annual flows of 0.5 cfs (±0.01 m^3/s) or less at the upper boundary (Figure 3).

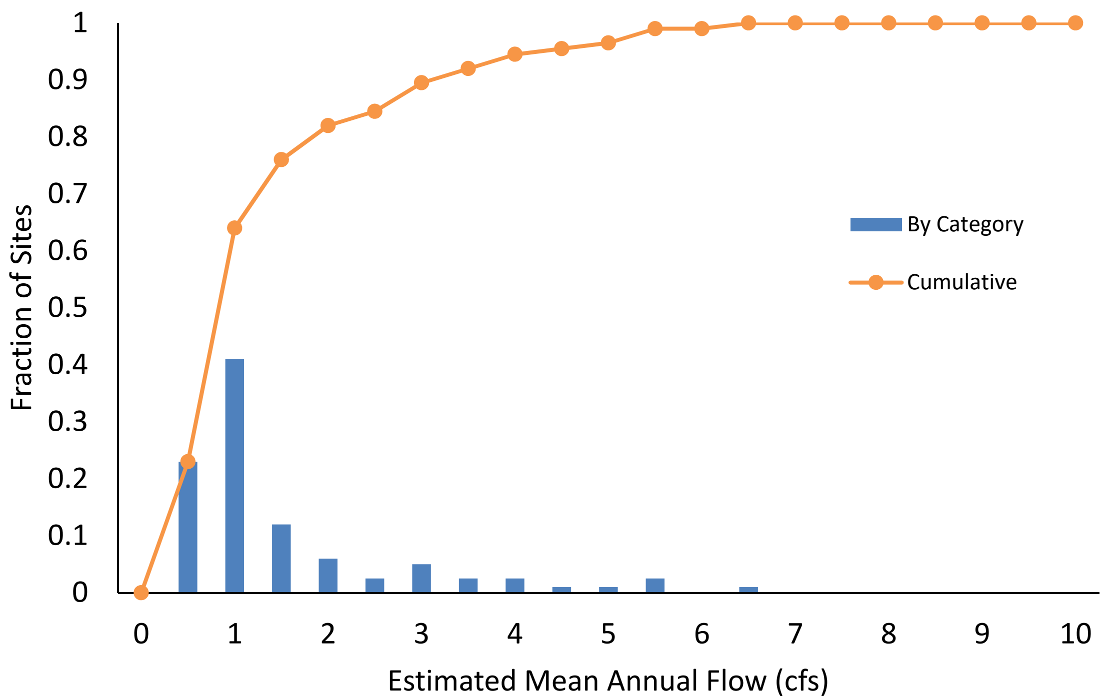

Figure 3. Estimated mean annual flows at uppermost fish locations in 79 streams in western Washington (Cascade foothills and Willapa Hills; Fransen et al. 1998).

The amount of drainage area required to generate a channel with a perennial source of water is not the same for all basins and varies with climate, geology, topography of the basin, and ecoregion (Montgomery 1999). For example, in coastal areas of Washington, perennial flow is often established in watersheds as small as 13 acres (5.3 ha), while the rest of western Washington needs a basin area of approximately 52 acres (21 ha) to establish perennial flow. Eastern Washington, on average, requires a basin area of approximately 300 acres (121.4 ha) to establish perennial flow (FFR 1999). Studies have shown that BFW is highly correlated with drainage area. For example, Beechie and Imaki (2014) developed an equation for BFW for Columbia Basin streams based on annual precipitation and catchment (drainage) area. Although their equation was developed for larger streams, we tested their equation using empirical BFW data from multiple smaller streams across Washington State and found that it accurately predicted BFW in headwater streams. This indicates that BFW serves as a good proxy for catchment/drainage area.

Food Resources

Many studies, particularly in Pacific Northwest streams, have demonstrated strong food limitations for fish inhabiting (using) small streams (Warren et al. 1964; Mason 1976; Naiman and Sedell 1980; Bisson and Bilby 1998). Headwater segments are often characterized by closed forest canopies, requiring primary energy sources from allochthonous inputs of coarse particulate organic matter (CPOM). Shredder organisms occur in these reaches and feed on this CPOM. These aquatic organisms, along with any terrestrial invertebrates that fall into the stream, comprise the food base for trout and other predators (Vannote et al. 1980; Hawkins and Sedell 1981; Triska et al. 1982; Wipfli 1997). The total production of macroinvertebrate organisms is substantially lower in small headwater stream reaches than in the larger, lower-gradient reaches further downstream (Northcote and Hartmann 1988; Haggerty et al. 2004). As a result, resident fishes in headwater stream reaches tend to be small bodied, which limits their ability to negotiate obstacles to upstream movement and migration.

Fish Habitat Assessment Method (FHAM)

Water typing surveyors have used professional judgment to estimate "habitat likely to be used by fish" when proposing regulatory fish bearing/non-fish bearing water (F/N) breaks. Stream segments that are accessible to fish and exhibit the same characteristics to those of fish-bearing reaches are typically assumed to be fish habitat, whether or not fish are present at the time of a survey. Surveyors have assessed barriers and measurable changes in stream size and/or gradient to estimate the EOF habitat (Cupp 2002; Cole et al. 2006). Although research is somewhat limited, the upstream extent of fish distribution in forest lands appears to be strongly influenced by stream size, channel gradient, and access to suitable habitat (Fransen et al. 2006; PHB Science Panel 2018). In response to these findings, the Board adopted a methodology (FHAM) intended to be repeatable, implementable, and enforceable. The FHAM describes PHBs that reflect a change in the reach characteristics to provide a last detected fish point above which a protocol electrofishing survey would be undertaken (Figure 4).

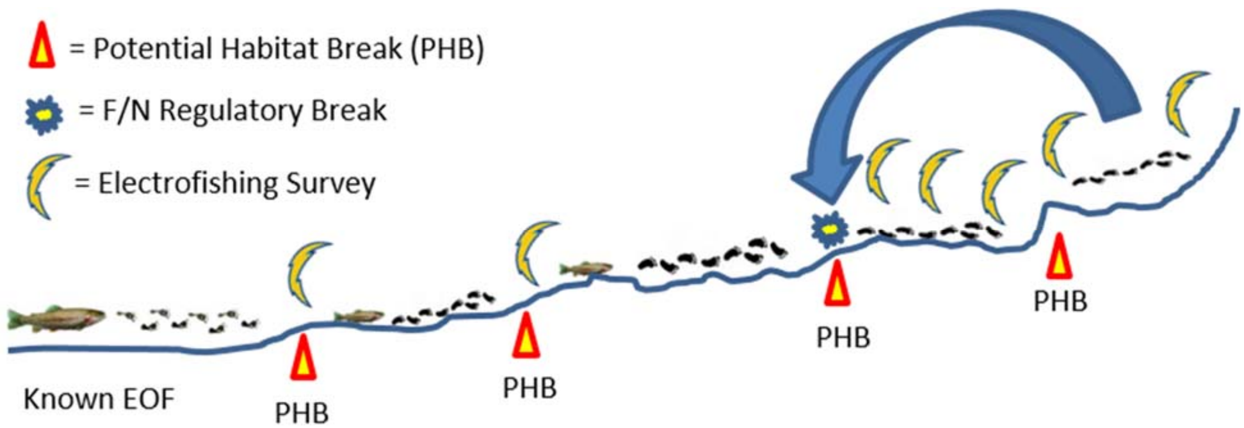

Figure 4. Example of how the PHB criteria and Fish Habitat Assessment Methodology (FHAM) are applied in the field. The first step is to identify the last detected fish (end of fish) location. Once the point is identified, the survey team would begin to measure bankfull width, gradient, and barrier (obstacle) criteria while moving upstream. Once a point in the stream meeting one of the PHB criterion (gradient, barrier, change in channel width) is identified, the survey team would apply a fish survey (e.g., electrofishing) upstream of the PHB to determine if fish are present upstream. If sampling yields no fish ¼ mile upstream, then the F/N break would occur at the location where the survey commenced (see arrow in the figure). If fish are encountered above any PHB, the process of measuring and moving upstream would repeat until fish are not encountered.

Currently, specific PHBs are based on stream size, gradient, and access to suitable habitat. Changes in these criteria are measured from the last known fish observation and again when the PHB criteria are met upstream of that location. The PHB Science Panel recently reviewed the available science and data on PHBs and provided recommendations to the Board for specific PHB criteria for eastern and western Washington (PHB Science Panel 2018). In developing our recommendations, we considered a variety of potential PHB attributes, including the physical features of a stream channel, water quality and quantity parameters, and other factors that might contribute to measurable habitat breaks. These attributes were evaluated in terms of their simplicity, objectivity, accuracy, and repeatability in the field, as well as the amount and relevance of existing scientific literature pertaining to each attribute. We concluded that it is possible to identify PHBs based on <u>stream size</u>, <u>channel gradient</u>, and non-permanent deformable (obstacles) and <u>permanent natural barriers</u>. These three attributes satisfied the objectives of simplicity, objectivity, accuracy, ease of measure, and repeatability, can be consistently identified in the field, and can be incorporated into a practical survey protocol. Based on available data, we provided recommendations for PHB criteria based on stream size, channel gradient, and permanent natural barriers. The Board then selected three potential combinations of criteria at their 14 February 2018 meeting and instructed the PHB Science Panel to develop a field study to evaluate the performance of PHBs used in FHAM to identify the appropriate locations for regulatory breaks between Type F and Type N waters (Table 1). It was important to the Board for the panel to determine which criteria most reliably identify PHBs in eastern and western Washington. The Board also instructed the Science Panel to stratify sampling by ecoregion and to examine crew variability in identifying PHBs especially evaluating aspects of field measurement practicality and repeatability.

Table 1. Three combinations of barrier, gradient, and width PHBs selected for evaluation by the Washington Forest Practices Board.

Type	Description of criteria
Criteria 1	
Barrier	Gradient >20%, and barrier elevation difference is greater than BFW
Gradient	10% gradient threshold (Upstream Grad>10% and downstream Grad<10%)
Width	2 ft upstream threshold (Upstream BFW <2ft)
Criteria 2	
Barrier	Gradient >30%, and barrier elevation difference is greater than twice BFW
Gradient	Gradient difference >= 5% (upstream grad - downstream grad >=5) and Downstream gradient >10%
Width	2 ft upstream threshold (Upstream BFW <2ft)
Criteria 3	
Barrier	Gradient >20%, and barrier elevation difference is greater than BFW
Gradient	Gradient difference >= 5% (upstream grad - downstream grad >=5)

Width	20% loss in width. Upstream to downstream width ratio <=.8

Study Purpose

The purpose of this study is to develop criteria for accurately identifying PHBs and to evaluate the utility of PHB criteria selected by the Board for use in the FHAM as part of a water typing rule. The study is designed to 1) determine which combinations of gradient, channel width, barriers to migration, and other physical habitat and geomorphic conditions of the Board identified PHB criteria best identifies last detected fish location in an objective and repeatable manner[2] as applied in the FHAM and 2) evaluate if a set or combination of empirically derived criteria are better at identifying the starting point at which a protocol survey would begin. Additionally, this study is intended to provide insight into how last detected fish points, EOF habitat, and PHBs proposed by the Washington Forest Practice Board may vary across ecoregions, seasons, and years. The study will evaluate the PHB criteria selected by the Board to be used in FHAM as part of a water-typing rule and explore potentially useful attributes that may help to more accurately describe PHB (Table 1). It is designed to identify PHB criteria that can be used to identify EOF habitat in forested streams across Washington and to better understand how PHBs may be influenced by seasonal and annual variability and by location within Washington State (e.g., reduce uncertainty). The overall goal is to test the reliability of PHB criteria as an aid in identifying EOF habitat in an objective and repeatable manner[3]

It is important to note that this study is not intended to evaluate the water typing system, the FHAM, or describe how the regulatory Type F/N break should be determined. Other factors such as temperature, flow, water quality, and biological interactions are important covariates that influence the distribution of fishes but do not affect PHBs. Therefore, they are not included in this study.

[2] While the study will gather considerable information on fish distribution, it is not a long-term (>25 years) study on the upper limits of fish distribution per se.
[3] While the study will gather considerable information on fish distribution, it is not a long-term (>25 years) study on the upper limits of fish distribution per se.

Study Questions

This study is designed to answer the following questions:

- Do the PHB criteria provided by the Washington Forest Practices Board accurately capture the EOF habitat when applied in the Fish Habitat Assessment Methodology (FHAM)?
- Based on data collected, what is the most accurate combination of metrics for determining PHB by region or ecoregion?
- Are there differences in PHB criteria by Environmental Protection Agency (EPA) Level III ecoregion, eastern vs western Washington, or some other geographic or landscape strata?
- Are there additional variables (e.g., geology, drainage area, valley width, land use, channel type, and stand age) that could improve the accuracy of existing criteria?
- What is the influence of season/timing of survey on PHB identification?
- What is the typical inter-annual variability in last detected fish and PHBs?
- Can protocols used to describe PHB be consistently applied among survey crews and be expected to provide similar results in practice?

Answering these questions requires identifying the last detected fish and surveying habitat above and below these points in a random representative sample of streams across the state.

Methods

Study Design

We propose to determine the location of last detectable fish at 245 sites in forested watersheds of EPA Level III ecoregions across Washington State and measure the habitat characteristics (gradient, channel width, barriers) using a long-profile survey 200 m above and 100 m below the last detected fish. These surveys will provide the data necessary to evaluate differences among PHB criteria across ecoregions. Based on variability in the data examined from existing water type modification forms (WTMFs) that includes information on gradient, channel width, and barriers, we estimate that a sample size of 35 sites per ecoregion will be needed to determine if there are differences among ecoregions. Sample sizes were estimated from data on upstream and downstream changes in gradient surrounding end of fish points for the "Coast Range" ecoregion. We felt these data, which were collected using similar methods, accurately represent the variability we will encounter during the proposed PHB study. Because the data showed a non-parametric distribution, we estimated minimum sample sizes for each ecoregion using three approaches: power estimates for t-tests, samples required to estimate the mean, and a bootstrapping routine to estimate samples for non-parametric tests (Wilcoxon and Kolmogorov-Smirnov). All three methods suggested that a sample size of approximately 35 or more sites was needed to detect differences among ecoregions (See Appendix A for details). We would expect that data collected with consistent methods and crews would have lower variability than the WTMF data we used to estimate sample size. This was supported from data collected under the pilot study, which had lower variance around gradient and change in gradient seen than the WTMF data and suggested a sample size of 35 sites per ecoregion was appropriate.

Existing water type modification (WTM) data show geographic differences in the PHB criteria and F/N breaks for gradient, channel width, and barriers between eastern and western Washington and in some cases ecoregions. Ecoregions are defined by unique combinations of variables such as geology, climate, landforms, and vegetation that can be clustered geographically, reflecting ecosystem conditions (Omernik 1987)[4]. While there are nine EPA Level III ecoregions in Washington State, the Columbia Plateau ecoregion has little forest cover and only a small portion the Willamette ecoregion is in Washington State, leaving seven ecoregions in our proposed study.

Site Identification

The DNR database includes data layers of all modeled F/N breaks for all streams in the state of Washington as well as more than 28,000 points where a WTMF was submitted to modify the water type. The modeled F/N breaks include hundreds of thousands of potential breaks across the landscape. However, it is currently unclear whether these points are accessible or how accurate they are in terms of above and below end of fish. For our study, this uncertainty creates

[4] We considered other finer scale stratification (e.g., geology, channel type, elevation, valley confinement), but these were not logistically feasible and would greatly increase the sample size, cost and time needed to complete the study. The Washington Forest Practices Board also instructed the PHB Science Panel to develop a study plan that specifically included stratification by ecoregion.

many logistical issues for field crews (e.g., land ownership, access points, roads) that could make field sampling of these points extremely costly. Moreover, more than a thousand water type modifications are submitted every year to correct modeled F/N breaks and DNR water type maps. The DNR's water typing database contains over 28,000 stream location points that have been visited over the past 15 years to establish the F/N regulatory break on state, private, and in some cases, federal lands. We propose to select a stratified random sample of these points to choose sites for this study. These sites have verified F/N breaks and information that in some cases includes monumented benchmarks in the field identifying specifically where the last detected fish was located on a particular date. We propose to revisit these sites annually for three years to clarify how the location of the last detected fish may change over short (months to 3 years) and longer (> 3 years) periods and how those locations may change under a variety of physical disturbances and weather conditions. While the WTMFs will be used to help screen potential sites, the habitat data in the WTMFs have been shown to be inconsistently collected and not usable for this study.

Our plan is to sample 35 randomly selected suitable sites annually in each ecoregion over the course of this 3-year study (Figure 5). We suspect that many randomly drawn WTM points will not be suitable for this study for a variety of reasons, including problems associated with access (e.g., landownership, road failures, etc.), manmade barriers, potential upstream source populations, or active timber harvest activities near the riparian management zone. We will randomly select a group of 100 WTM points in each region to be used in a consecutive sampling frame (See Appendix B).

