FA-07 RESERVOIR TRIBUTARY HABITAT ASSESSMENT INTERIM REPORT

SKAGIT RIVER HYDROELECTRIC PROJECT
FERC NO. 553

Seattle City Light

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March 2022
Initial Study Report

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List of Acronyms and Abbreviations

BMI ....benthic macroinvertebrate
City Light ....Seattle City Light
DEM...........................Digital Elevation Model
FERC..........................Federal Energy Regulatory Commission
GIS ....Geographic Information System
HARP ....Habitat Assessment and Restoration Planning
IP ....Intrinsic Potential
ISR ....Initial Study Report
LiDAR........................Light Detection and Ranging
LP ....licensing participant
m ....meter
mi ....mile(s)
NMFS.........................National Marine Fisheries Service
Project ....Skagit River Hydroelectric Project
RM ....river mile
RSP ....Revised Study Plan
SPD ....Study Plan Determination
UCM ....Unit Characteristic Method
USGS .........................U.S. Geological Survey
USR............................Updated Study Report

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1.0 INTRODUCTION

The FA-07 Reservoir Tributary Habitat Assessment is being conducted in support of the relicensing of the Skagit River Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 553, as identified in the Revised Study Plan (RSP) submitted by Seattle City Light (City Light) on April 7, 2021 (City Light 2021). On June 9, 2021, City Light filed a "Notice of Certain Agreements on Study Plans for the Skagit Relicensing" (June 9, 2021 Notice)[1] that detailed additional modifications to the RSP agreed to between City Light and supporting licensing participants (LP) (which include the Swinomish Indian Tribal Community, Upper Skagit Indian Tribe, National Marine Fisheries Service [NMFS], National Park Service, U.S. Fish and Wildlife Service, Washington State Department of Ecology, and Washington Department of Fish and Wildlife). The June 9, 2021 Notice included agreed to modifications to the Reservoir Tributary Habitat Assessment.

In its July 16, 2021 Study Plan Determination (SPD), FERC approved the Reservoir Tributary Habitat Assessment Study with modifications. FERC did not recommend that City Light be required to conduct any of the proposed studies to map and characterize tributary habitat and develop production estimates for anadromous salmon or any other fish species in tributaries to the Project's reservoirs. Notwithstanding, City Light is implementing the Reservoir Tributary Habitat Assessment as proposed in the RSP, with the agreed to modifications described in the June 9, 2021 Notice (see Section 2).

FERC's SPD required City Light to conduct a desktop analysis to quantify the acreages of reservoir shoreline/bed that are subject to frequent fluctuations or extended drawdowns under normal operating conditions. That study component, the GIS-Based Reservoir Littoral Zone Evaluation, is addressed in this Initial Study Report (ISR) as a separate technical memorandum, because the scope of this study is confined to tributaries to the Project reservoirs.

This interim report on the 2021 study efforts is being filed with FERC as part of City Light's ISR. City Light will perform additional work for this study in 2022 and include a report in the Updated Study Report (USR) in March 2023.

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[1] Referred to by FERC in its July 16, 2021 Study Plan Determination as the "updated RSP."

2.0 STUDY GOALS AND OBJECTIVES

The goal of this study is to evaluate the availability and production potential of habitat for Chinook Salmon (*Oncorhynchus tshawytscha)*, Coho Salmon (*O. kisutch*), Sockeye Salmon (*O. nerka*), and steelhead (*O. mykiss*) (collectively the target species) in select tributaries to Project reservoirs. Tributaries to be evaluated include (1) Stetattle Creek (tributary to Gorge Lake); (2) Thunder Creek (tributary to Diablo Lake); and (3) nine tributaries to Ross Lake, i.e., Canyon, Little Beaver, Big Beaver, Hozomeen, McMillan, Devils, Granite, and Three Fools creeks and the upper Skagit River. These tributaries were identified by NMFS in its Study Request 3 as those that are "…reasonably large enough to support populations of anadromous fishes…"

Results of this Reservoir Tributary Habitat Assessment will be integrated with results of the FA-04 Fish Passage Technical Studies Program (Fish Passage Study; City Light 2022b) and other studies conducted during relicensing to identify constraints and assess benefits and risks of providing fish passage and access to habitats upstream of the Project dams, consistent with the approach recommended in Anderson et al. (2014). The results of the Reservoir Tributary Habitat Assessment and/or the Fish Passage Study may include the identification of next steps or additional studies that are warranted to further evaluate the feasibility and efficacy of fish passage (e.g., juvenile reservoir transit and mortality) and to address other concerns raised in Anderson et al. (2014) as determined appropriate.

Specific objectives of this study are listed below:

(1) Apply the NetMap Intrinsic Potential (IP) model (e.g., Burnett et al. 2007) to map and characterize the extent of potential spawning and rearing habitat for the target species within tributaries based on geomorphic habitat suitability measures.

(2) Use physical habitat variables to estimate juvenile rearing habitat capacity, i.e., productivity potential, (e.g., Cooper et al. 2020) for the target species within potentially suitable reaches identified by IP modeling.

(3) Evaluate the results of Objective 2 in the context of results from the Factors Limiting Native Salmonids above Skagit River Dams study (Food Web Study) [2,3] (Beauchamp, in development).

The June 9, 2021 Notice commitments incorporated within this Reservoir Tributary Habitat Assessment are identified in Section 2.1.

2.1 Status of June 9, 2021 Notice Commitments

The status of each Reservoir Tributary Habitat Assessment commitment included in the June 9, 2021 Notice is summarized in Table 2.1-1.

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2 Specifically, refinement of habitat capacity estimates based on estimated growth potential for introduced fish; growth potential will be based on surrogate species that currently reside in the reservoir tributaries (i.e., Rainbow Trout).

3 The Food Web Study is an ongoing voluntary study (outside the FERC-approved study plan) developed in consultation with the Flow/Non-Flow Committee and initiated prior to the Project relicensing proceedings. It is not included in City Light's RSP or ISR, except by reference.

Table 2.1-1. Status of Reservoir Tributary Habitat Assessment modifications identified in the June 9, 2021 Notice.

Study Modifications identified in the June 9, 2021 Notice: As Written	Status
City Light will move forward with NetMap and commence scheduling collection of LiDAR during Q4 2021. City Light will collaborate with the LPs to determine where additional LiDAR data is needed in tributaries, including within Canada, based on review of existing LiDAR and existing NetMap information.	IP modeling is underway, and results will be evaluated with LPs to determine if there is a need to conduct Light Detection and Ranging (LiDAR) in Canada or the U.S.
City Light will clarify that FA-07 will analyze tributary habitat in Canada and on U.S. Forest Service lands consistent with the list provided by LPs.	The scope of this study's assessment has been modified to include not only the streams identified in the RSP but also those in Canada and the U.S. identified by LPs in their study requests.
City Light will add Gorge reservoir to the Food Web study with the methodology to be determined based on LP discussion with Dave Beauchamp.	Meetings are underway to discuss an approach to assessing food web dynamics in Gorge Lake. NOTE: The Reservoir Tributary Habitat Assessment addresses reservoir tributary habitat capacity only. Bioenergetics results for tributaries derived by the U.S. Geological Survey (USGS), namely estimated growth potential in streams, will be used to refine the estimates of capacity derived from the Unit Characteristic Method (UCM). However, results that pertain specifically to reservoirs will be included in the USGS Food Web Study report.
Action Item: City Light will give a presentation on how CE-QUAL modeling in combination with bioenergetics work could be used to address issues such as zooplankton prey availability in the reservoirs. City Light will modify the study plan to clarify that it will evaluate macroinvertebrate and zooplankton prey availability in all reservoirs for integration in the food web analysis, incorporation into the CE-QUAL or other modeling efforts, and collect additional data to inform that modeling effort based upon input from LPs. See also modifications to FA-01 regarding nutrient dynamics.	City Light and LPs agreed to a one-year plan for benthic macroinvertebrate (BMI) and invertebrate drift sampling strategies. Data from this sampling will inform the Food Web Study. After one year, City Light and LPs will revisit the plan to determine next steps. Discussions are underway between City Light and LPs to determine how reservoir and riverine nutrient dynamics will be evaluated with the CE-QUAL-W2 model, after which any remaining data needs pertaining to zooplankton will be addressed by sampling. Results of reservoir BMI and drift sampling will be reported in the FA-01a Water Quality Monitoring Study report for the USR and, as appropriate, the USGS Food Web Study report.
Link prey availability and project operations with hydrodynamic or productivity model.	The hydrodynamic model is linked to operations (operations dictate flows that serve as input to the CE-QUAL-W2 model) both for evaluating existing operations and potential future operating scenarios.

Study Modifications identified in the June 9, 2021 Notice: As Written	Status
City Light will adopt the methodology referenced by NMFS in its study plan to quantify habitat.	The methodology identified by NMFS, i.e., following the procedures of Burnett et al. (2007) and Cooper et al. (2020) was used as the basis of the RSP, as indicated in the RSP objectives shown above.
Action item: City Light will review reports referenced by USIT and evaluate whether there is a proposal it could make based on those reports that would be responsive. City Light will conduct GIS assessment of habitat in the littoral and varial zone in 2021 and evaluate and determine parameters and metrics for representative field sample frames if warranted to evaluate habitat quality in a workshop with the LPs. Meeting proposed for Q3 2021.	This LP request for a Geographic Information System (GIS) assessment of habitat in the littoral and varial zone was also required by FERC in its SPD and is being conducted as a standalone desktop analysis. A draft technical memorandum of results is expected early in 2022.
City Light will modify the study plan to include anadromous and non-native species.	As of the drafting of this ISR, NetMap IP modeling is nearing completion for Chinook and Coho salmon and steelhead. IP modeling for Sockeye Salmon will begin when a parameterized model is created for this species. Evaluation of tributary production potential of Bull Trout, Rainbow Trout, Dolly Varden, and Brook Trout is included in the scope of the Food Web Study, so these species are already being addressed.
City Light will clarify the study plan to address this issue [i.e., conduct field verification of a subset of habitat to correct modeling errors].	The Reservoir Tributary Habitat Assessment study design specifically contains an extensive field survey component, which will be framed based on the results of the IP modeling.
City Light will discuss with USGS incorporation of [existing continuous temperature and drift sampling] data or collection of new data on a subset of tributaries to address this issue. This is consistent with how the methodology that will be used by Cooper et al. as well (related to the IP and tributary assessment). City Light will collaborate with LPs on next steps after the results of IP modeling are available. City Light acknowledges that in the event that additional sampling is warranted, City Light will develop such sampling in collaboration with the LPs- as informed by NPS Appendix A.	Along with temperature data collected by USGS, there are numerous tributary and reservoir sites where ongoing temperature monitoring is being conducted. Analysis of an extensive dataset containing the results of past and ongoing temperature monitoring will be presented in the FA-01a Water Quality Monitoring Study Interim Report for the ISR (City Light 2022a). Temperature data that have undergone Quality Assurance/Quality Control analysis will be available for multiple studies, including the Food Web Study and Reservoir Tributary Habitat Assessment. Drift data collected as part of the FA-01a Water Quality Monitoring Study and the Food Web Study will inform bioenergetics modeling.
City Light will [incorporate] this [i.e., evaluate competition with redside shiner and juvenile salmonids in reservoirs] in the food web study scope and provide cross- reference to specific provisions of the study plan, and will revisit with LPs after a plan to evaluate prey resources availability is developed.	This is a central element of the Food Web Study and will be discussed in the Food Web Study report.

Study Modifications identified in the June 9, 2021 Notice: As Written	Status
City Light will conduct GIS assessment of habitat in the littoral and varial zones in 2021 and collaboratively evaluate and determine parameters and metrics for representative sampling of habitat quality in a workshop with LPs. Meeting proposed for Q3 2021.	This LP request for a GIS assessment of habitat in the littoral and varial zone was also required by FERC in its SPD and is being conducted as a standalone desktop analysis. A draft technical memorandum of results is expected early in 2022.
City Light will hold a workshop to address this [i.e., refine methods of assessing habitat production potential] issue.	Four workshops have been held with LPs, and others are scheduled, to refine the spatial scope and methods for this study.

3.0 STUDY AREA

The study is being conducted in tributaries to Project reservoirs, both in the U.S. and Canada. The spatial scope for stream habitat surveys is currently being formulated in collaboration with LPs and is expected to be finalized in early 2022 (see 6.1 of this study plan). A provisional list of tributary reaches to be evaluated is shown in Table 3.0-1 (see Section 4.0 for a status update on developing the spatial scope of this study), and maps of the general study area are shown in Figure 3.0-1. This list of tributaries represents a significant expansion of spatial scope, per City Light's June 9, 2021 Notice, relative to the list of streams identified in the RSP.

Table 3.0-1. Provisional list of streams/stream reaches to be evaluated for the Reservoir Tributary Habitat Assessment.

River/Stream Name	Reach Description	Length (mi)[1]	Gradient (%)
Ross Lake, British Columbia			
Skagit River	Ross Lake to Klesilkwa River	10.9	< 1
Skagit River	Klesilkwa River to barrier falls near Snass Creek	10.6	< 1
Klesilkwa River	Skagit River to Silverhope Divide	8.9	< 1
Sumallo River	Skagit River to Ferguson Creek	10.3	< 1
Ferguson Creek	Sumallo River to Highway 3 crossing	2.4	2
Nepopekum Creek	Skagit River to start of canyon section	1.7	3
Nepopekum Creek	Start of canyon section to near Poland Creek	5.8	5
Sumallo River	Ferguson Creek to end 3rd order	7.5	5
Maselpanik Creek	Klesilkwa River to end 3rd order	7.6	6
Snass Creek	Skagit River to Dry Lake	2.4	6
Ferguson Creek	Highway 3 crossing to end 3rd order	2.3	9
Klesilkwa River	Silverhope Divide to end 3rd order	2.3	10
Twentysix Mile Creek	Skagit River to end 3rd order	3.6	11
Marmotte Creek	Skagit River to end 3rd order	2.7	12
Ross Lake, U.S.			
Big Beaver Creek	Ross Lake to McMillan Creek	9.1	< 1
Ruby Creek	Ross Lake to confluence with Canyon/Granite creeks	3.4	2
Canyon Creek	Ruby Creek to Slate Creek	7.4	2
Lightning Creek	Ross Lake to Three Fools Creek	2.2	2
Lightning Creek	Three Fools Creek to Freezeout Creek	5.5	2
Little Beaver Creek	Ross Lake to end 3rd order	15.0	2
Big Beaver Creek	McMillan Creek to Luna Creek	4.3	3
Granite Creek	Ruby Creek to falls (indistinct barrier)	5.5	4
Luna Creek	Big Beaver Creek to end 3rd order	2.8	4
Lightning Creek	Freezeout Creek to Boundary Creek	3.9	4
Three Fools Creek	Lightning Creek to Castle Creek	6.3	4
Castle Creek	Three Fools Creek to Rustle Creek	3.6	6
Canyon Creek	Slate Creek to barrier falls	2.6	7
NF Canyon Creek	Canyon Creek to barrier falls	0.6	7
East Creek	Granite Creek to end 3rd order	4.3	10

River/Stream Name	Reach Description	Length (mi)[1]	Gradient (%)
Cabinet Creek	Granite Creek to end 3rd order	2.0	13
Slate Creek	Barrier likely at RM[2] 0.6	0.6	TBD
Hozomeen Creek	To be determined	TBD	TBD
McMillan Creek	To be determined	TBD	TBD
Devils Creek	To be determined	TBD	TBD
Diablo Lake			
Thunder Creek	To be determined	TBD	TBD
Gorge Lake			
Stetattle Creek	To be determined	TBD	TBD

1 mi = mile(s)
2 RM = river mile

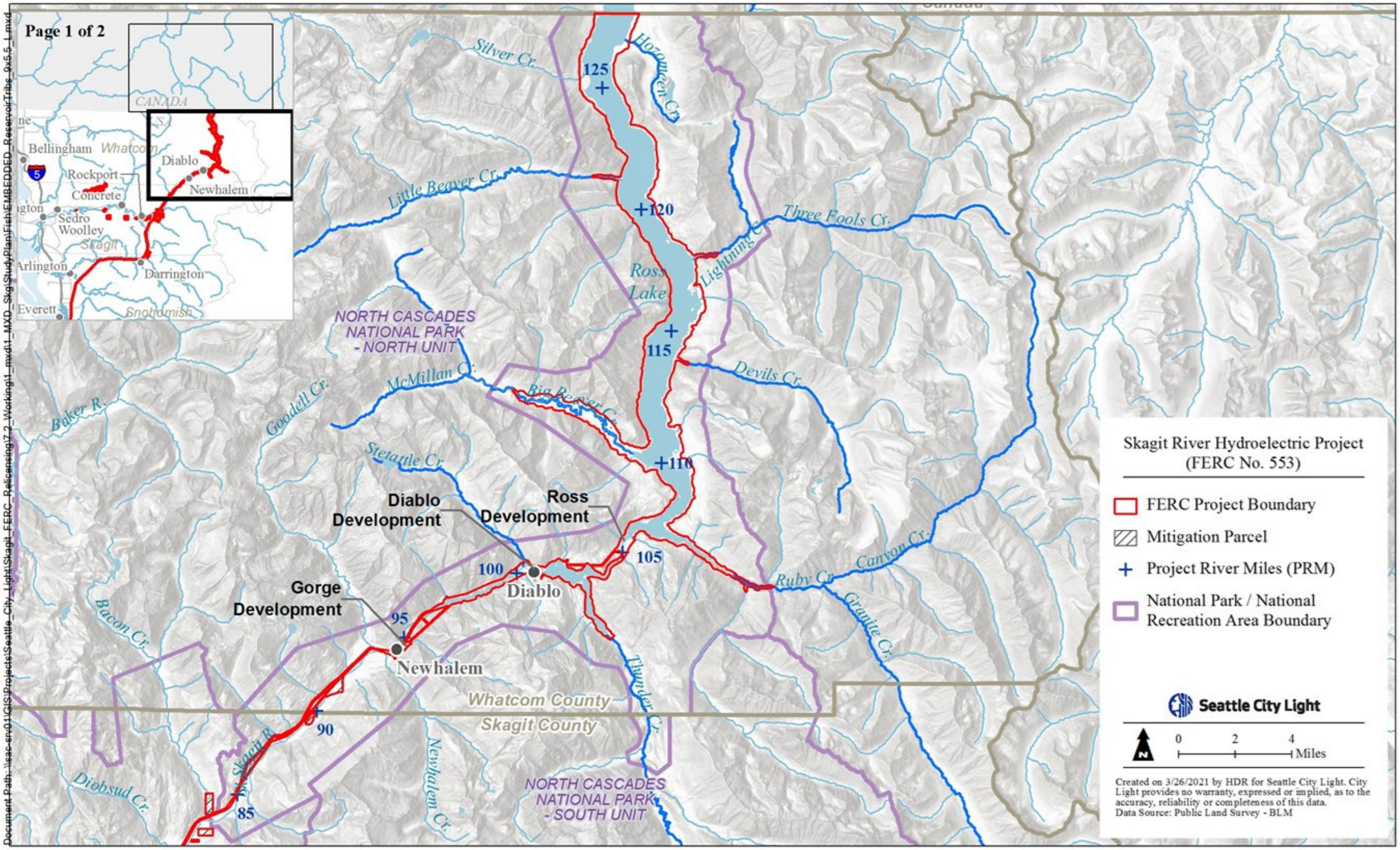

Figure 3.0-1. General study area for the Reservoir Tributary Habitat Assessment in the U.S. (page 1 of 2).

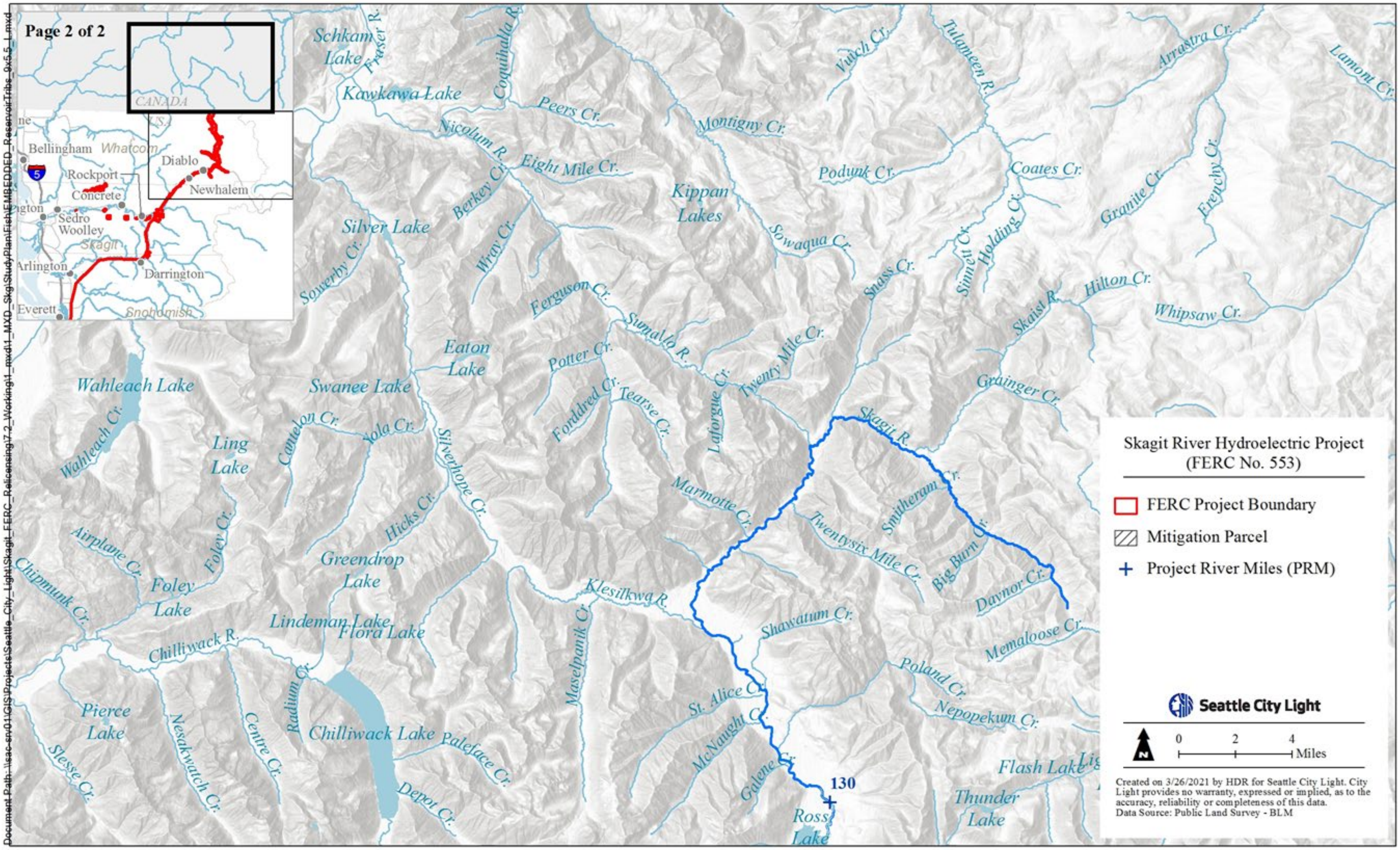

Figure 3.0-1. General study area for the Reservoir Tributary Habitat Assessment in Canada (page 2 of 2).

4.0 METHODS

The following subsections describe the status of efforts, as of February 2022, that are underway to address the study objectives. City Light is currently collaborating with LPs to finalize a geographical scope for data collection in tributaries and refine methods that will be used to collect and analyze data. Workshops are underway and will continue into the first quarter of 2022, at which time the study design is expected to be finalized. A full description of methods, including a final geographical scope of analysis, will be presented in the study report to be included in the USR. Agendas and presentation materials for the three Reservoir Tributary Habitat Assessment workshops conducted as of the drafting of this study report (July 13, 2021, October 25, 2021, December 21, 2021, and February 15, 2022) are provided as Attachment A.

4.1 IP Modeling and Spatial Scope of Habitat Surveys

Limits to the extent of potential anadromous fish habitat are being estimated by IP modeling using NetMap, which predicts habitat availability in GIS using a Digital Elevation Model (DEM).[4] IP models are a type of habitat suitability model used to identify stream reaches with the potential to host a particular species. The model runs are based on a framework that focuses on landscape features not easily modified by human influence; that is, attributes that typically do not vary appreciably from historical conditions. The model uses relationships between these landscape features and habitat preferences to create species, or life-stage-specific, index curves. NetMap virtual watershed, which creates an analytic stream network, provides the basis for the IP modeling of the reservoirs' stream drainages. IP modeling is intended for broad-scale assessments, and will be used in this study to help define the spatial extent of ground surveys conducted to evaluate habitat capacity in the tributaries of interest.

The analytical steps associated with IP modeling include (1) delineation of potential anadromous fish distribution ("end of anadromy") in tributaries based on simple rule-based criteria; (2) assessing potential natural barriers based on gradient thresholds and elevation drops; and (3) assessing habitat suitability with IP models applied to the streams/reaches of interest (see Table 3.0-1).

As noted above, the RSP identifies four target species: Chinook, Coho, and Sockeye salmon, and steelhead. IP modeling runs will be conducted for these four species. Evaluation of tributary production potential of Bull Trout, Rainbow Trout, Dolly Varden, and Brook Trout is included in the scope of the Food Web Study, so these species are already being addressed. Parameterized IP models exist for steelhead and Coho and Chinook salmon in the Pacific Northwest and California. Habitat suitability criteria will be developed to assess Sockeye Salmon, a species for which IP models have not yet been parameterized.

The spatial scope of habitat surveys needed to address Objective 2 of this study is currently being refined by City Light in collaboration with LPs. Table 3.0-1 provides a list of stream reaches that may undergo physical habitat surveys. However, as of the filing of this ISR, IP modeling has not yet been completed for the study area; as a result, it is still undetermined how far upstream habitat surveys may need to extend to document barriers to upstream passage of anadromous fish. The

4 NetMap coverage for tributaries in the U.S. is at 10-meter (m) pixel resolution; 20-m pixel resolution is available for the upper Skagit drainage in Canada.

total length of each reach to be surveyed, contingent upon the location of barriers, will also need to be ascertained before a subsampling method can be developed for conducting habitat surveys.

As of the filing of the ISR, draft IP modeling results have been developed for tributaries to the reservoirs, both in the U.S. and Canada, which include potential distributions (end of anadromy) and habitat quality (low, medium, and high) for Chinook and Coho salmon and steelhead. These draft results are shown in the presentation materials included in Attachment A. Also being discussed are the potential effects of DEM resolution (10-meter [m], 20-m, and LiDAR based) and the potential utility of LiDAR given that all tributaries of interest will undergo full stream surveys.

4.2 Habitat Surveys in Tributaries

City Light and LPs are currently discussing the methodology to be applied to estimate juvenile rearing habitat capacity (production potential) in tributary reaches identified by the IP model to be potentially suitable for the target species. The RSP states that parr capacity (the estimated number of parr that can be supported by a given tributary or reach within a tributary) will be characterized using spatial analysis to quantify and characterize tributaries upstream of the Project dams to create a data collection and extrapolation framework, which will be followed by ground-based surveys of accessible salmonid rearing habitat (see Cooper et al. 2020), as needed to augment existing habitat data. Habitat data collected in the field will serve as input to a juvenile capacity estimation tool, adapted as necessary to relate habitat conditions to parr density (number/unit area) for the target species using surrogate parr densities from local watersheds to the extent feasible. The approach used to estimate juvenile capacity will be adjusted to local conditions to account for site-specific hydrology, climate conditions, and geomorphology. Parr densities will be calculated at the habitat-unit scale and extrapolated to reach and watershed scales.

During the October 25, 2021 Reservoir Tributary Habitat Assessment Workshop, City Light described the major types of available fish habitat models and explained that model selection depends on goals and objectives, questions being asked, need for model transparency, and available data and resources. It was agreed that a limiting factors/capacity model is most appropriate for this study, and City Light reviewed the advantages of the UCM (the method proposed in the RSP, which was recommended by LPs in their respective study requests). The UCM is advantageous because it is (1) based on standard survey data; (2) can be modified based on available information; (3) is based on transparent, easily understood calculations; (4) has been applied to many salmonid species; and (5) has been linked to IP modeling and bioenergetics in other basins. Output from the UCM can also serve as input to more complex basin-wide life-cycle models, such as the Resources Habitat Assessment and Restoration Planning (HARP) Model, (National Oceanic and Atmospheric Administration Fisheries, in progress), should such an undertaking be considered in the future.

The UCM is built upon information derived at the habitat unit level: habitat type, depth, available cover, and substrate, which influence fish density and thereby production capacity of a stream. Once physical habitat data are obtained, empirical estimates of fish density from the literature (or local data if available) are assigned to habitat units, with densities adjusted based on depth, substrate, and cover. Density estimates can be further adjusted based on temperature, nutrients, invertebrate drift, or information available for other environmental variables. Physical habitat data will be collected within yet-to-be-determined tributary reaches (see Table 3.0-1), and density estimates can then be based on the literature, for example, Cramer and Ackerman (2009) and Cooper et al. (2020), among others.

4.3 Integration of Habitat Survey and Bioenergetic Modeling Results

The goal of the Food Web Study is to identify and quantify factors that limit recruitment or production of native adfluvial salmonids that populate the Project reservoirs and their tributaries. The component of this ongoing study germane to this relicensing-related assessment of tributary habitat capacity is the evaluation of salmonid growth potential in tributaries. Related to this, the original scope of the Food Web Study was expanded in 2021 to conduct bioenergetic simulations in tributaries that had not already been modeled by Beauchamp (in development; e.g., Thompson and Beauchamp 2016). These simulations are based on available information, potentially extrapolating from existing salmonid diet or stream temperature data and/or collecting additional bioenergetics data (e.g., temperature and food availability) during upcoming habitat surveys (see Section 4.2 of this study report).

Objective 3 of this study involves the evaluation of the UCM results (Objective 2) in the context of results from the Food Web Study, specifically estimating growth potential of introduced anadromous fish in the tributaries to the reservoirs. These tributaries are often cool and characterized by relatively low food availability, which has the potential to influence growth rates of any introduced fish (Beauchamp 2009). The exact means by which the UCM and tributary bioenergetics results will be integrated is currently being formulated, and the final approach to the integration will be detailed in the USR.

5.0 PRELIMINARY RESULTS

Results of IP modeling, habitat surveys in tributaries and application of the UCM, and integration of the habitat survey with individual growth potential, results will be presented in the study report to be included in the USR.

6.0 SUMMARY

6.1 Study Implementation Status

As of February 2022, discussions are underway regarding the following study elements, as described in Section 4:

- IP Modeling and Spatial Scope of Habitat Surveys.
- Habitat Surveys in Tributaries.
- Integration of Habitat Survey and Bioenergetic Modeling Results.

City Light, in collaboration with LPs, will implement the next steps listed below (estimated completion dates are provided in parentheses):

- IP Modeling:
  - Complete IP model runs for steelhead and salmon species for which parameterized models exist (March 2022);
  - Develop habitat suitability criteria for Sockeye Salmon and apply IP model (March 2022);
  - Evaluate IP model run results with LPs and modify habitat index criteria if needed (March – April 2022); and
  - Decide whether current NetMap DEMs are suitable or if LiDAR is needed for any parts of the reservoirs' drainages (April 2022).
- UCM/Bioenergetics:
  - Confirm habitat/environmental factors to be included in the UCM (May 2022);
  - Complete design of habitat surveys to ensure proper data collection (June 2022);
  - Update density and scalars/preference curves based on recent and/or local data (June 2022);
  - Confirm the extent of fish distribution in each tributary of interest, using IP modeling and ground-truthing to confirm the locations of upstream passage barriers, as necessary (July-October 2022);
  - Conduct field data collection, data analysis, and modeling (commencing August 2022); and
  - Integrate the results of the UCM with output from bioenergetics modeling, specifically tributary growth potential, being conducted as part of the Food Web Study.

7.0 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

There are no variances or proposed modifications to the FERC-approved elements of this study. The status of commitments from the June 9, 2021 Notice is described in Section 2.1 of this study report.

8.0 REFERENCES

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RESERVOIR TRIBUTARY HABITAT ASSESSMENT
INTERIM REPORT

ATTACHMENT A

RESERVOIR TRIBUTARY HABITAT ASSESSMENT
WORKSHOP MATERIALS
JULY 13, 2021, OCTOBER 25, 2021, DECEMBER 21, 2021, AND
FEBRUARY 15, 2022

Seattle City Light

MEETING AGENDA

Skagit Hydroelectric Project Relicensing Meeting

FA-07 Reservoir Tributary Habitat Assessment and Food Web Study Workshop

July 13, 2021, 8:30 am – 12:30 pm

WebEx Meeting: [LINK HERE]

Conference Call: +1-510-338-9438 **Access code:** 1820848114
(Meeting ID: 1820 84 8114)

MEETING PURPOSE

- Discuss Revised Scope of Food Web Study
- Discuss Methods for Tributary Habitat Capacity Assessment
- Discuss FA-07 potential linkages to CE-QUAL Modeling and the FA-01 Water Quality Monitoring Study
- Identify path forward on FA-07 discussion needs

FACILITATOR

Thomas Christian, Triangle Associates

AGENDA

8:30 – 8:45am [15 mins]	**Introductions** – *Facilitator (Triangle)* ▪ Roll call introduction ▪ Review agenda and meeting objectives
8:45 – 10:15am [90 minutes]	**Bioenergetics Model Presentation -** *Dave Beauchamp (USGS)* ▪ Overview of additional Food Web Study scope to support LP data requests ▪ Discussion of addition of Gorge Lake data collection and recommendations for a methods approach
10:15 – 10:20am [5 minutes]	**Break**
10:20 – 11:50am [90 minutes]	**Discussion of Approach to Tributary Habitat Potential Assessment -** *Jeff Fisher (City Light)* ▪ Overview of Intrinsic Potential (IP) modeling output/setting the limits for tributary habitat capacity assessment ▪ Study timeline in response to commitment letter ▪ Discussion; ○ Anadromous species list ○ Tributary list ○ Challenges and uncertainties for implementation
11:50 – 11:55am [5 minutes]	**Break**

11:55am – 12:25pm [30 minutes]	**Start Discussion on Model Integration -** *City Light / Licensing Participants* ▪ Integrating reservoir modeling outputs with tributary modeling outputs o *Approach to defining "end of anadromy" in a future meeting* o *Littoral outputs** ▪ Review and discuss capability of Bioenergetics Model, intrinsic potential, and CE-QUAL Model opportunities and limitations for model outputs
12:20 – 12:30 [10 minutes]	**Action Item Review and Agenda Items/Approach for Additional Meetings**
12:30 pm	**Meeting Adjourned**

Bioenergetic constraints on fish growth in reservoir & tributaries above Skagit River Dams

USGS Western Fisheries Research Center

Photo: J. Duda

git reservoirs

- and concern over native populations?

Credit: NPS

Rainbow trout

Credit: Cameron Miller

Invasive redside shiner

Credit: NPS

- **<u>What is limiting production of native fishes</u>?**
  - Lack of recruitment of juvenile salmonids
  - Temperature? Prey availability? Predation? Competition?
  - Feasibility of anadromous salmonid introductions?

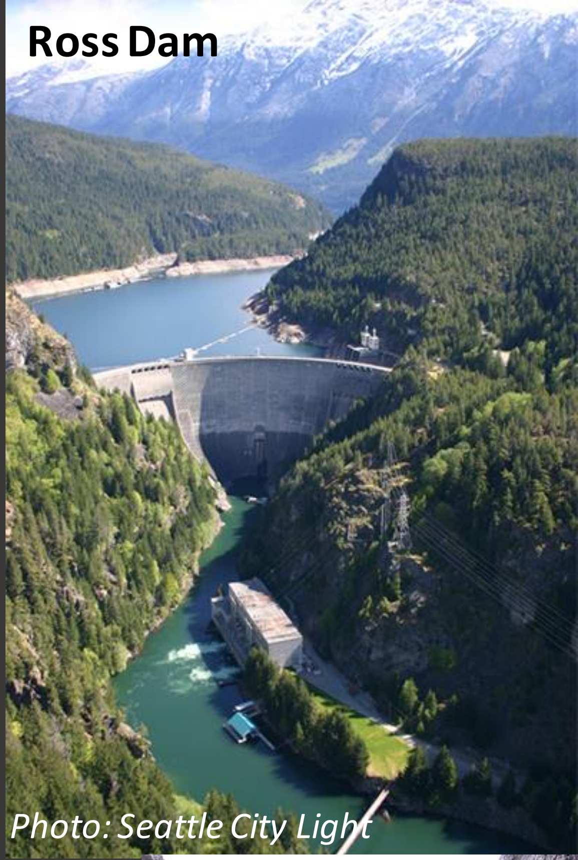


Photo: Seattle City Light

Photo: Seattle City Light

Quantifying food web interactions

- Bioenergetics framework

Food – Waste – Metabolism = Growth

Food = Growth + Waste + Metabolism

- Field data:
  - Measured growth
  - Stable isotope analysis
  - Diet analysis
  - Reservoir temperature profiles
  - Predator/prey energy densities

Estimating Consumption Demand

Quantify Predation or Potential Competition

Inputs from Sampling/Literature:

Growth: $W_0 \rightarrow W_t$

Diet proportions by Wt thru time

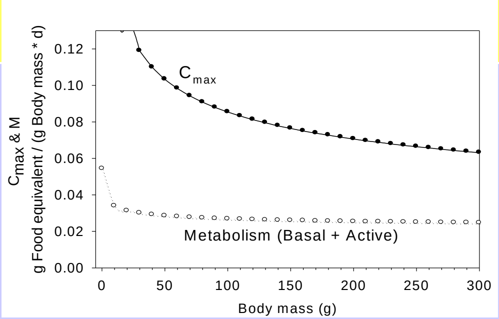
Predator Energy Density (J/g)

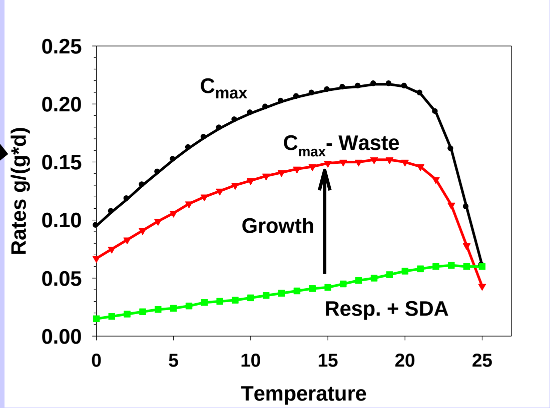
Prey Energy Density (J/g)

Thermal Experience thru time

Bioenergetics Model

$$C = M + W + G$$





How much food must be **Consumed** to satisfy observed **Growth**?

1-Daily Consumption g/d by prey group

2-Feeding Rate %Cmax

CML Bull T ~30%Cmax

Daily time step

Simulation day 0 → day t

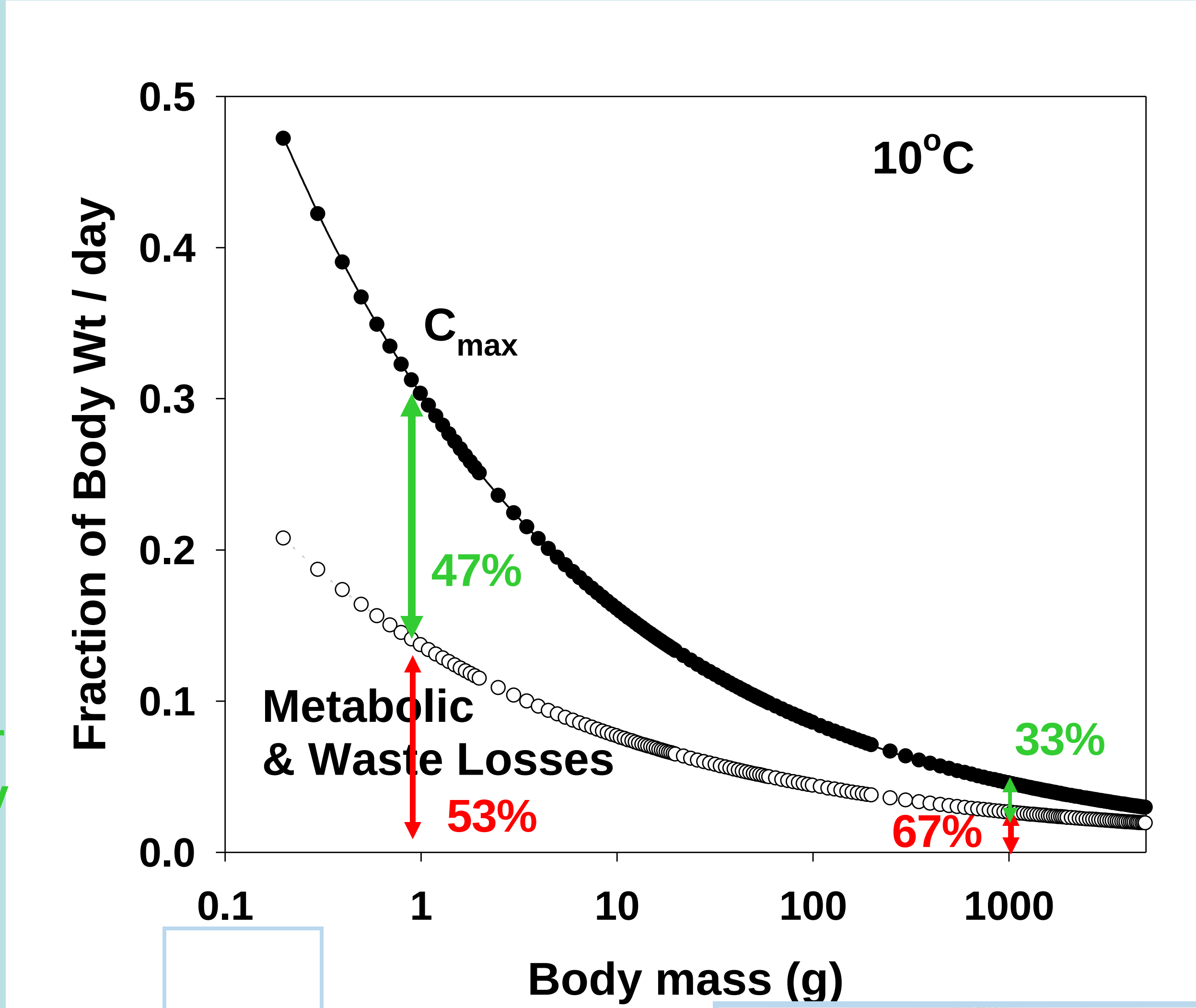
Asymmetric Rates of Energy Gain vs Loss

$G = C - (M + W)$

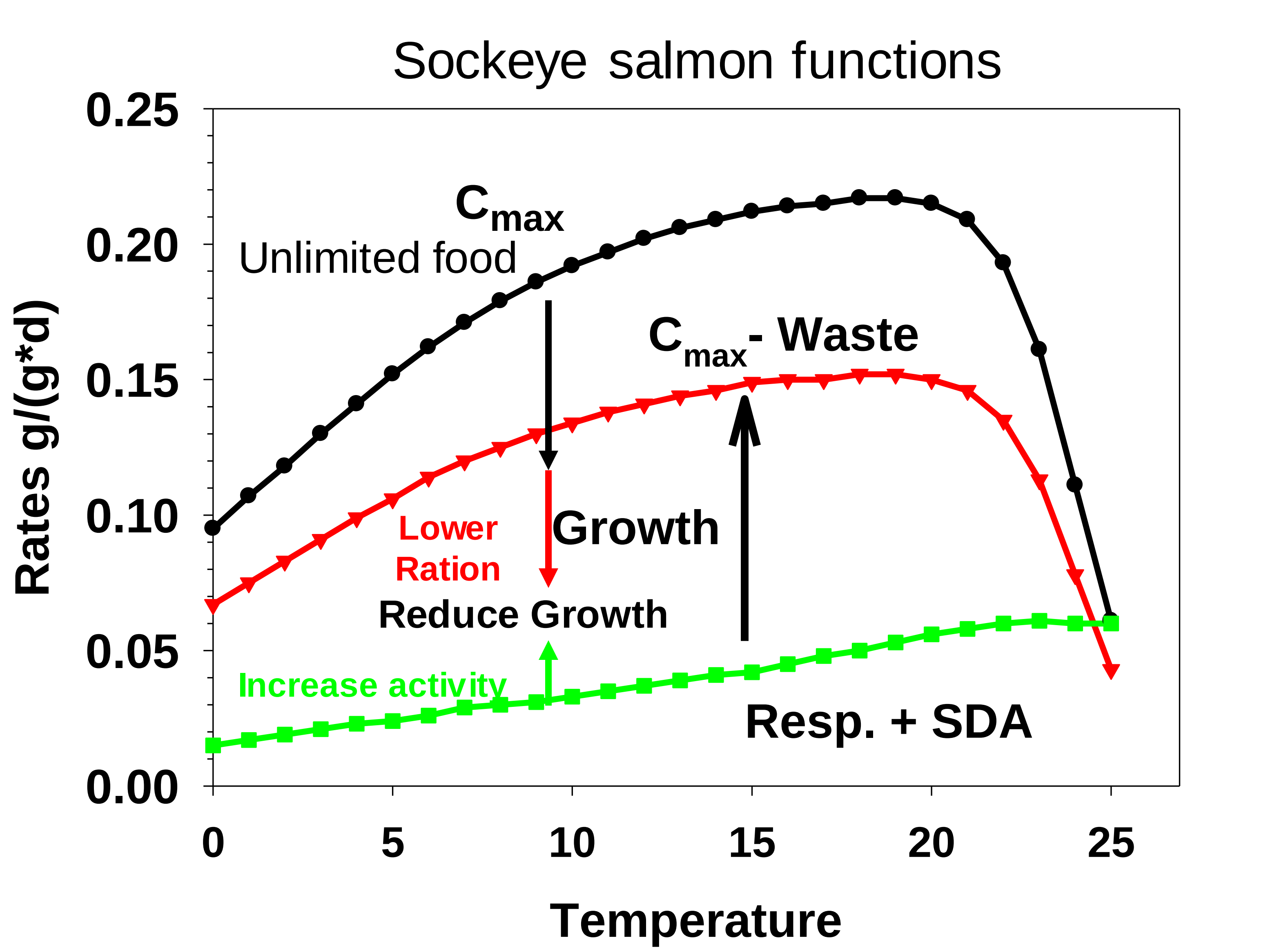
C_{max} declines faster than Metabolic + Waste Losses

M + W Losses higher % of C_{max} for larger fish

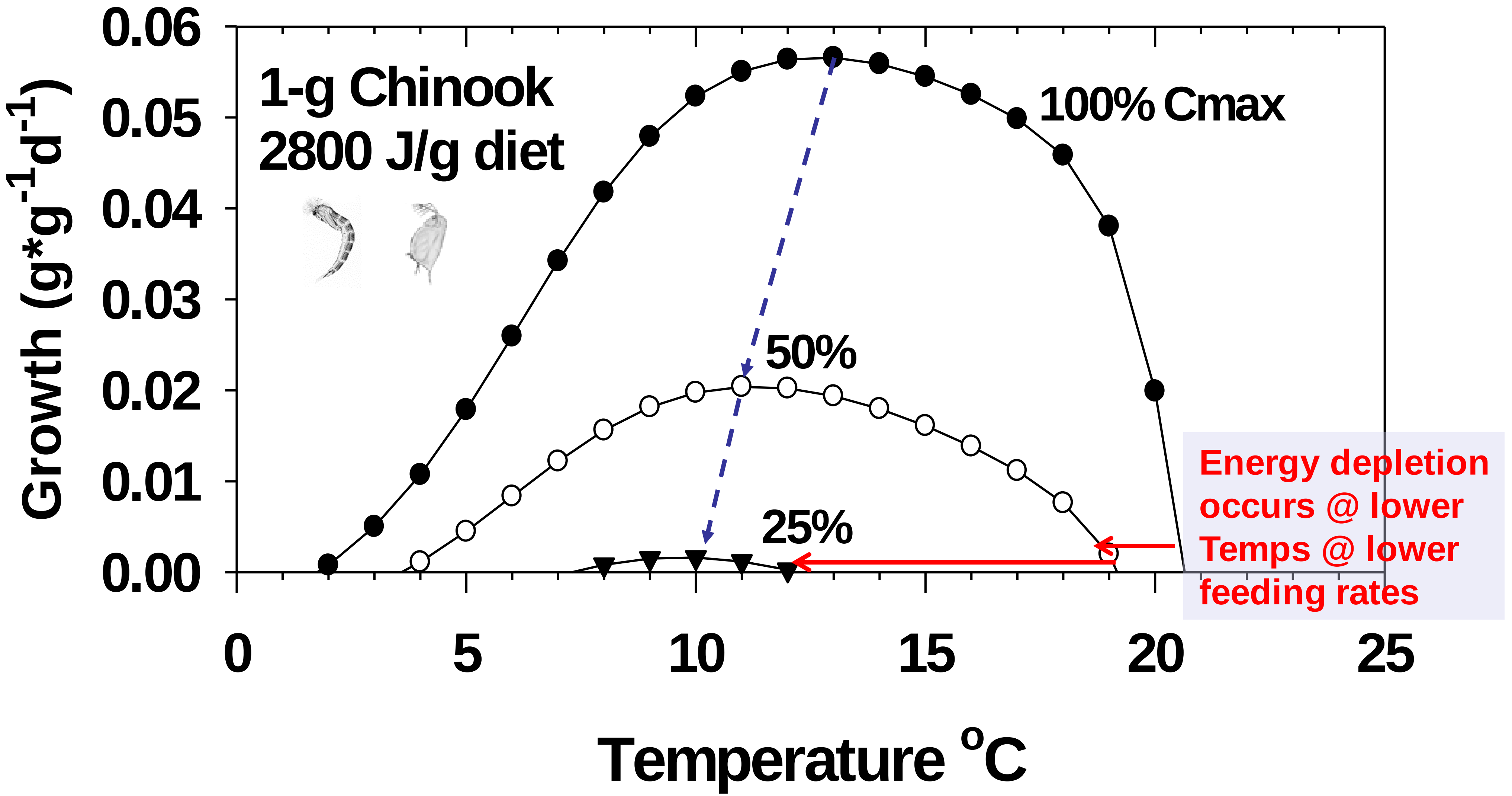
Smaller Salmon have higher Scope for Growth or Activity Than Larger Salmon Under similar conditions



Temperature-Dependent Energy Budget

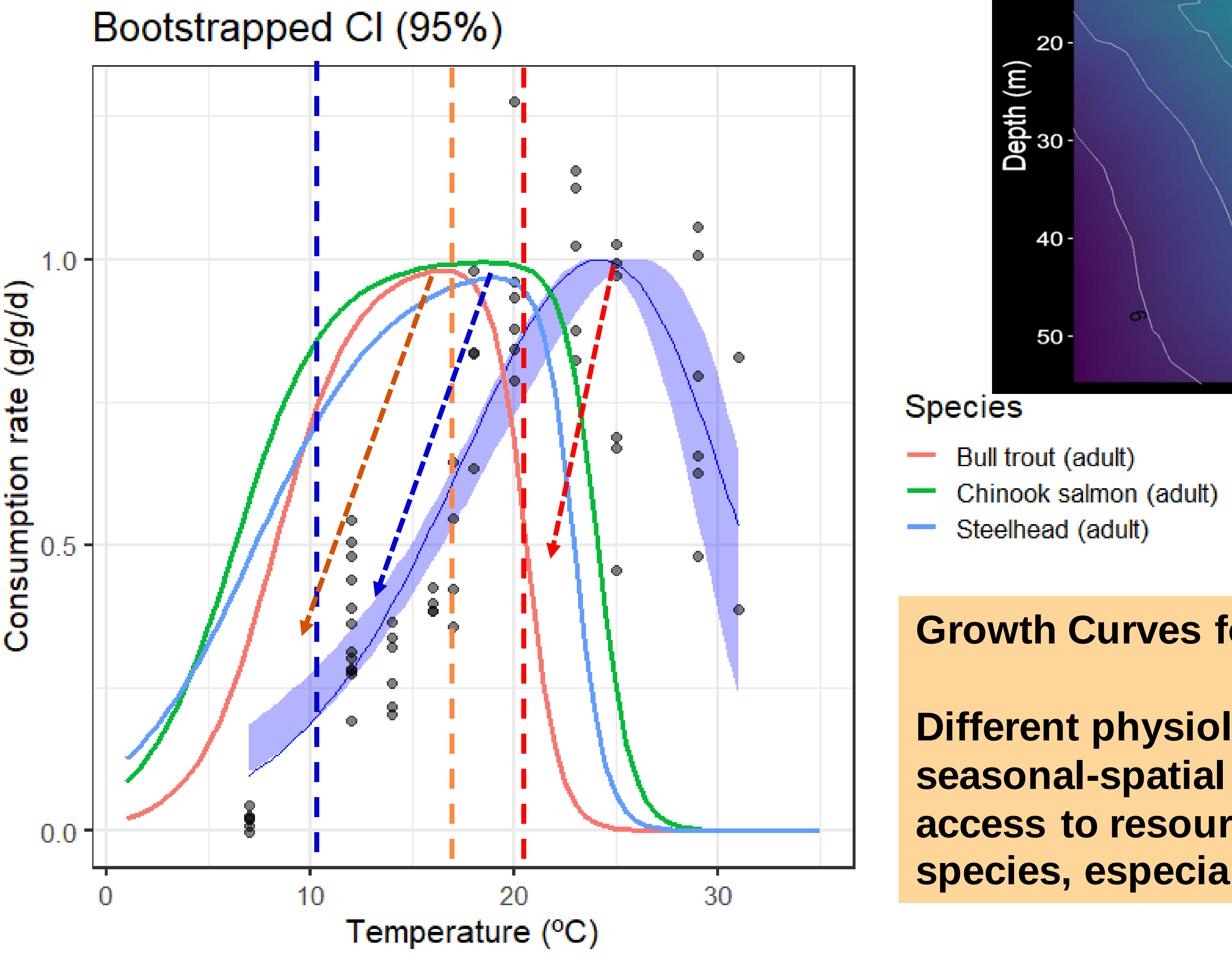


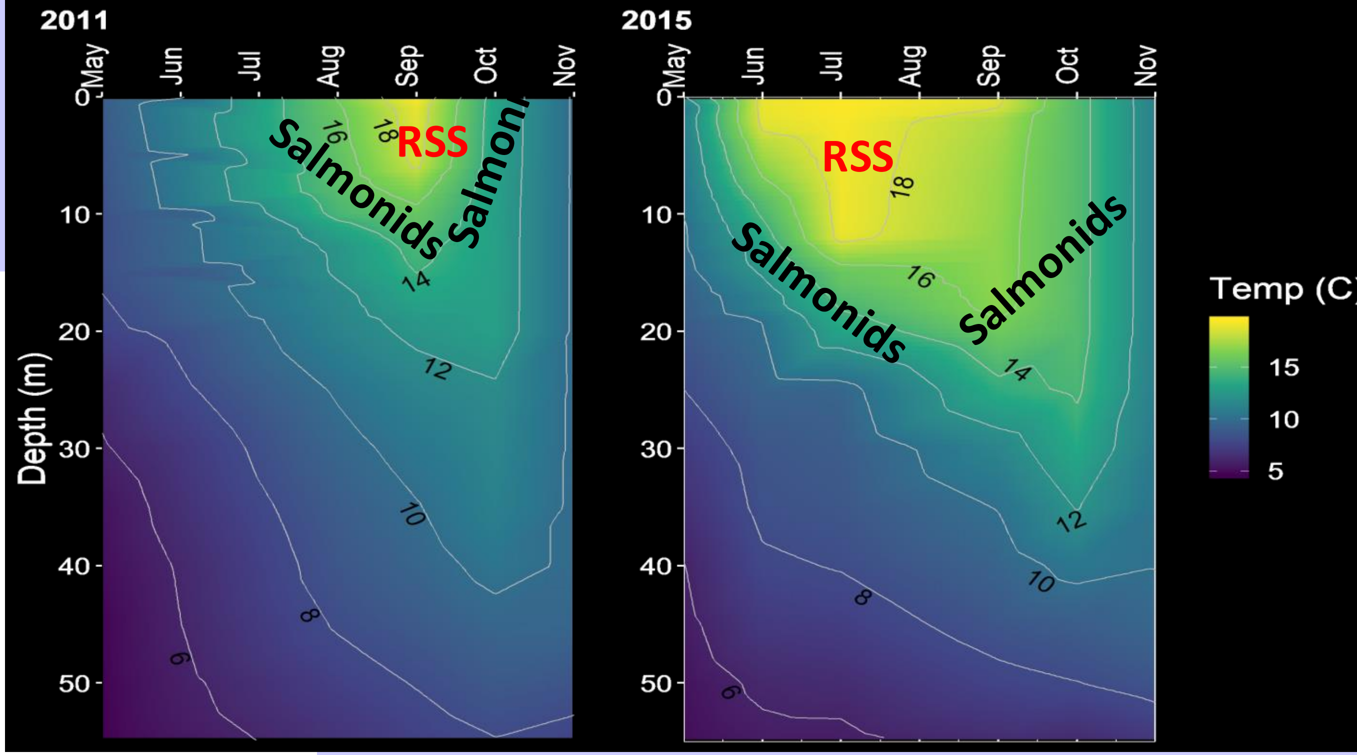
“Optimal” Temperature Declines at Reduced Feeding Rate