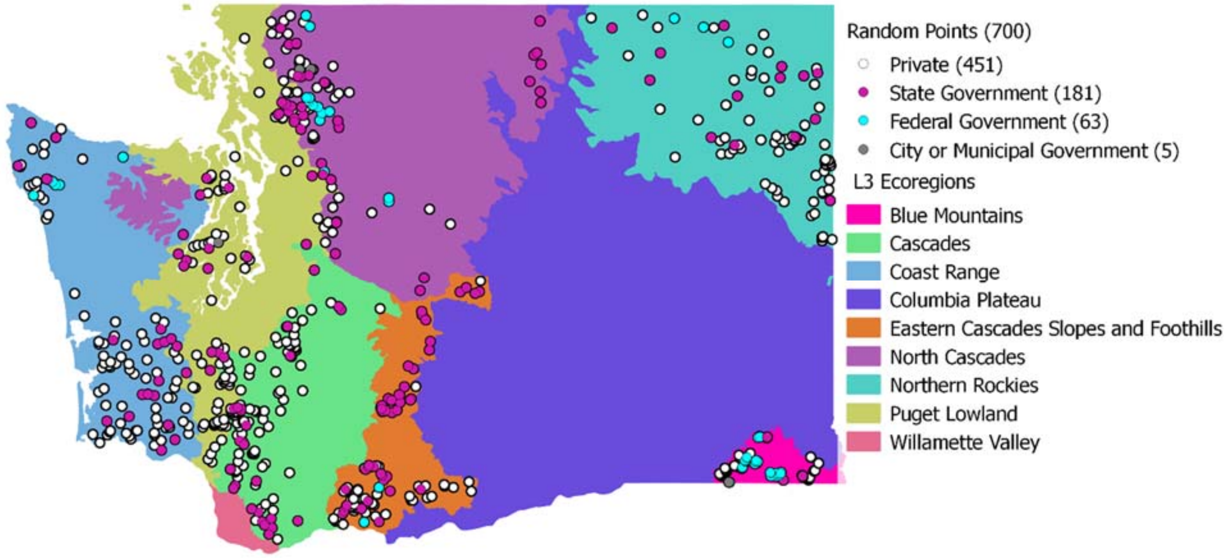

Figure 5. Randomly drawn potential F/N breaks from existing Water Type Modification Forms (WTMF) for inclusion in study. There are 100 random points for each of the Environmental Protection Agency Level III ecoregions. The Columbia Plateau and Willamette Valley were excluded due to lack of forest cover.

Prior to sampling, each of the 100 randomly selected sites will be numbered from 1 to 100. The first 35 suitable sites in each ecoregion will be selected as potential sample sites. Each site will be scouted prior to the sampling season to determine if the site is appropriate for a complete field study. If a site fails to meet the criteria we describe above, the scout will choose the next site identified in the sample pool and perform the same survey. Once we have identified the pool of 35 suitable sites, field crews will perform the full field survey. If sites do not meet our criteria, we will document why sites were excluded and the rationale for their exclusion. Our experience with studies of this nature suggests that more than one third of all sites will not be suitable. If less than 35 suitable sites are identified from our initial random sample of 100 sites, we will draw another random sample of 25 sites from the DNR database and evaluate these sites with a similar process until we locate 35 suitable sites.

Sampling Frequency and Season

All 245 sites will be sampled every year during spring to early summer (current protocol electrofishing survey window of Mar 1 to July 15) for three years to examine inter-annual changes in last detected fish. In addition, one third of all sites will be resampled each year during summer low flow (July 16 to September 30) and fall to early winter (October 1 to December 31) (Table 2) to evaluate seasonal changes in last detected fish. A minimum time span of 30 days will lapse between sampling at the same sampling location. Winter sampling would also be beneficial, but because of snow and access issues, it will not be feasible at most locations. Seasonal sampling sites will be randomly selected from the 245 sites for each year across ecoregions. All sites will receive summer and fall sampling in at least one year. Of the 60 randomly selected sites sampled seasonally (summer low flow through early winter) in all three years 30 sites will be in ecoregions east of the cascades and 30 will be west of the cascades) to allow examination of seasonal variation through time (Table 2).

Protocol Electrofishing and Habitat Surveys

Prior to sampling a site, crews will review existing information from the WTMF on access, previous location of last detected fish and habitat data, and obtain landowner permission for access and sampling. Field crews will use DNR protocol electrofishing surveys to determine last detected fish (DNR 2002)[5] (Figure 6a). The GPS coordinates of each last detected fish location will be recorded, and the location will be flagged and monumented with a marker including the survey date on an adjacent tree. The fish species and approximate sizes will be recorded. The crew will measure 100 m downstream using a tape measure or hip-chain to determine the beginning point for the stream habitat survey.

Table 2. Overall sampling schedule by calendar year and season 2018 to 2022. All sites will be sampled in spring to early summer (March 1 to July 15) with 1/3 of sites each year being resampled in late summer (July 16 to September 30) and fall to early winter (October 1 to

[5] This includes electrofishing ¼ mile above the last known fish location to ensure that no fish are found above this point, as well as confirming there is no "perched habitat" or ponds or lakes containing fish above this point. In many cases, due to the size of these streams, ¼ mile extends to perennial flow initiation and the end of an actual stream channel.

December 31). A pilot study sampling 27 sites in eastern (15 sites) and western Washington (12 sites) was completed in September 2018.

	Number of Sites Sampled				
Sampling Event	Pilot year (2018)	Year 1 (2019)	Year 2 (2020)	Year 3 (2021)	Year 4 (2022)
Spring to early summer		245 (35/ecoregion)	245 (35/ecoregion)	245 (35/ecoregion)	NA
Summer low-flow	27 to test methods	82 (1/3)	142 (60 same as year 1; plus 1/3, 82 sites)	142 (60 same as year 1; plus 1/3, 82 sites)	NA
Fall to early winter (same sites as summer sampling)		82 (1/3)	142 (60 same as year 1; plus 1/3, 82 sites)	142 (60 same as year 1; plus 1/3, 82 sites)	NA
Reporting	Pilot study report	Annual report	Annual Report	Annual Report	Final Report

Water temperature, conductivity, and electrofishing setting (e.g., voltage, frequency, pulse width) will be recorded at the beginning of each electrofishing survey. We will also record electrofishing survey time. A previous study of variability on the upper limits of fish distribution in headwater streams suggested that over 90% of the interannual variation in the last detected fish location occurred in less than 200 m upstream and downstream of an last detected fish location (Cole et al. 2006).

A longitudinal thalweg profile survey will be used to survey gradient, bankfull and wetted width, depth, streambed elevation, habitat type, presence of large wood, substrate, and any steps or potential fish migration barriers 100 m below and 200 m above last detected fish (Figure 6b). While a thalweg distance of 20 times bankfull width is typically surveyed to adequately define habitat (Harrelson et al. 1994; Rosgen 1994), this may not provide an adequate sample reach in small streams (<2 m wide). Instead, we will use a distance of 200 m above and 100 m below the last detected fish. This approach involves surveying the streambed elevation along the deepest portion of the stream (the thalweg), yielding a two-dimensional longitudinal profile of streambed elevations and has been shown to be a reliable and consistent method for measuring change in stream morphology and fish habitat independent of flow (Mossop and Bradford 2006). The survey is designed to capture changes in bed topography and habitat types by surveying more points in reaches that have more variable bed morphology. Rather than fixed distances, inflection points in topography are surveyed to capture changes in thalweg topography and gradient. Typically, 40 or more locations along the thalweg will be measured to adequately capture topographic changes within a 100-m reach. A laser range finder mounted on a monopod and a target on a second monopod will be used to collect distance and elevation data. All data will be entered into a computer tablet in the field. Measurements at each point will include depth, wetted widths, bankfull width, substrate size (i.e., boulder, cobble, gravel, sand, or less than sand), and habitat type (i.e., cascade, riffle, glide, or pool). Pools will be defined by minimum size and residual pool depth criteria (Pleus et al. 1999). All points or inflection points that meet the PHB criteria determined by the Board will be noted. For steps and potential migration barriers, the crew will record whether the step is formed by wood, bedrock, or another substrate. The presence of wood is particularly important because wood-formed barriers are considered deformable barriers and are not PHBs. Crews will also note whether flow is continuous or intermittent, the presence of beaver dams, groundwater inputs, and any other unusual features that could influence fish distribution. Because sites will generally be in small constrained streams that are unlikely to change significantly throughout the sampling year, it is likely that the habitat survey data for each stream will only need to be collected once each year. However, if the last detected fish point moves significantly (>20 m) from one season to the next, the survey will be repeated to assure we have a complete survey 200 m above and 100 m below the last detected fish found during each sampling event (Figure 6c). A similar protocol based on Mossop and Bradford (2006) has been used to survey barrier removal projects on small streams throughout the Columbia River Basin (See Appendix C for example of field protocol and data sheet) (https://www.monitoringresources.org/Document/Method/Details/4075). Water temperature to the nearest 0.1 °C, and conductivity (micro-Seimens) will also be recorded at the beginning and end of each electrofishing survey.

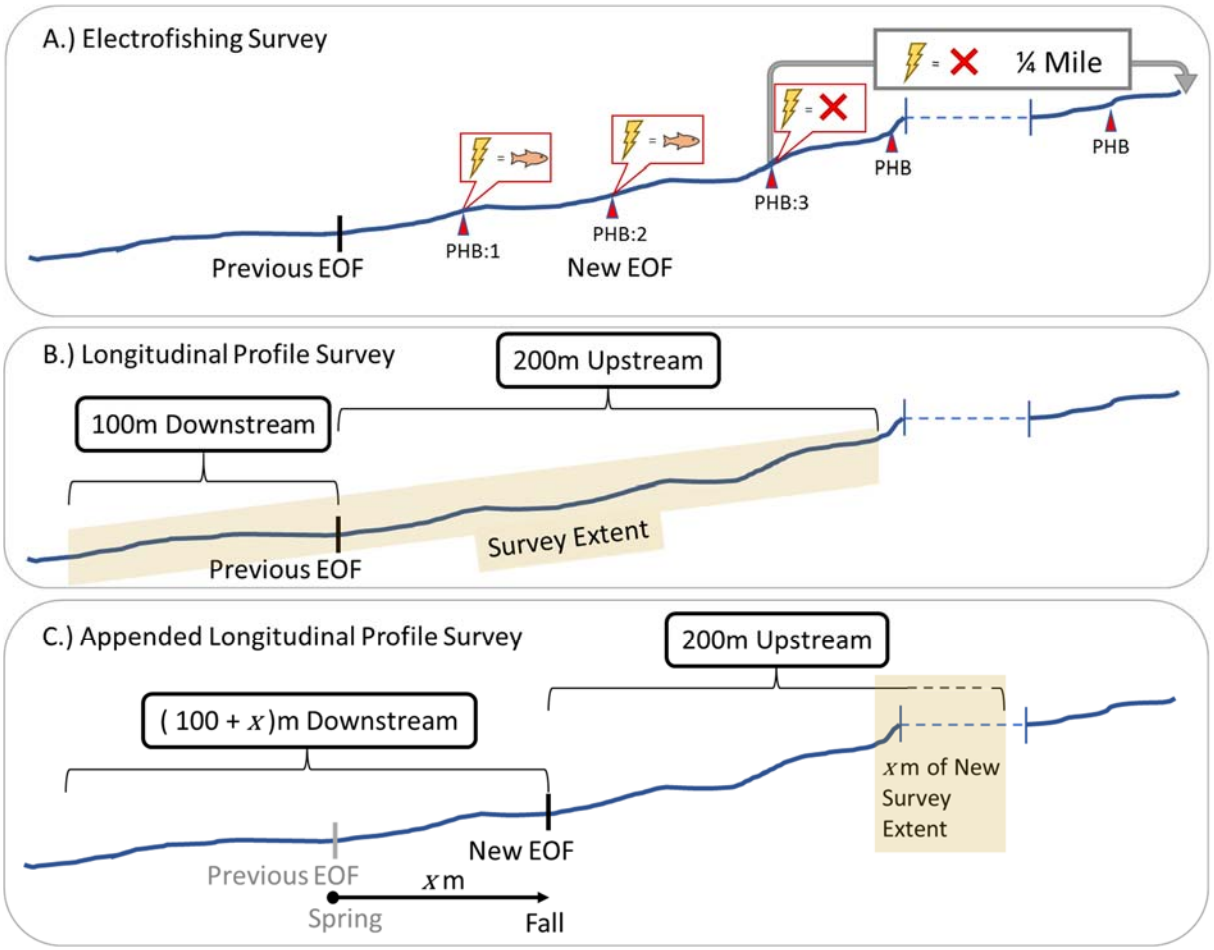

Figure 6. Components of field surveys demonstrating extents of protocol electrofishing survey to determine last detected fish point (A), the initial longitudinal profile habitat survey (B), and example of how longitudinal profile survey would be appended if follow up protocol electrofishing surveys show that the last detected fish has moved (C).

Evaluations of various regional stream habitat survey protocols have demonstrated that with well-trained field crews, measurement error is small relative to naturally occurring variability amongst sites (Kershner et al. 2002; Roper et al. 2002; Whitacre et al. 2007). Therefore, all crews will participate in a three to five-day training course each year prior to initiation of spring sampling to assure consistency among crews in determining last detected fish, surveying habitat features (long-profiles), and data collection. Moreover, to quantify variability among crews in conducting longitudinal surveys, we propose that 10% of all sites sampled each spring should be resampled by other crews every year (i.e., 10% of the sites will have three replicate surveys). Since variation in stream flow during subsequent surveys does not affect the longitudinal profile, we assume that variability among crews will be minimal.

Additional Information Collected (Explanatory Variables)

We will also collect data on several other factors that are thought to play a role in last detected fish point and identification of PHBs. These include: elevation, aspect, drainage area, valley width, geology, channel type, stand age, time since harvest, whether last detected fish and PHB is at a mid-channel point (mainstem or terminal) or confluence (tributary or lateral tributary), dominant drainage area geology, and whether a stream is accessible to anadromous fish or only resident fish. Many of these variables will be derived from existing GIS data layers. Drainage area and valley width are important because they are proxies for stream size, while other explanatory variables are other potential methods to stratify PHBs. While it is not initially possible to stratify site selection by these variables, they provide important information that may help explain differences in last detected fish and PHBs within and among ecoregions.

Data Analyses

The protocol electrofishing and habitat survey provides a rich data set to help inform and validate potential PHB definitions. The data, summarized in Figure 7, include measurements of elevation, channel width, substrate, habitat unit type, and the last detected fish and F/N points.

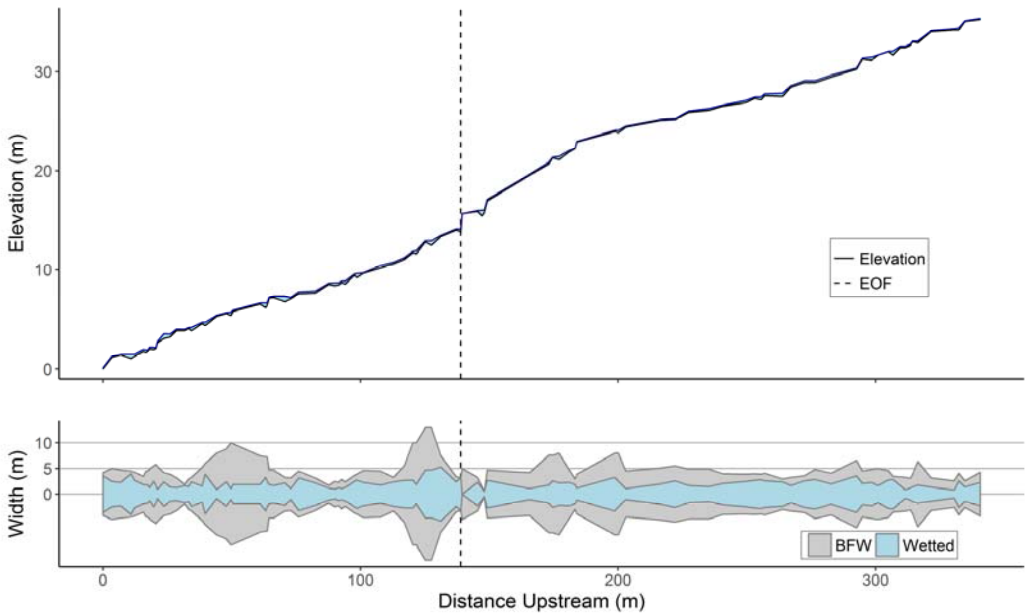

Figure 7. Example of long-profile from a western Washington PHB pilot study site showing stream bed elevation, water surface elevation, bankfull width (BFW), and wetted width (lower panel of each figure) along the surveyed stream thalweg. Additional data collected but not shown include substrate, habitat type (pool, riffle/cascade)>

For each surveyed point, we will test where the F/N break (first PHB encountered above last detected fish) would be located under various recommended PHB definitions. We will use the longitudinal profile from each surveyed reach to evaluate changes in gradient and channel width. Reach gradient will be calculated using a moving window approach that evaluates gradient over a specific length such as 20 bankfull channel widths (DNR 2004). In this way, any changes in physical conditions upstream and downstream of the last detected fish point are scaled to the size of the channel.

Beginning at the last detected fish point, the moving window will be used to examine the upstream and downstream gradient and width (as well as other possible factors as determined by PHB recommendations) to determine if these conditions meet the definition for a PHB according to various sets of recommendations (Figure 8). For each set of PHB recommendations, it is important that the first PHB encountered as the window moves upstream is identified under that set of recommendations.