Temperature-dependent Growth:

Redside Shiners, Bull Trout, Rainbow Trout





Growth Curves for Redside Shiners nearing completion

Different physiological responses to temperature structure seasonal-spatial (depth) distribution, access to resources & strength of interactions among species, especially related to thermal stratification

Relevant References

16 Predator–Prey Interactions

David A. Beauchamp, David H. Wahl, and Brett M. Johnson

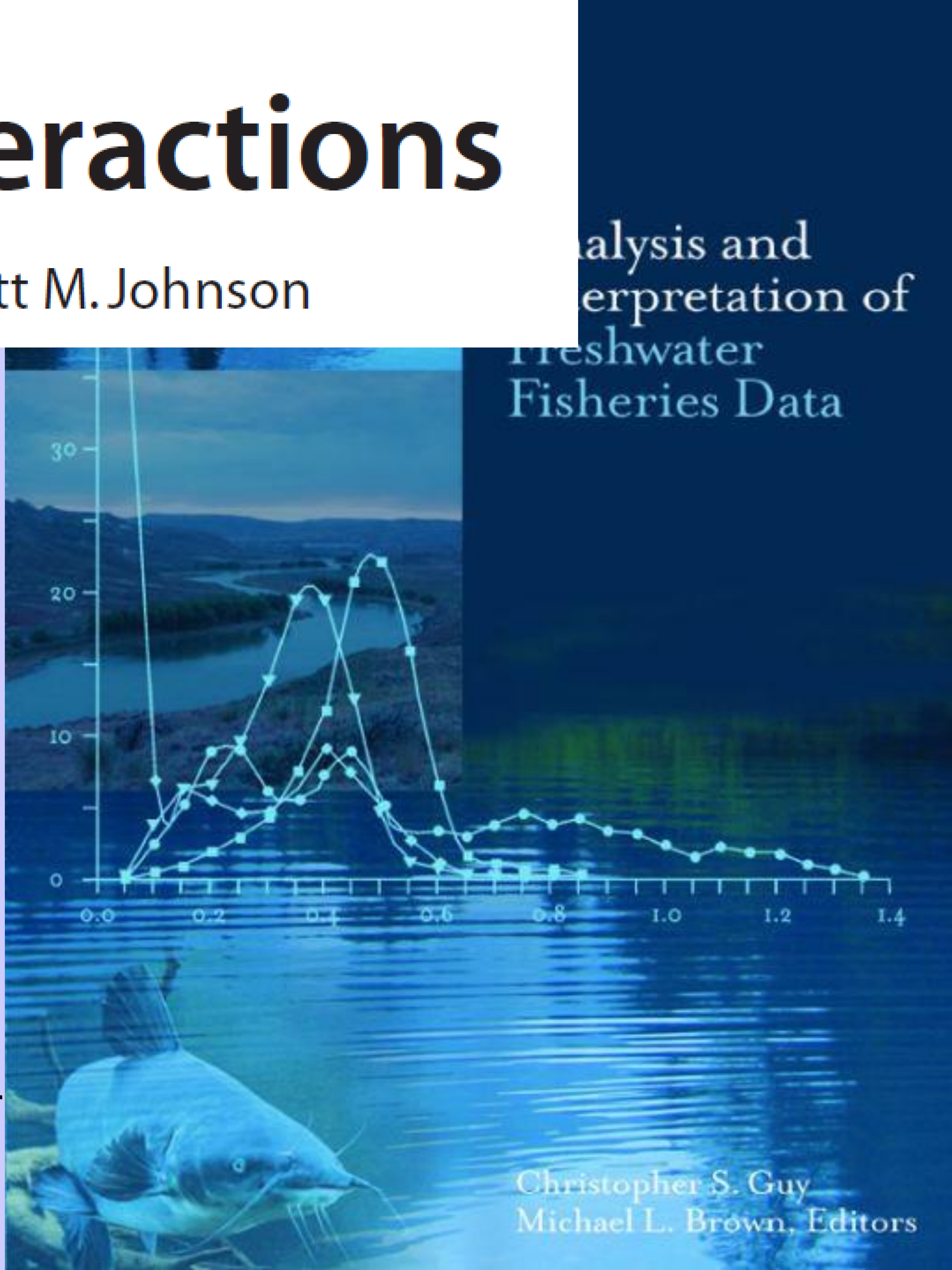
Beauchamp, D.A., D. Wahl, and B. M. Johnson. 2007. Predator-Prey Interactions. Pages 765-842. *In* C.S. Guy and M.J. Brown, editors, Analysis and interpretation of inland fisheries data. American Fisheries Society. Bethesda, Maryland.
(2nd Edition in progress): Quantifying food web interactions

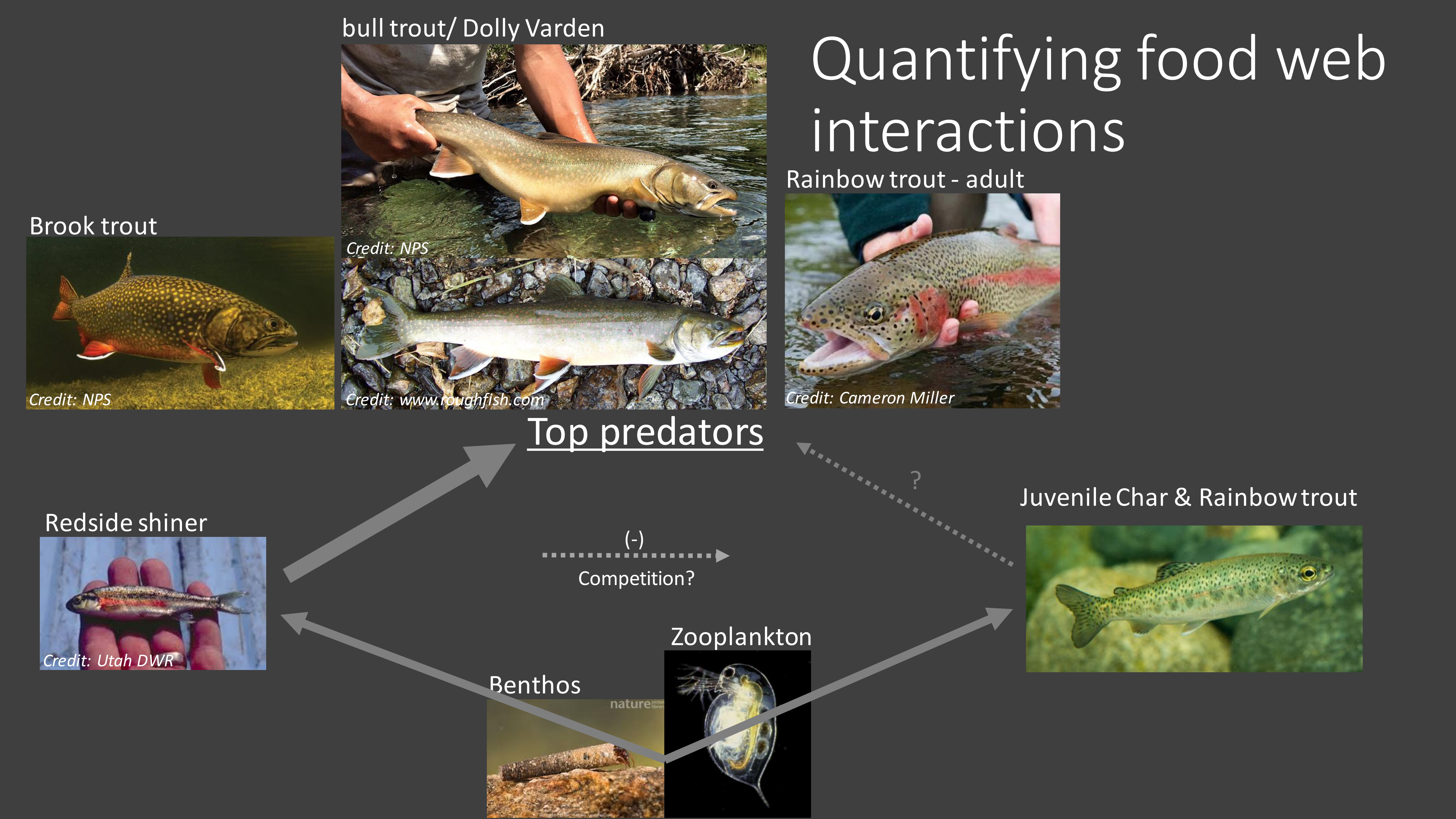
Beauchamp, D. A. 2009. Bioenergetic Ontogeny: Linking climate and mass-specific feeding to life-cycle growth and survival of salmon. Pages 53-72 *In* C. Zimmerman and C.C. Krueger, editors. Pacific Salmon: Ecology and Management of Western Alaska's Populations. American Fisheries Society Symposium 70. Bethesda, Maryland. Factors affecting individual growth

Beauchamp, D.A., D. Parrish, and R. Whaley. 2009. Salmonids/coldwater species in large standing waters, Chapter 7 Pages 97-117 *In* S. Bonar, D. Willis, and W. Hubert, editors. Standard Sampling Methods for North American Freshwater Fishes. American Fisheries Society. Bethesda, Maryland.
(2nd Edition in progress): Sampling salmonids in large lakes & reservoirs

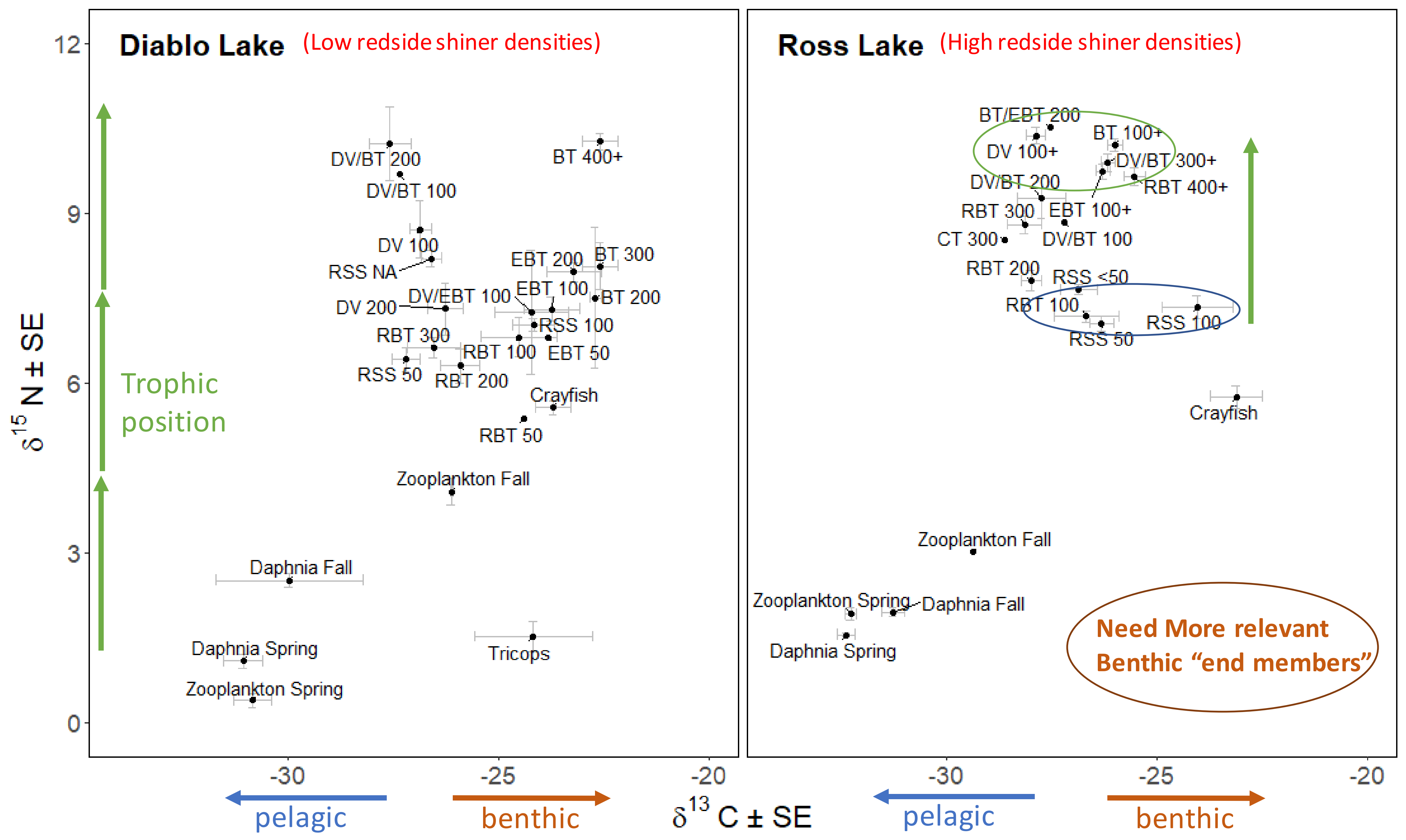
Sorel*, M.H., A.G. Hansen, K.A. Connelly, and D.A. Beauchamp. 2016. Trophic feasibility of reintroducing anadromous salmonids in three reservoirs on the North Fork Lewis River, Washington: Prey supply and consumption demand of resident fishes, Transactions of the American Fisheries Society 145:1331-1347.

Thompson*, J.N., and D.A. Beauchamp. 2016. Growth of juvenile steelhead under size-selective pressure limited by seasonal bioenergetic and environmental constraints. Journal of Fish Biology 89:1720-1739.




Quantifying food web interactions
bull trout/ Dolly Varden
Credit: NPS
Credit: www.roughfish.com
Brook trout
Credit: NPS
Rainbow trout - adult
Credit: Cameron Miller
Top predators
?
Juvenile Char & Rainbow trout
Redside shiner
Credit: Utah DWR
(-)
Competition?
Zooplankton
Benthos
nature

Food web structure: stable isotopes



Estimating Predation Mortality or Seasonal Food Supply:Demand

Temporal Diet Composition

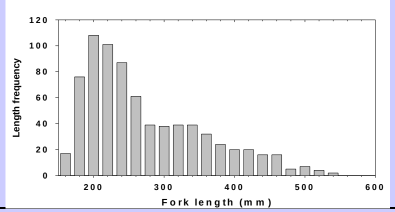
Consumer Growth

Predator Energy Density

Prey Energy Density

Thermal Experience

Bioenergetics Model



Consumer Size Structure & Abundance

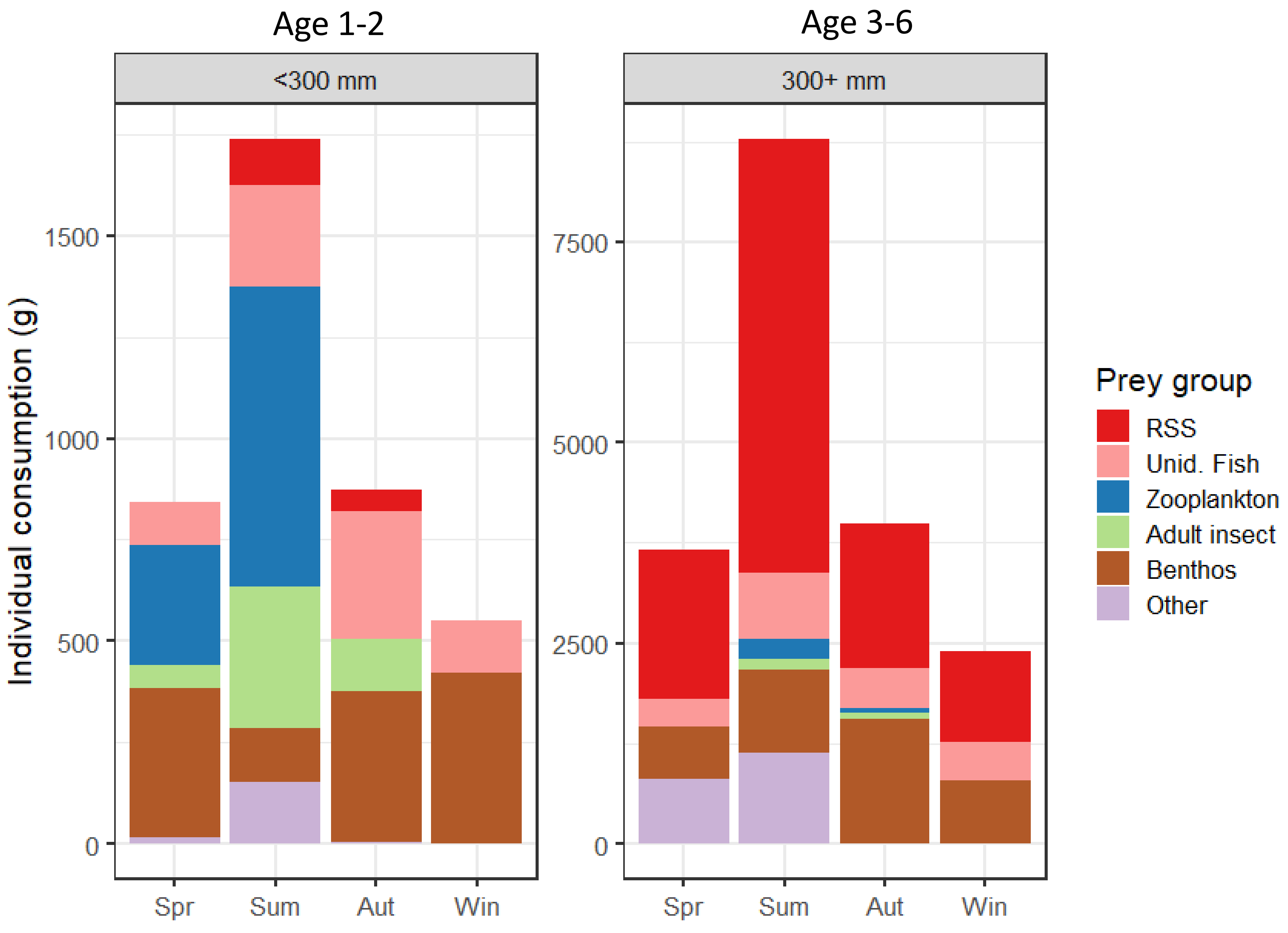
Consumption Estimate

Population Consumption

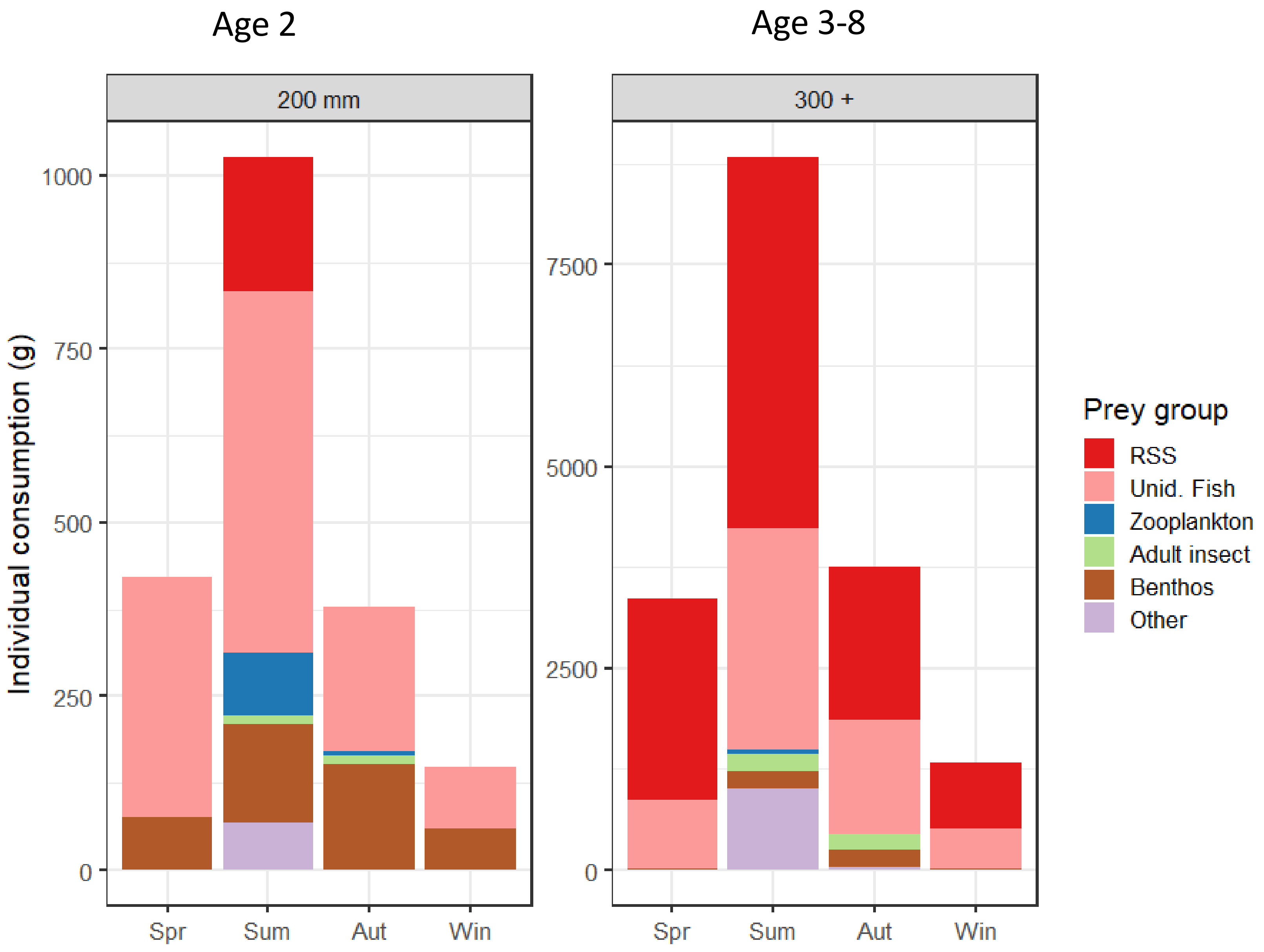
Biomass of Exploitable prey

Predation Mortality Consumption as % of Prey Biomass or Production

Rainbow trout individual consumption (pooled within size classes)

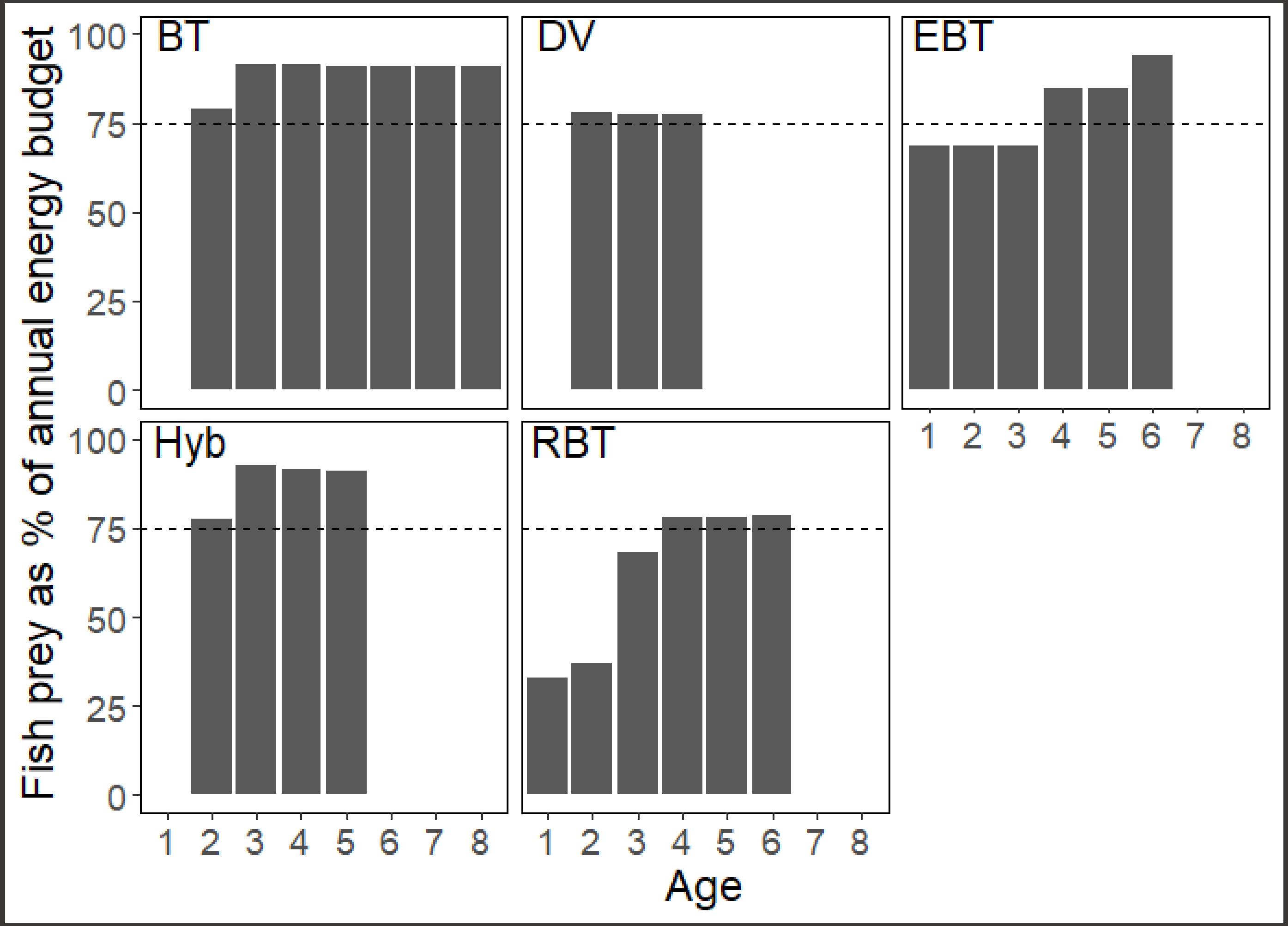


Bull trout individual consumption (pooled within size classes)



How important are fish as prey?

- A look at simulated annual energy budgets
- > 75% percent of energy budget for all species at some point in their lake residency



Fish predation by native & invasive salmonids

Bull trout

Rainbow trout - adult

Brook trout

Dolly varden

Native char hybrids

	Population (Age 2+)
BT/ Hybrids	1,000
DV	117
EBT	260
RBT	2,138

Relative predation rates
Referenced to 1,000 BT/Hyb
> Age 2 in reservoir

<u>Top predators</u>

?