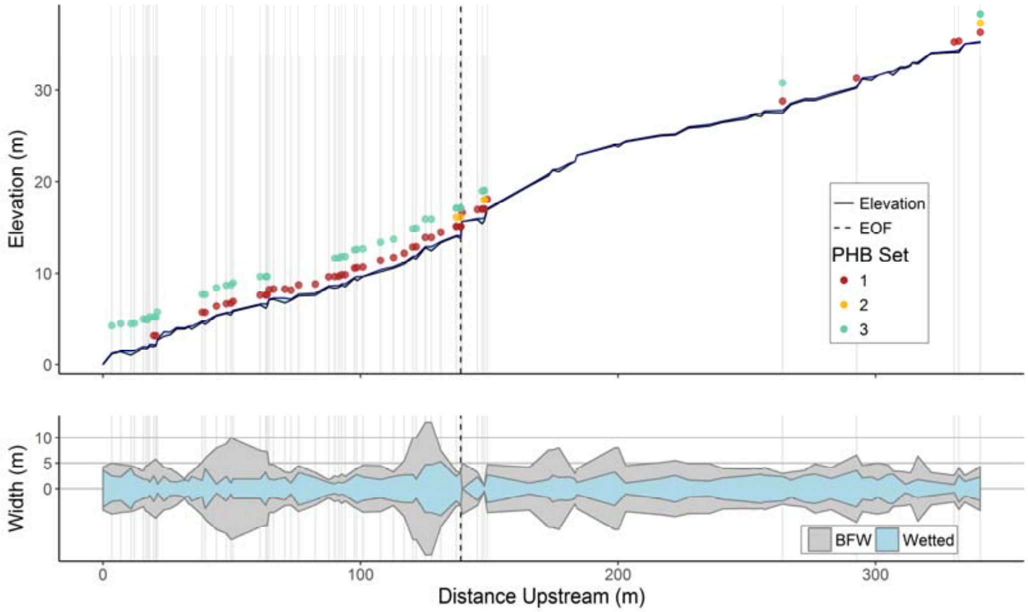

Figure 8: Example of frequency of PHB occurrence along stream profile upstream from last detected fish for different PHB recommendations (Y-axis) for a PHB pilot study site in western Washington. Each vertical line represents a potential PHB. The dotted line indicates the last recorded fish.

Finally, the first PHB identified from determined by the PHB recommendation set, will be compared to the last detected fish location determined by the survey crew, to estimate the distance to the first PHB identified upstream for each set of PHB recommendations. We will calculate this distance for each recommendation set and create density plots (histograms) for the distribution of distances from last detected fish (Figure 9). Tests of central tendency (T-tests, Wilcoxon rank-sum tests, ANOVA) will be used to analyze the mean response between the different PHB recommendations, while distribution tests (i.e. Kolmogorov-Smirnov) will be used to analyze the variance and overall shape of the response (Table 3). Comparing and analyzing these distributions by ecoregion will help determine how different PHB recommendations will play out across the state, and to see if there is consistent bias in how these recommendations would place F/N breaks across ecoregions.

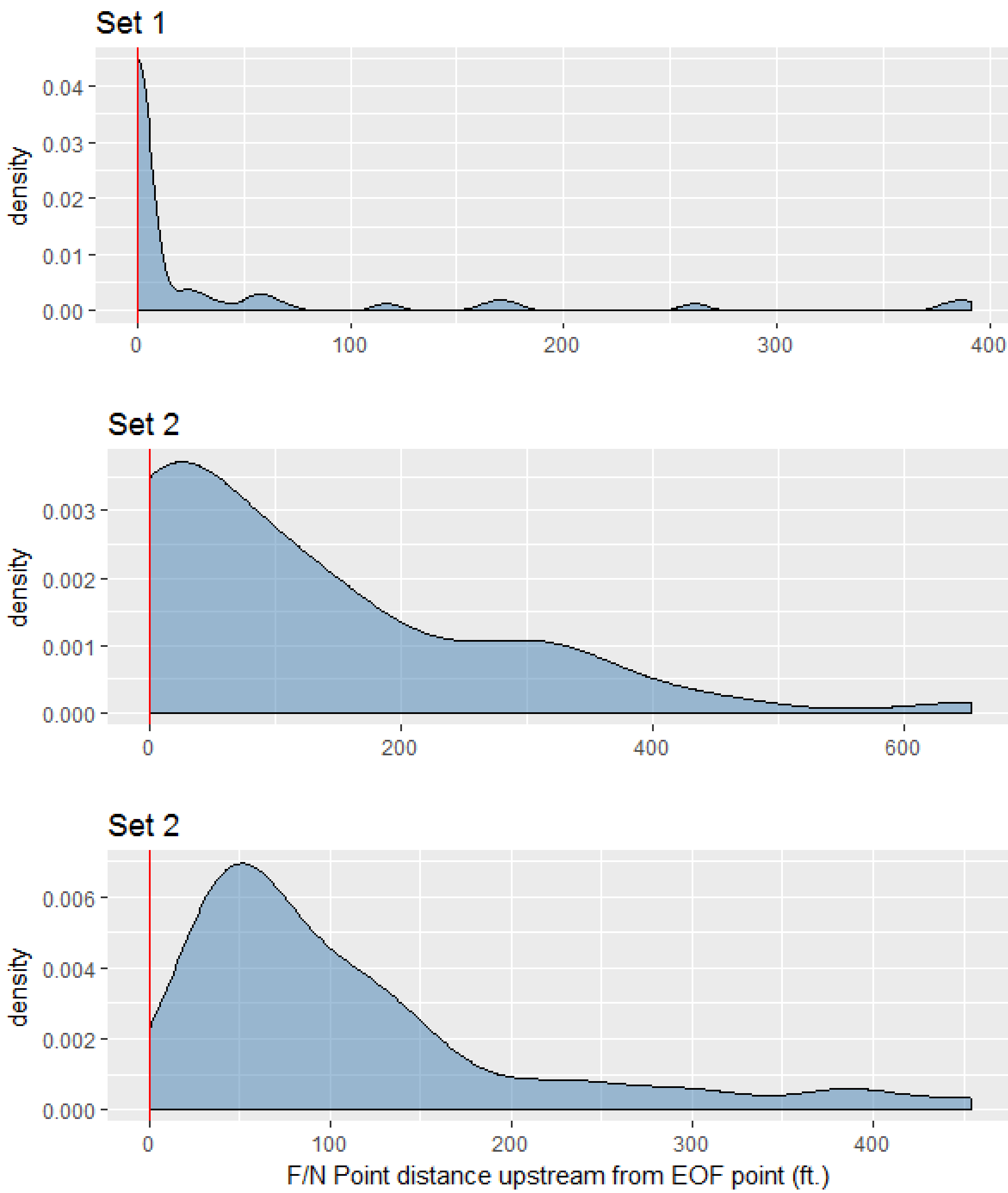

Figure 9. Example of density plots (histograms) for the distribution of distances from last detected fish that will be used to examine three different sets of PHB criteria. The above density plots or histograms demonstrate how far upstream of the last detected fish the F/N break would be placed for each set of criteria.

The additional information (e.g., elevation, aspect, drainage area, valley width, geology, channel type, stand age, time since harvest) collected with surveys will be used to explore whether these variables enhance the utility of our existing analysis and if so, which variables should be added to a potential survey protocol. These variables will be analyzed with random forest models using a suite of these factors in the analysis. Random forests models offer several benefits: they work with non-parametric data without transformations, they work well with correlated variables, and they bin continuous data into discrete categories as part of the analysis, as opposed to arbitrary bins assigned *a priori*. Moreover, since most of the explanatory variables are additional strata to consider and random forests bin data, it is well suited for the suite of explanatory variables we are examining. Once factors are selected, we will test for significant differences in F/N break placement similar to the ecoregion analysis. Other exploratory tools like covariate analysis and biplots will be used to determine whether additional factors should be considered for inclusion in PHB determinations. This process is iterative, with a new round of analysis occurring for each set of proposed PHB definitions.

A final objective of the study is to assess crew variability when applying protocol and surveys. Given sample size and time required to collect data, at least three crews will be needed to collect data. As noted previously, 10% of sites will be surveyed by all crews. To test crew variability, we will compare longitudinal profiles collected by the crews to compare among crews the total number of PHBs identified and the distance of PHBS from last detected fish using an ANOVA or mixed effects model (Table 3).

Table 3. Description of data analyses procedures and statistical methods that will be used to analyze data and answer key study questions.

Analysis	Framework
Locate PHBs on measured streams	Moving window determined by BFW to evaluate gradient and width along the collected long profile data.

Determine how frequently PHBs are located at the last detected fish point	Summarize the first PHB encountered on each stream, and bin PHBs within 5 and 10 m of last detected fish.
Compare PHB placements between definitions	• Use first PHB upstream from last detected fish to calculate distance from last detected fish. • Statistical summaries and visual comparisons of bar-plots, box and whisker plots, and Kernel density functions. • Central tendency tests (T-tests, ANOVA). • Distributions tests (KS tests and their derivatives Anderson-Darling and the Cramer Von-Mises Test).
Compare PHB placement across ecoregions for each definition	As above but analyzing distributions of each definition set separately across ecoregions.
Tests for year and season effect	• Statistical summaries and visual comparisons of last detected fish location change, and the distance to the first upstream PHB. • T-tests, ANOVA, and GLMs depending on the number of repeat samples/current stage of study. •
Consider additional Strata	Random Forest modeling • Highlight variables of importance under each definition set and compare. • Determine if there are consistent parameters/strata associated with extreme values.
Refine definitions to improve consistency	• Identify factors that affect outliers, and important parameters from the Random Forest Modeling. Additional exploratory analysis using biplots, covariate analysis, etc. • Consider and test appropriate hierarchical factors in PHB definitions. For example, Definition 1a may apply to streams with elevations less than some threshold α, and Definition 1b would apply to streams with elevations greater than α. • Test to see if modifications to the PHB definitions produce more consistent results. Rerun the analyses using the revised definitions to test effects.

Assess crew variability when applying survey protocol	Compare long profile data and resulting PHB placement among streams surveyed by multiple crews. Analyze the number of PHBs found, as well as the distance to PHBs upstream from the last detected fish point • ANOVA / Mixed effect models to test differences between crews.

Exploratory tools like covariate analysis and biplots will be used to determine whether additional factors should be considered for inclusion in PHB determination. Similar to the ecoregion analysis, we will also test for significant differences in PHB break placement by categories based on geology (lithology), elevation band, aspect, and other factors.

Potential Challenges

Although the methods we propose have been widely used to quantify habitat conditions and identify last detected fish, there are some potential challenges. These include location of suitable sites, access to initially identified sites, and access to sites throughout the year. First, we assume that because we are using points with existing WTMF data, the sites will be accessible and that last detected fish will be within an area covered by the WTMF. It is possible that we may not have access to chosen sample sites due to changes in land ownership, landowner willingness, or changes in the road networks. Thus, if a site is not suitable due to access or other reasons (e.g., entire stream is Type F, stream is dry during wet season, or other reasons) a different site (the next consecutive site number from the initial random selection) would be used to replace the non-suitable site. We expect the random sample of 100 sites per ecoregion will allow us to select the 35 sites needed to satisfy the sample size requirement. A more challenging scenario would be if accessibility changes between or among seasons and years. For example, forest fires, heavy early or late snow, or road failures could affect repeat surveys at a site. In such cases, we would continue to sample sites during other seasons and years when possible. However, with 245 sites statewide, even if a handful of sites cannot be sampled as scheduled, we feel that there will still be a large enough sample size per ecoregion, in eastern and western Washington, and statewide to adequately evaluate different PHB criteria.

The first challenge will be largely financial and could result from underestimating or overestimated the amount of time and cost needed to adequately sample sites initially and repeatedly. Similarly, we need to ensure that the data collected will allow us to answer the PHB study questions. To successfully conduct such a large multi-year study as this, it is critical to implement a feasibility study to confirm the time and cost needed to sample each site and to assess the feasibility and performance of the protocols. To proactively assess these critical uncertainties, we conducted a pilot (feasibility) study in August of 2018 to test and refine protocols, confirm the time needed to collect data at a site, and examine the feasibility of collecting data on bankfull depth, width:depth ratio, large wood, evidence of hyporheic/groundwater sources, lithology, and other potential explanatory variables related to instream habitat and stream type. The pilot study included conducting longitudinal thalweg profile surveys upstream and downstream of known last detected fish points at 27 sites on private, state, and federal forestlands in western and eastern Washington. The analysis of longitudinal survey data from the pilot study demonstrated that PHBs based on gradient, BFW, and obstacles being examined by the Board could be easily determined from the survey data. The field surveys helped identify several modifications to the initial proposed protocol that are needed to assure the proposed and other potential PHBs can be easily identified (e.g., spacing of the survey points, habitat types, minimum habitat length, and substrate categories). It also provided important information on time needed to conduct surveys, which we have incorporated into the study plan and estimated cost to conduct the full validation study.

Another challenge is that this study does not address long-term changes in small streams that may render them unsuitable for fish occupancy, or conversely, may render previously unsuitable streams habitable for fish. At any point in time, some headwater streams are not used by fish during any season of the year due to a blockage to invasion or to unfavorable physical conditions (e.g., gradient) in the channel itself. Factors that determine whether small streams can be used by fish are typically related to disturbances such as exceptionally high discharge, landslides, debris flows, and windstorms. Such episodic disturbances are erratic and can be widely spaced in time (decades to centuries), but their overall effect in drainage systems is to create a mosaic of streams suitable for fish occupancy that changes over long intervals (often hundreds of years) in response to local disturbance regimes (Penaluna et al. 2018). An important implication of the notion that the potential use of small tributaries by fish can change over time is that while some tributaries are not now occupied by fish, there is no guarantee that they may not become suitable in the future, or that tributary streams which are currently habitable will always remain so. This study, however, does not address the expansion and contraction of fish habitat over long time intervals because the methods cannot predict with certainty where and in what form large disturbances capable of transforming a stream segment's ability to support fish will occur.

Expected Results and Additional Studies

Highly precise measurements of stream channel conditions both upstream and downstream of last detected fish locations will provide a nearly continuous dataset of physical features (PHB) that have the potential to inhibit fish movement. Thus, we will be able to objectively identify the PHB criteria most closely associated with last detected fish and the next upstream PHB. We expect that the study will validate the PHB criteria for gradient, channel width, and barriers that are most frequently associated with the PHB most closely associated with the last detected fish point. In addition, we are confident the methods will test the different PHB criteria under consideration by the Board in 2018. Seasonal and inter-annual sampling will allow us to examine the variation of last detected fish across years and seasons, which will help identify PHBs that consistently mark last detected fish across years, seasons, and flow conditions. Because we will be using sites for which a WTMF exists and last detected fish was potentially identified, examining longer-term inter-annual variation in last detected fish may be possible for a subset of sites where last detected fish has been previously identified and monumented. In addition, the 245 sites used in this study could be revisited several years from now to look at longer-term changes in last detected fish if desired.

Ultimately, our analysis should provide information to the Board related to the mean distance from last detected fish for different PHB criteria being examined, how that differs among years and seasons and whether one set of criteria performs better in terms of consistently identifying EOF habitat and last detected fish across seasons and years, and whether different PHB criteria should be applied for different ecoregions or should be stratified by other factors. While the focus of the study is to test the three different sets of PHB criteria being examined by the board, we expect that our analyses will help identify other criteria that might more consistently capture last detected fish and EOF habitat. Finally, our results should also help inform the protocols for measuring gradient, bankfull width, and obstacles in the field to minimize variability among field crews and assure consistent identification of PHBs.

Included in the current budget is a collaborative complementary study with the U.S. Forest Service to compare environmental DNA (eDNA) and electrofishing to identify fish habitat. Environmental DNA is a rapidly evolving and promising technique for identifying presence of species based on presence of their DNA in water sample (Rees et al. 2014; Jane et al. 2015). Because last detected fish is being identified, a companion study using eDNA techniques will be conducted to compare electrofishing and eDNA for detecting upper limits of fish distribution. Filtered water samples will be collected above and below the last detected fish point determined by electrofishing to examine the accuracy of eDNA at determining last detected fish. Recent studies have indicated that the number of samples required to accurately determine the presences of a fish species is dependent upon the volume of flow and drainage area (Goldberg et al. 2015; Jane et al. 2015). Despite this, eDNA shows promise in determining species presence or absence, and determining fish distribution. This study will be conducted during the second year of the overall study at seasonally sampled sites (82 sites) with the assistance of an additional crew member focused on collecting two eDNA water samples above and below the last detected fish detected with electrofishing (6 samples per sites x 82 sites x 3 seasons). This is a unique opportunity to collaborate with the U.S. Forest Service to complete the eDNA study. If the AMP were to conduct a similar eDNA study on its own, doing so would be more costly.

There are also some modifications or additions to the proposed PHB criteria evaluation study that could be beneficial and influence cost. First, the main cost of the study is in field data collection. Potentially identifying ways to reduce the number of sites sampled per ecoregion would affect the cost of the study. We had initially estimated sample size of 50 sites per ecoregion might be needed, but further analysis of WTMF data using a slightly less conservative statistical power (Type II error) coupled with evidence from the pilot study indicated that a sample size of

30 to 35 would be appropriate. Further, reducing the sample size would reduce the cost of the study, but reducing the number of samples to less than 35 per ecoregion would prevent us from examining differences among ecoregions. It should be noted that some costs are fixed (e.g., analysis, reporting, permitting) and will change little if the total number of sites sampled changes. Second, we initially propose to sample all sites in spring, late summer, and fall to early winter over the course of this study (see Table 2). While mid to late winter sampling (January 1 to March 1) would be helpful, most sites in eastern Washington and sites above 1500 ft in elevation in western Washington, will be inaccessible during much of the winter due to snow. However, winter sampling may be possible and could be conducted at some of the randomly selected lower elevation sites in western Washington ecoregions. This is of particular importance for anadromous fish like juvenile coho salmon, which may move several kilometers upstream or downstream in fall in search of overwintering areas or in summer to avoid ephemeral reaches or to find cold-water refugia (Skeesick 1970; Peterson 1982; Wiggington et al. 2006). The total cost of adding this to the study would depend upon the number of sites needed.

Once the main study is completed, a follow-up analysis will be necessary to examine variability in survey crews in identifying selected PHBs and whether this varies by ecoregion. Moreover, focus should be placed on specific protocols used to consistently and accurately identify and measure PHBs, including gradient, bankfull width, barriers, and any other PHB criteria identified in this study.

This study is specifically designed to test PHB criteria and explore the potential for other variables to provide useful information to refine PHB. While we are exploring a number of variables that have shown potential as co-variates in other similar types of studies, there is no guarantee that these variables may provide any additional insight. We will attempt to explore the usefulness of these variables in our early data analyses to evaluate whether to continue their use, but it may be difficult to judge until the larger dataset is available. We will use these analyses as one part of the overall program to make recommendations regarding PHB criteria.

We will also examine seasonal, short-term, and medium-term (3 to 10 years) changes in end of fish at more than 200 headwater streams across the state stratified by ecoregion. While it lays the groundwork for continued monitoring of long-term variability in the upper end of fish distribution, it is not specifically a long-term study (>25 years) on variability in the upper end of fish distribution. We strongly recommend that sites continue to be periodically revisited (every 5 or 10 years) to examine this variability, but doing so is beyond the current scope of this study.

Budget

The total estimate project cost including the pilot study in summer of 2018 (FY2019) is approximately $3.5 million. The pilot study demonstrated that initial site visits may take 2 full days to survey due to the time needed to clear necessary vegetation prior to survey. The proposed budget assumes that it would cost approximately $2400 for initial spring sampling at each selected site, with follow-up sampling costs of approximately $1200 per site visit (Table 4). All 245 sites would be sampled each year during the spring sampling window, whereas late summer and fall to early winter sampling would be repeated at one third of the sites (82) during each of the three years of the study (2020, 2021, and 2022). In addition, 60 of the seasonal sampling sites would be sampled across each year to examine inter-annual variability in seasonal sampling. Ten percent of all sites will also be resampled by all field crews in each year to examine crew variability.

Table 4. Estimated coast per major task by state fiscal year (July 1 to June 30) to implement study. Budget in FY2019 includes pilot study in summer of calendar year 2018, site reconnaissance and logistics, and spring sampling in calendar year 2019.

Task	FY2019	FY2020	FY2021	FY2022	FY2023	Total
Study design, coordination, site reconnaissance, permitting, crew training	147,400	105,000	87,000	82,500	N/A	421,900
Field sampling – Spring (245 sites)	563,500	465,500	490,000	N/A	N/A	1,519,000
Field sampling – Summer (82+60)	N/A	118,404	169,053	172,694	N/A	460,151
Field sampling – Fall (82+60); pilot in FY 19	121,000	118,404	169,053	172,694	N/A	581,151
Crew variability (10% of sites – all crews)	25,000	30,000	30,000	30,000	N/A	115,000
eDNA sampling (82 sites 3 times)		50,000				50,000
eDNA Lab Analysis and reporting		60,000	104,000			164,000
Data analysis and reporting	0	34,000	34,000	34,000	78,163	180,163
Project Management	12,000	14,769	15,132	15,506	15,262	72,669
Total	868,900	996,077	1,098,238	507,394	93,425	3,564,034

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Appendices

Appendix A. Details of sample size estimation.

Estimating required sample sizes depends on the population variance, which is generally unknown. Pilot projects, published values, and data proxies are often used to derive an estimate of the population variance to use in sample size calculations. Here, we rely on the provided Land Owner Sample Data set (PHB Science Panel 2018) to get an estimate of variance across an ecoregion.

The sample data exists across multiple ecoregions and contains habitat measurements surrounding each End of Fish (last detected fish) point. The data were reduced by only considering points within the "Coast Range" ecoregion. This level of granularity matches our proposed sampling strata and should give us insight into the variance of within an individual ecoregion. Moreover, similar to the proposed PHB study, these data were collected with consistent methods, while data in other ecoregions were collected with a variety of inconsistent methods. Of the metrics proposed and analyzed, difference in upstream and downstream gradient was the most normal and didn't include suspect channel width data. A square-root transformation further normalizes the distribution by pulling in the long right tail, but it still fails to pass the Shapiro-Wilks test for normality.

Because the sample data shows a non-parametric distribution, we estimated samples desired for each ecoregion in multiple ways including: 1) samples required to estimate the mean 2) power estimates for t-tests, and finally, 3) a bootstrapping routine to estimate samples for non-parametric tests (Wilcoxon and Kolmogorov-Smirnov). Power tests and mean estimates were applied to both the raw distribution, as well as the square-root transformed version.

First, calculating the number of samples required to estimate a population mean with a stated margin of error and certainty is accomplished using the following formula:

$$= \frac{\left(_{\frac{}{2}} \right)^2 \quad ^2}{^2}$$

Where is the Z-score corresponding to the desired confidence level , ^{2} is the estimated variance, and is the accepted margin of error. This can be stated as "Based on the assumption of population standard deviation being , we require a sample size of to achieve margin of error at the $(100 -\ )$% confidence level". This formulation depends on both a stated confidence level, and acceptable margin of error.

Second, power estimates for t-tests have similar requirements to calculating samples required to estimate a population mean, but rely on , the difference to be detected between the two samples, instead of a general error term . Additionally, power estimates require desired power levels to be defined to calculate the number of samples required in each group.

Finally, a bootstrapping routine was used to determine the number of samples required to detect a given difference in means using non-parametric tests. The routine can be summarized as follows:

1.) Shift empirical distribution by , by the desired difference to be detected.
2.) Draw samples from the original and shifted distributions
3.) Test with Wilcoxon and KS tests.
4.) Record if the test successfully detected the shift
5.) Repeat (2-4) many times (~10,000)
6.) Calculate the percent of replicates that failed to detect the shift.
7.) Repeat (2-6) for a range of sample sizes .
8.) Repeat (1-7) for a range of differences .

Results of the bootstrapping process can be visualized as a heatmap, depicting the percent of replicates that failed to detect the difference in samples for each combination of ⍰ and ⍰ (Figure A-1).

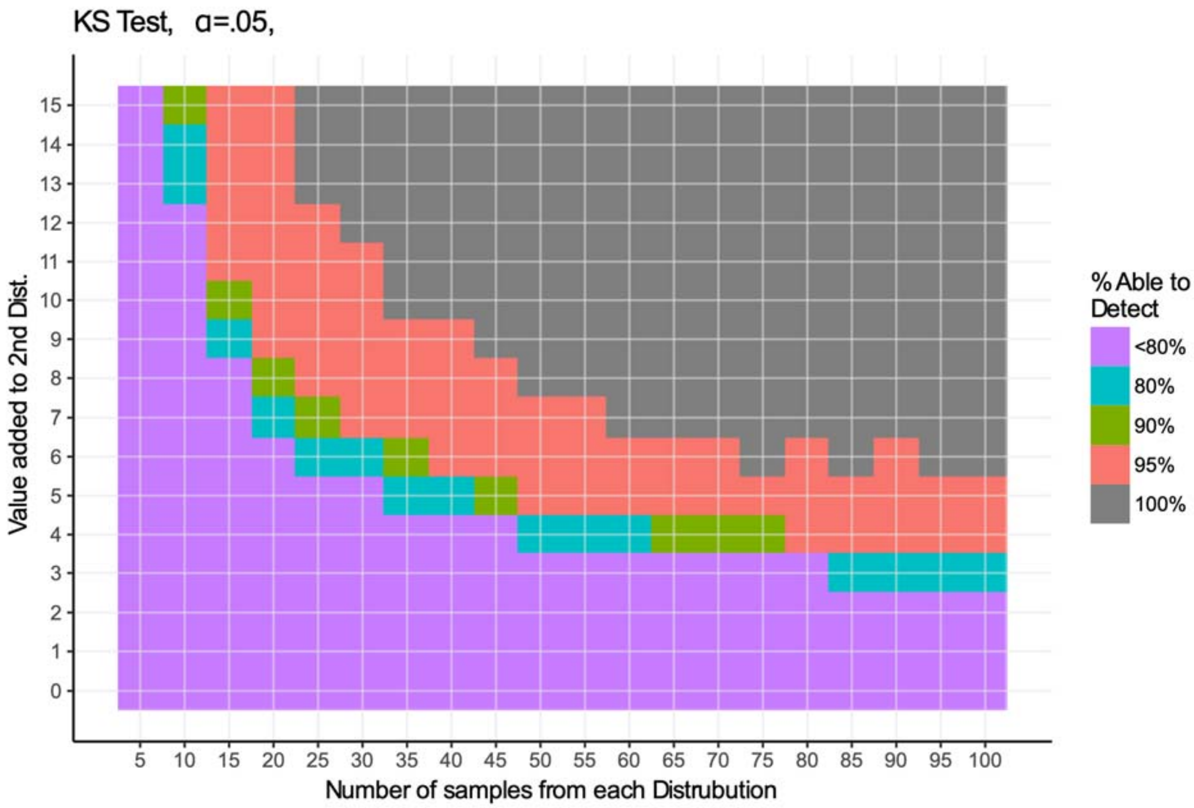

Figure A-1. Heatmap depicting results of bootstrapping procedure. Values have been binned to demarcate 100, 95, 90, and 80% detection rates (statistical power). In this example, 50 samples would be required to detect a difference of 5 units (gradient) with a 95% detection rate. Similarly, 35 samples would be needed to detect a difference of 5 units with an 80% detection rate.

Results from these estimation procedures are presented in Table A-1. The original and transformed distributions were used for estimating the mean, and t-test power estimates, while only the original distribution was used in the bootstrapping procedure, as it did not rely on assumptions of normality. For brevity, a limited selection of the bootstrapping results is reported.

Table A-1. Sample size estimation results from three estimation procedures. Both "Unmodified" and "Transformed" distributions were analyzed for the parametric tests.

Estimates for mean:					
Unmodified		0.05	96.79	2.5	60
Unmodified		0.1	96.79	2.5	42
Transformed		0.05	1.11	0.3	48

Power t-test	**Power**				
Unmodified	0.9	0.05	96.79	5	82
Unmodified	0.9	0.1	96.79	5	67
Unmodified	0.8	0.1	96.79	5	49
Transformed	0.9	0.05	1.11	0.6	65
Transformed	0.9	0.1	1.11	0.6	54
Transformed	0.8	0.1	1.11	0.6	39

Bootstrap	**% Detection**		**Replicates**		
Wilcox	0.95	0.05	10000	5	50
Wilcox	0.9	0.05	10000	5	40
Wilcox	0.8	0.05	10000	5	30
KS	0.95	0.05	10000	5	50
KS	0.9	0.05	10000	5	45
KS	0.8	0.05	10000	5	35
Wilcox	0.95	0.1	10000	5	40
Wilcox	0.9	0.1	10000	5	35
Wilcox	0.8	0.1	10000	5	25
KS	0.95	0.1	10000	5	40
KS	0.9	0.1	10000	5	40
KS	0.8	0.1	10000	5	30

Appendix B. Example of 100 randomly selected sites for Cascades ecoregion including coordinates, basin name, elevation and land ownership. Ownership includes state, private and federal, though none of the points initially drawn from Cascades ecoregion were on federal lands.

POTENTIAL SITE	LATITUDE	LONGITUDE	BASIN NAME	ELEVATION	OWNERSHIP
1	47.03665	-121.97784	CARBON	1863	Private

2	47.10311	-121.89528	CARBON	2734	Private
3	46.99179	-122.05019	CARBON	1835	Private
4	46.13615	-122.57758	COWEEMAN	1152	Private
5	46.18591	-122.57078	COWEEMAN	1299	Private
6	45.82154	-122.25116	EAST FORK	1192	Private
7	45.83294	-122.36226	EAST FORK	1071	Private
8	45.86038	-122.32221	EAST FORK	2101	Private
9	45.73984	-122.33419	EAST FORK	1431	State
10	45.74782	-122.35548	EAST FORK	1330	State
11	45.76818	-122.26947	EAST FORK	2047	State
12	45.72529	-122.33179	EAST FORK	1512	State
13	45.80921	-122.38803	EAST FORK	1696	State
14	45.83117	-122.45127	EAST FORK	603	State
15	46.75158	-121.99434	GLACIER	1710	Private
16	46.71016	-122.22684	GLACIER	1559	Private
17	47.14867	-121.71266	GREEN WATERS	1619	Private
18	47.12430	-121.64195	GREEN WATERS	2350	State
19	46.10235	-122.35119	KALAMA	1467	Private
20	46.11008	-122.52981	KALAMA	1586	Private
21	46.03625	-122.58254	KALAMA	666	Private
22	46.12191	-122.32454	KALAMA	1668	Private
23	46.06947	-122.60266	KALAMA	860	Private
24	46.07809	-122.61313	KALAMA	601	Private
25	46.08089	-122.59259	KALAMA	827	Private
26	46.08495	-122.64968	KALAMA	801	State gov.
27	46.08752	-122.64951	KALAMA	829	State
28	47.11133	-121.25556	LITTLE NACHES	3765	Private
29	47.35756	-121.86811	LOWER GREEN	1328	State
30	46.84699	-122.03678	MASHEL-OHOP	2883	Private
31	46.85823	-122.04889	MASHEL-OHOP	2484	Private
32	46.80739	-122.08029	MASHEL-OHOP	2314	Private
33	46.92991	-122.22823	MASHEL-OHOP	763	Private
34	46.86879	-122.04818	MASHEL-OHOP	2719	Private
35	46.80953	-122.36960	MASHEL-OHOP	1233	Private
36	46.87684	-122.08648	MASHEL-OHOP	2481	Private
37	46.87757	-122.08933	MASHEL-OHOP	2355	Private

38	46.88170	-122.10328	MASHEL-OHOP	2835	Private
39	46.89287	-122.20396	MASHEL-OHOP	1387	Private
40	46.90079	-122.12769	MASHEL-OHOP	2342	Private
41	46.83691	-122.11397	MASHEL-OHOP	1743	Private
42	46.81273	-122.09325	MASHEL-OHOP	2046	State
43	45.98551	-122.41624	MERWIN	240	Private
44	45.89619	-122.25015	MERWIN	1914	Private
45	45.98041	-122.60519	MERWIN	1340	State
46	45.96363	-122.61993	MERWIN	461	State
47	46.01024	-122.40774	MERWIN	1679	State
48	46.86160	-122.76084	PRAIRIE	414	Private
49	47.10485	-121.61934	RAINIER	2132	State
50	45.75600	-122.41526	SALMON	558	Private
51	46.76764	-122.67439	SKOOKUMCHUCK	772	Private
52	46.72918	-122.46672	SKOOKUMCHUCK	2176	Private
53	46.72896	-122.66033	SKOOKUMCHUCK	1229	Private
54	46.69183	-122.47518	SKOOKUMCHUCK	2036	Private
55	46.83056	-122.75269	SKOOKUMCHUCK	899	State
56	46.83616	-122.82352	SKOOKUMCHUCK	489	State
57	46.80377	-122.70844	SKOOKUMCHUCK	638	State
58	47.52035	-121.94305	SQUAK	815	State
59	46.06407	-122.09884	ST HELENS	1013	Private
60	46.57485	-122.20169	TILTON-KIONA	1312	Private
61	46.46372	-122.42906	TILTON-KIONA	992	Private
62	46.58998	-121.97669	TILTON-KIONA	2523	Private
63	46.58887	-122.18366	TILTON-KIONA	1393	Private
64	46.47259	-122.46905	TILTON-KIONA	727	Private
65	46.53276	-122.15547	TILTON-KIONA	1020	Private
66	46.45616	-122.40366	TILTON-KIONA	1358	Private
67	46.45721	-122.41196	TILTON-KIONA	1225	Private
68	46.46133	-122.18169	TILTON-KIONA	993	Private
69	46.45976	-122.33460	TILTON-KIONA	2192	Private
70	46.45858	-122.41527	TILTON-KIONA	1194	Private
71	46.46195	-122.41682	TILTON-KIONA	1231	Private
72	46.38237	-122.58493	TOUTLE	826	Private
73	46.38971	-122.53364	TOUTLE	924	Private

74	46.39143	-122.47983	TOUTLE	1195	Private
75	46.39482	-122.52192	TOUTLE	972	Private
76	46.18449	-122.42676	TOUTLE	2509	Private
77	46.18624	-122.44654	TOUTLE	2041	Private
78	46.30538	-122.58529	TOUTLE	1429	Private
79	46.19308	-122.43555	TOUTLE	2075	Private
80	46.36050	-122.29501	TOUTLE	2009	Private
81	46.20363	-122.42296	TOUTLE	2470	Private
82	46.31487	-122.54222	TOUTLE	1433	Private
83	46.40769	-122.34573	TOUTLE	1967	Private
84	46.36063	-122.56427	TOUTLE	1086	Private
85	46.32399	-122.38076	TOUTLE	2425	Private
86	46.26112	-122.53349	TOUTLE	1178	State
87	46.26970	-122.56339	TOUTLE	1394	State
88	46.36804	-122.50197	TOUTLE	1440	State
89	46.24599	-122.52188	TOUTLE	992	State
90	46.85890	-122.70516	UPPER CHEHALIS	329	Private
91	46.67033	-122.63627	UPPER CHEHALIS	1105	Private
92	46.67820	-122.70085	UPPER CHEHALIS	658	Private
93	46.99542	-122.12728	UPPER PUYALLUP	1590	Private
94	46.94556	-122.05719	UPPER PUYALLUP	1518	Private
95	46.89987	-122.04643	UPPER PUYALLUP	1724	Private
96	46.99932	-122.11715	UPPER PUYALLUP	1729	State
97	45.63382	-122.21104	WASHOUGAL	721	Private
98	45.70737	-122.26008	WASHOUGAL	1466	State
99	45.66612	-122.29105	WASHOUGAL	1098	State
100	45.75315	-122.02144	WIND	1235	State

Appendix C. Step-by-step instructions for longitudinal thalweg profile used by BPA for evaluations of barrier removal projects (modified from https://www.monitoringresource).