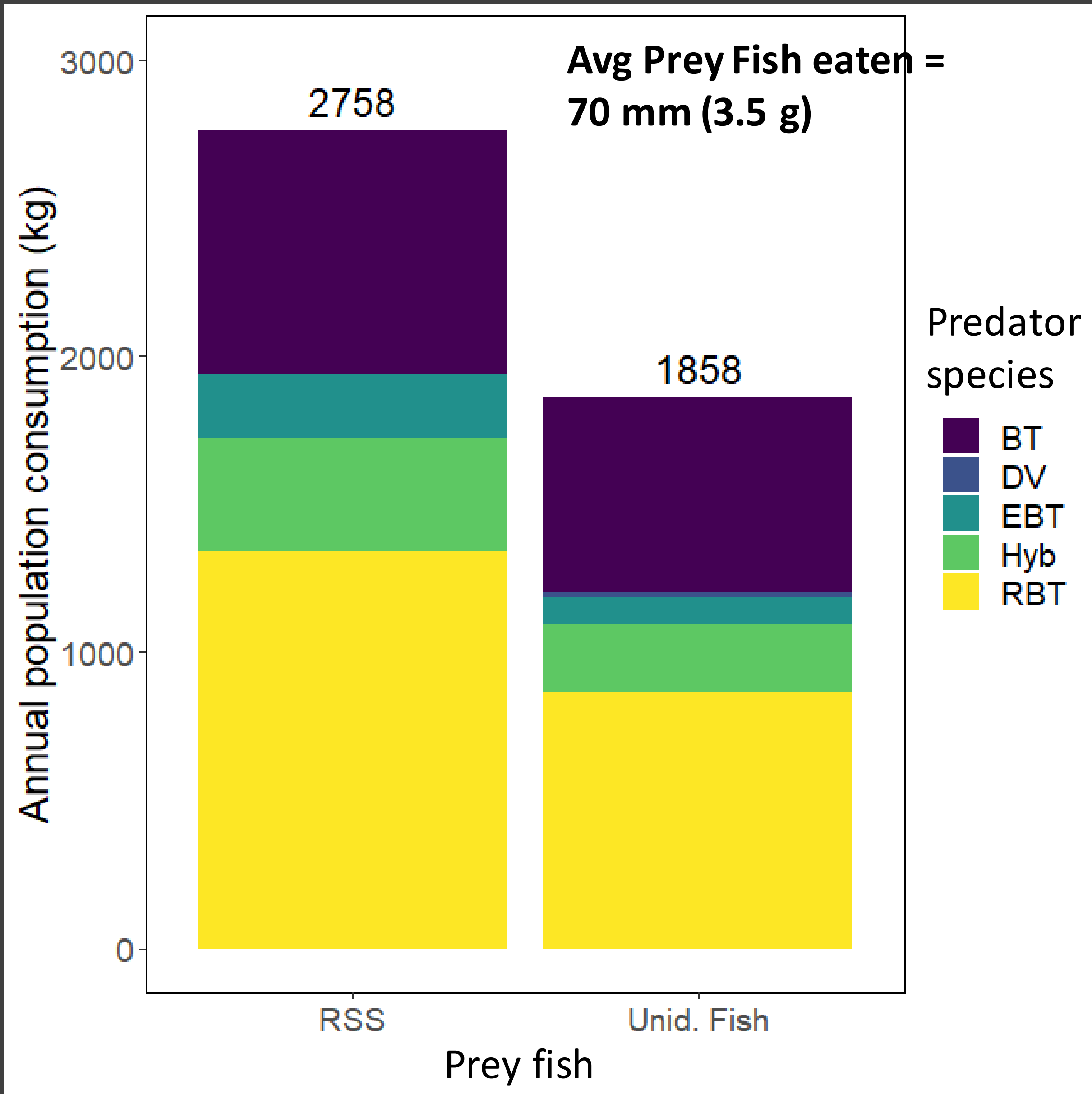
*If just **1-5%** of these unidentified fish prey were salmonids, that would result in significant mortality for age 0-1:

> 50% mort for bull trout

> 25% mort for rainbows

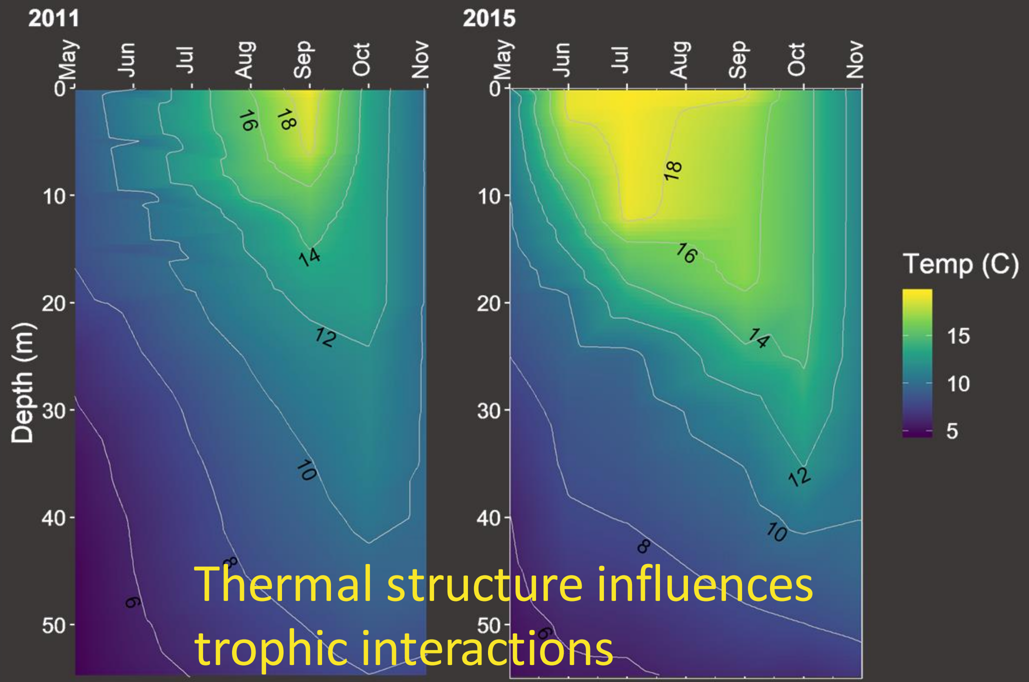
Redside shiner

Rainbow trout - juvenile



Next steps & Implications

- Estimating redside shiner population densities
  - Hydroacoustic surveys
- Resource competition: quantifying redside shiner consumption
  - Parameterizing a bioenergetics model (nearly complete)



Thermal structure influences trophic interactions

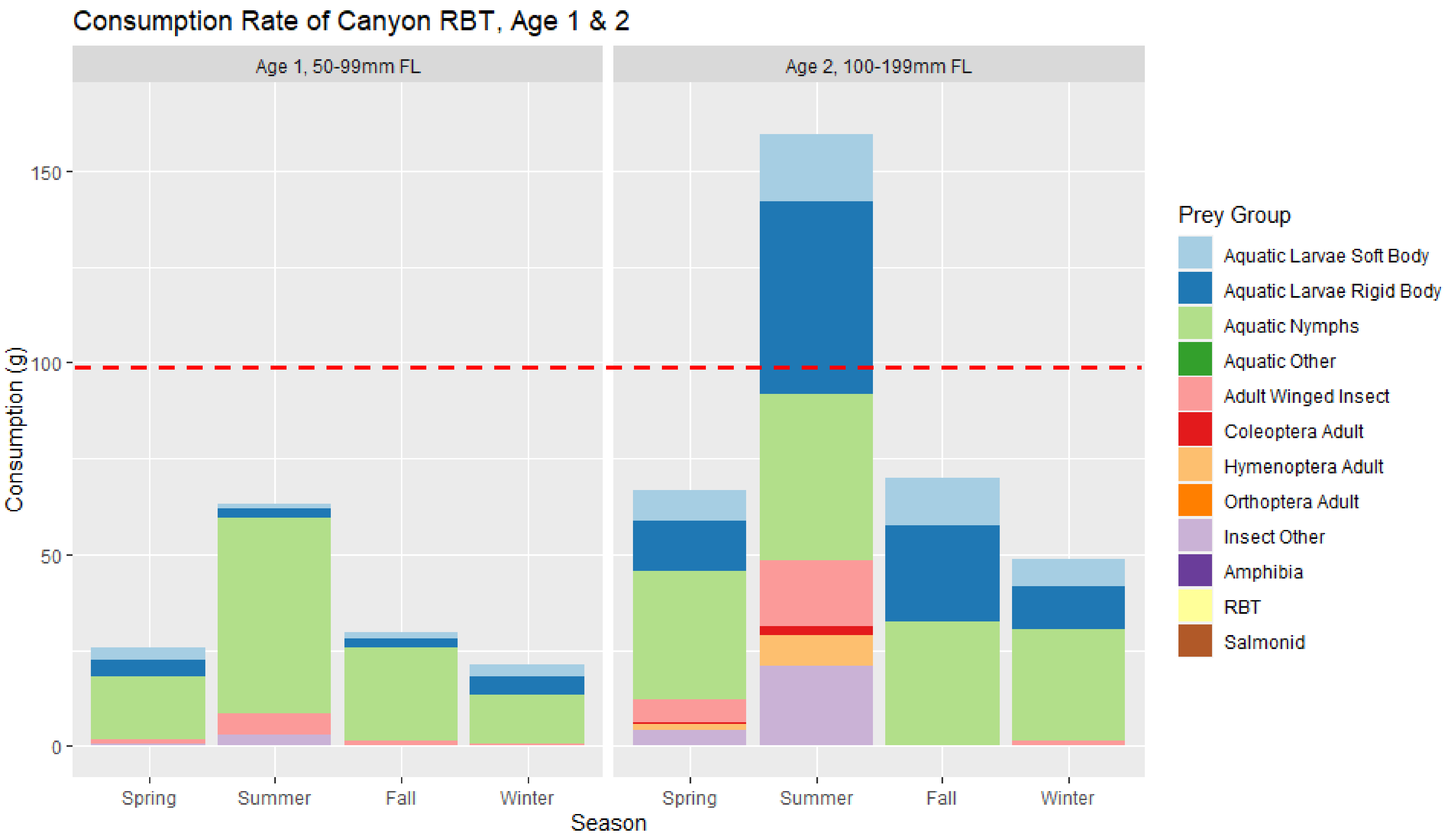
Bull trout in British Columbia
credit: Joel Sartore

Upper Skagit Tributary Bioenergetics Modeling

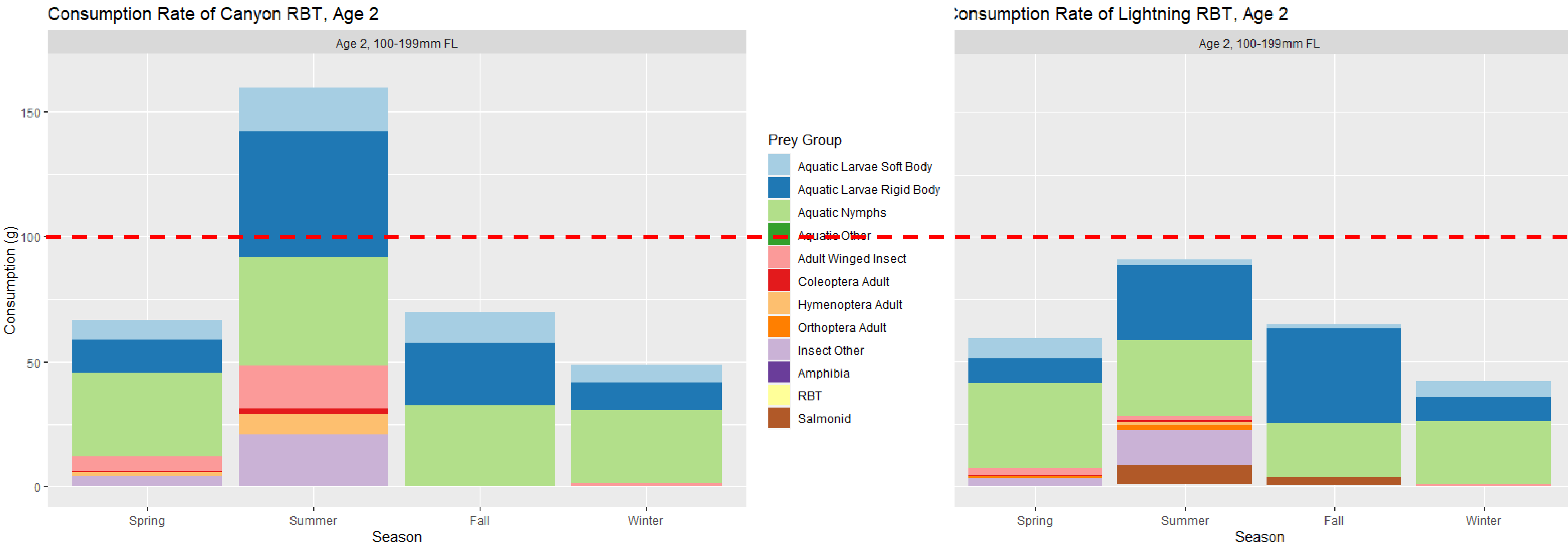
Cabled Temperature Logger

Drift Sampling

Consumption by Age: Canyon Creek-RB Trout



Consumption: Canyon vs Lightning Cr, RB Trout



Growth

Rainbow Trout - Canyon Creek 2018

Age	Size Class (mm FL)	Simulation Start Date	Simulation Length (days)	Initial mass (g)	Final mass (g)	*Skagit Adult Steelhead size at 2nd annulus (g)	Spawning loss (% BW)	Total Growth (g)	pCmax	Total Consumption (g)	GE (%)
1-2	50-99	5/1/2018	365	3.08	14.27	20.9	0	11.19	0.31	140	8.0%
2-3	100-199	5/1/2018	365	14.27	42.14	-	0	27.87	0.33	346	8.1%

- Growth data: 2018
- Temperature: Aug and Sep of 2019 + Ruby 2019
- Diet proportions: 2019
- *from Thompson and Beauchamp 2016

Growth

Rainbow Trout - Canyon Creek 2018

Age	Size Class (mm FL)	Simulation Start Date	Simulation Length (days)	Initial mass (g)	Final mass (g)	*Skagit Returning Adult size at 2nd annulus (g)	Spawning loss (% of BW)	Total Growth (g)	pCmax	Total Consumption (g)	GE (%)
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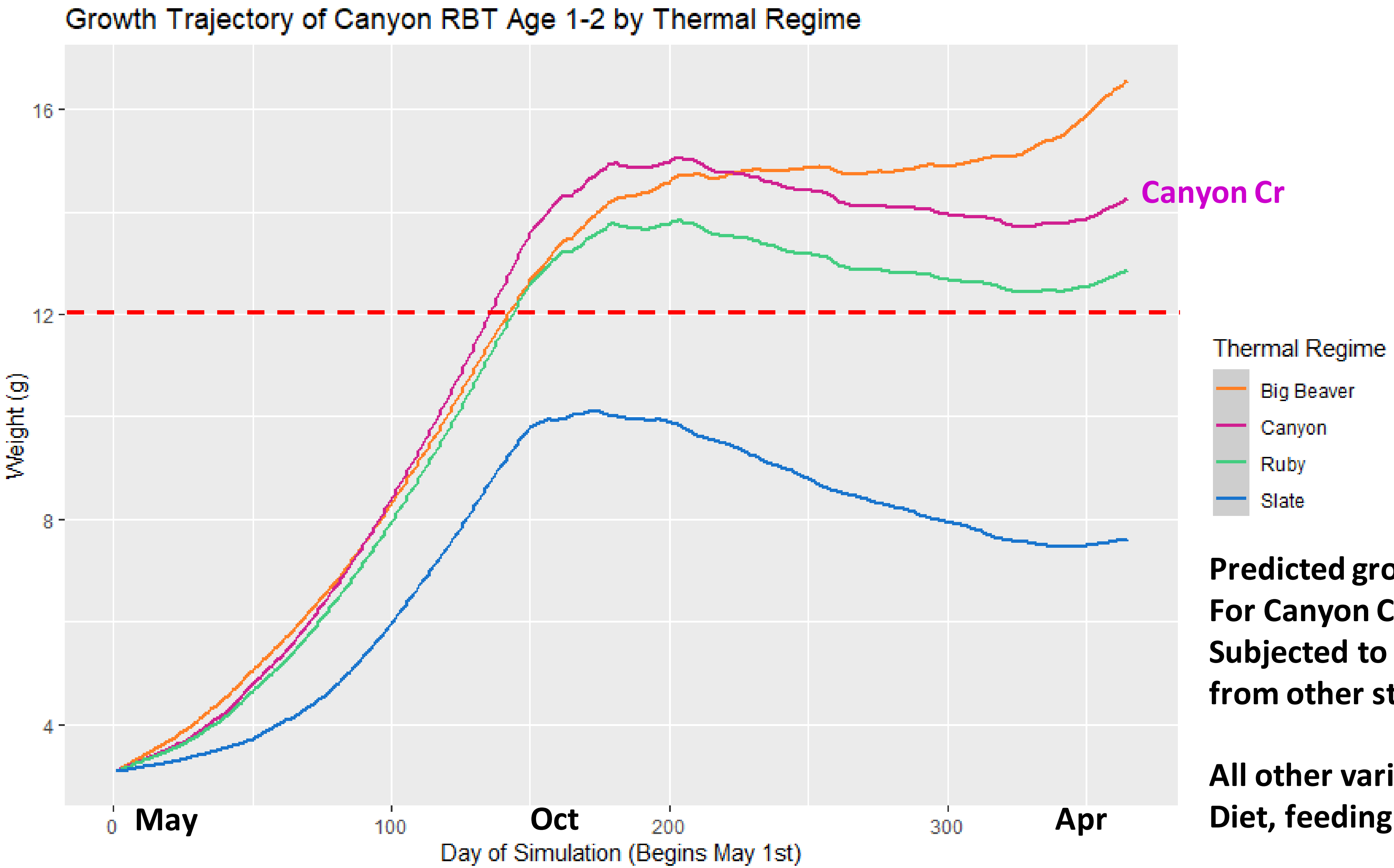
Rainbow Trout - Lightning Creek 2018

Age	Size Class (mm FL)	Simulation Start Date	Simulation Length (days)	Initial mass (g)	Final mass (g)	*Skagit Returning Adult size at 2nd annulus (g)	Spawning loss (% of BW)	Total Growth (g)	pCmax	Total Consumption (g)	GE (%)
1-2	50-99	5/1/2018	365	2.74	11.81	20.9	0	9.07	0.28	109	8.3%
2-3	100-199	5/1/2018	365	11.81	33.6	-	0	21.79	0.29	257	8.5%
3-4	100-199	5/1/2018	365	33.6	95.29	-		61.69	0.35	644	9.6%
4-5	200-299	5/1/2018	365	95.29	131.81	-		36.52	0.31	859	4.3%

Growth data: 2018, temperature: 2018 + Big Beaver, diet prop: 2018 + NFCanyon Fall 2019

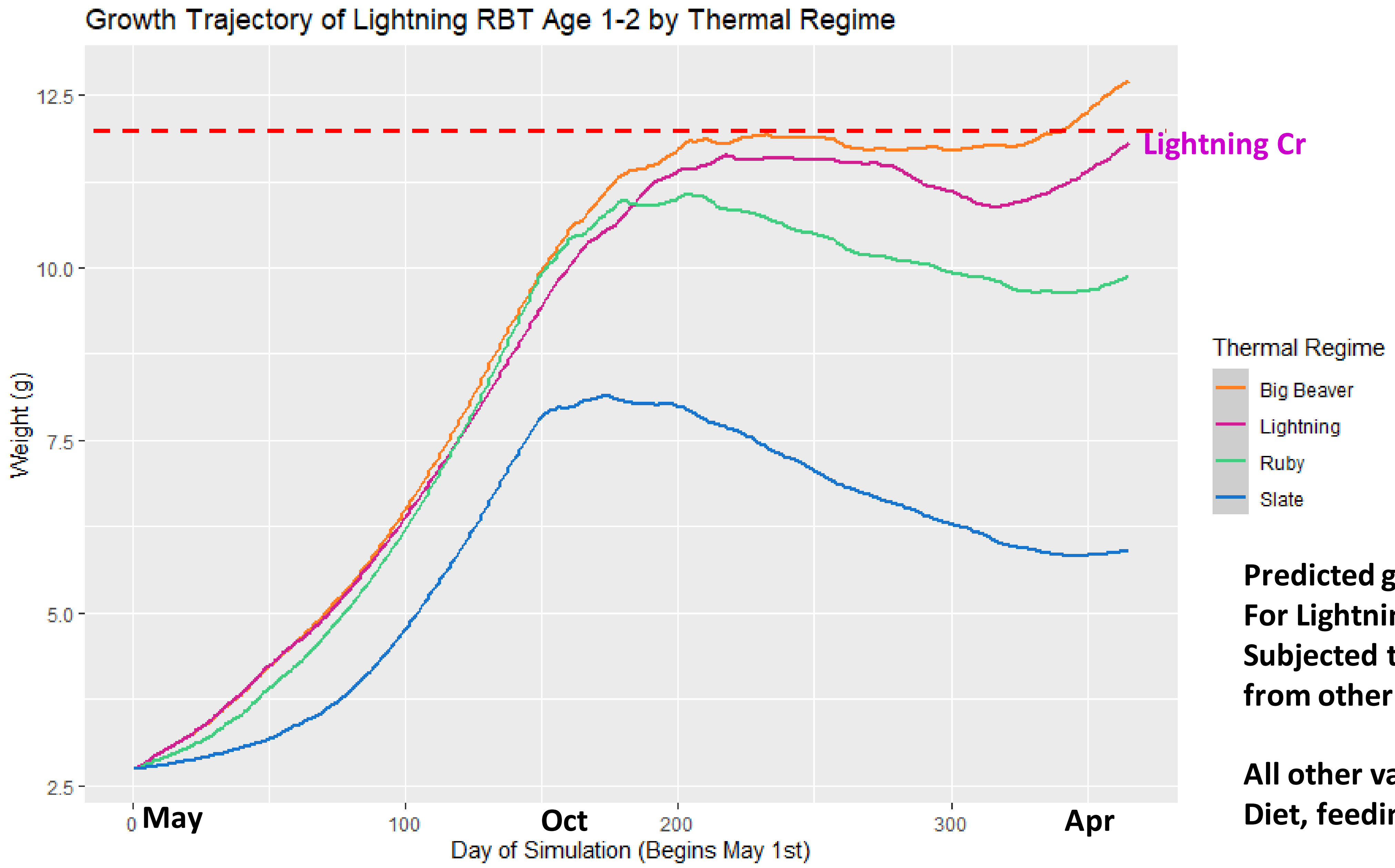
Growth Under Different Thermal Regimes: Canyon RBT



Predicted growth trajectories For Canyon Cr Rainbow trout Subjected to thermal regimes from other streams.

All other variables from Canyon: Diet, feeding rate, initial Wt

Growth Under Different Thermal Regimes: Lightning RBT



Predicted growth trajectories For Lightning Cr Rainbow trout Subjected to thermal regimes from other streams.

All other variables from Lightning: Diet, feeding rate, initial Wt

Combine Bioenergetic Processes; based on Temperature & Food Supply, with “Intrinsic Potential” evaluations based on Physical Habitat

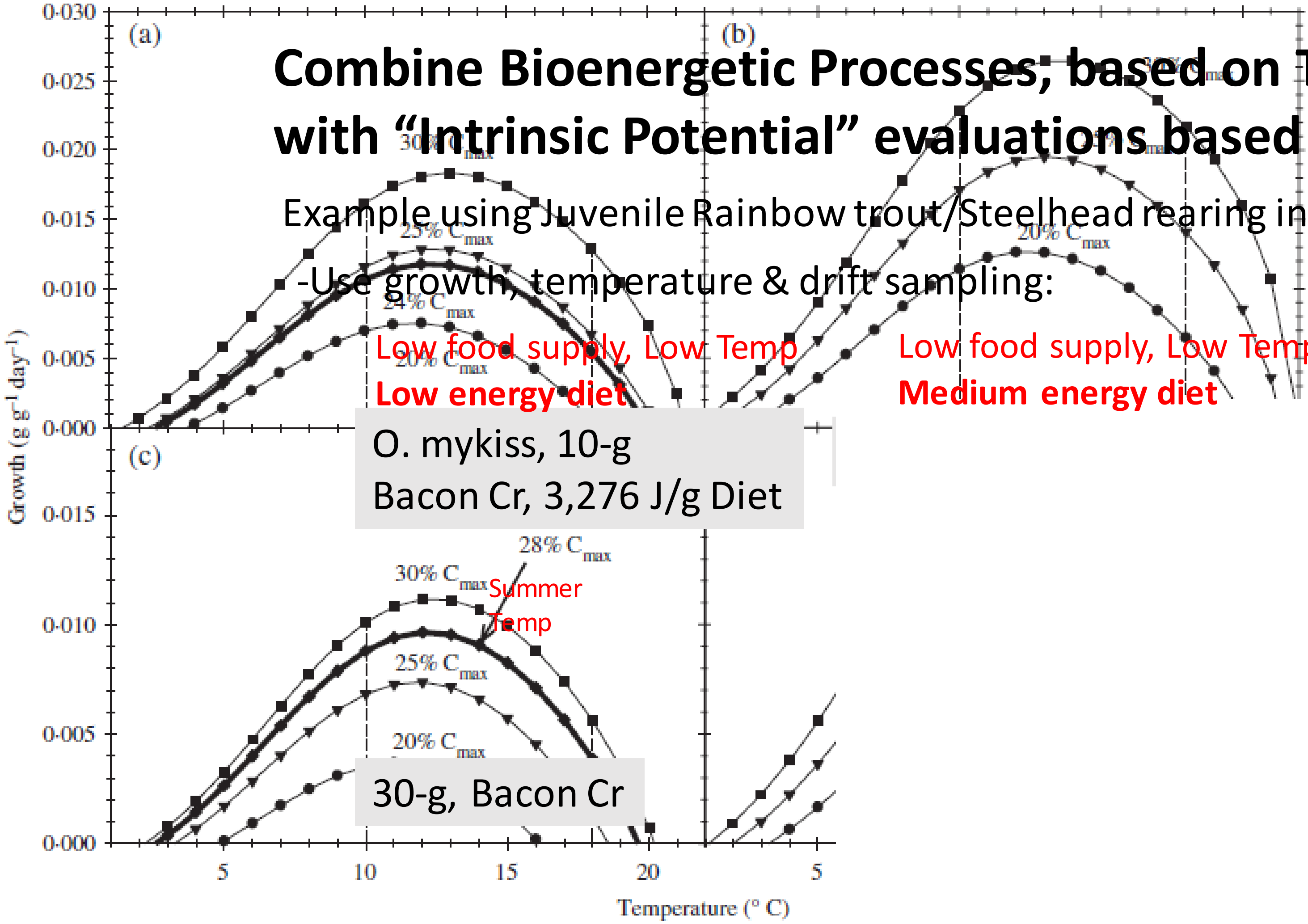
Example using Juvenile Rainbow trout/Steelhead rearing in Skagit tributaries below dams

-Use growth, temperature & drift sampling:

Low food supply, Low Temp
Low energy diet

Low food supply, Low Temp,
Medium energy diet

Low food supply, **Warmer Temp**,
Medium energy diet



Thompson & Beauchamp 2016. Growth of juvenile steelhead under size-selective pressure limited by seasonal bioenergetics & environmental constraints. J. Fish Biol. 89:1720-1739.

Summary

- Quantified Food web dynamics in the reservoirs will estimate the net effect of predation, competition, or temporal prey supply limitations on native juvenile salmonid recruitment & introduced anadromous salmonids
  - Seasonal consumption demand versus food supply for zooplankton, benthos between invasive Redside Shiners & Juvenile Salmonids
    - Quantify surplus carrying capacity for lake-rearing anadromous salmonids (Sorel et al 2016)
  - Seasonal predation mortality imposed on juvenile salmonids & Redside Shiners
    - Estimate predation risk to anadromous salmonids rearing/migrating through reservoirs
- Bioenergetic growth potential in tributaries
  - Complementary with NetMap's physical template (e.g., if physical habitat suitable, is there sufficient growth potential to support anadromy at acceptable levels?)
  - Predict growth performance related to temporal food supply & thermal regime for specific tributaries

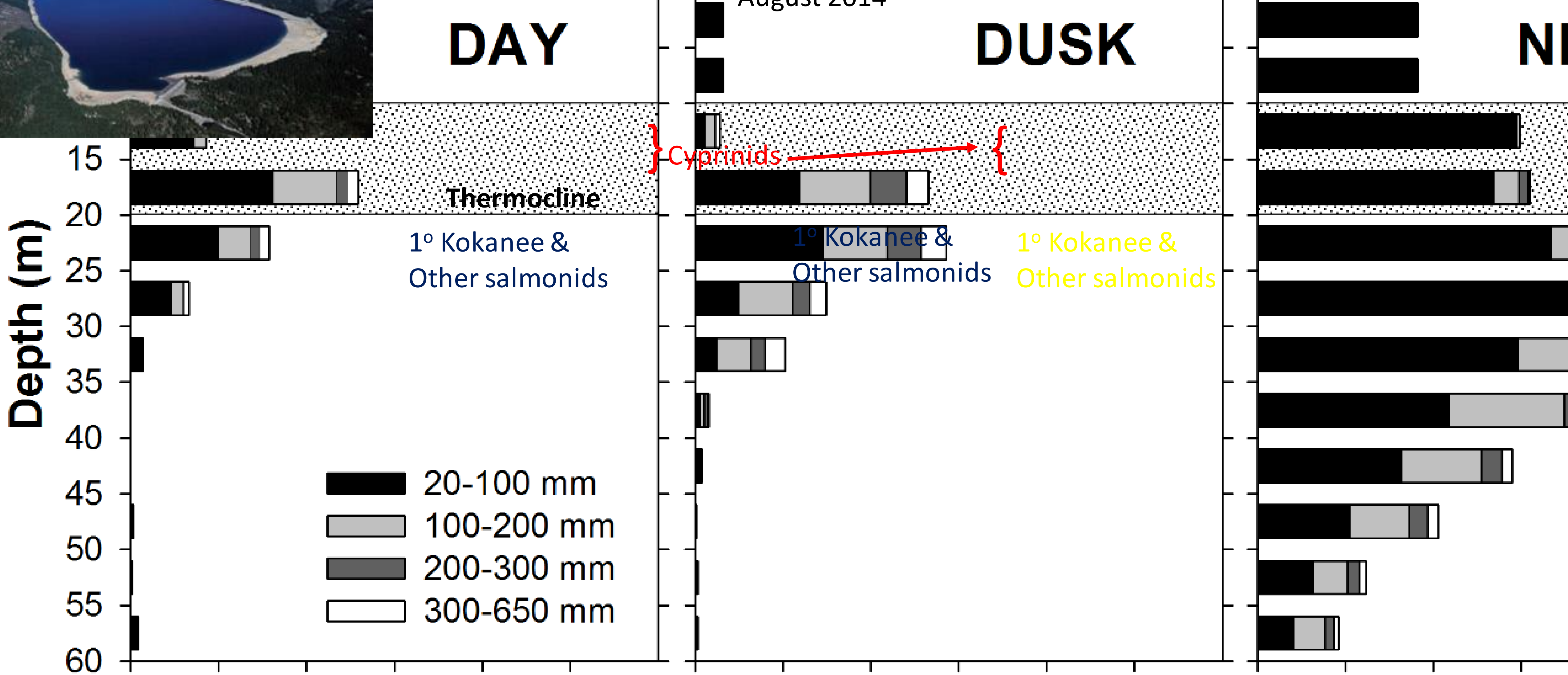
Supplementary Slides

ution among Species

Kachess Lake

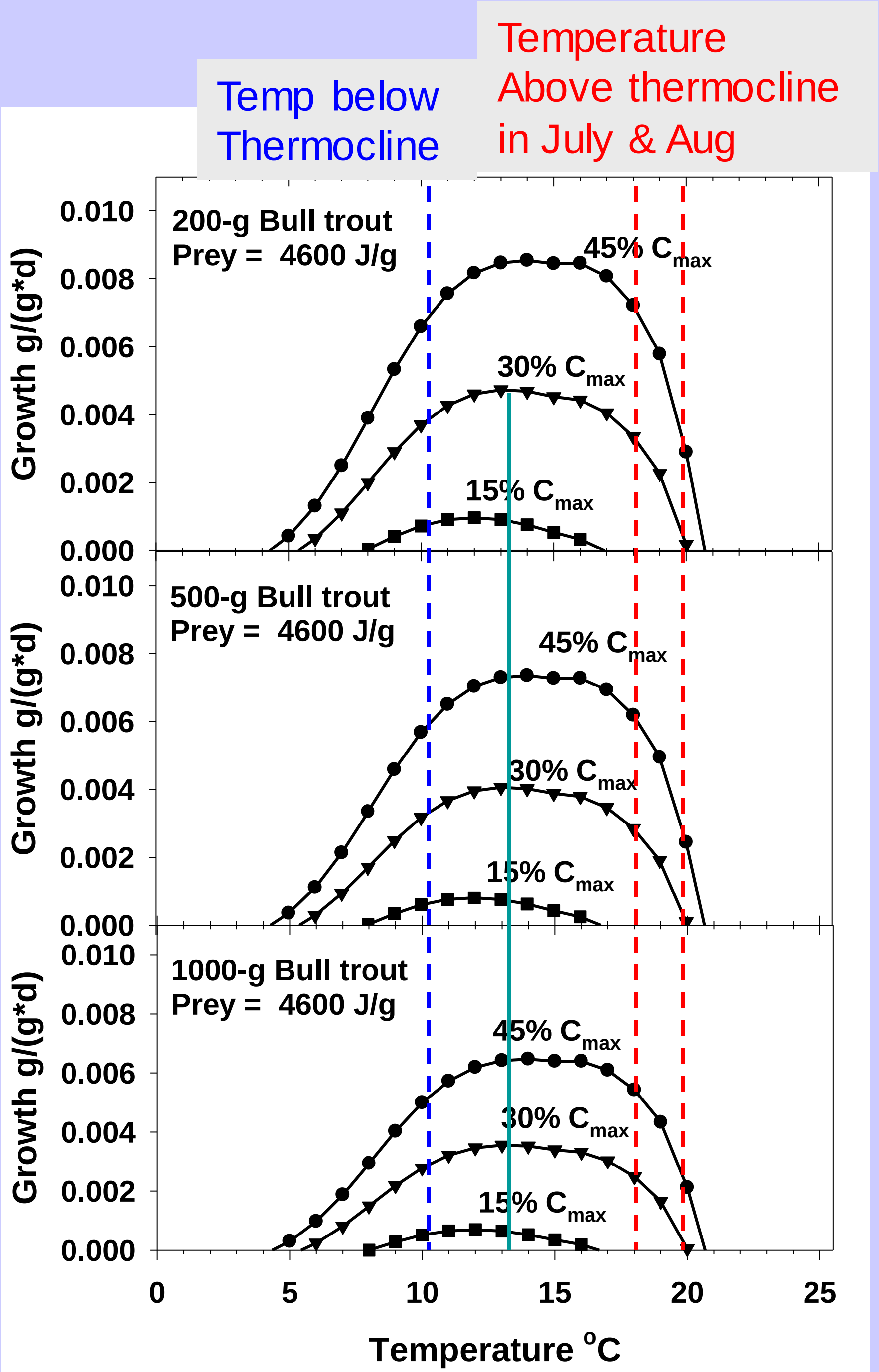
ill nets

August 2014



Hansen et al. 2015

Thermal Growth & Feeding Response by Bull Trout in Chester Morse



Estimated feeding rate for Adult bull trout averaged **30% Cmax**

Primarily feeding on:

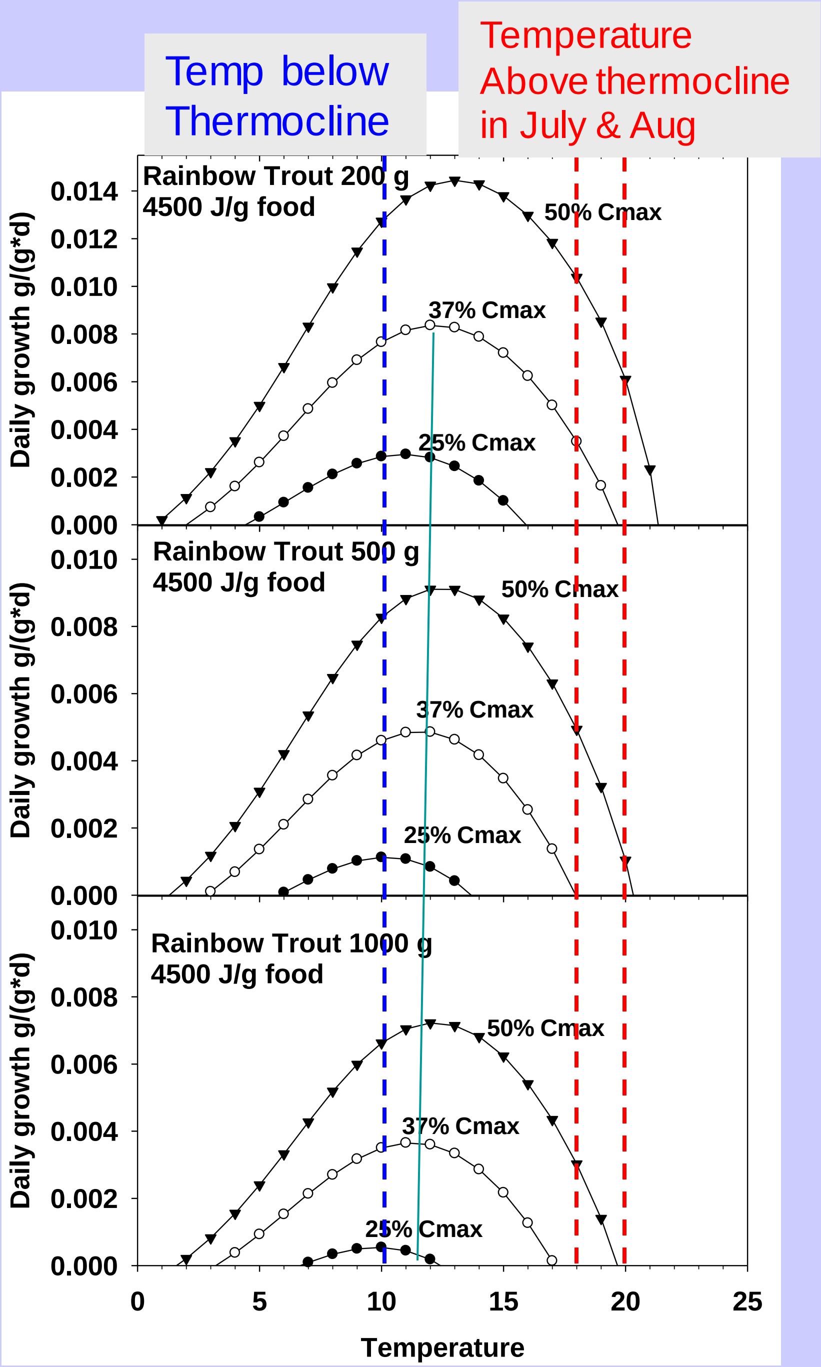
Shorthead sculpin (**Sum**, Fall-Win)

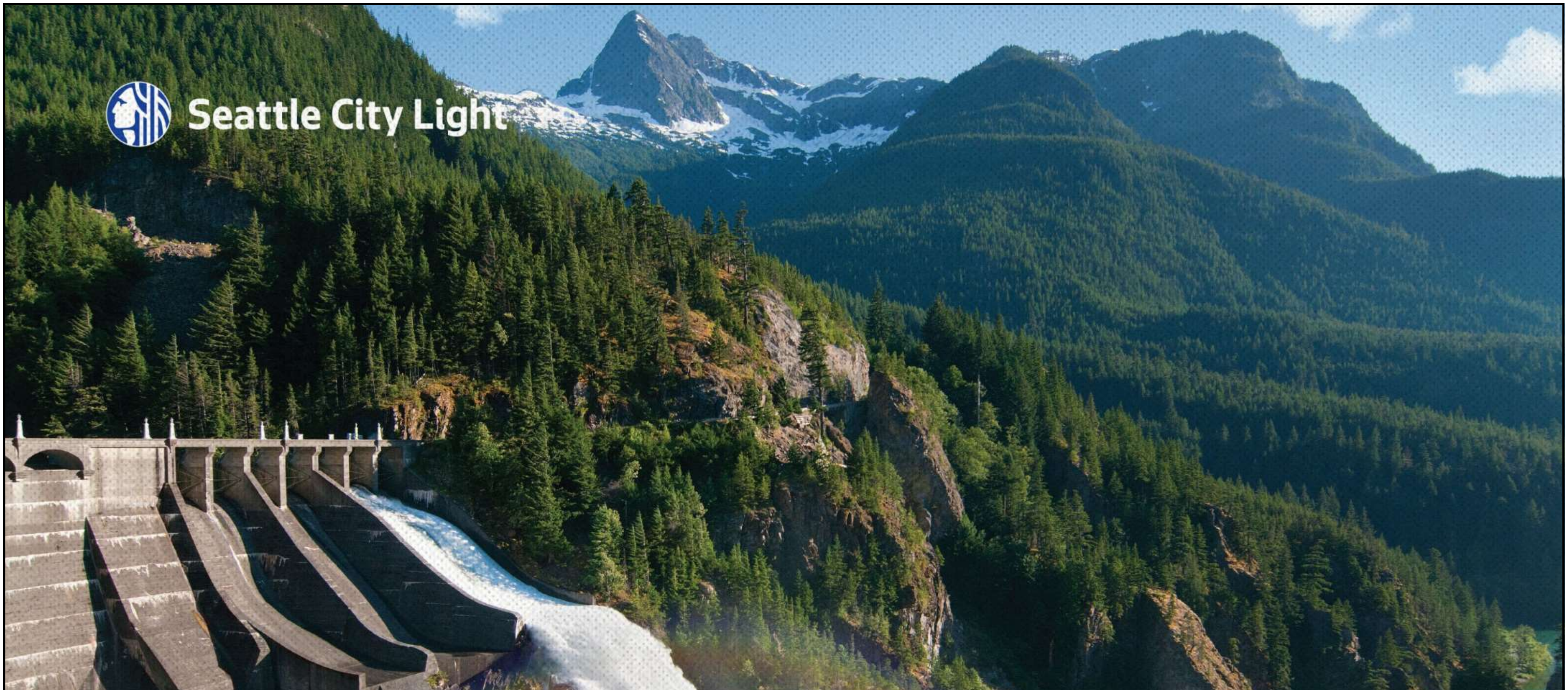
Pygmy whitefish (**Spr**, Fall-Win)

Thermal Growth & Feeding Response by Rainbow Trout in Chester Morse

Estimated feeding rate for Adult Rainbow trout averaged **37% Cmax**

Primarily feeding on high-energy Benthic inverts:
Arachnids, Caddis, Leeches, Crayfish, etc.





INTRINSIC POTENTIAL MODELING OF ANADROMOUS SALMONIDS IN SKAGIT RIVER RESERVOIR TRIBUTARIES

Jeff Fisher (SCL) and Jeff Duda (USGS)| July 13, 2021

Seattle City Light

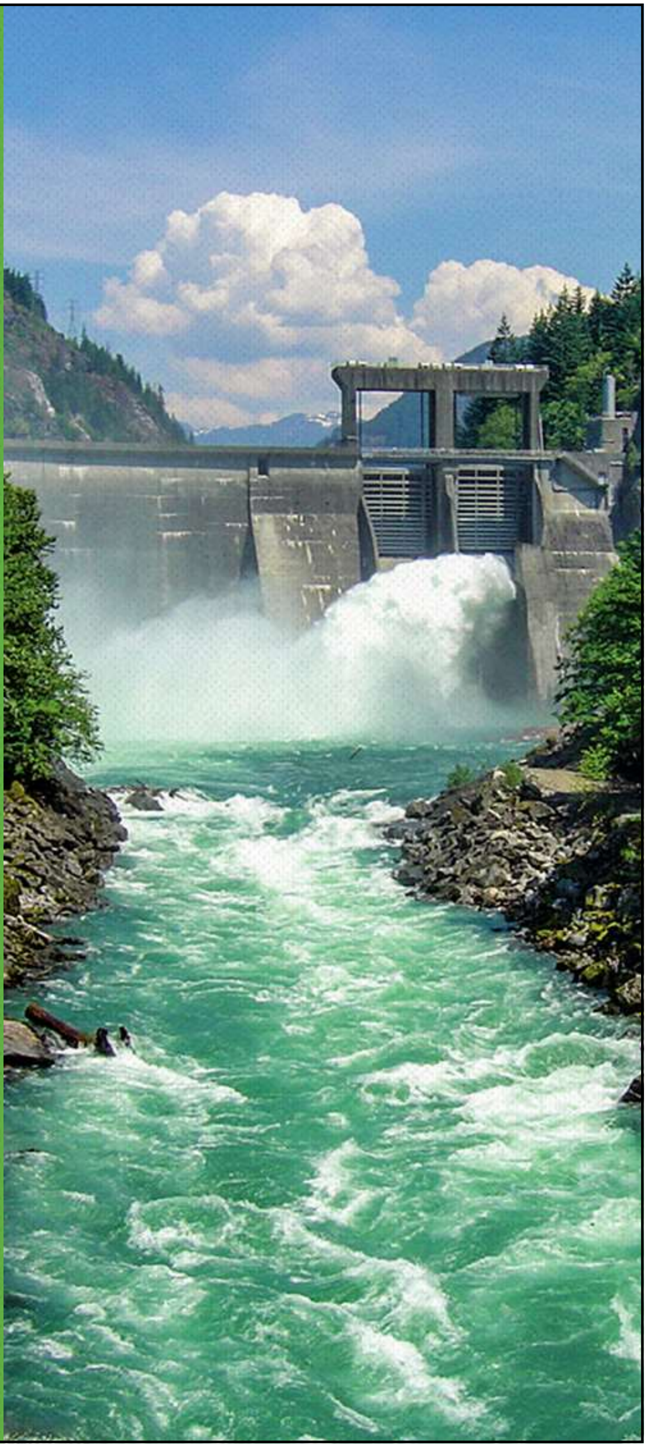
STUDY OBJECTIVES

(1) Apply NetMap spatial coverage and Intrinsic Potential modeling (e.g., Benda et al 2007; Burnett et al. 2007) to create synthetic stream layer and gradient, channel confinement and discharge.

(2) Use IP modeling to score habitat potential of accessible reaches for target species based on suitability curves.

(3) Use physical habitat variables to estimate juvenile rearing habitat capacity, i.e., productivity potential, (e.g., Cooper et al. 2020) for the target species within potentially suitable reaches identified from Intrinsic Potential modeling.

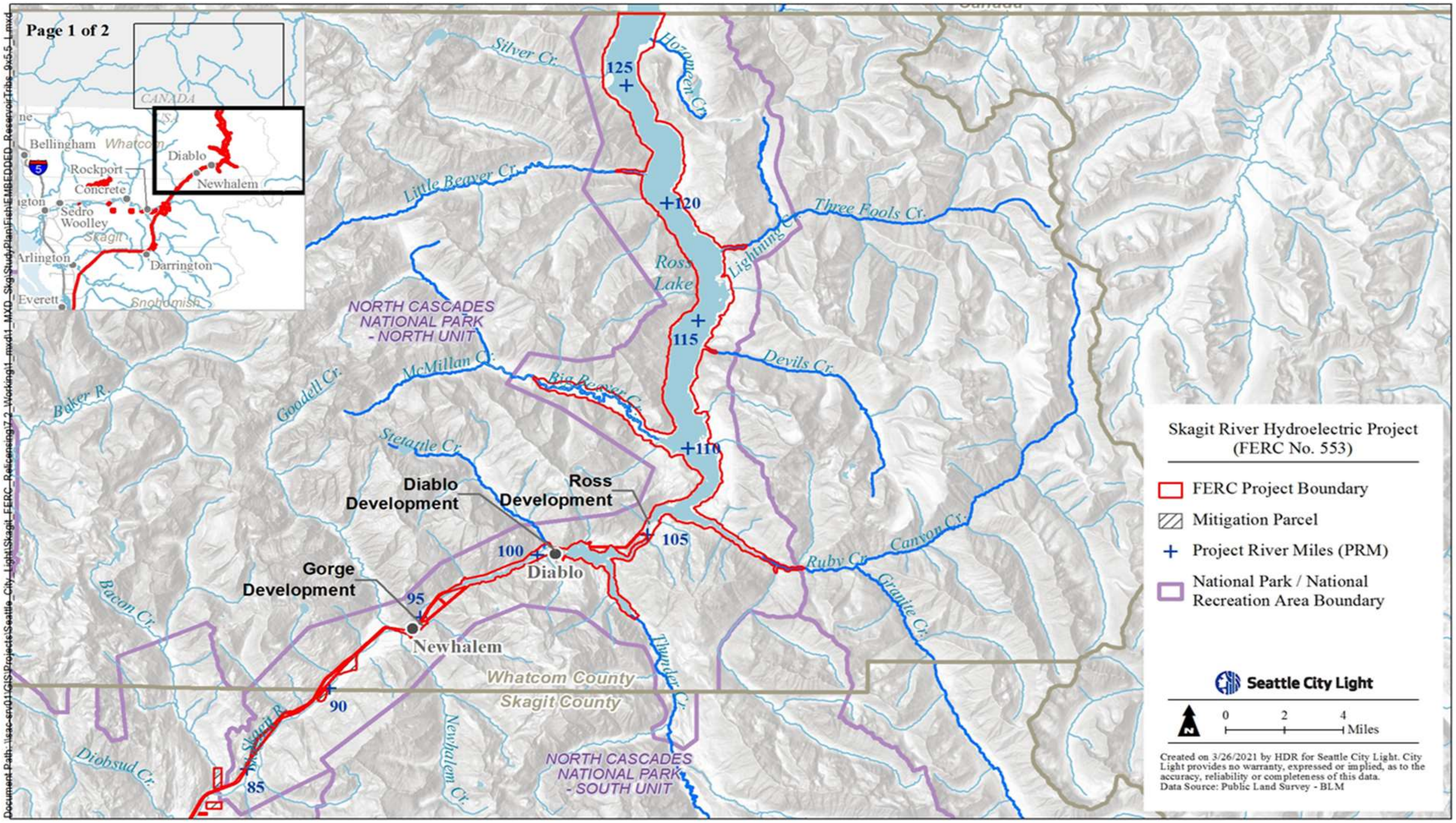
(4) Integrate results with outputs of the ongoing Food Web Bioenergetics Study



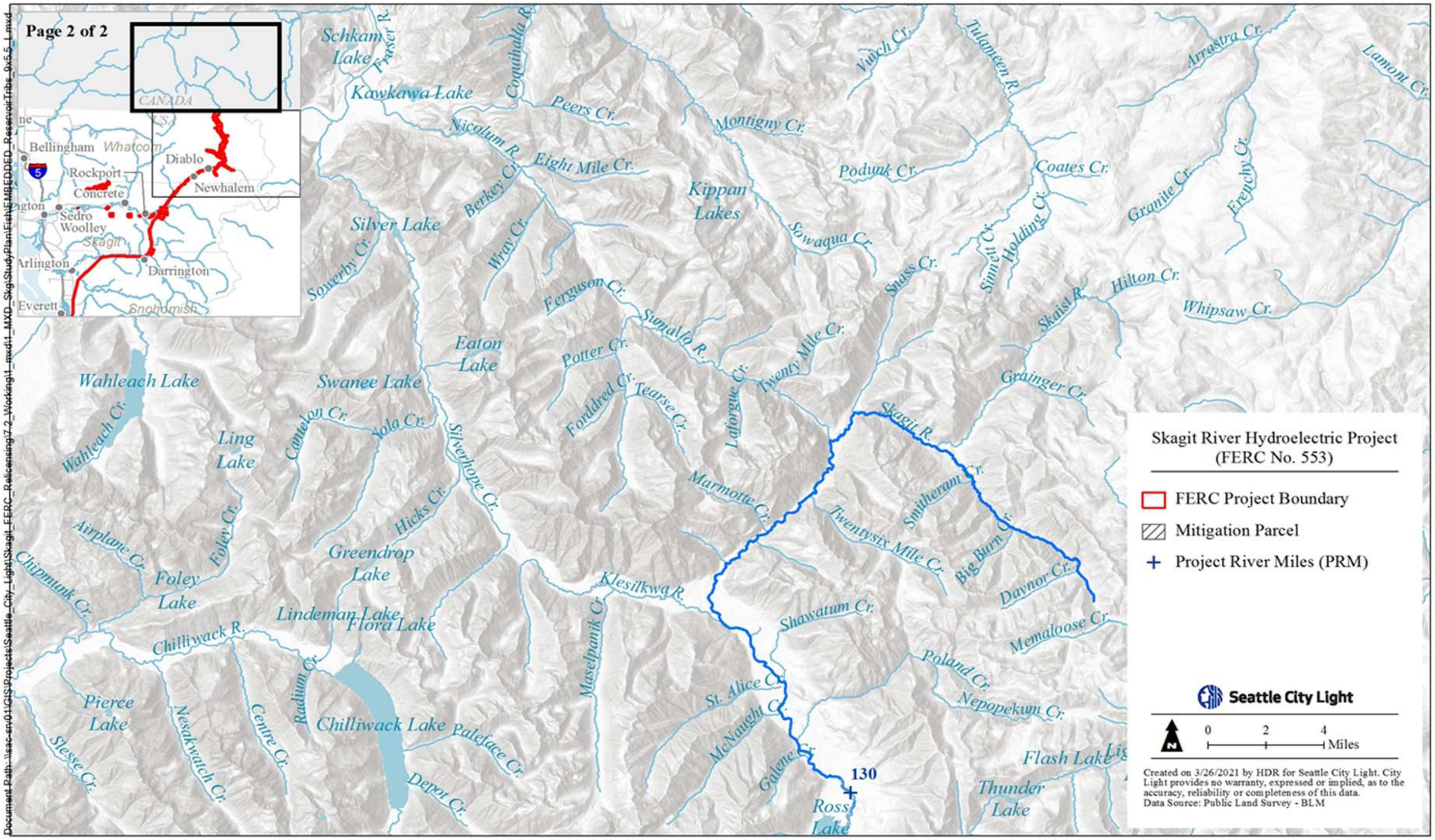
TARGET SPECIES

- Resident salmonids:
  - Bull trout
  - Dolly Varden
  - Rainbow trout
- Potentially introduced anadromous salmonids:
  - Steelhead
  - Chinook salmon
  - Coho salmon
  - Sockeye salmon
  - Chum salmon
  - Pink salmon
- Non-native species?

STUDY AREA—U.S. SIDE



STUDY AREA—CANADIAN PORTION OF WATERSHED



UPPER SKAGIT PASSAGE BARRIERS (NPS)

ASSESSMENT AREA—ACCESSIBLE HABITATS

Table 1. British Columbia streams with accessible habitat to fish from Ross Reservoir (NPS, used by permission).

Stream/River Name	Reach Description	Length (mi)	Gradient
Skagit River	Ross Lake to Klesilkwa River	10.9	< 1%
	Klesilkwa River to barrier falls near Snass Creek	10.6	< 1%
Klesilkwa River	Skagit River to Silverhope Divide	8.9	< 1%
Sumallo River	Skagit River to Ferguson Creek	10.3	< 1%
Ferguson Creek	Sumallo River to Highway 3 crossing	2.4	2%
Nepopekum Creek	Skagit River to start of canyon section	1.7	3%
Nepopekum Creek	Start of canyon to near Poland Creek	5.8	5%
Sumallo River	Ferguson Creek to end 3rd Order	7.5	5%
Maselpanik Creek	Klesilkwa River to end 3rd Order	7.6	6%
Snass Creek	Skagit River to Dry Lake	2.4	6%
Ferguson Creek	Highway 3 crossing to end 3rd Order	2.3	9%
Klesilkwa River	Silverhope Divide to end 3rd Order	2.3	10%
Twentysix Mile Creek	Skagit River to end 3rd Order	3.6	11%
Marmotte Creek	Skagit River to end 3rd Order	2.7	12%

Table 2. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS, used by permission).