Step 1: Prepare the proper equipment for a longitudinal profile. Equipment that can be used includes a surveyor's level, a measurement tape of sufficient length (typically at least 30 meters), and a stadia rod (see Harrelson et al. 1994 for details). Other options include a laser or other range finder with an accuracy of <4 cm that is fitted onto a monopod with a leveling bubble, together with a target placed on another monopod that can be adjusted to the height of the surveyor's laser range finder. In addition, it is important to carry a stadia rod or measuring stick to measure stream depths and widths. A simpler option is to mark off the monopod in 10ths of a meter and use it to measure stream depths and/or widths.

Step 2: Make sure the laser range finder "zeros out" in terms of vertical distance (VD on the screen for a LaserTech range finder) with the monopod. Adjust the monopod containing the laser range finder on a flat surface near the site so the vertical distance reading on the laser range finder reads at least 0.01 m when shooting the monopod target; ideally it should read 0.00 m. This means that the laser range finder is set to shoot at the same level as the monopod target and will allow the surveyors to read differences in elevation.

Step 3: A two or three-person crew consisting of a surveyor, monopod or rod person, and data recorder. If using a two people, the data recorder can also carry the stadia rod to measure depths and widths.

Step 4: Have the data recorder complete the header information on the form entitled "modified thalweg profile for full barrier removal" or, if using a tablet or iPad, have data recorder enter information in the tablet.

Step 5: Begin at the downstream end (station "0") of the longitudinal profile. Surveys should begin and end at riffle crests (the location in a riffle with the highest elevation) for streams with a pool–riffle structure. Station "0" will be put into the data sheet at distance of 0.0 and vertical elevation of 0.00. Water depth and wetted width will be measured to the nearest tenth of a meter. Substrate will be visually identified directly beneath the thalweg measurement and categorized as boulder, cobble, gravel, sand, or finer than sand. Habitat will be visually identified and categorized as pool, riffle, or glide.

Step 6: Once properly located, the monopod with target and stadia rod will then start to measure streambed elevation and associated habitat characteristics at the channel thalweg. The monopod holder with target will move a distance equal to the wetted width as well as every break in channel slope. The next station will become station “1.” The laser range finder will stay at station “0” and call out the horizontal distance to identify the distance from station “0” to station “1”, which will be entered by the data recorder.

Step 7: The laser range finder person will then call out the vertical distance to the data recorder. The data recorder will next use the stadia rod to measure the water depth at the point of the monopod, as well as the wetted width. If there is an island or gravel bar (dry area) within the wetted width make sure to measure the wetted width on each size of the dry area and sum the wetted widths. The monopod holder will identify the category of substrate as well as the habitat unit associated with the point at station “1”, which will be either cascade, riffle, pool, or glide. If the point is either at the top, maximum depth, or tailout of the pool then the monopod holder will also identify those characteristics. A minimum of 50 points should be surveyed in 100 m.

Notes for step 7 – Interval distance should be adjusted to bed morphology such that reaches containing more variable bed morphology will be sampled using a shorter interval. The rod should be supported, when necessary, to prevent it from sinking into areas with finer, softer substrates.

Step 8: Once the point at station “1” is shot and the data collected, then the laser range finder person will move to where the monopod with target is located and put the laser range finder and its associated holder down at the same exact location as the targeted monopod. The monopod with target will then be moved to the next break in slope or wetted channel width and identify that as station “2”. Stations will be surveyed until the survey crew get to the upper terminus of that reach. GPS coordinates will be then checked again against the original GPS point identified at the terminus to make sure the crew surveyed the entire reach. In general, the survey should include between 40 to 100 stations.

Table C-1 below provides an example of data typical collected with above protocol. A key difference would be that for the DNR PHB study bankfull width would be measured at every station rather than just every 25 meters.

Table C-1. Example of long-profiled data collected using the above protocol. Unpublished Bonneville Power Administration data from Corral Creek, Idaho. For the proposed PHB study, bankfull width would be recorded at every station.

Station	Distance (m)	Cummulative Distance	Elevation (m)	Cumulative Elevation	Depth (m)	Wet width (m)	Bankfull width	Max, tail, top	Substrate	Unit	Comments
0	0	0	0	0	0.19	1.9	2.5		C	R	
1	1.47	1.47	-0.04	-0.04	0.2	1.85			B	R	
2	2.28	3.75	0.27	0.23	0.2	1.92			C	R	
3	2.41	6.16	0.11	0.34	0.15	2.1			B	R	
4	4.13	10.29	0.27	0.61	0.1	2.5			C	R	
5	2.93	13.22	0.23	0.84	0.13	3.2			G	R	
6	1.74	14.96	0.01	0.85	0.08	4.3			G	R	
7	0.89	15.85	0.15	1	0.16	3.9			SA	R	
8	1.85	17.7	0.13	1.13	0.05	2.2		TAIL	SA	R/P	
9	1.4	19.1	-0.19	0.94	0.26	2.1		MAX	SA	P	
10	1.1	20.2	0.15	1.09	0.09	1.8		TOP	G	P	Tail of next pool
11	1.21	21.41	-0.2	0.89	0.28	2.3		MAX	SA	P	
12	1.3	22.71	0.09	0.98	0.13	1.8		TOP	G	P/R	Start of riffle
13	3.16	25.87	0.13	1.11	0.05	3.3		TAIL	SA	R/P	Start of pool
14	1.12	26.99	-0.19	0.92	0.28	3.9		MAX	G	P	
15	0.92	27.91	0.12	1.04	0.14	1.25		TOP	SA	R/P	Top of pool
16	1.23	29.14	-0.03	1.01	0.17	1.2	4.5	TAIL	G	P	Start of pool
17	1.86	31	-0.18	0.83	0.28	2.1		MAX	G	P	
18	1.17	32.17	0.19	1.02	0.06	3.5		TOP	C	R/P	
19	3.68	35.85	0.12	1.14	0.14	2.5			C	R	
20	3.42	39.27	0.24	1.38	0.09	2.8		TAIL	G	R/P	Top of pool
21	2.13	41.4	-0.24	1.14	0.31	3.2		MAX	G	P	
22	1.9	43.3	0.16	1.3	0.11	2.75		TOP	C	P/R	
23	4.5	47.8	0.08	1.38	0.22	2			C	R	
24	1.73	49.53	0.13	1.51	0.17	2.5			B	R	
25	1.46	50.99	-0.11	1.4	0.2	3.4			G	G	
26	1.98	52.97	0.06	1.46	0.15	3.3			C	R	
27	5.19	58.16	0.27	1.73	0.06	2.6		TAIL	G	R/P	
28	2.12	60.28	-0.3	1.43	0.35	1.8		MAX	G	P	
29	0.89	61.17	0.25	1.68	0.07	1.35		TOP	C	P/R	
30	2.9	64.07	0.09	1.77	0.13	2.3			G	R	
31	2.92	66.99	0.04	1.81	0.19	2.2	3.4		G	R	
32	5	71.99	0	1.81	0.17	1.9	2.65		B	R	Culvert/barrier
33	1.71	73.7	0.23	2.04	0.07	1.65			C	R	
34	2.82	76.52	0.11	2.15	0.2	3.32			B	R	
35	0.63	77.15	0.58	2.73	0.2	3.75		TAIL	SA	R/P	
36	0.37	77.52	-0.36	2.37	0.36	3.75		MAX	SA	P	
37	2.93	80.45	0.22	2.59	0.17	2.35		TOP	G	P/R	
38	4.8	85.25	0.12	2.71	0.14	2.9			G	R	
39	4.07	89.32	-0.08	2.63	0.25	1.7			C	R	
40	6.07	95.39	0.28	2.91	0.19	1.75			G	R	
41	7.75	103.14	0.33	3.24	0.13	1.62			SA	R	
42	3.22	106.36	-0.06	3.18	0.21	1.71			C	R	
43	2.28	108.64	0.1	3.28	0.15	2.02	3.14		C	R	
44	6.82	115.46	0.27	3.55	0.21	2.21			C	R	
45	4.92	120.38	0.24	3.79	0.12	2.3			G	R	
46	3.82	124.2	0.29	4.08	0.09	1.3		TAIL	G	R/P	
47	1.07	125.27	-0.12	3.96	0.24	1.14		MAX	G	P	
48	2.06	127.33	0.07	4.03	0.19	1.8		TOP	G	P/R	
49	0.66	127.99	0	4.03	0.19	1.2			G	R	
50	4.09	132.08	0.27	4.3	0.13	2.25		TAIL	SA	R/P	
51	2.78	134.86	-0.35	3.95	0.45	2.65		MAX	G	P	
52	0.86	135.72	0.45	4.4	0.02	2.3		TOP	G	P/R	
53	2.25	137.97	0.07	4.47	0.13	2.1	3.6		G	R	

Comment Ranking Critera:

Green: Discretionary recommendation which requires no action by the authors (any comment not designated a ranking assume Green)

Yellow: Additional Information or clarification is requried from the author before the document can move forward;

Red: A fatal flaw which must be corrected before the document will be approved and moved forward;

Comment #	Page	Line	Reviewer	Comment	Ranking	Statement/Issue/Problem
1	Cover	3	Harry Bell	It was refreshing to see the focus expected variation and the effort to determine sample sizes that hopefully provide confidence intervals and associated probabilities that are useful for informed policy. The final report results should clearly distinguish between metrics for the sample and those inferred for the entire population sampled. Few policy people		
2	Cover	3	Harry Bell	Frequent references and conclusions from the pilot study need more transparency showing data and analyses. Without that a cloud of policy influence and beliefs vs. facts will overshadow legitimate study results.		
3	Cover	3	Harry Bell	Rather than stratify by physical regions it may be useful to grouping stream reaches by elevation, aspect, precipitation, geology, etc. and then looking at EOF and PHBs specific for each strata.		
4	Cover	3	Harry Bell	I may have misunderstood if the EOF calls from the WTMFs include any habitat above the last fish detection. If so, it is not clear how errors in identifying		

5	Cover		Doug Martin, Don Nauer, and Marc Gauthier	Primary concern is weakness of analytical approach to objectively derive PHBs and EOF habitat. Revised text is required to explicitly describe approach for objectively deriving PHB criteria from empirical data, and then use objective criteria to evaluate Board proposed PHBs. In contrast, the primary focus of current approach is to evaluate the suitability of Board selected PHB proposals; with the option (not required) to develop objective PHB criteria. Needs to go beyond evaluating the current, but determining the "correct" PHBs.	Red	
6	i	19	Mark Hicks	I made small edits to this summary just to try and make it more clear and correct –separating the proposed PHBs from how the final selected PHB would be used etc.. Redlined the "Summary" section with proposed language changes -HOW TO ADDRESS?		
7	i	21	Debbie Kay	Another cogent item for this list would be seasonal hydrologic disturbance.		
8	i	23	Harry Bell	Was there or should there be a distinction between continuously flowing Np and intermittent Ns waters?		
9	i	28	Harry Bell	There are large streams—especially the west cascades—that don't have fish due to natural barriers. Please clarify the population of streams that you intend to draw inferences about and how they differ from all other streams.		
10	i	30	Harry Bell	By who and using what criteria?		

11	i		Don Nauer	The water typing rule writing committee is struggling with this lack of confidence for detecting fish with a single-pass survey as well since fish detection is paramount for the analysis of the PHB criteria that are associated with the downstream-most feature.		
12			Don Nauer	See WDFW comment on this study purpose statement that contradicts with Study Purpose statement highlighted in yellow on page 12, located above Study questions.		
13	i	34	Harry Bell	This suggests that PHB's are assumed to be EOF.		
14	i		Marc Gauthier	These first two sentences highlight previous comments and suggest that this is not as simple as only compare the current options.		

15	i		Marc Gauthier	This is a major shortcoming of this study. This starts us of with a bias subset of EOF points. The random selection should include any F/N break point that was included in an approved FPA. This would give a larger and more representative sample pool while removing the bias. If it is good enough to allow for an approved application, it should be good enough for this study. In addition, to ensure EOF points land in similar locations regardless of current and past management strategies we should also consider sites managed by program partners, I.E. Federal, Tribal and Lands operating under other HCPs. This would give a more representative array of sites across the state.		
16	i	42	Harry Bell	How will you do this since that is what the study is designed to do?		
17	i		Don Nauer	Another plea to use, “last detected fish”, to clearly state to board or policy member that this is a variable term and location that can change with each electrofishing survey and may or may not represent the “end of fish” or fish distribution in a surveyed stream….every EOF term should be replaced with LAST DETECED FISH to be crystal clear.		
18	i		Don Nauer	WDFW too is concerned with bias associated with site selection		

19	i		Marc Gauthier	The current protocol focuses only on pools. There are opinions that suggest that fish can be missed that occupy riffles and other non-pool habitat. We should discuss the pros and cons of continuous electrofishing surveys. The data could be valuable by ensuring all fish present are identified while also providing insight to question of effectiveness of the current protocol.		
20	i		Don Nauer	I agree with Marc here that the survey protocol should be complete and rigorous and not confined to some pool size. It is imperative that the FIRST fish above a potential PHB is detected and not missed. Therefore, all holding habitat needs to be investigated.		
21	i		Don Nauer	WDFW has repeatedly stated that BFW can be informative but not a determinant for fish habitat since it is not a good surrogate for flow and is inconsistent in its measurement and how it relates to the reach length. ISPR was adamant about this as well and their objection for use as variable rather than at most, a co-variate, must be clearly stated.		
22	i	45	Harry Bell	With or without replacement and why?		
23	ii	49	Mark Hicks	Confusing since it reads to suggest you may not collect the data if the change is in some direction. It is not made clear by the sentence that follows it. Maybe delete this clause and simply tie it to the next sentence: …to append upstream or downstream data so as to ensure there are habitat data 200 m…		

24	ii	52	Mark Hicks	Seems like you are playing with terminology here mixing potential fish habitat with the habitat at the EOF points. Don't say you are defining end of potential fish habitat if you are really just doing end of fish plus distance to next PHB as these are not the same. This does not mean what you derive is not the best we can hope for of course. I am just asking that the discussion be more careful about mixing these topics up.		
25	v	92	Harry Bell	Does this include habitat above the last fish detection? If so, how is (or was during previous type calls) that habitat identified? Are measurements from the last fish or the last habitat above the last fish? If policy has directed use of habitat above the last fish as a starting point for measuring to the next PHB, then your results are not "scientifically" objective.		
26	1	115	Mark Hicks	ADD TEXT: used, or potentially could be		
27	1	120	Mark Hicks	CHANGED TEXT: ~~the~~ an		
28	1	122	Mark Hicks	A discussion of the map seems important to this discussion since you jump to a statement about WTMFs being used to change the water type maps. ADDED TEXT: DNR provides a map showing where a model has determine fish bearing stream segments occur but this model is known to produce some incorrect assessments.		

29	1	125	Mark Hicks	ADDED TEXT: Landowners may use the physical criteria, the locations shown on the DNR map, or the results from protocol electrofishing. Landowners If a landowner finds that an alternative point better represents the end of fish, they may request that point be used to set the regulatory boundary in applying		
30	2	134	Mark Hicks	Only DNR forester needs to be in agreement so this is mischaracterizing the actual process. No agreement by anyone else is needed to approve a WTMF. CHANGED TEXT: and ~~agree upon~~ determine		
31	2	135	jason walters	The way this reads it suggests that every ID Team results in the adjustment of the F/N Break. This is not true… in some (many) cases it is just an opportunity to provide more information, clarify things, etc.		
32	2	141	Harry Bell	Is this restricted to electrofishing? If not, what other survey methods does this include? If only electrofishing than say so.		
33	2	142	Mark Hicks	ADDED TEXT: and the end point of waters to be protected for fish habitat		
34	2	142	jason walters	Don't surveys start with a location of 'known fish use'???		
35	2	145	Mark Hicks	EOF is not correct here. It is simply the end of F-typed waters. It is a process based decision that may or may not represent the true end of fish, or end of fish habitat.		
36	2	147	Harry Bell	While this sounds nice on paper, the WTM process and the use of ID Teams is very subjective the out comes of which are very dependent on the beliefs and agenda of the participants. Not a very good basis for an objective study.		

37	2	147	Mark Hicks	ADDED TEXT: is commonly added above these points when establishing the regulatory point that will be used as the end of fish habitat.		
38	2	147	Mark Hicks	This is pretty definitively written statement for having no clear basis other than one person's unpublished data.		
39	3	162	Mark Hicks	Flow and channel size can act independently so this is not a combined criteria/factor.		
40	3	162	Harry Bell	Interspecies competition? Also, figure 3 below recognizes the importance of flow in uppermost fish locations. You seem to conveniently gloss over it here.		
41	3	167	Mark Hicks	CHANGED TEXT: ~~apparently~~ additional		
42	3	171	Harry Bell	What about a trench/chut picture?		
43	4	174	Mark Hicks	CHANGED TEXT: ~~measured~~ commonly expressed		
44	5	204	Mark Hicks	This is useful in the context of many of the EOF points, but should be used carefully if applied across the state in a protocol to create PHBs.		
45	5	209	Mark Hicks	See passage work done at Hells Gate in the Fraser River where fish negotiate current much higher than what they can theoretically pass through. Hypotheses is they are hugging the bottom along the channel margins where drag and eddy currents bring the resistance down to a level that allows passage.		

46	5	212	Mark Hicks	This is supported by passage work done at Hells Gate in the Fraser River where fish negotiate current much higher than what they can theoretically pass through. Hypotheses there is also that they are hugging the bottom along the channel margins where drag and eddy currents bring the resistance down to a level that allows passage.		
47	5	216	Mark Hicks	Shouldn' this be in the next section on Gradient?		
48	5	221	jason walters	Why include discussion of vertical barrier height in this 'non-vertical obstacle' section???		
49	5	223	jason walters	Providing information on associated channel width, when talking about channel gradient, is critical to understanding this issue.		
50	6	238	jason walters	I don't understand why this information is presented as it is. Why put the focus on the 'exception' to the rule like is done here. Doesn't it make more sense to focus on the habitat characteristics where we usually/typically find fish (e.g. the <15% habitats mentioned above) and then speak to the more-rare cases after? Feels like a slanted way to present this information.		
51	6	242	Mark Hicks	Substantial characterizations such as this demand more references.		
52	7	256	Debbie Kay	It's a surrogate for the volume of stream discharge? Velocity? Both? A metric would be a helpful descriptor here.		
53	7	257	Mark Hicks	You have flow and width here. Which one are you saying is important?		
54	7	259	Mark Hicks	ADDED TEXT: in Washington		

55	7	261	Mark Hicks	ADDED TEXT: boundary of fish presence		
56	7	261	Mark Hicks	MODIFIED TEXT: boundary		
57	8	262	Mark Hicks	MODIFIED TEXT: boundary		
58	8	263	Mark Hicks	MODIFIED TEXT: boundary		
59	8		Don Nauer	Again, only if it is represented consistently within a reach and accurately measured by the surveyor – we know from experience that this is typically not the case.		
60	8	271	Mark Hicks	Check against CMER UMPPF data findings used to evaluate point of perennial flow.		
61	8	275	Debbie Kay	This kind of logic can fail to work in glaciated systems where the uppermost parts of the system consist of large headwater wetland complexes.		
62	8	279	Harry Bell	Without confidence intervals and probabilities this is a very subjective conclusion. Maybe include your data as unpublished in the references.		
63	9	279	Mark Hicks	Provide results in a figure at least so reader can get a sense of at least what you consider accurate.		

64	9	283	Jamie Glasgow	Inhabiting vs. using? Think about high flow refuge… Fish Habitat (010) isn't contingent on food.		
65	9	283	Chris Mendoza	Agree, which is why laterals / tributaries may not contain fish all seasons		
66	9	291	Harry Bell	What about one and 2 yr. salmonids?		
67	9	292	Harry Bell	This suggests that these small fish and headwater streams have only a marginal contribution to productive fish runs and species survival. References and discussion?		
68	9	293	Mark Hicks	Smaller size is an advantage when moving through slash and other jams.		
69	9	299	Mark Hicks	MODIFIED TEXT: Surveyors commonly assessed barriers and record measurable changes in stream size and/or gradient in their work to provide a basis for suggesting the point that represents EOF habitat		
70	9	299	Mark Hicks	This seems to lack a purpose. And how was this information used? What was the basis for making a habitat call? Why are you citing Cupp and Cole?		
71	9	302	Harry Bell	It would be helpful to define this here.		
72	9	304	Mark Hicks	If you are not really identifying the end of potential fish habitat this term should be revised so that it is more accurate that you are establishing the regulatory break between fish and nonfish waters.		
73	9	306	Mark Hicks	This is an okay way to describe it as well.		
74	10	306	Mark Hicks	DELETED TEXT: ~~and provide a suitable location to initiate a protocol survey~~		
75	10	306	Mark Hicks	The fact you start wherever the highest previously recorded fish location is really is not worth mentioning.		

76	10	306	Mark Hicks	This is not really a point worth mentioning in text unless you want to explain why – which I take to be that it avoid unnecessary use		
77	10	312	Mark Hicks	ADDED TEXT: the highest prior known location for fish~~EOF (end of fish)~~ location. Once~~ the EOF~~ this location is		
78	10	312	Mark Hicks	Very confusing to call the point you start EOF given is also the term you have been using to represent the EOF.		
79	10	313	Harry Bell	If the EOF is from a concurrence WTMF (an imperfect and highly subjective process) it could be upstream from the actual EOF there by confirming the error. Ditto for EOF per rule default physical criteria.		
80	10	317	Mark Hicks	Don't you have a minimum distance? You should given the PHBs may be numerous if you pick small changes in physical parameters.		
81	10	317	Jamie Glasgow	Incorrect. This contradicts Fig. 5, below. Greater of 1/4 mile or the next PHB.		
82	10	317	Chris Mendoza	Agree, also the language we agreed to in BM 23.		
83	11	331	Mark Hicks	Seems the panel came up with recommendations worth testing rather than a scientific finding that they will work. Suggest softening the conclusion.		
84	11	331	Mark Hicks	DELETED TEXT: We concluded that ~~it is a possible to identify PHBs based on~~ stream size,		

85	11		Don Nauer	I agree with Doug, except I believe this has been discussed as something learned from the pilot study. However, testing commonly used field instruments such as clinometers and simple rangefinders, board manual members discovered they were not as successful to produce consistent gradient/obstacle results when compared to the highly accurate stream profiles produced in the pilot study.		
86	11	337	Mark Hicks	Not clear here that this included stakeholder recommended PHB (my perception), or did the panel conclude and thus support all of those being tested.		
87	11		Don Nauer	Repeating again, how will PHB alternatives not identified by the board be validated?		
88	11		Doug Martin	Suggest adding qualifier: (ease of measure and repeatability)	Green	
89	11	345	Mark Hicks	Do you really need both to be a barrier? Maybe this should be "or". Also does the data really support not having a length criteria for a gradient barrier?		
90	12	347	jason walters	The single biggest fundamental flaw in my opinion with the study design and site selection is that it does appear that 'laterals' will be essentially ignored. Given that the intersection of non-fish bearing streams with larger fish-bearing mainstems represent such a large percentage of F/N break locations across the landscape, how can this be the case? Wouldn't we want to understand these sites, as well, the variability seen at these locations, etc.? Prior CMER work		

91	12		Doug Martin/Don Nauer	Proposed PHBs are subjective; based on a combination of science and BPJ. Thus empirically derived criteria needed before you can evaluate…	Red	
92	12	352	Mark Hicks	ADDED TEXT: short-term AND COMMENT:Three years is still a very short period of time and may easily fall within a homogenous period of annual precipitation patterns. Local variation as commonly occurs even within ecoregions may simply become statistical variability that will be lost in the analysis unless relationships between the EOF and the flow regime is directly factored into the analysis.		
93	12	353	Mark Hicks	DELETED TEXT: Washington State. ~~(e.g., reduce uncertainty)~~		
94	12	355	Mark Hicks	It absolutely should if this is to be deemed a validation study for the FHAM rule. The PHB use the FHAM to establish the F/N break. Just knowing if the PHBs sometimes represent the EOF is not useful outside of the context in which it will be applied. Will a second validation study be conducted to see if the results identify the end of fish habitat if the PHBs are used in the FHAM rules? This seems like a very big deal.		
95	12	358	Harry Bell	Since the size and timing of high (not necessarily peak) flows may provide important windows of upstream access over a particular PHB, some measure of flow or fine grained precipitation—that is not captured by the ecoreagions—should be considered beyond being a covariate.		

96	12	358	Mark Hicks	MODIFIED TEXT: fishes but ~~do not affect~~ operate separately from the physical-habitat based PHBs the Board has asked us to test. ~~Therefore~~ Even though they may have some effect on where we will find fish, they are not included in this study since we believe...		
97	12	359	Harry Bell	Since these criteria, once tested, are the physical limitations to fish occupancy, is it fair to say that all of the other “covariates” could limit the ability for fish to reach the EOF habitat as identified by the selected criteria? What about interactions between the above criteria and say very local variations in water flow or precipitation?		
98	12	359	Mark Hicks	COMMENT FOR ABOVE WORDING "believe" Explain why rather than just say you are not going to include them. I am sure you discussed this and have a reason.		
99	12		Doug Martin	This phrase is problematic as it implies that the proposed BHPs will be use in FHAM, as if they are only option? Suggest rewriting as shown in my edits to remove implied language.	Yellow	
100	12		Don Nauer	Here lies the contradiction from the pother purpose statement above.		
101	12		Doug Martin	Questions revised for clarification and study guidance	Yellow	
102	12		Marc Gauthier	Who is defining accurately?		
103	12		Don Nauer	Here is the fundamental problem and confusion over terminology; Does EOF mean the same to everyone – last detected fish from a survey or the end of fish distribution? And how does this relate to the end of fish habitat; the ultimate question?		

104	12		Marc Gauthier	This question cannot be answered without a policy determination of acceptable risk.		
105	12		Don Nauer	Especially when no flow is encountered in which to detect fish from the electrofishing survey or eDNA sample. Flow is required to survey which creates a bias in detection results that compromises the ability to associate “last fish” with a feature or any criteria. ISPR spoke to this as well.		
106	12	362	Mark Hicks	WORD CHANGE: ~~accepted~~ provided		
107	12	364	Mark Hicks	I read this and wonder given your prior paragraph, what you mean by accurate since you appear not to be intending to test the PHBs in the context they would actually be used in.		
108	12		Mark Hicks	DELETED: ~~(>25 years)~~ study on the upper limits of fish distribution ~~per se~~.		
109	12	365	Debbie Kay	Again, geologic subtype, specifically montane vs flat headwater systems should be a third consideration. You have it in the question below, but it would be nice to have it repeated here.		
110	13	366	Mark Hicks	ADDED TEXT: or performance		
111	12	370	Debbie Kay	Headwater system type? Those that begin as headwater wetlands vs those that begin as groundwater or snowmelt inputs?		
112	13	371	Mark Hicks	Do you mean criteria expressed as finite limits rather than proportional change?		

113	12	372	Debbie Kay	And is it regionally different?		
114	13	373	Mark Hicks	Maybe delete the word typical or explain how it will be used to constrain your analysis and why.		
115	13	376	Mark Hicks	It would be nice if your terminology was not so overlapping: Type F/N break, EOF, EOF habitat, habitat. Here you mean HFF (highest found fish)		
116	13		Don Nauer	Several ISAG members asked how the analysis would consider obstacles located downstream more than 100 meters from fish detections that demonstrated fish could pass? This was never explained or resolved in any discussion with the authors or study plan revision.		
117	13	381	Mark Hicks	MODIFIED TEXT: We propose to determine the location of the last ~~end of~~ fish ~~use~~ at		
118	13	382	Mark Hicks	MODIFIED TEXT: measure select physical ~~the~~ habitat		
119	13	383	Mark Hicks	Isn't the protocol to shock ¼ mile upstream? Why not extend it that little much more so you are testing part of the protocol itself?		
120	13	384	Mark Hicks	CHANGED: ~~necessary~~ used		
121	13	387	Harry Bell	In order to estimate sample size you must have some idea, for each metric, the desired accuracy range and associated probabilities. What are they? Why? Looking at Table A-1 I don't see how you got to only 35 sites. Also, the .8 power of the t-test and .8 % detection of the Bootstrap procedure have significant policy ramifications that need explanation sufficiently for informed policy decisions.		

122	13	388	Debbie Kay	It would be nice, even if it's not in one ecoregion, to be able to have a subsample of these sites that are also statistically analyzed as those with low-gradient headwaters.		
123	13	389	Mark Hicks	MODIFIED TEXT: ~~We felt t~~These data, which were collected using similar methods, should reasonable ~~accurately~~ represent		
124	14	396	Mark Hicks	MODIFIED TEXT: We ~~would~~ expect that data collected with consistent methods and crews ~~would~~ will have lower variability than the WTMF data we used to estimate the sample size. This expectation was supported from data collected under the pilot study, which had lower variance around gradient and change in dradient ~~seen~~ than the WTMF data and ~~suggested a~~ supported the decision to use a sample size of 35 sites per ecoregion ~~was appropriate~~.		
125	14	407	Mark Hicks	MODIFIED TEXT: portion of the Willamette ecoregion is in Washington State~~, leaving seven ecoregions in our proposed study~~.		
126	15	417	Mark Hicks	Did you consider the potential bias that might be connected with this information set? These are locations where proponents saw sufficient value in changing the mapped points. If the mapped point was correct or near known fish would the sites have been protocol electric fished and would the results be submitted for modifying the map at a frequency equal to those where there was an expected or known large discrepancy. If you are randomly selecting from a		
127	15	420	Mark Hicks	No. They are approved regulatory points, but many were never verified by DNR or field ID Teams.		
128	15	423	Mark Hicks	CHANGED: long time TO longer time		
129	15	427	Mark Hicks	CHANGED: goal TO plan		

130	15	430	Mark Hicks	Why would an N stream be one of your WTMF verified sites in the sample pool?		
131	15		Mark Hicks	DELETED: non-fish bearing streams AND COMMENTED: I am concerned with this. How do you defend not using sites that turn out to have fish above the point approved as the end of fish habitat in the WTMF? Why are you not introducing a downstream bias with this selection criteria? Does this mean you are only going to use ones where you know nothing about them and thus assume they are at the point once identified as EOF?		
132	15	430	Jamie Glasgow	Highlighted "manmade barriers". No actual comment provided.		
133	16	444	Jamie Glasgow	What's to keep landowners from nixing access to sites they suspect will show unfavorable results? In the end, only sites that area pproved by landowners are used... See comment on p. 41. There should be a subset of sites on fed lands, including some unmanaged NPS sites, to see if the results from landowner sites are impacted by their logging legacies.		
134	16	444	Chris Mendoza	Agree. Site Selection needs to be random w/o landowner discretion. Fed lands would be ideal for comparison		
135	16	459	Harry Bell	Will this enable you to tease out regional interactions with seasonal changes? Explain why or why not.		

136	16	451	Debbie Kay	This is where it would be nice to break out a statistical subset of these sites that can be analyzed as low-gradient. They don't need to be an additional set as long as they are in defensible numbers. I just want them to come from watersheds that don't have headwaters in the mountains.		
137	16	453	Mark Hicks	ADDED TEXT: 245		
138	17	454	Mark Hicks	CHANGED TEXT: ~~In addition~~ Sixty sites will be selected for sampling, ~~one third of all sites will be resampled each year~~ for three years during		
139	17	457	Mark Hicks	You have not separated your early and late season periods by enough to claim them as being distinct representations of seasonal movement. At least set a minimum time span between sampling at the same site. For example, if you take a sample on July 14 and call it your early season and July 20th and call it your late season you will be claiming incorrectly that they represent intra annual variability.		

140	17	457	Mark Hicks	CHANGED TEXT: In addition to these sixty three-year sample sites, 22 additional sites will be selected at random and sampled in year one and an additional 82 sites will be selected and sampled in year three during the summer low flow and fall to early winter periods. ~~Winter sampling would also be beneficial, but because of snow and access issues, it will not be feasible at most locations. Seasonal sampling sites will be randomly selected from the 245 sites for each year across ecoregions. All sites will receive summer and fall sampling in at least one year.~~ ADDED COMMENT: I suggest you don'e talk about winter sampling if you are not going to be doing it.		
141	16		Doug Martin	Number of fish needs to be recoreded. Facilitates CPUE	Red	
142	16	457	Jamie Glasgow	Leaving this question completely unaddressed is unacceptable. 010 doesn't say 'used by fish between March and December…' Could stratify the sites such that ~25% are surveyable in the winter (for example).		
143	16	457	Chris Mendoza	The last CMER Seasonal fish distribution study we did (Cole and Lemke 2003) found that water quality conditions reduced detection rates. Could still do in lowland streams		
144	17	457	Mark Hicks	You said all sites would be sampled in the summer at least once, but if you are choosing them at random that would not make sense – you are actually reducing your sample pool which is different.		