Stream/River Name	Reach Description	Length (mi)	Gradient
Big Beaver Creek	Ross Lake to McMillan Creek	9.1	<1%
Ruby Creek	Ross Lake to confluence with Canyon and Granite Creeks	3.4	2%
Canyon Creek	Ruby Creek to Slate Creek	7.4	2%
Lightning Creek	Ross Lake to Three Fools Creek	2.2	2%
Lightning Creek	Three Fools Creek to Freezeout Creek	5.5	2%
Little Beaver	Ross Lake to end 3rd Order	15	2%
Big Beaver Creek	McMillan Creek to Luna Creek	4.3	3%
Granite Creek	Ruby Creek to falls (indistinct barrier).	5.5	4%
Luna Creek	Big Beaver Creek to end 3rd Order	2.8	4%
Lightning Creek	Freezeout Creek to Boundary Creek	3.9	4%
Three Fools Creek	Lightning Creek to Castle Creek	6.3	4%
Castle Creek	Three Fools Creek to Rustle Creek	3.6	6%
Canyon Creek	Slate Creek to barrier falls.	2.6	7%
North Fork Canyon Creek	Canyon Creek to barrier falls	0.6	7%
East Creek	Granite Creek to end 3rd Order	4.3	10%
Cabinet Creek	Granite Creek to end 3rd Order	2	13%
Slate Creek	Barrier likely at 0.6 RM	NA	NA

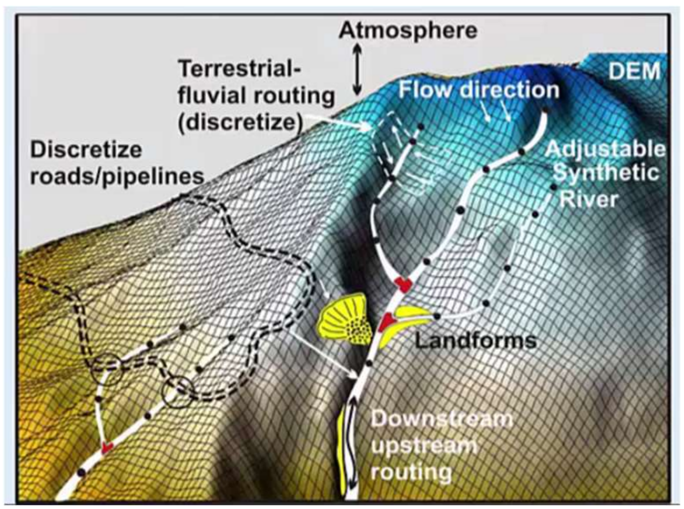
OVERVIEW OF PROPOSED METHODS FOR DISCUSSION

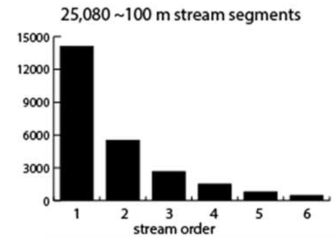
- Use NetMap (Benda et al. 2007) from existing topographic data (10-m DEM in US and 20-m DEM in BC) to screen availability of spawning or rearing habitat for different species based on geomorphic habitat suitability measures for stream reaches.
- Use Intrinsic Potential Modeling to develop habitat suitability curves and score the suitability of accessible habitat for the target species (Bennett et al. 2007, Agrawal et al. 2005).
- Estimate juvenile rearing capacity (production potential) of tributary reaches identified by Intrinsic Potential modeling to *refine* estimates of habitat suitable for one or more of the target species (Cooper et al. 2020).
    - Field-based assessment to verify physical habitat attributes identified by NetMap/IP that affect production potential so habitat capacity can be more accurately integrated with bioenergetics modeling at the tributary scale.

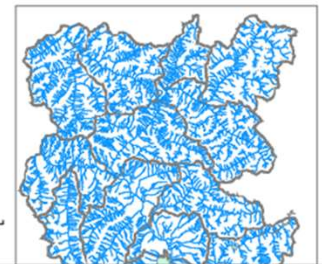
NetMap
GIS-based numerical models + DEM

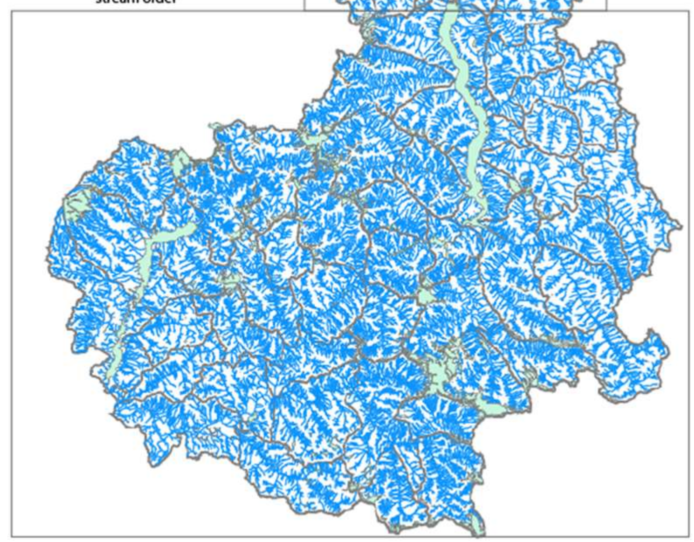
Vector “synthetic” stream channels derived from NetMap numerical model and DEMs.

NetMap
Synthetic stream layer







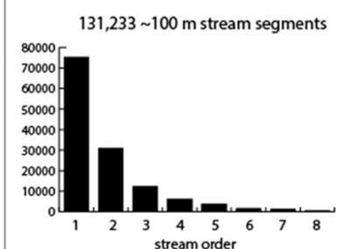


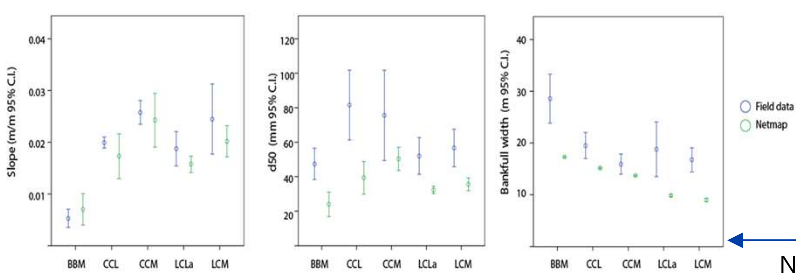
Updated NetMap Dataset for Canadian portion of the Upper Skagit Watershed. Completed in 2018.

Based on 20 m DEM

Existing NetMap dataset for US portion of the Upper Skagit Watershed.

Based on 10 m DEM

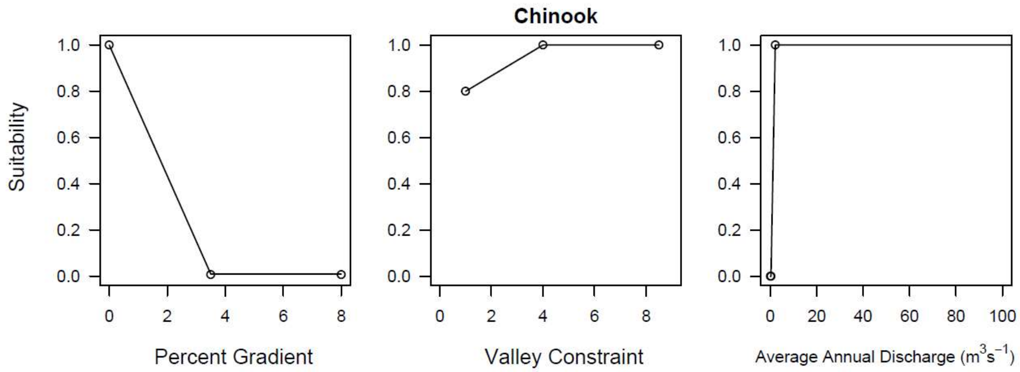




NetMap estimates vs. Field based variables

IP MODELS FOR POTENTIAL ANADROMOUS SALMON INTRODUCTION

- Use existing Northwest IP models from the literature and existing species distribution maps to create an "ensemble" of IP scores for each species. A range of habitat suitability curves will be based on scores from the literature.

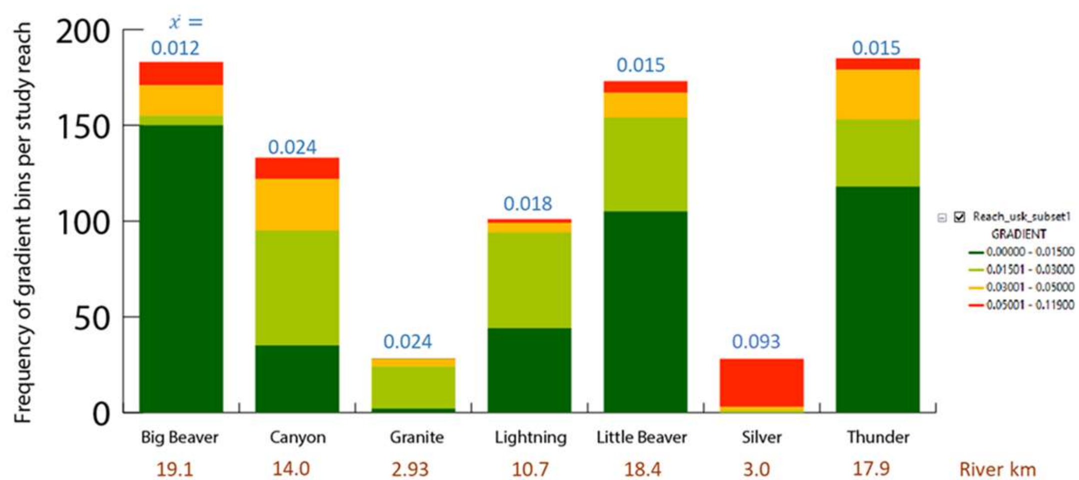


Example suitability curves from Agrawal et al. 2005

- Assign each ~100 m stream segment a species-specific IP category (i.e., Low, Medium, and High), creating species specific maps for the Upper Skagit.

IP MODELS FOR POTENTIAL ANADROMOUS SALMON INTRODUCTION: ESTIMATING HABITAT EXTENT

- Determine the length of stream habitat in each IP category
- Describe synthetically derived habitat features of each stream segment/IP category



Example habitat feature extraction from NETMAP, showing habitat length, average gradient, and gradient categories.

JUVENILE PARR CAPACITY MODELING

- Follow-on from IP modeling to further refine IP estimates.
  - Refinement of IP modeling in select areas where resolution needs confirmation.
- Field-based unit characterization method (UCM) at unit scale to project salmonid densities (# fish/m2), coupled to reach scaled considerations.
  - Reach scale consideration of pH, turbidity, embeddedness, temperature

MODEL FLOWCHART FOR STREAM CAPACITY MODELING FOR JUVENILE SALMONID REARING USING THE UNIT CHARACTERISTIC METHOD

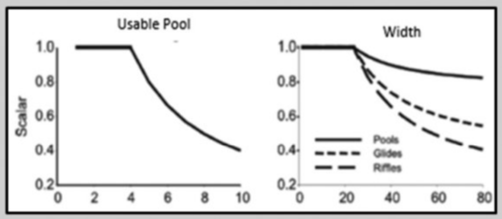
Capacity = (Σ Area*den*chnl*dep*cvr)*(prod)*(temp)

Pool **Area** (length*width)
x
Standard ST Pool **Density**: 0.17
Standard CH Pool **Density**: 0.24

Fastwater **Area** (length*width)
x
Standard ST Fastwater **Density**: 0.03
Standard CH Fastwater **Density**: 0.024

Flatwater **Area** (length*width)
x
Standard ST Flatwater **Density**: 0.08
Standard CH Flatwater **Denisty**: 0.07

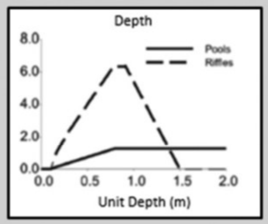
Unit Scale Parameters



Usable Area: ***Chnl***

Flatwater: if W > 24: (@-24) x 0.35/W + 24/W
Pool: If W > 24: (@-24) x 0.75/W + 24/W
If L > 4 x W: L = 4 x W
Fastwater: if W > 24: (W-24) x 0.15/W + 24/W

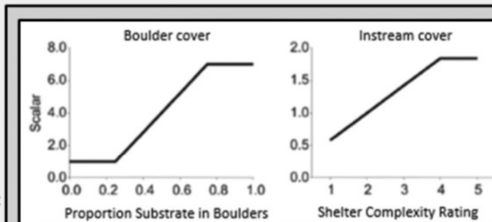
Where W = wetted width, L = wetted length



Depth: ***Dep***

Pool & Flatwater: If D is < 0.10: 0.0*D
If D is 0.10 - 0.80: (0.30* D - 0.027)/0.17
if D is >0.8: 0.22/0.17
Fastwater: If D is < 0.1: 0.0 * D
If D is 0.10 - 0.16: (0.5*D - 0.5)/0.03
If D is 0.16 - 0.30: (0.29*D - 0.017)/0.03
If D is 0.30 - 0.80: (0.25*D - 0.003)/0.03
If D is 0.80 - 0.90: 0.20/0.03
If D is 0.90 - 1.50: (-0.32*D + 0.485)/0.03
If D is >1.50: 0

where D = depth in meters



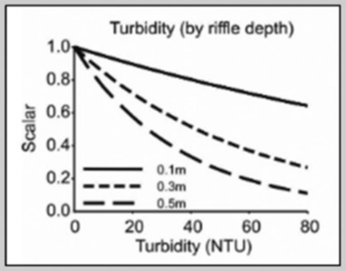
Instream Cover: ***Cvr***

Pool & Flatwater: if wood complexity = 1: 0.58
If wood complexity = 2: 1.00
If wood complexity = 3: 1.42
If wood complexity = 4 or 5: 1.84
Fastwater: if Bpr < 0.25: 1.0
If Bpr is 0.25 – 0.75: 1 + 12 x (Bpr – 0.25)
If Bpr >0.75: 7.0

Where Bpr = proportion substrate in fastwater comprised of boulders

REACH-SCALE PRODUCTIVITY PARAMETERS FOR ADJUSTING CAPACITY WITH REARING SUITABILITY CURVES

Productivity Parameters

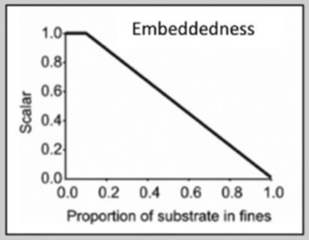


Turbidity: ***turb***

If Dr is < 0.3m: 10^(2-(1+0.024*N)*0.1)/10^2-0.1
If Dr is 0.3-0.5m: 10^(2-(1+0.024*N)*0.3))/10^2-0.3
If Dr is > 0.5m: 10^(2-(1+0.024*N)*0.5))/10^2-0.5

where Dr = mean depth of riffles within the reach; N = NTU

✖

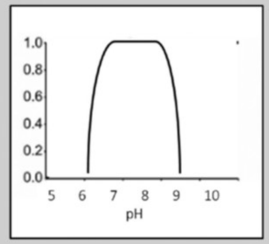


Embeddedness: ***Fines***

If Fp is <0.1: 1.0
If Fp is ≥0.1: 1.11 – 1.1*Fp

Where Fp = proportion of substrate in riffles comprised of fines

✖

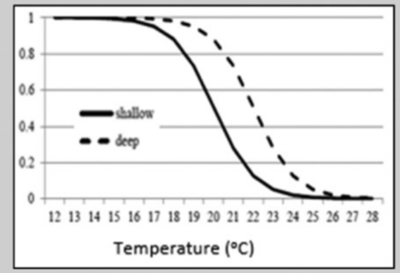


pH

If pH < 7: 0.8052* pH – 4.402
If pH is 7.0-8.0: 1.0
If pH > 8: -1*8.1 + 9

✖

Temperature Parameter



Temperature: ***Temp***

Tsi = 1/(1/(1+e^-a-bTi)

Where Tsi = Temp scalar for capacity for reach i in a given week
a = intercept of logit(Tsi) = 19.63
b = slope of logit(Tsi) = -0.98
e = natural logarithm base
T = weekly average temperature (WAT) for reach i in a given week

NEXT STEPS AND ANTICIPATED MILESTONES

- First IP modeling results by October 2021 for selected species.
  - Workshop anticipated
- Full IP modeling results by November 2021 for full complement of species
- LIDAR scheduling, 2021 q4 (in process*).
- Field data collection of parr capacity (2022—q2/q3)
- Parr capacity modeling (Cooper et al.) applied to Netmap Derived species-specific stream maps (2022/23)
- Integration of parr capacity modeling with Bioenergetics (2022, q 4).
- Subsequent workshops to be scheduled, with specific milestones TBD with LP input.

Skagit Hydroelectric Project Relicensing Meeting

FA-07 Tributary & Reservoir Habitat Workshop #2

October 25, 2021, 1:00 pm – 4:00 pm

WebEx Meeting: [LINK HERE]

Conference Call: +1-510-338-9438
Access code: 25556380707
(Meeting ID: XafZK9pNb33**)**

MEETING PURPOSE

- Review approach to Intrinsic Potential modeling.
- Discuss scope modifications to the ongoing USGS Food Web Study.
- Update on Tributary Habitat Potential Assessment.

RESOURCES

- NOA Commitments
- Reservoir Work Group Discussion Tracker

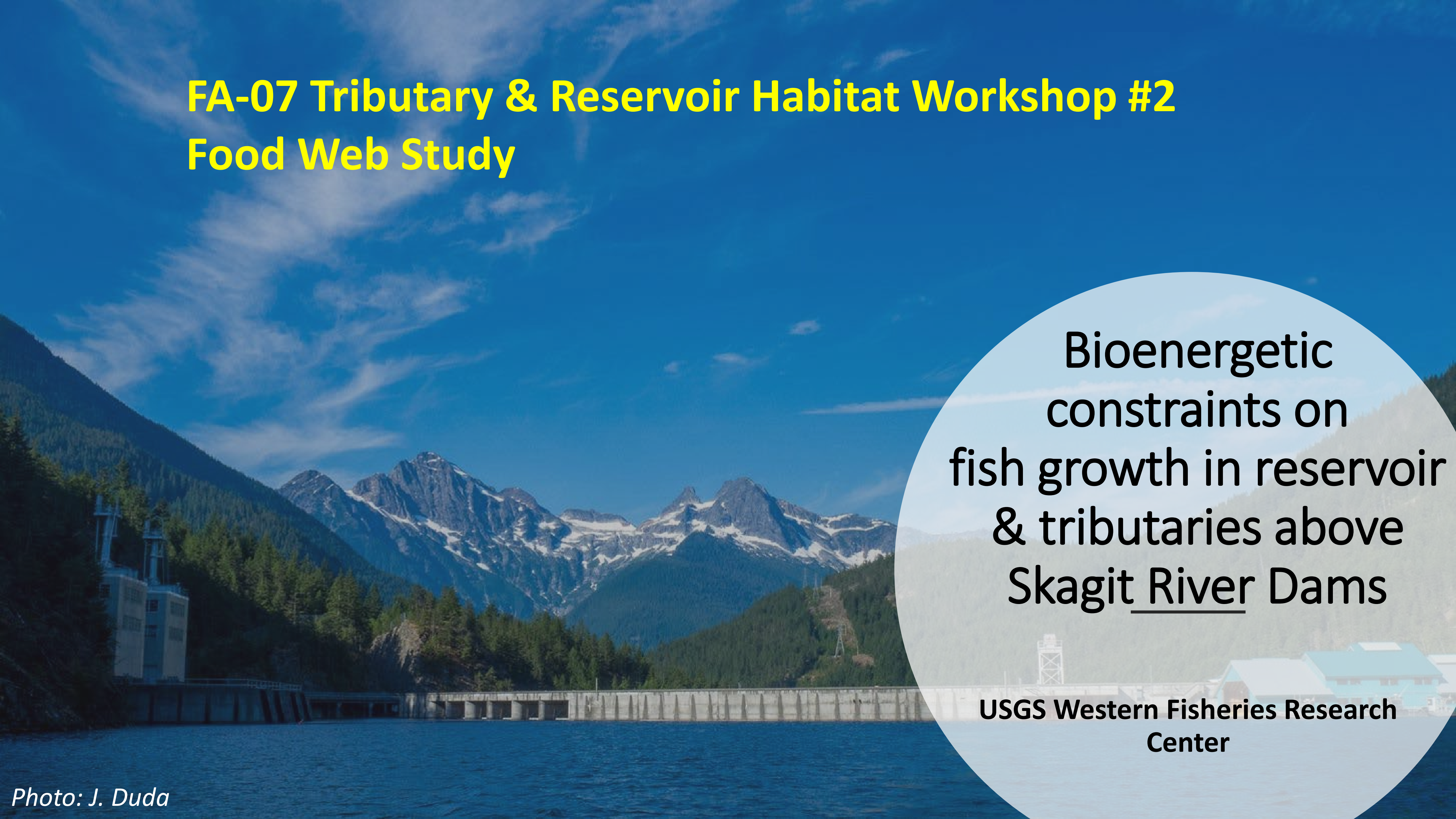
AGENDA

1:00 – 1:15 pm [15 mins]	**Introductions** – *Greer Maier (Facilitator, Triangle Associates)* • Roll call introductions • Review meeting context and previous summary and action items • Review meeting objectives and agenda items
1:15 – 2:15 pm [1 hour]	**Intrinsic Potential (IP) Modeling *(I and A)*** - *Jeff Duda (USGS) and Jeff Fisher (City Light)* • Review status of initial IP modeling runs • Discuss what will constitute suitable habitat (results range 0-1) • Sufficiency of 10-m DEMs (20-m DEMs in Canada) • Discuss how to evaluate and address natural barriers • Discuss approach to addressing non-native species, spring/summer Chinook, and summer steelhead in the IP modeling • Discuss potential uses/benefits of LiDAR data • Bathymetry update
2:15 – 2:45 pm [30 min]	**Update on Tributary Habitat Potential Assessment *(I and A)*** – *Phil Roni (Cramer Fish Sciences) and Jeff Fisher (City Light)* • Discussion of tributary habitat capacity assessment methods • Linking Food Web Study outputs to tributary production capacity estimates • Timeline for assessment and results

2:45 – 3:45 pm [1 hour]	**Food Web Study (*I & A*)** – *Dave Beauchamp (USGS) and Jeff Fisher (City Light)* ***(A)*** • Brief overview of food web study • Review stable isotope sampling, 2020 versus 2021 • Discuss options for assessing Gorge Lake's food web suitability for supporting reintroduced anadromous fish • Discussion of zooplankton/BMI sampling being shifted to FA-01
3:45 – 4:00 pm [15 mins]	**Action Item Review and Agenda Items/Approach for Additional Meetings –** *Greer Maier (Facilitator, Triangle Associates)* ***(I)*** ▪ Action Items, new discussion topics, and next steps ▪ Review future workshop topics: o Applicability, if any, of HSCs developed for instream flow modeling for FA-07. o Integration of Food Web Study Results with Operations Model CE-QUAL-W2. o Littoral habitat assessment (GIS-based) o Adequacy of data collection in FA-01
4:00 pm	**Meeting Adjourned**

Agenda Topic Goals: I=Information, A=Advise, C=Concurrence

FA-07 Tributary & Reservoir Habitat Workshop #2
Food Web Study



Bioenergetic constraints on fish growth in reservoir & tributaries above Skagit River Dams

USGS Western Fisheries Research Center

Photo: J. Duda

OUTLINE
Information Requests Related to Reservoir Food Web

- <u>Temporal Food Supply/carrying capacity is the common theme</u>
- Zooplankton Sampling
  - Objectives: Monthly depth-stratified density, biomass
  - Spatial-temporal coverage consistent with objectives
- Benthic Macroinvertebrate Sampling
  - Objectives: Provide stable isotope signatures for benthic consumers
  - Spatial-temporal coverage consistent with objectives
- Stable Isotope supplemental sampling: 2020 v 2021 samples
- Gorge Reservoir Food Web analysis for feasibility of supporting introduced anadromous salmonids

Upper Skagit reservoirs

- FERC relicense and concern over native populations?

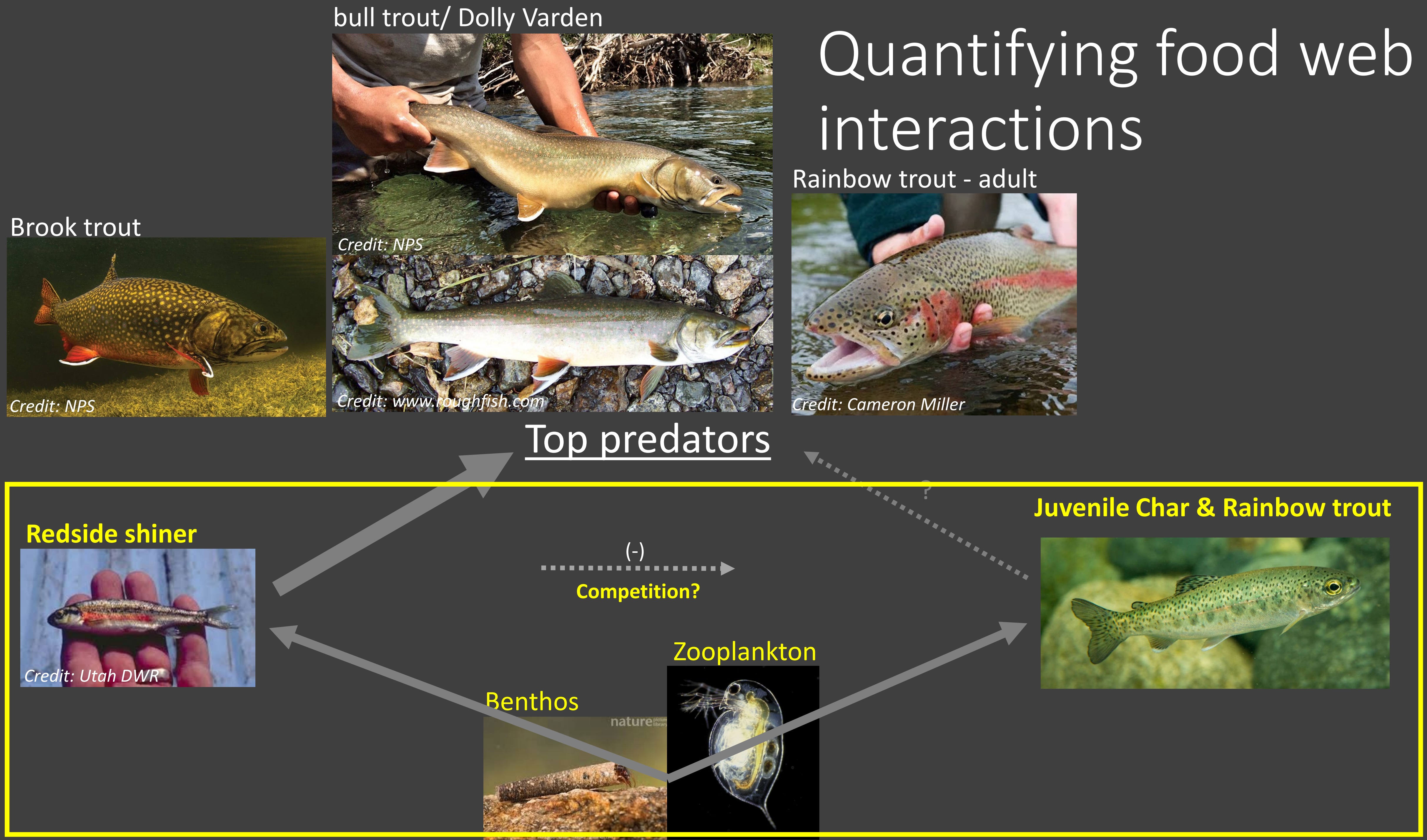
ESA-listed Bull Trout

Rainbow Trout

Invasive Redside Shiner

- **What is limiting production of native fishes?**
  - Lack of recruitment of juvenile salmonids
  - Temperature? Prey availability? Predation? Competition?
  - **Feasibility of anadromous salmonid introductions?**