145	17	460	Mark Hicks	Of the 60 randomly selected sites ~~will be~~sampled seasonally (summer low flow through early winter) in all three years to allow examination of seasonal variation through time ~~(~~30 sites will be in ecoregions east of the cascades and 30 will be west of the cascades~~)~~ ~~to allow examination of seasonal variation through time~~ (Table 2).		
146	17	460	Mark Hicks	I took a shot at cleaning this paragraph so better matched Table 2 and was less confusing to me.		
147	16	461	Debbie Kay	Has eDNA been excluded from the sampling protocol? In the low-gradient systems, particularly during the winter, the streams will overtop bankfull and spread into floodplain and forested wetland environments. This becomes difficult to sample with electrofishing due to lack of confinement; eDNA as a substitute in conditions like this would be highly informative. It would be nice to consider this in these environments as a back-up way to gather needed data, even if the technology is not used in all instances. That said, electrofishing comes with a risk of missing fish. Using eDNA as a backup testing method can strengthen the results by providing additional confirmation at each site.		
148	17	461	Mark Hicks	It seems odd to me that you are not sampling the 82 summer-fall sites for all three years. Doing so while also randomly adding 82 sites additional sites in both years two and three should be more powerful and at little difference in cost.		

149	17	465	Mark Hicks	I must restate my concern with a method that screens out only those sites that do not have fish above the point in the WTMF. I also must note you have said nothing whether the point they are found must be in the same spot as the WTMF or how far down from that point they may be. All you should want to know is where the end of fish is at the beginning of your study. Alternatively, but still questionably, if the last fish point in the protocol survey is well defined/marked you could use the new found last fish point as a data point in assessing inter annual variability.		
150	17	468	Mark Hicks	Need more on how your protocols for determining species and size. For example are you collecting them with dip nets and placing them in buckets to categorize them, then dumping them pack in the reach? Why approximate size? How are you intending to use this information? You won't accurately know their ages and you won't know where they have been or what PHBs or barriers they may have passed by, if any.		

151	17	468	Mark Hicks	There seems to be a real chance by only looking 100 m downstream you will not record PHB that the fish passed which are the same ones that lie just upstream of the EOF points you identify. How is a feature a sound PHB if does not generally serve as a break in habitat use overall? You seem to run a real risk of limiting the location of where you are looking so much that you do not see the larger patterns of occupation and you will get results that are as much by chance as related to the criteria for the PHB you are testing.		
152	17	475	Jamie Glasgow	Only at the end here do you mention the east vs west split, but seeing this simply raises question to me about what split you are doing for the other summer-fall		
153	17	475	Chris Mendoza	I took a shot at cleaning this paragraph so better matched Table 2 and was less confusing to me.		
154	18		Doug Martin	It seems odd to me that you are not sampling the 82 summer-fall sites for all three years. Doing so while also randomly adding 82 sites additional sites in both years two and three should be more powerful and at little difference in cost.	Yellow	
155	18		Don Nauer	Agree with Doug, the 20 BFWs should describe sufficient reach distance from which to compare channel morphology and potential habitat change		
156	18		Doug Martin	Need to include steps-features. They are unique and not the same as pool, riffle, etc.	Red	

157	18		Doug Martin	Clarify if this is a field-call by surveyors or if this is done during data analysis. Note, the Pleus et al. criteria are not suitable (i.e., too conservative) for juveniles and should not be used in the field to define pools . Best to simply measure pool features regardless of size/depth and use data in analysis to define what is suitable.	Yellow	
158	18		Doug Martin	Revise. It is very important to objectively identify and quantify deformable barriers (step-features) because there are considerable differences in longevity depending on forming agent (e.g. distinguish logs from debris jams). Suggest using step-feature criteria from: Jackson, C. R., and C. A. Sturm. 2002. Woody debris and channel morphology in first- and second-order forested channels in Washington's coast ranges. Water Resources Research 38(9). Also, knowledge of deformable barriers will inform how large wood recruitment influences spatial patterns of fish distribution and associations with buffers	Red	
159	18		Don Nauer	We agree with Doug's concern for the influence of wood features on fish distribution and detection (the most valuable result from the Cole study) and need for accurate identification and measurements.		
160	18	479	Mark Hicks	ADDED TEXT: short term		
161	19	487	Mark Hicks	So is this the EOF your field team validates or is it the EOF that is in the WTMF? It should be whichever point is farthest upstream. If the EOF at the time you survey for site selection is more than 100 m below the EOF determined in the WTMF, then you need to survey the		

162	18	502	Debbie Kay	There is a risk, if using a computer to calculate these points, that the same feature may be identified 2 or more times based on starting point measurements. Our field work looking at these points showed that the point at which the beginning of an inflection was measured changed by 20-40 feet or more, based on where people were standing when they took their measurements. This is an inherent risk. My concern is that PHBs are double counted on the program when the change in both locations refer to the same feature. Is there a way to double-check for this in the field when standing and looking for the features? Perhaps an alarm that goes off if two PHBs are within a certain distance of one another and the ability to check whether they are part of the same feature or separate features?		
163	19	502	Mark Hicks	ADDED TEXT: Where wood appears to form or contribute to a PHB, or mitigates a PHB, it will be captured in the notes. For COMMENT: I really think this is an opportunity to consider the positive functions of LWD rather than simply focusing on them as barriers.		
164	19	506	Mark Hicks	Good. Reasonable approach.		
165	18	507	Debbie Kay	Do you have an alternate sampling plan for streams that are in winter floodplain or associated wetland systems? Are you planning to exclude those systems?		
166	20	518	Mark Hicks	CHANGED TEXT: surveys demonstrating including the extents of protocol electrofishing survey to determine end of fish (EOF) (A), the initial longitudinal profile physical habitat survey (B), and an example		

167	20	524	Harry Bell	Not clear.		
168	20		Doug Martin/Don Nauer	Analysis section needs to be revised to explicitly describe approach for deriving PHB criteria from empirical field data. Then use these criteria to evaluate Board selected options. Also, there should not be any restriction on variables defining PHB criteria. Yes, test performance of three proposed variables. However, likely that basin area/flow will be key predictor? So need to show performance with competing models.	red	
169	20		Marc Gauthier	Agree with Doug and this once again highlights the imperative to develop an acceptable risk threshold.		
170	21		Marc Gauthier	Agree this is worth discussion		
171	21	530	Mark Hicks	Doesn't make sense as written, the first clause is not related to the second. Your variability would be predominately due to crew variability if habitat variables remain constant with different flows.		
172	21	535	Mark Hicks	ADDED TEXT: age, history of management (broadcast burning, stream cleaning, splash dams) time		

173	20	536	Harry Bell	Since there is clearly an interaction between drainage area and patterns of precipitation on channel formation, you should collect enough information to test whether the Level III Ecoregion stratification is fine grained enough to make inferences about the three sets of PHB criteria.		
174	21		Doug Martin	Need to indicate you will also examine a range to find the best predictor	Red	
175	21		Marc Gauthier	Yes, but FHAM board manual fiel crew tested this metric [20 bfw] and it seemed reasonable		
176	21	540	Mark Hicks	Why? Seems simple enough to stratify by the major geo-variables (e.g., basin size and orientation) that you are determining remotely.		
177	22	549	Mark Hicks	Maybe you need a summary table of all of the variables you are collecting since this is not a complete description.		
178	21	552	Harry Bell	Just a point of observation—the entire distance above the EOF has a bank full width greater than the 2' criteria threshold.		
179	21	555	Harry Bell	Are these those in Table 1?		
180	22	558	Mark Hicks	Such as? You should have a specific decision here. Do you have a minimum or maximum? This seems really important to identifying and standardizing a PHB.		
181	22	558	Mark Hicks	What is the basis for assuming a PHB metric, say gradient, is scaled to the width of the channel? I certainly would not assume that it is. It will be the same species and the same size, so flow velocity would be the variant that would change their ability to pass any potential PHB. Width is important by providing horizontal variability in flow which create channel complexity and pathways around/through potential obstacles.		

182	22	573	Harry Bell	Not clear.		
183	22	573	Jamie Glasgow	This should be blind, and I’m not sure how it can be. EOF will be monumented, and the data used to find the PHB will exist only for 400m centered on the EOF.		
184	22	573	Chris Mendoza	We talked about this at ISAG. A logistical nightmare to make it blind.		
185	24		Doug Martin	Because flow is known to be a key predictor of habitat you are likely to find this important influence on PHB by hydrologic/eco region. There should not be any restriction on variables defining PHB criteria	Red	
186	25	591	Mark Hicks	What is a “random forest model”? You should provide a reference or a better description.		
187	24	596	Harry Bell	Not clear.		
188	24	599	Harry Bell	Explain what these are.		
189	24		Doug Martin	Revise to be consistent with questions on page 12-13	Red	
190	24	608	Harry Bell	How will you deal with variability when you find it? To avoid a third field visit to resolve differences the second crew should collect data and make comparisons in order to correct problems before the first crew leaves the site.		
191	24		Don Nauer	Again, flow is not only a key habitat predictor, but also necessary to detect fish presence in the first place that will directly affect consideration for obstacle criteria		
192	25	606	Mark Hicks	TEXT CHANGE: by ~~the~~ different crews to ~~compare among crews~~ by examining the		
193	25		Doug Martin	Revise to be consistent with revised analyses; objectively derive PHB criteria approach	Red	

194	25	610	Mark Hicks	Not clear to me what binning within 5 and 10 m means. What if it is not within 5 and 10 m? Are you saying you will only track PHBs if they occur within 5 and 10 m of EOF, and why have two distances to bin them within? Why did you chose these distances? How will you deal with not having one near the EOF point?		
195	26	614	Debbie Kay	You are using precise scientific equipment. It is important to make recommendations regarding PHBs that can be determined within the range of error of standard field equipment, such as a clinometer with the typical error of 3 percent gradient.		
196	26	623	Jamie Glasgow	As stated before, landowners have complete control over sample site selection.		
197	26	623	Harry Bell	These suggest errors in the WTMF EOF calls and should be recorded and reported.		
198	26	623	Chris Mendoza	Agree, we need to guard against potential bias based on landowner discretion. DNR could treat WTMFs like Compliance Monitoring Program - just give prior notice of entry.		
199	27	656	Debbie Kay	It also does not address the uppermost extent of fish when the streams are at carrying capacity and not at the depressed stock levels of current day.		
200	27		Doug Martin	True, Note, the inclusion of ephemeral barriers (e.g., large wood, jams) in the data collection could be used to inform how wood recruitment and probable increase of wood-barriers (e.g, buffers) can affect spatial distribution patterns over long-term.	Green	

201	27		Don Nauer	This statement captures the questionable results from a single visit survey and even the proposed 3 visits will not resolve the dilemma of how many visits are necessary for fish use confirmation.		
202	28		Doug Martin	This is not an addition, but essential part of analysis, as per need for revisions noted above	Red	
203	28		Doug Martin	Note the potential to examine effects of wood recruitment over time and how affects frequency of deformable barriers and spatial patterns. See comment above	Yellow	
204	28	657	Mark Hicks	CHANGED TEXT: ~~invasion~~ emigration		
205	29		Doug Martin	What about fish abundance? Suggest you include catch per unit effort estimates to facilitate evaluation of eDNA detection in relation to abundance?	Yellow	
206	29		Don Nauer	Doug makes a good point. However, we don't want to subject the local population to too much E-fishing effort and harm in order to answer this density question.		
207	29	675	Mark Hicks	CHANGED TEXT: frequently ~~associated with~~near the EOF. In addition, we are confident the methods will ~~test the~~provide metrics that can be used to compare the different		
208	29	676	Mark Hicks	CHANGED TEXT: consistently~~ mark~~ occur near the EOF point across years		

209	29	679	Mark Hicks	Seem like you should prioritize these sites in your screening criteria to see if you can get enough samples that will facilitate doing this. I really see this added benefit the only potential overriding reason for using WTMF as the pool for drawing samples.		
210	29	686	Mark Hicks	You will need to assess why fish are not found below PHBs that they passed or exist downstream and a basis for asserting why the PHB limited the distribution further upstream in order to really assert you have a method for identifying the end of habitat. I do not see how you will do this in this study. This is essentially developing a method to implement the old “Lenny memo” and create a standard protocol for hanging the		
211	29	687	Mark Hicks	a consistent point to demarcate the regulatory boundary between Type F and Type N waters which ~~EOF habitat and EOF~~is relatively stable across seasons and years. The study will also provide a basis for		
212	29	687	Mark Hicks	You will need to assess why fish are not found below PHBs that they passed or exist downstream and a basis for asserting why the PHB limited the distribution further upstream in order to really assert you have a method for identifying the end of habitat. I do not see		
213	30	705	Mark Hicks	Odd to hire someone simply to take a few samples. I hope the USFS is simply sending someone out the PHB field crew.		
214	30	709	Mark Hicks	CHANGED TEXT: study. If the AMP were to conduct a~~A~~ similar eDNA study on its own, doing so ~~would require all the proposed fish and habitat surveying , and in the absence of the PHB study,~~ would be ~~very~~ more costly .		
215	30	709	Mark Hicks	Not true in my perspective, surveying habitat is not required to examine the use of eDNA.		

216	30	710	Mark Hicks	This statement seemed at best an unnecessary exaggeration. I suggest deletion or editing as suggested. Really the entire paragraph is irrelevant to the PHB study design and it contains no study design elements of merit.		
217	30	711	Mark Hicks	ADDED TEXT: proposed PHB criteria evlaution study		
218	30	715	Mark Hicks	What did you change it to and why other than allowing the acceptance of fewer samples?		
219	29	719	Harry Bell	In addition you will be less able to test if ecoregions are still too coarse of stratification or how other conditions within ecoregions affect the EOF. Both are extremely		
220	29-30	724	Jamie Glasgow	This is necessary and very possible.		
221	29-30	724	Chris Mendoza	Agree. Particularly in lowland coho rearing streams		
222	31	729	Mark Hicks	DELETE: ~~coldwater~~		
223	30	730	Harry Bell	This seems critically important especially for coastal landscapes. Why is this not part of the study plan rather than an optional add-on?		
224	31	739	Mark Hicks	CHANGED WORDING: provide~~ the same~~any more insight~~ here~~.		
225	31	743	Mark Hicks	REMOVED: ~~to 10 years COMMENT: ~~You did not discuss this time frame in the body of this study design. Is this a “maybe we will have some data points we can use to examine longer term changes” issue? If so drop it here and if not explain it in the methods.		
226	31	746	Mark Hicks	DELETED: ~~(>25 years)~~		

227	32	752	Mark Hicks	Non-technical issue: Will it require a similar level of field effort to implement the PHB criteria if adopted by the Board? Would doing any less result in identification of the same PHB points? This pertains to the purpose of doing this project. It seems really important to the question of whether this effort results in a successful outcome in terms of water typing and needs to be addressed in this study plan. Maybe in a section on project risks or needed supplemental field work. This study is much closer to a rule tool and that objective needs to be front and center in its design and in communications with the Board and TFW Policy		
228	32	758	Mark Hicks	DELETED:). ~~In addition, 60 of the seasonal sampling sites would be sampled across each year to examine inter-annual variability in seasonal sampling. Ten percent of all sites will also be resampled by all field crews in each year to examine crew variability.~~ COMMENT: This last sentence is not a budget issue.		
229	33	766	Mark Hicks	Odd that out-year costs are so high given it will be in the first year when most of this work will occur.		
230	33	766	Mark Hicks	This is less than 10% of the total cost for field monitoring. More explanation in the body seems needed on how you are doing the QC on your field crews.		
231	33	766	Mark Hicks	If this is simply equipment I get this, but not if it is hiring an extra staff person to also collect the data. The methods are not that difficult.		
232	33	766	Mark Hicks	ADDED TEXT: eDNA COMMENT: Is this eDNA? Say what it is for.		
233	41	978	Harry Bell	?		

234	44	999	Mark Hicks	Symbols not appearing in text.		
235			Jim Matthews	1. Study Sites will be selected only from a pool of past Water Type Modification Forms (WTMF).		
236			jim matthews	Ø WTMFs are not randomly selected or distributed. Frequently WTMFs are clustered in areas planned for timber harvest. Many of these WTMF streams would now be expected to have some level of recent timber harvest around them. Undisturbed or lesser disturbed streams would be expected to be under sampled with this approach. Further, a greater proportion of protocol surveys and submitted WTMFs are focused on downgrading Type F segments, while surveys that confirm fish use are typically not reported on currently designated Type F streams. WTMFs also have a wide range in quality, how well they followed protocol survey requirements, and the accuracy of their findings. All of these factors will insert bias into the study.		
237			jim matthews	1. The study relies heavily on, and is predicated on, locating an end-of-fish (EOF) point to then evaluate PHBs above it.		
238			jim matthews	Ø The EOF point from WTMFs or protocol surveys conducted on a particular day may not be accurate. In the CMER Annual and Seasonal Variability Fish Distribution Study (Cole and Lemke, 2006), one study stream was later found to have fish more than a kilometer above their established EOF point. Fish have also been found at a later date above some WTMFs. PHBs should be assessed well below and above EOF.		

239			jim matthews	1. The study only evaluates the proposed PHB criteria above the EOF for a particular survey day.		
240			jim matthews	Ø Little or no investigation is done on what stream conditions are passable or useable by fish. What if fish pass similar PHB criteria downstream or in other streams? Would this mean that the PHB criteria are invalid or they aren't a good determinant for what limits upstream fish use?		
241			jim matthews	1. The Pilot Study was useful and valuable. The Pilot Study raised several questions about the proposed PHB criteria and the Study Plan. The data and details from the Pilot Study should be made available to better understand how the PHBs were assessed and designated.		
242			jim matthews	Ø Several of the Pilot Study streams had PHBs below the EOF. If fish are passing these PHB criteria, are they truly a PHB? Shouldn't the PHB Study investigate and evaluate conditions that fish have passed downstream of EOF? Below are some examples from the Pilot Study that highlight these questions and concerns:		
243			jim matthews	· From Page 11 and Figure 5 of the Pilot Study Report. A number of the PHBs, especially from proposed PHB Criteria 1 and 3, were found below the EOF on this western Washington Pilot Study site. **Fish apparently have passed these proposed PHBs. Does this mean the proposed PHBs are invalid, especially for Criteria 1 and 3? Does this mean the proposed PHBs don't adequately capture what limits fish passage and use?**		

244			jim matthews	· From Page 15 of the Pilot Study Report. Very similar PHBs for gradient appear to have been found below and above the EOF for **Site 8 in Stevens County**. **What is different about the PHBs for Gradient above and below the EOF? They appear to be quite similar. Is the PHB criteria valid if fish are passing it?**		
245			jim matthews	· From page 25 of the Pilot Study. **Site 19 in Thurston County** has a number of Gradient and some Obstacle PHBs below the EOF, and appear to be similar to the PHBs above the EOF. **Again, how are these PHBs if they occur below the EOF? How are the PHBs above the EOF different than those below? Do the proposed PHB criteria actually capture what limits fish passage and use?**		
246			jim matthews	· From Page 23 of the Pilot Study. **Site 15 in Clallam County** had a large number of Gradient PHBs and some Obstacle PHBs below the EOF. **How are these PHBs below the EOF different than the PHBs above the EOF?** This site also had the **highest overall channel gradient at 26.0%**, with what appears to be considerable in-channel wood loading and step/pools from the stream width profile. **How does the study plan account for differences in channel wood loading and step/pools to determine PHBs? If a stream has future improvements in wood loading and/or step/pools, how would that affect upper fish distribution or what constitutes a PHB?**		

247			jim matthews	· <u>From Page 27 of the Pilot Study.</u> **Site 23 in Thurston County** appears to show the larger PHB below the EOF than anything above the EOF for 200 meters. **What constitutes a PHB when fish were found above the largest gradient/obstacle in the survey? How does the study confidently determine what is a PHB or whether the PHB criteria are appropriate?**		
			Mark Hayes	Major limitations		
248				1) Circularity of the study design – the question purported to be addressed in the study design depends on definitions that are also part of the target.		
249				2) Random selection from approved water typing modification forms biases the study to a subset of the landscape that prevents generalization outside that subset.		
250				3) Single pass determination of end of fish (EOF) location does not address detectability with the suite of covariates that can influence end of fish (EOF) location. Hence, confidence in what is the actual EOF is low.		
251				4) EOF *per se* is irregularly equated with EOF habitat, which makes the intent unclear.		
				Other issues		
252				1) Of the 10 items list by ISPR to be addressed in the negotiations in order to gain acceptance by ISPR from the summary of the 24 October 2018 meeting, only 4 were effectively addressed, 3 were at best only partially addressed, and the remaining were not really addressed at all clearly changes were made to the text.		

253				2) Given that an important part of this study is to inform aspects of the water typing rule, it is unclear why the first step was not taken to evaluate the effectiveness of existing rule. No AMP study has ever evaluated the effectiveness of the existing, so how do we know we have a problem.		
254				3) The presumptive acceptable report is dated 11/5/18, whereas the Vogt communication to DNR from 13 November 2018 states that all concerns [of ISPR] were met in the revised PHS study plan date 11/6/18. This creates uncertainty as to whether the report provide to CMER for review is the correct one.		
255				4) Based on the structure of the AMP, the AMPA is intended to be the firewall between Science & Policy, the AMPA is also on the Science Panel, the AMPA also administers the contract, and the AMPA hired the mediator on the contract. This complex logistic handling through the AMPA raises concern about unbiased handling of the report development process.		
256				5) The basis of the prediction of BFW in headwater streams from the equation developed for larger streams is stated as being accurate, but the evidence of that basis is not provided.		

Response
Thank you.
Thank you for the comment. The Pilot study supported approach utulized in the development of the study design. Not necessary to include everything contained in the pilot as part of the final study design.
All of this data will be collected during the study design. Sample size will limit the power in this approach. The final analysis of the data will inform whether or not these items are important to establishing PHBs.
The EOF points from WTMs does not include that information but surveying 200 M above (is part of the study) this point determined during field work will address this point.

Panel respectfully disagrees with commentor. The goals and objectives have been clarified through earlier reviews and is addressed in locations within the document. Panel suggest that the reviewer look at the last paragraph on page 28 (line 655) of the study design. The Panel wants to be clear that this study cannot provide with absolute certainty which criteria are the correct ones for determining PHBs. It will however provide the Board with information on the three sets of criteria they directed the Panel to assess along with the ability to evaluate other critiera or combinations of criteria as well in an objective and quantititative way that could be used to define PHBs and meet the objectives of the FHAM.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Agree with comment and believe point is captured by inclusion of flow.
Not necessary distinction.
The sample population only includes streams with previously collected fish data.
Did not include information that can be used to identify PHBs consistently.

Comment noted glossery chaned line 92 End of Fish (Last detected fish from a protocol survey)
We clarified purpose of study
PHBs are nested in the FHAM method and it’s the application of FHAm that will be used to determine end of fish habitat. HANDE LANGUAGE TO: The purpose of the proposed study is to determine which combinations of gradient, channel width, barriers to migration, and other physical habitat and geomorphic conditions can be used to most accurately define PHBs applied in the FHAM to identify EOF habitat across Washington State.
We clarified purpose of study

We respectfully disagree. Using sites with EOF points will leverage existing data. Marc has not provided any evidence that only using water mod forms has lead to or results in bias to the process presented in the study design; despite speculating that this is the case repeatedly. Federal lands have not been excluded and are within the universe of available sites that could be sampled in this study.
Comment addressed with change to line 34.
Panel agrees that should use the phrase "last detected fish" rather than EOF throughout document. Plan on making this change within text and glossary.
See response to previous comment.

Not a true statement that the study design is focused on pools but the field protocols do require that a minimum of six pools must be shocked. The long profile will identify pools, riffles, etc. Electrofishing will not be restricted to pools.
See response to previous comment
We respectfully disagree and feel that the literature supports our use of BFW. It should also be noted that we will be measuring wetted width as well.
Without replacement we sample each site multiple times.
Agreed. (deleted end of line 49 see master document.)

Comment appears to miss the point authors are making here. No change made to language. Authors have been precise in the language used to identify these terms. The habitat survey data are continuous in contrast to how PHBs are used in FHAM, which the comment identifies.
Language changed.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
No data was derived from the map. Adding this to the discussion will likely lead to more discussion.

We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Accepted comment.
see comment above and revised text.
Refer to Board Manual this is outside the purpose of this study. For the study electrofishing is the method being used to identify EOF.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Agree with comment see revision.
Agree.
Paragraph is for context. Comment is related to frustration with processes outside of study.

We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Paragraph is for context. Comment is related to frustration with processes outside of study.
Disagree with need to make change.
We disagree.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Not needed. See Hawkins et al 1993
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Thanks for the comment.
We covered topic in sentence.

Topic has been covered.
Wanted to emphasize non-vertical obstacles.
Believe this is important context. Part of the same study. ISPR thought this was important.
Good point but study only reported discharge and not channel width. However we clarified that these are headwaters stream 1-3 order.
Asked to include this during earlier review process. The inclusion of Cole proveds more context to the exceptions in a more balanced approach.
We believe references are adequate.
Text added see master doc.
see above.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.

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We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Our pilot study demonstrated that the long profile survey we will use consistently measures gradient, bankfull width etc. It seems the commentor confuses the protocol application with the research study. The protocol that can be used by practitioners will be different than the protocol used in research. At the conclusion of the research, it will be very important for the project team to work with ISAG on methods that can be repeatedly applied to identify the recommended PHBs.
Comment noted.
We evaluated the model in streams across Washington including streams with glacial history. However we stratify by ecoregion in study and will be able to determine if the relationship is different in glaciated streams.
see Beechie and Imaki.
see response to previous comments.

added text.
see above.
All age classes are included.
Respectfully disagree.
Comment noted.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Disagree with need to make change.
will change suitable to fish.
Accurate desctiption as written to describe FHAM.
OK
That piece is a critical part of sentence. CHANGE: need to reorder sequence with survey language preceeding habitat.
see previous response.

see previous response.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Appears you are mixing eof with eof habitat. The study focuses upon PHBs and utilized contemporary eof data.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
Text corrected.
see above.
The assignment was to design the study to test the prescribed PHB criteria.
No changes made to existing text.

Comment noted. At the conclusion of the project it will be important for the project team to work with ISAG to ensure consistency and repeatability in survey methods and tools.
Not relevant to this study design.
We added text to clarify that we will evaluate other alternatives to determine which combinations of gradient, width, and barriers perform best.
Text modified as suggested
These are the criteria as written and the Board is considering. The study should help to clarify this comment.
We are drawing a random sample and laterals should be represented in the proportion they occur in the sample draw database. We agreee with your rationale on why they are important to consider.

Appears that reviewer misinterpreted intent of the language. Commentor needs to provide information to support his statement. Panel disagrees with his statement and his position. Panel defined PHB based on well defined and well studied upper locations of fish taken from the literature.
Comment noted.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
It is a validation of the PHBs not the FHAM process.
The purpose of seasonality is to capture the variability of PHBs including hydrologic conditions that co-occur across seasons.

We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
While this is true the intent of study to be conducted across seasons and over a three year period across ecoregions is intended to understand that phenomenon.
Respectfully disagree with word revisions.
Modified test to clarify.
Comment noted
We accepted some of suggested edits and clarified the purpose
Comment noted
Indicated that EOF is really last detected fish

Panel uncertain as to what this is from the reviewer perspective. Panel beleves that this is a question that will need to be addressed by Policy that will be informed by this work.
This is why we will survey in multiple seasons and years
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
We are not testing FHAM. We are identifying appropriate OHB criteria.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
The study will stratify by ecoregion and determine if the relationship are different across stream types.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
The study will stratify by ecoregion and determine if the relationship are different across stream types.
This is a placeholder to address the Board's discussion on whether or not to include an "anadromous floor". No change.

The study will stratify by ecoregion and determine if the relationship are different across regions.
No changes made to existing text.
Agreed.
This study is to determine what gradient, channel width, and blockages are most appropriate to use as PHB criteria. The Panel understands that as survey work moves upstream beyond the last detectable fish that the physical stream conditions that result in a barrier to further fish passage may not have been a barrier to fish passage lower in the system.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
The fish survey is a 1/4 mile but the habitat survey is upstream 200 m upstream from last fish.
We will consider your comments and make changes where they are appropriate. Comments that we were looking for were to be related to the study design not ones on background and context.
All good points. All points were considered during study design development. These were used for sample size estimate not for policy decisions. We have the data and can make it available upon request.

The study will stratify by ecoregion and determine if the relationship are different across regions. We expect to have a range of gradients, sizes, and presence of barriers (permanent and deformable) across ecoregions.
Comment noted.
Comment noted.
Comment noted.
Do not have any evidence that sites are biased but they are represented of sites that get water typed on forest and fish lands.
Comment noted.
Comment noted.
Comment noted.

Agreed and revised.
Comment noted.
Comment noted.
We do not have any evidence that this would be a problem. If it occurs will be shared with tfw community and FPB.
see above
That is the intent of study.

Commented noted.
Comment noted.
Comment noted.
Good comment. We will establish a minimum 30 to 45 day separation of sampling take at the same site. (Modify test)

Comment noted.
This study is not a population study. This study will follow the protocol survey methods, and will focus on using the presence of last detected fish to inform the physical habitat surevey. The physical habitat survey is the basis for determining the PHB and is informed by the last detected fish---not the other way around.
Good comment. We will establish a minimum 30 to 45 day separation of sampling take at the same site. (Modify test)
Comment noted.
Sampling without replacement. Replication occurs annually at 245 sites already.

Comment noted.
Comment noted.
The eDNA sampling is a separate component to be led by Forest Service. The details of the study desing are pending, and a more detailed field sampling protocol will be presented and discussed with ISAG prior to implementation.
Sampling without replacement.

see previous responses.
A fish is a fish. We are not conducting a population survey.

Every PHB will be a unique feature. Repeated sampling will help identify if that is the case.
Comment noted.
Comment noted.
Test modified to indicate channel morphology and habitat. The purpose of the seasonal sample is to capture how the last detected fish may change throughout the year at 245 sites (with existing strata).
See response to previous comment
Ok

We clarified that these would be identified in the field. We would also can examine these in office with data.
Don't see clear criteria, but we can use these if they are clear
See previous comment
Comment noted.
it is the field crew determine eof point. The wtmf will be used for context over the longer time series.

When a fish location is determined the distance to the next PHB will be established. This will minimize this issue. Additional analysis after the data is collected may be useful.
Not relevant to this study. Wood is considered a deformable barrier and does not apply to field protocol.
Thanks.
No and we are not planning to exclude any system at this time.
Comment noted.

Modified text.
We tested ability to identify PHBs in pilot study and will use a similar approach to look at other combinations of criteria and other predictors
We describe "describe" risk in terms of using type 1 and type II error. I terms of risk of making policy decisions on protecting fish habitat or electrofishing, that is a policy decision for Board. The recommended "risk" for the Board to accept is not a scientific question, although in discussion with ISAG there may be opportunities to express probabilities to inform the Boards decision.
Comment noted.
We agree.
Not relevant to this study design. No change in text.

Noted and discussed within the paragraph.
Text modified to clarify
Comment noted.
Not feasible.
List of metrics in text of methods and in figure caption. Additional table not necessary.
True.
Yes.
The decision will be determined based upon the data collected. The data will be collected at a resolution that will allow analysis at different scales.
The decision will be determined based upon the data collected. The width and gradient data will be collected at a resolution that will allow analysis at different scales.

Comment noted.
Comment noted.
Comment noted.
Agreed.
Will provide additional reference to clarify.
Comment noted.
Comment noted.
Revised to be consistent.
Comment noted.
Agreed.
Will provide additional reference to clarify.
Revised to be consistent.

5 and 10 m were chosen as proximal distances. Actual distances will be informed by the study results. (4th ?) Those will not be counted in the frequency.
Good comment agree. It will be important to have interaction with practitioners to ensure field measurements are of sufficient quality. Study may recommend minimum type of equipment needed to complete surveys in the future.
Not an accurate statement.
Good point.
Landowner access agreement will be acquired prior to entry of private property. Do not anticipate problems.
Study is attempting to address this issue through multi-year and multi-seasonal sampling.
Comment noted.

Actually each site will be visited 5 times. Annually, for three years, and in all three seasons in on year. Also since sites will be previously identified last detected fish, it will mean that we will have longer term data for some sites.
Text modified to clarify
Conducting detailed wood surveys is beyond the scope of the study. We will identify deformable barriers as previously noted.
Comment noted.
See previous response to comment about CPUE. It is not the purpose of this study to complete a population assessment within the basins included in this work. The study design does not include an aspect where crews are to capture and handle fish. The more data the crew has to collect during survey activities adds more time and cost to the overall cost of the project. Adding field task should only occur when it has been determined that acquisition of the additional data will provide important information that would help the Board in determing if and when rule modification is warranted.
Comment noted.
Comment noted.
Comment noted.

We are prioritizing those sites.
This is beyond the scope of this study.
Comment noted.
Comment noted.
Comment noted
Comment noted.
A missed opportunty to not do eDNA and habitat at the same time.

Respectfully disagree.
Comment noted.
Described in paragraph and appendix.
Agreed.
Comment noted
Comment noted
Comment noted.
Because of the size, cost, and complexity of study we thought that it was best that this be a supplemental study.
Comment noted.
Comment noted.
Comment noted.

No once the appropriate PHB criteria have been identified.
Disagree. This is a budget issue since collecting data is the most expensive component of the study.
Board is and has changed the entire budget due to project phasing and continues to evaluate cost. It is important that the first year of the study ends on July 1, 1019.
This is the additional cost of multiple crews resampling the same site to look at crew variability.
Comment noted
Comment noted
Uncertain as to intent of (?).

Will make sure this is taken care of in final version.
Comment noted
Comment noted
This is why it is important to sample intra- and inter-annually at each site.

This is why it is important to sample intra- and inter-annually at each site.
These are potential habitat breaks intended to be applied at the upper extent of the distribution of fish.
comment noted
These are potential habitat breaks intended to be applied at the upper extent of the distribution of fish.
Pilot study question---dealt with separately.

Pilot study question---dealt with separately.
Pilot study question---dealt with separately.
Pilot study question---dealt with separately.

Pilot study question---dealt with separately.
Respectfully disagree.
WTMF represent private and state forest lands across the state. No indication that sites outside of the WTMF range of sites would be any different - no evidence of bias.
Multiple season and multiple year surveys to get at this issue.
Respectfully disagree.
ISPR was comfortable with the way that their comments were addressed. Your interpretation of how comments made by someone else were or were not addressed is erroneous.

Comment noted. We were hoping to get comments on the scientific underpinnings of the report (see above comments) rather than general process issue questions/comments/misunderstandings.
The report provided to you was the same version. If you were indeed confused, you should have sought an answer.
The AMPA was the project manager as assigned by the Board. The Board decided upon the degree to which the firewall exists (please see Board Manual Sxn 22). The AE of ISPR handles that process independently from the AMPA or stakeholders and in no way is influenced by any of the AMP participants.
For the purposes for which it is used is not necessary. Particularly since the study does not rely upon the model (measurements are taken in the field)