Quantifying food web interactions



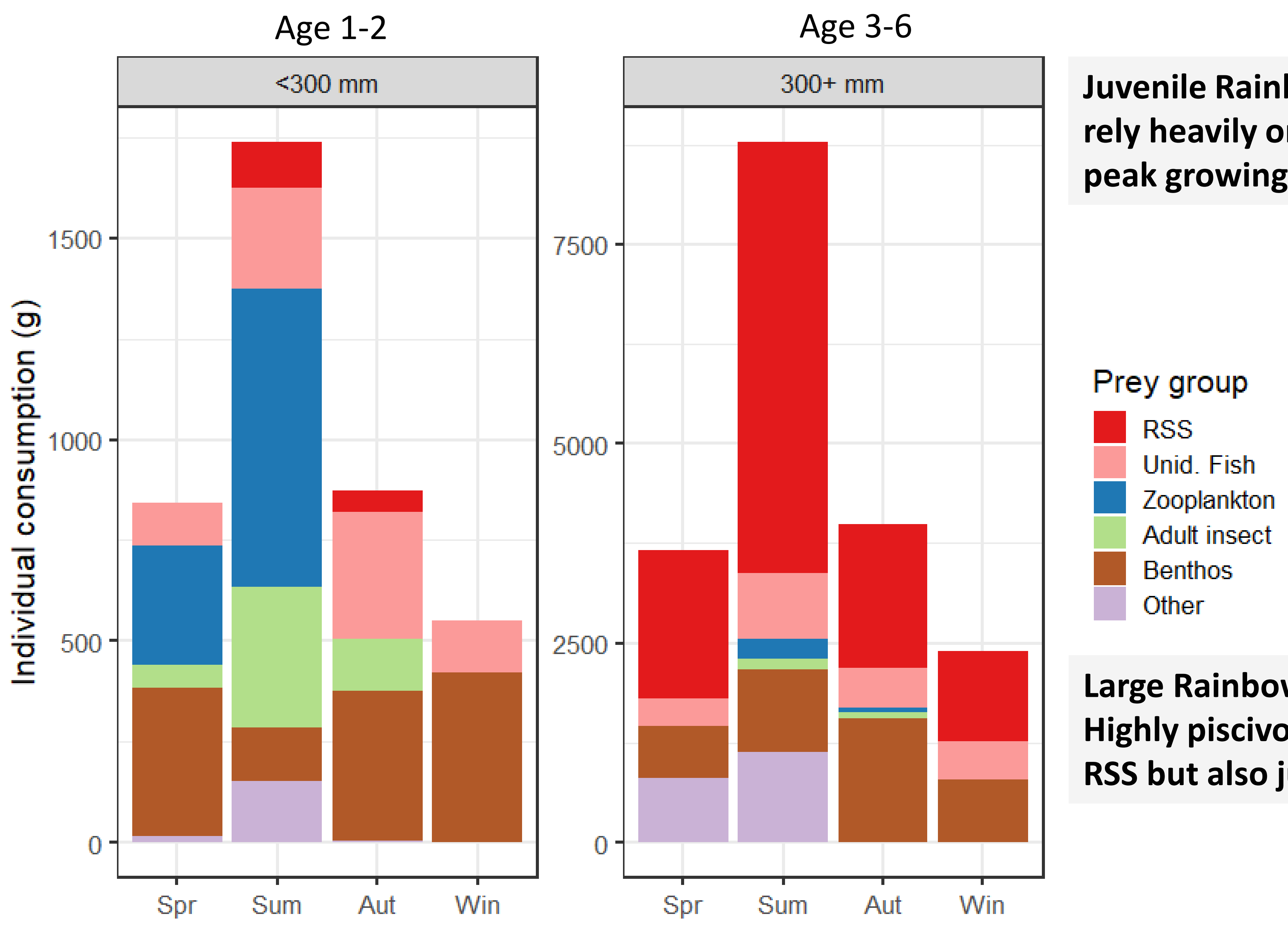
Propensity for Tributary versus Reservoir Rearing by Anadromous Salmonid Species

- Sockeye- “Obligate” lake-rearing from fry emergence to smolt
- Chinook (Ocean & Stream-type)- Variable use of stream and lake/reservoir habitats
  - ~immediate fry migration & rearing in lake (e.g., NF Clackamas, Lakes Washington, Quinault, Willamette reservoirs)
  - Delayed entry and Lake rearing (Washington, Wenatchee, etc.)
  - Smolts rear in streams and simply migrate through lakes/reservoirs
- Coho- Primarily stream-rearing, but common in inundated zones of lakes and reservoirs (e.g. NF Clackamas)
- Steelhead- Primarily stream-rearing
- Pink & Chum- Typically stream-rearing with close/easy access to estuary
  - One rare case of lake-rearing pink salmon reported in AK

Temporal Food Supply/Carrying Capacity in Reservoirs-Zooplankton

- Monthly depth-stratified *Daphnia* density, biomass & Production during growing season
- Estimate monthly consumption demand by existing consumers (mostly Redside Shiners, juvenile trout & char)
- Estimate monthly consumption demand v Prey supply under different scenarios:
  - accessibility to epilimnion due to thermal barriers
  - different levels of risk associated with assumptions for surplus capacity & uncertainty

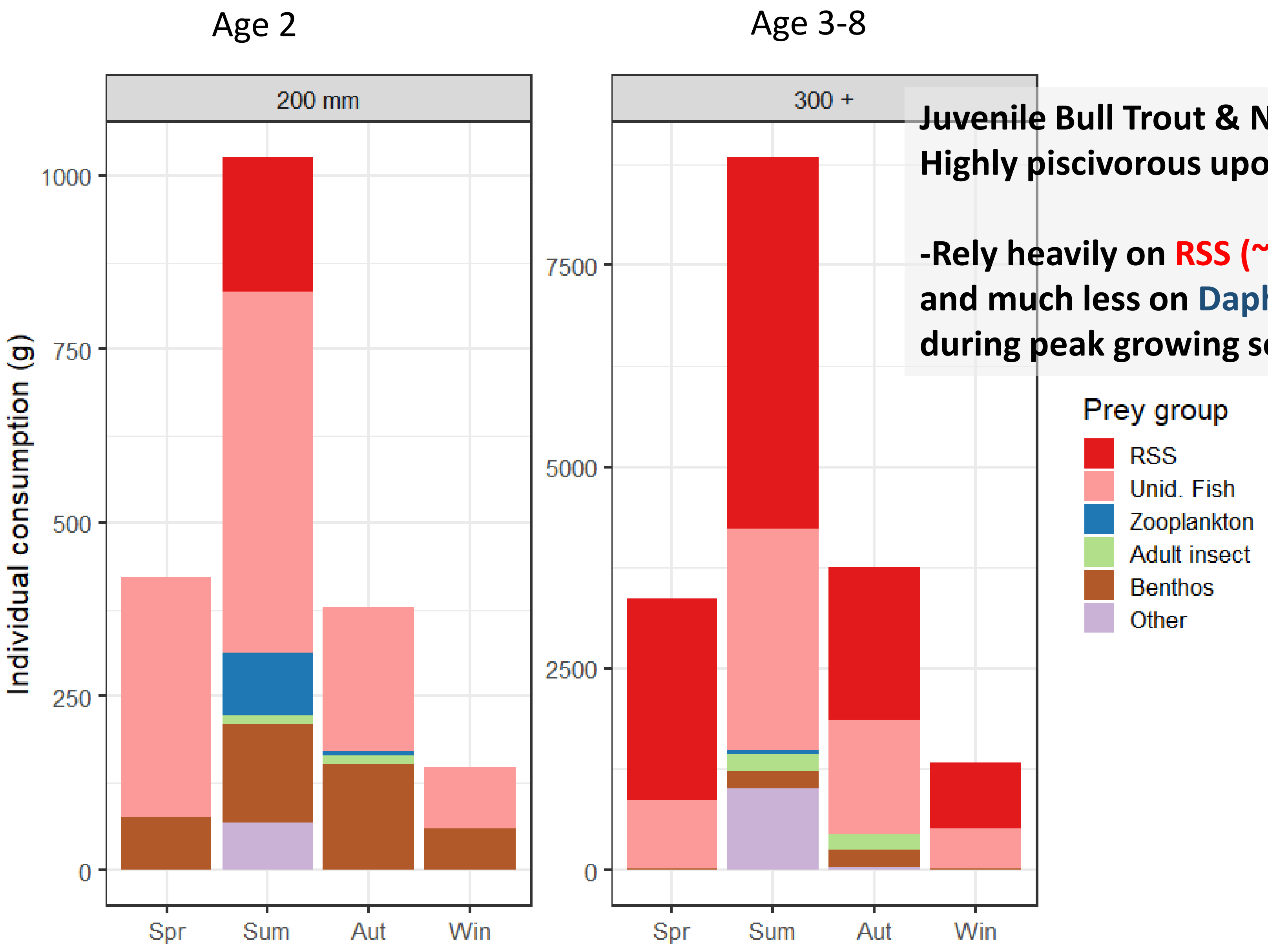
Rainbow trout individual consumption (pooled within size classes)



Juvenile Rainbow Trout (FL < 300 mm) rely heavily on Daphnia & Benthos during peak growing season ~80% of energy budget

Large Rainbow Trout (FL ≥ 300 mm) are Highly piscivorous, feeding predominantly on RSS but also juvenile salmonids

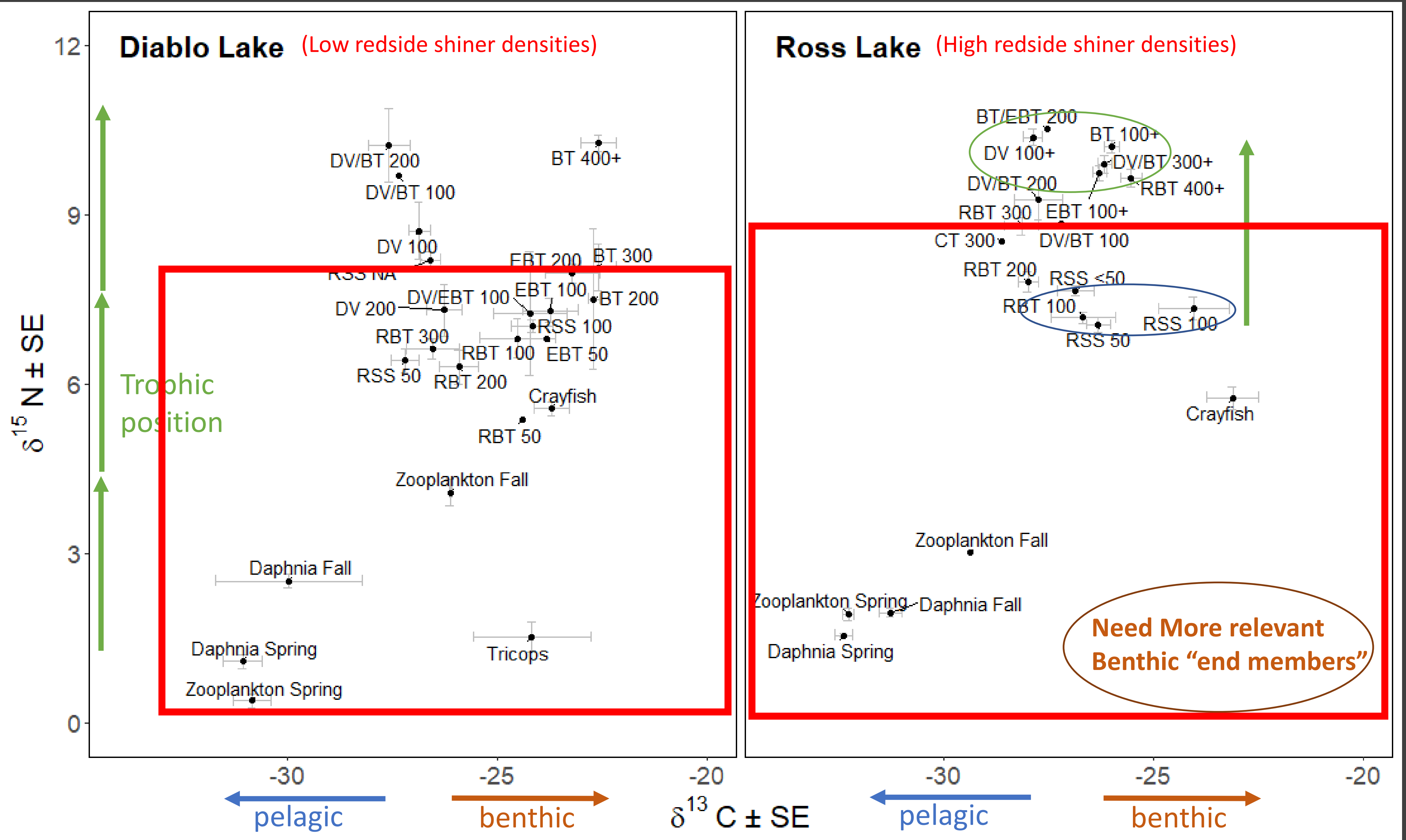
Bull trout individual consumption (pooled within size classes)



Juvenile Bull Trout & NC (FL < 300 mm) are already Highly piscivorous upon lake entry.

-Rely heavily on RSS (~70% of energy budget) and much less on Daphnia (~5%) & Benthos (~20%) during peak growing season

Food web structure: stable isotopes



Estimating Predation Mortality or Seasonal Food Supply:Demand

Temporal Diet Composition

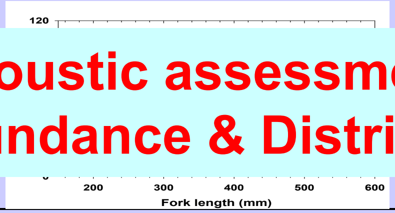
Consumer Growth

Predator Energy Density

Prey Energy Density

Thermal Experience

Bioenergetics Model



Hydroacoustic assessment of RSS Abundance & Distribution

Consumer Size Structure & Abundance

Consumption Estimate

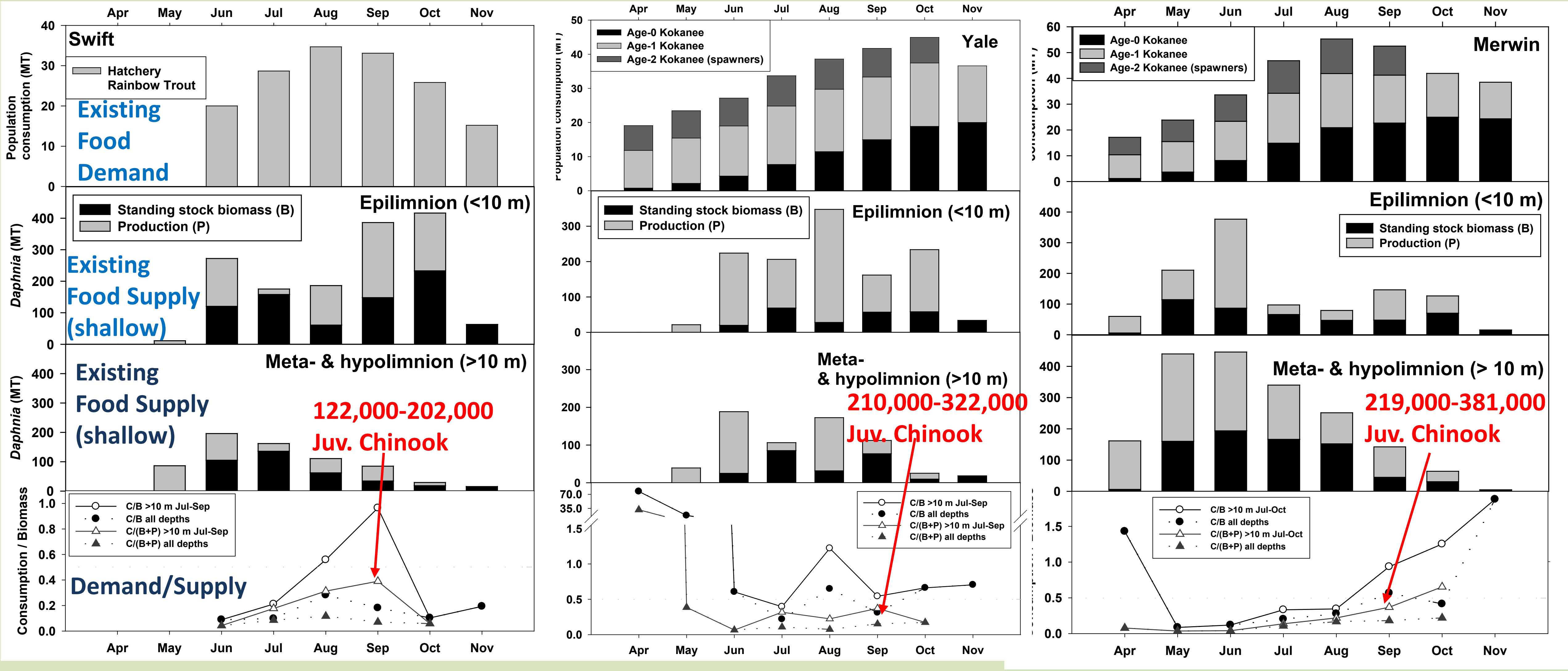
Population Consumption

Monthly Daphnia biomass & Prod By depth interval

Monthly Demand/Supply for *Daphnia* by depth interval

Seasonal Carrying Capacity of Lewis River Reservoirs:

Surplus Capacity Available for Additional Anadromous Salmonids (N fry entering)

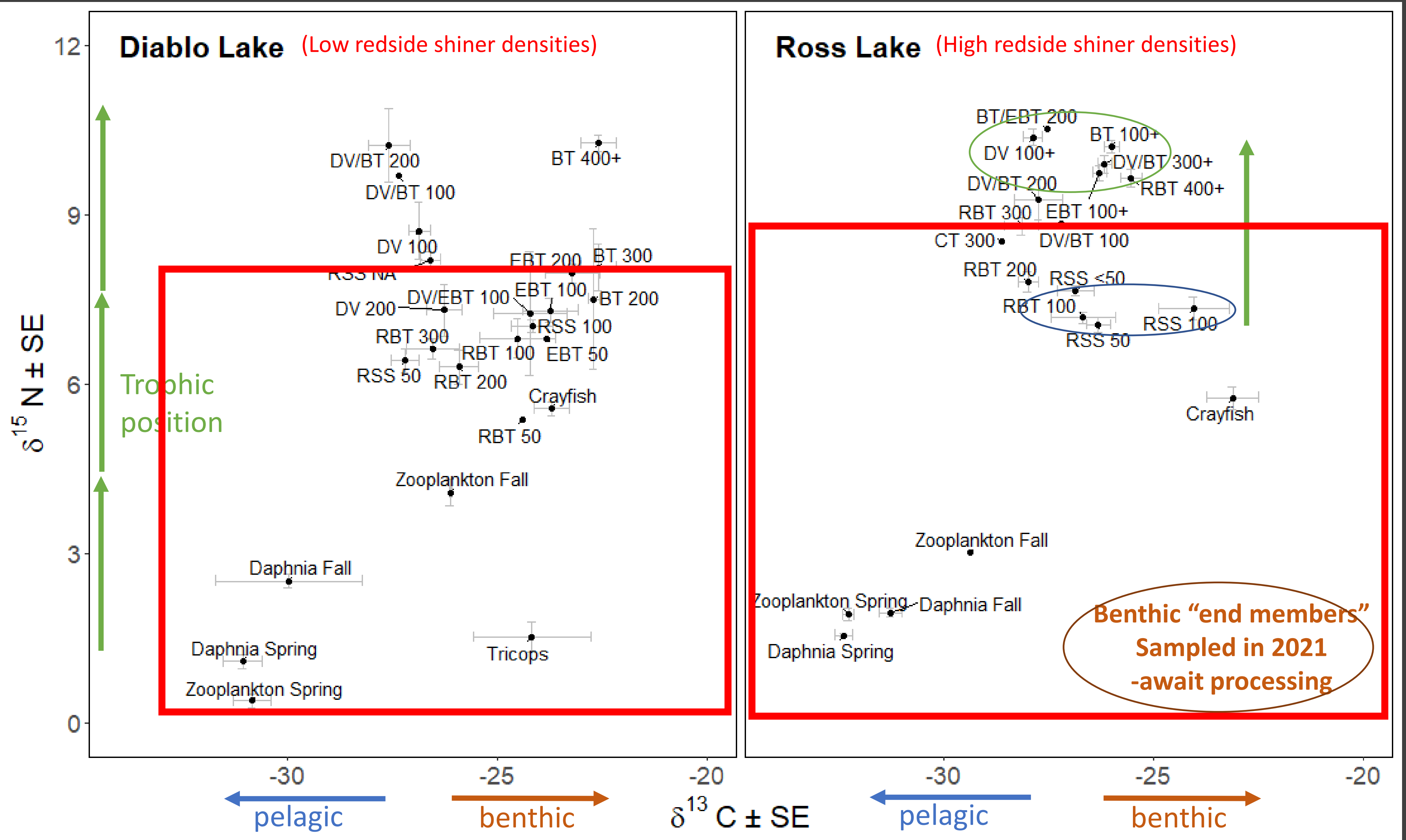


Sorel et al. 2016 TAFS 145:1331-1347

Temporal Food Supply/Carrying Capacity in Reservoirs: Benthic Macroinvertebrates

- **Benthic Macroinvertebrate Sampling**
  - **Objectives: provide representative samples for stable isotope values of benthic prey in reservoirs**
  - **Baited benthic traps, Ponar Grabs, miscellaneous methods**
  - **Remainder beyond current scope, thus shifted to FA-01**
- **Stable Isotope supplemental sampling: 2020 v 2021 samples:**
  - **Collect a strategic subsample of key consumers in the reservoir (juv Rainbow Trout, different size classes of RSS, Adult trout and char) to verify that the new benthic samples & vertebrate consumers map onto similar trophic positions in del C13 & del N15 space**

Food web structure: stable isotopes



Gorge Reservoir Food Web Challenges

- Flowing water habitat, unstratified, unlike Ross & Diablo
  - Different thermal structure & prey community (benthos & fish prey)
- Stocked rainbow trout
  - Complicates estimates of natural age & growth as bioenergetic inputs
  - Complicates use of stable isotopes as surrogates for diet (residual signal from hatchery feeding remains until after significant growth on natural prey occurs)
- USGS did not sample Gorge, so all data and samples would either need to come from NOCA or be generated via new dedicated field sampling
- NOCA has tentatively agreed to allow use of their samples & data

Gorge Food Web feasibility analysis for supporting introduced anadromous salmonids

- Options depend on accessibility & inventory of NOCA fish samples
  - Focus on Rainbow trout as surrogates for juv salmon, but need to account for hatchery effects on age & growth, stable isotopes
  - Only use stable isotopes for fish that have >2x Body Wt at release
  - Screen scale-based size-at-age for hatchery anomalies
  - Use July diets if available to supplement SIA
- Bioenergetics analysis of growth performance & consumption demand under ambient thermal regime & prey availability
  - Use fitted feeding rate to assess probable growth potential for additional anadromous salmonid production
  - Potentially deploy drift samples in reservoir margins to gain crude evaluation of food supply & quality for reservoir rearing salmonids
  - Potential predation losses for rearing or migrant salmonids?

FA-07 TRIBUTARY HABITAT ASSESSMENT

Estimate Juvenile Rearing Capacity in Tributaries

P. Roni and H. Berge | October 25, 2021

SCOPE – OBJECTIVES OF FA-07

- Intrinsic Potential modeling to identify reaches that have the potential to support spawning and rearing salmonids (J. Duda USGS).

- **Estimate juvenile rearing habitat capacity (production potential) in tributary reaches identified by Intrinsic Potential modeling to be potentially suitable for the target species.**

- Evaluate habitat capacity/production potential in the context of the ongoing Food Web Study results (D. Beauchamp USGS).

MAJOR TYPES OF FISH-HABITAT MODEL

- Limiting factors/Capacity
  - Habitat area and fish density
  - QRF, FDAT
- Habitat suitability (PHABSIM, HSI)
  - Requires hydraulic model
- Net rate of energy intake (NREI)
  - HSI with food web component
- Ecosystem diagnosis & treatment (EDT)
- Life-cycle models
  - HARP is latest)

Model complexity

MAJOR TYPES OF FISH-HABITAT MODEL

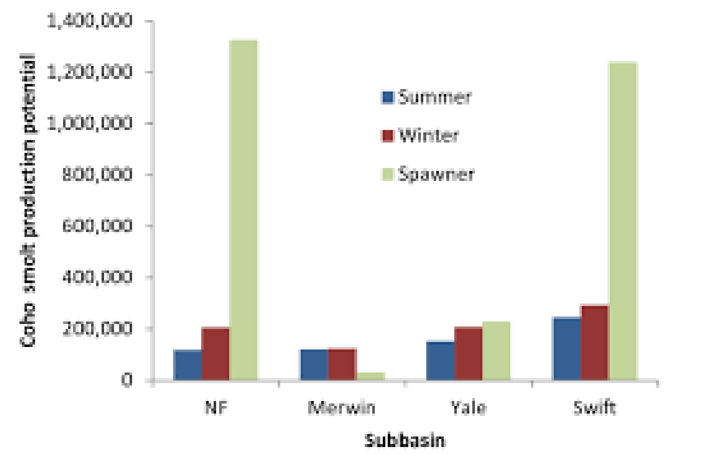
Which model is most appropriate depends in part upon

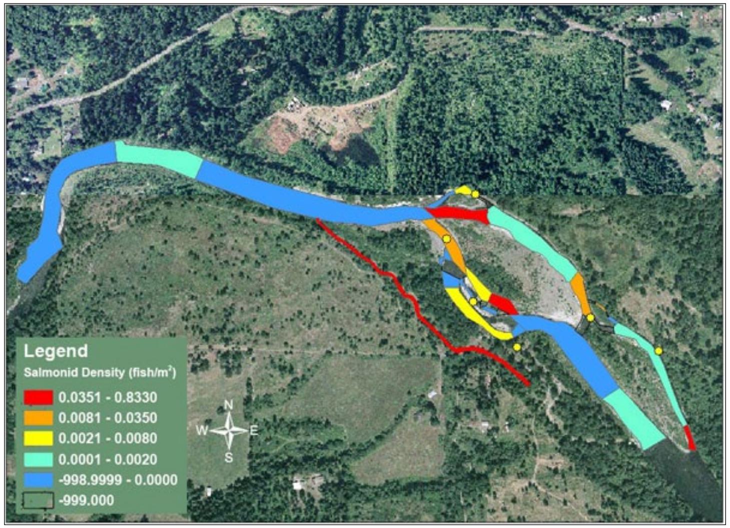
1. Goals and objectives
2. Questions
3. Need for transparency
4. Data and resources

Model complexity

LIMITING FACTORS/CAPACITY MODELS

- Limiting factors/capacity
  - Reeves et 1989
  - Beechie et al. 1994
  - Nickelson et al. 1994
  - Cramer and Ackerman 2009*
  - Roni and Timm 2016
  - Cooper et al. 2020*
- *UCM applied to Chinook, coho, steelhead, cutthroat, and bull trout



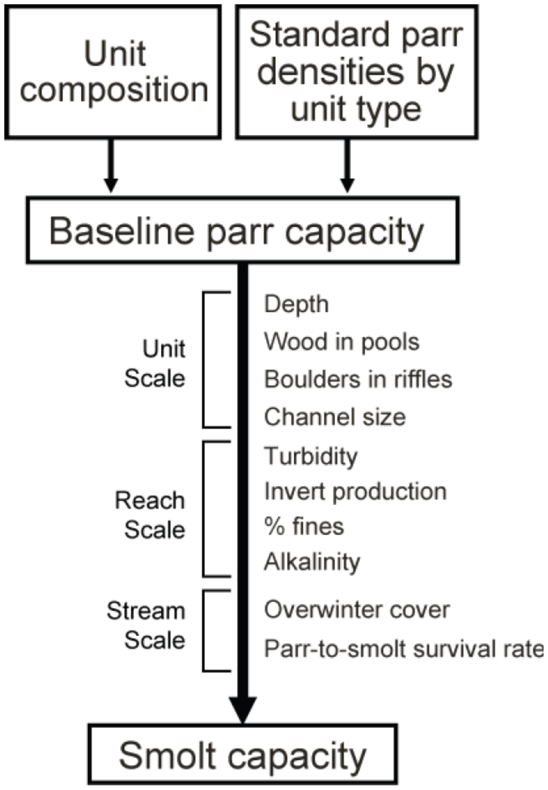


ADVANTAGES OF UCM (UNIT CHARACTERISTIC METHOD)

- Habitat-based (uses standard survey data)
- Can be modified based on available information
- Transparent data and calculations
- Has been done for many species
- Capacity estimates serve as input into more complex basin-wide life-cycle models (NOAA HARP)
- Has been linked to intrinsic potential and bioenergetics in other systems
- Like all models – it does have its limitations
  (e.g., scale, data and scalar inputs, linking of populations)

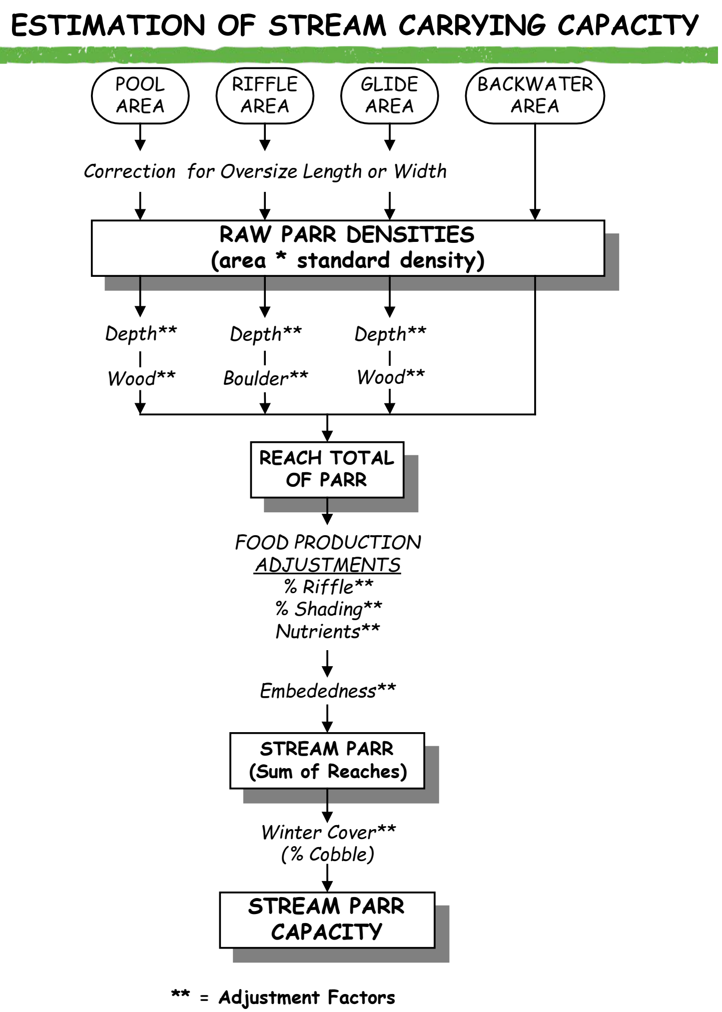
UCM OVERVIEW

- Within habitat unit amount of depth, cover, substrate have been shown to influence density/capacity
- Based on literature, assigns density based on habitat unit
- Adjusts those densities based on depth, substrate, cover
- Further adjusted based on temperature, nutrients, drift or other factors available



DATA NEEDS

- Habitat data
  - Need to collect
- Density and scalar data
  - Cramer and Ackerman 2007; Cooper et al. 2020, etc.



NEXT STEPS

- Confirm extent of distribution in each stream (USGS)
- Confirm factors to be included in UCM
- Modify habitat surveys to ensure
    - proper data collection (modify Level II or similar)
    - confirm barriers and extent of fish habitat
- Update density and scalars/preference curves based on more recent or local data
- Data collection
- Analysis and modeling

POTENTIAL MODIFICATIONS

- Local fish data – could collect if not available
- Literature review to update densities, scalars, or include addition factors
- Data needed for bioenergetics or linking to bioenergetics
- Ultimately, want to ensure data collection that allows most flexibility for UCM modeling

INTEGRATING FOOD WEB AND CAPACITY ESTIMATES

- Capacity model outputs
  - summer, winter, and spawner capacity
  - smolt production
  - parr migrants
- UCM can incorporate drift and temperature
- Opportunity to collect additional data for tributary bioenergetics during habitat surveys
- Link to bioenergetics to determine if adequate food resources to support migrants in reservoir
- Capacity required input into more complex life cycle model

Seattle City Light

QUESTIONS

2A-Intrinsic Potential (IP) modeling with NetMap-*An assessment of habitat suitability for salmonids across selected tributaries upstream of the Skagit River dams*

Jeff Duda, Jill Hardiman

U.S. Geological Survey, Western Fisheries Research Center

Jeff Fisher

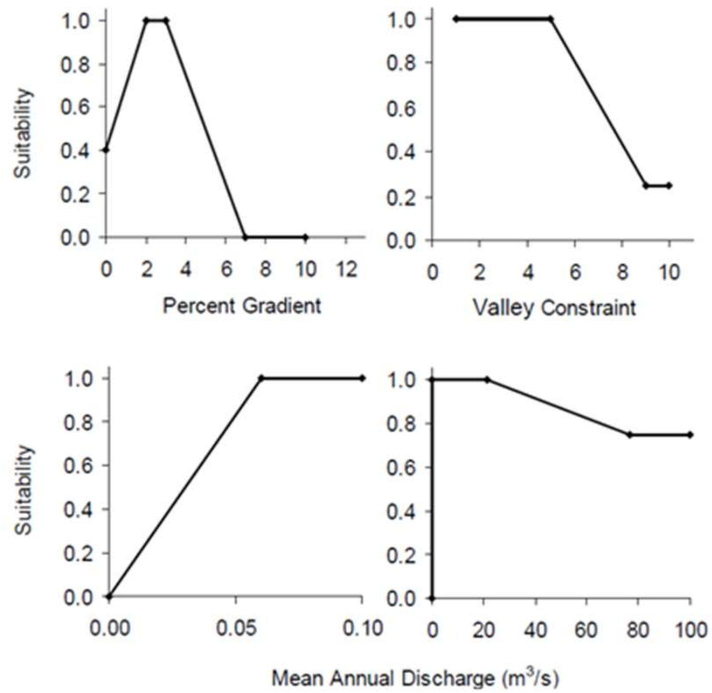
Seattle City Light

Outline

- Background on IP modeling approach
- First pass at creating IP distribution and running example IP model
  - Criteria for anadromous fish distribution – identifying potential natural barriers
  - Summary of fish distribution in US and Canada
- IP Model results
  - Steelhead example
- 20-m DEM, 10-m DEM and LiDAR

Intrinsic Potential (IP) Background

- IP models are a type of habitat suitability model used to identify stream reaches with potential to host a particular fish species
- Framework focuses on landscape features not easily modified by human influence (i.e., historical conditions).
- Uses relationships between these features and habitat preferences to create species or life-stage specific index curves
- Intended for broad scale assessments



Intrinsic Potential (IP) Background

- Parameterized IP models exist for several target species
- Most commonly used for Steelhead, Coho, and Chinook in the Pacific Northwest and California
- Pink and Chum parameterized for AK populations

Species	IP Model	Region	Gradient	Confinement	Discharge[1]	Other
Steelhead	Barnett 2007	PNW - OR	Yes	Yes	Yes	
	PSTRT	PNW - WA	Yes			Bankfull
	Agrawal 2005	N. CA	Yes	Yes	Yes	
	Waldo et al. 2013	PNW-WA	Yes		Yes	
	Cooney and Holzer 2006	PNW-WA	Yes	Yes	Yes	Bankfull
Coho	Barnett 2007	PNW-OR				
	Agrawal 2005		Yes	Yes	Yes	
	Romey 2018	AK	Yes	Yes	Yes	
Chinook	Agrawal 2005		Yes	Yes	Yes	
	Bidlack et al 2014	AK	Yes	No	Yes	% Glaciated
	Cooper et al 2020	N. CA	Yes	Yes	Yes	
	Connor et al 2015	PNW-WA	Yes	No	No	Bankfull, Mean elevation
	Cooney and Holzer 2006	PNW-WA	Yes	Yes	No	Bankfull
Chum	Romey 2018	AK	Yes	Yes	Yes	
Pink	Romey 2018	AK	Yes	Yes	Yes	

Basics of NETMAP

- NETMAP virtual watershed creates analytic stream network.
- Stream flow direction determined for each DEM-Based cell (i.e. nodes) and its neighbors
- Stream reaches ~ 100 m in length, but varies due to breaks at tributary junctions and gradient thresholds.

Netmap

GIS-based numerical models + DEM

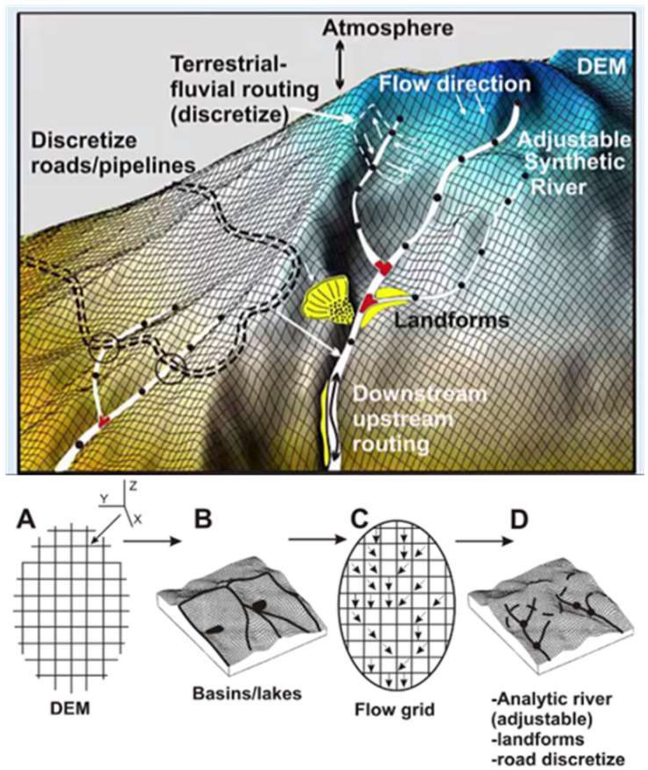


Image: Terrainworks

Basics of NETMAP

- Channel nodes based on smoothed flow paths based on the D-8 flow path (i.e., the flow direction based from each cell based on its 8 neighbors towards the steepest downslope neighbor).
- Channel nodes linked to adjacent upstream and downstream nodes in the channel network.
- Each node has a flow length and attributes (e.g., elevation, drop)
- Data attributes can be assigned to reaches derived solely from the DEM

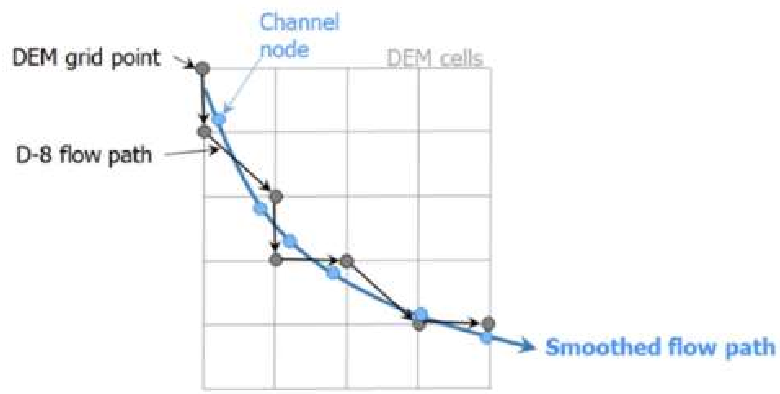
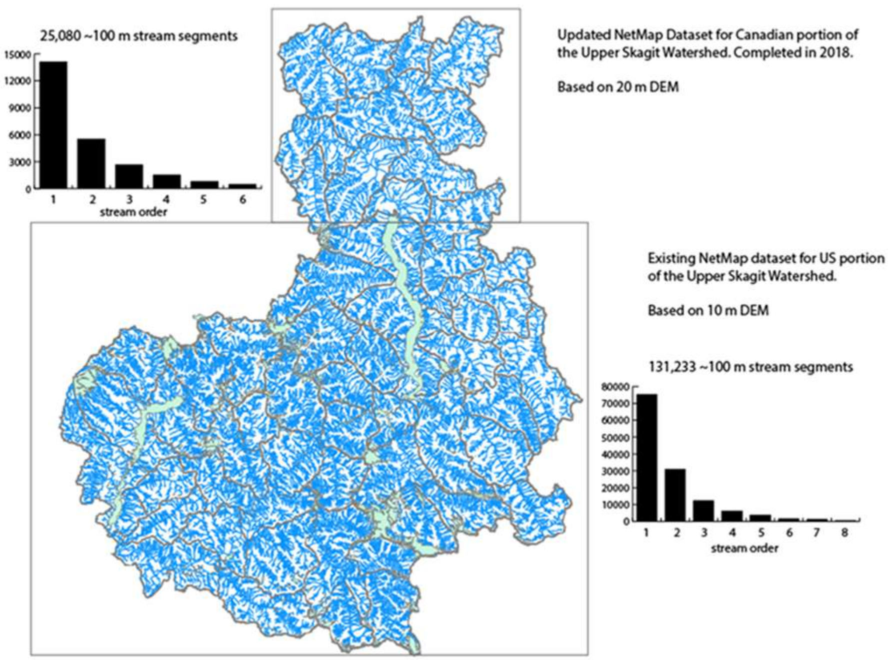


Image: Terrainworks

NETMAP: Upper Skagit

- US portion of Upper Skagit based on 10-m DEM
- Canadian portion built for this project with existing Canadian 20-m DEM
- Apply existing Intrinsic Potential Models to fish distribution to create maps of potential fish habitat upstream of Upper Skagit River dams.



Analysis Steps

1. Create potential anadromous fish distribution for tributaries upstream of Skagit Dams
2. Assess potential natural barriers based on Gradient thresholds and node elevation drops
3. Assess fish distribution with IP models applied to streams of interest (i.e., Tables 1 and 2 in Study Plan).

Table 1. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS, used with permission)

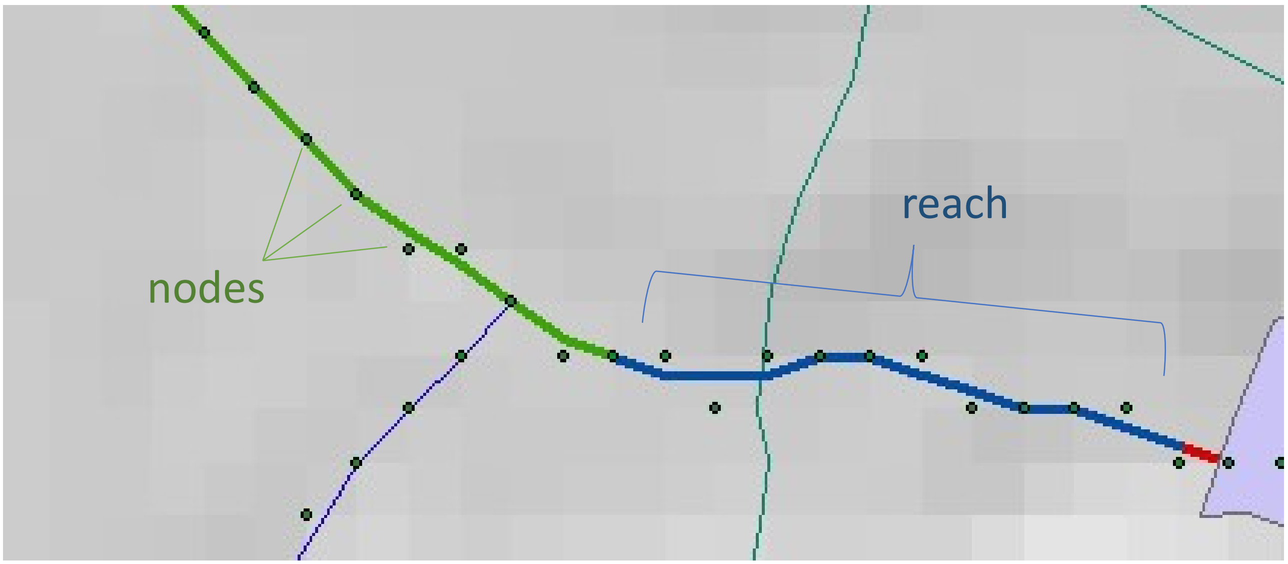
Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Skagit River	Ross to Klesilkwa	17.5	<1
	Klesilkwa to barrier falls near Snass	17.1	<1
Klesilkwa River	Skagit to Silverhope divide	14.3	<1
Sumallo River	Skagit to Ferguson	16.6	<1
Ferguson Creek	Sumallo R. to HWY3	3.9	2
Nepopekum Creek	Skagit to start of canyon	2.7	3
Nepopekum Creek	Start of Canyon to Poland cr.	9.3	5
Sumallo River	Ferguson to end 3rd order	12.1	5
Maselpanik Creek	Klesilkwa to end 3rd order	12.2	6
Snass Creek	Skagit R. to Dry Lake	3.9	6
Ferguson Creek	Hwy 3 to end 3rd order	3.7	9
Klesilkwa River	Silverhope Divide to end 3rd order	3.7	10
Twentysix Mile Creek	Skagit River to end 3rd order	5.8	11
Marmotte Creek	Marmotte Creek to end 3rd order	4.3	12

Table 2. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS, used with permission)

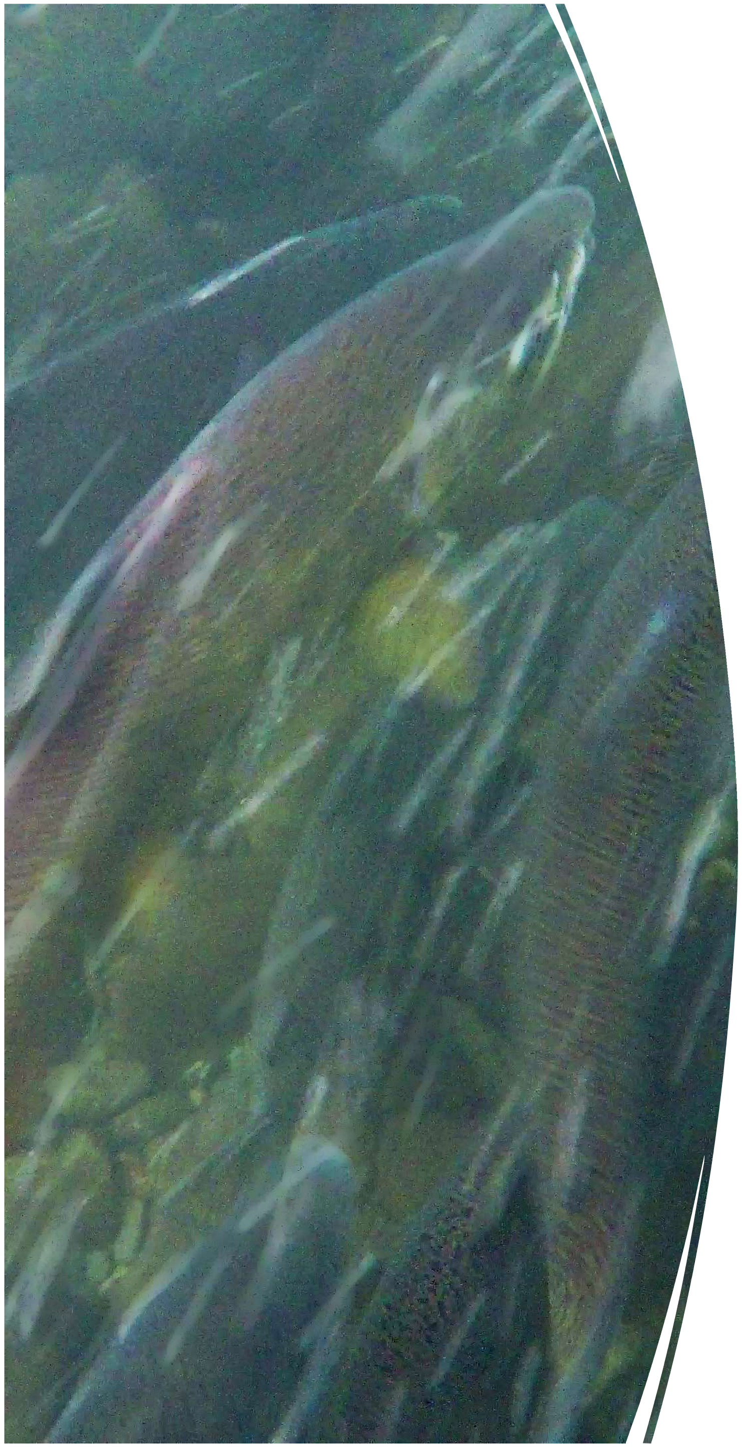
Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Big Beaver Creek	Ross to McMillan	14.6	<1
Ruby Creek	Ross to Canyon/Granite Confluence	5.5	2
Canyon Creek	Ruby to Slate Creek	11.9	2
Lightning Creek	Ross to Three Fools	3.5	2
Lightning Creek	Three Fools to Freezeout	8.8	2
Little Beaver Creek	Ross to end 3rd order	24.2	2
Granite Creek	Ruby to "indistinct barrier"	8.6	4
Luna Creek	Big Beaver to end 3rd order	4.5	4
Lightning Creek	Freezeout to Boundary	6.3	4
Three Fools Creek	Lightning to Castle	10.1	4
Castle Creek	Three Fools to Rustle	5.8	9
Canyon Creek	Slate to "barrier falls"	4.2	7
NF Canyon Creek	Canyon to "barrier falls"	1.0	7
East Creek	Granite to end 3rd order	6.9	12
Cabinet Creek	Granite to end 3rd order	3.2	13

+ Hozomeen, McMillan, Devil's

Extracting variables from the 'analytic river network'



Node Attributes	Reach attributes (examples)
Elevation	Gradient
DROP = potential barriers/waterfalls	Elevation
	Channel width and depth
	Shear stress
	Bed substrate
	Drainage area upstream



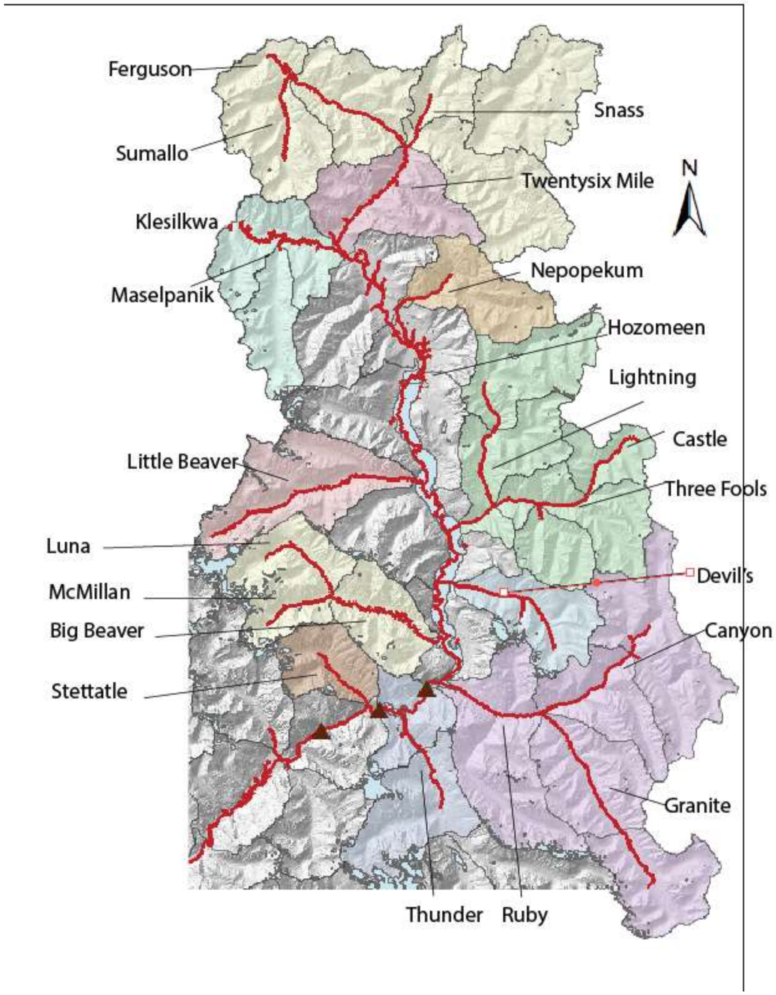
Creating potential anadromous fish distribution

- Use NETMAP virtual watershed and analysis tools to create ArcGIS stream layers
- Create 'end of anadromy' fish distribution based on simple rule-based criteria

Identifying potential natural barriers

- Natural fish passage barrier assessment estimated from reach gradient and node drops.
- Gradient: Gradient assessed at window of 69 m. All reaches with average gradient < 0.20 included.
- Node Drop: Node value >3.7 m in height

Anadromous fish distribution



Proposed potential anadromous fish distribution based on reaches with Gradient ≤ 0.20 and Node Drop ≤ 3.7 m *

*Some nodes > 3.7 m bypassed in order to extend distribution upstream.
*Most removed nodes with drops < 10 m single, isolated nodes.

Provisional data subject to change and not for distribution or attribution

BC Upper Skagit anadromous fish distribution

Table 1. British Columbia streams with accessible habitat to fish from Ross Reservoir (NPS)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Skagit River	Ross to Klesilkwa	17.6	<1
	Klesilkwa to barrier falls near Snass	17.1	<1
Klesilkwa	Skagit to Silverhope divide	14.3	<1
Sumallo	Skagit to Ferguson	16.6	<1
Ferguson Creek	Sumallo R. to HWY3	3.9	2
Nepopekum Creek	Skagit to start of canyon	2.7	3
Nepopekum Creek	Start of Canyon to Poland cr.	9.3	5
Sumallo River	Ferguson to end 3rd order	12.1	5
Maselpanik Creek	Klesilkwa to end 3rd order	12.2	6
Snass Creek	Skagit R. to Dry Lake	3.7	6
Ferguson Creek	Hwy 3 to end 3rd order	3.7	9
Klesilkwa	Silverhope Divide to end 3rd order	3.7	10
Twentysix Mile Creek	Skagit River to end 3rd order	5.8	11
Marmotte Creek	Marmotte Creek to end 3rd order	4.3	12

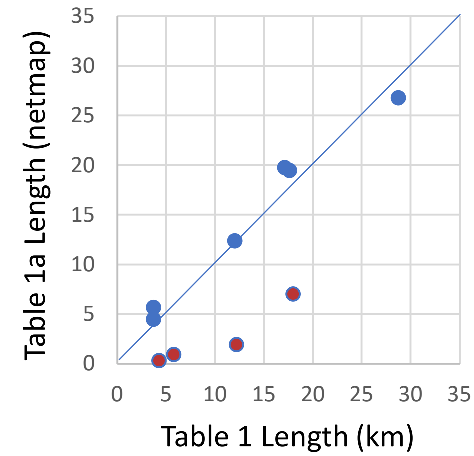
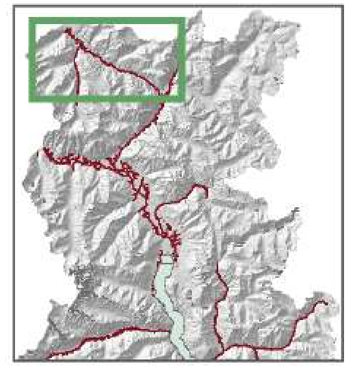


Table 1a. British Columbia streams with accessible habitat to anadromous fish from Ross Reservoir (NPS).

Subbasin	Stream Name	Reach Description	Total Length (km)	Ave. Width m ± SD (range)	Ave. Gradient % ± SD (range)	Ave. Annual Discharge (cms)
BC Skagit	Skagit Mainstem	Ross to Klesilkwa	19.5	26.2 ± 1.1 (24.2 – 28.2)	0.003 ± 0.004 (0 – 0.025)	16.7 ± 1.5 (14.1 – 19.8)
	Skagit Mainstem	Klesilkwa to potential barrier	19.8	20.2 ± 2.2 (14.0 – 22.0)	0.007 ± 0.001 (0 – 0.045)	9.6 ± 2.1 (4.2 – 11.4)
	Nepopekum Creek	Skagit to potential barrier (8.6 m drop)	12.4	8.8 ± 0.3 (8.1 – 9.2)	0.03 ± 2.2 (0 – 0.14)	1.5 ± 0.1 (1.2 – 1.6)
	Snass Creek	Snass to potential barrier (14.6 m drop)	4.5	6.8 ± 0.9 (5.1 – 7.6)	0.05 ± 0.04 (0 – 0.16)	0.9 ± 0.2 (0.4 – 1.1)
	Twentysix Mile Creek	Skagit to potential barrier (10.0 m drop)	0.9	6.4 ± 0.03 (6.3 – 6.4)	0.10 ± 0.03 (0.04 – 0.13)	0.7 ± 0.01 (0.72 – 0.74)
	Marmotte Creek	Skagit to potential barrier (8.6 m drop)	0.3	4.8 ± 0.01 (4.7 – 4.8)	0.07 ± 0.01 (0.05 – 0.08)	0.4 ± 0.001 (0.38 – 0.38)
Klesilkwa	Klesilkwa River	Skagit to Silverhope	7.0*	5.5 ± 1.11 (3.1 – 7.1)	0.003 ± 0.005 (0 – 0.03)	0.6 ± 0.22 (0.14 – 0.94)
	Maselpanik Creek	Klesilkwa to potential barrier (16.7 m drop)	1.9	10.8 ± 0.2 (10.3 – 11.1)	0.07 ± 0.04 (0.01 – 0.13)	2.4 ± 0.09 (2.1 – 2.5)
Sumallo	Sumallo River	Skagit to potential barrier	26.8	11.2 ± 2.7 (4.6 – 7.0)	0.01 ± 0.02 (0.0 – 0.08)	2.7 ± 1.3 (0.5 – 4.5)
	Ferguson Creek	Sumallo to potential barrier	5.7	5.6 ± 0.6 (5.4 – 14.5)	0.01 ± 0.02 (0.0 – 0.09)	0.6 ± 0.13 (0.4 – 0.9)

Provisional data subject to change and not for distribution or attribution

BC Example ‘end of fish’ distribution



Ferguson Creek

Tributary of the Sumallo River

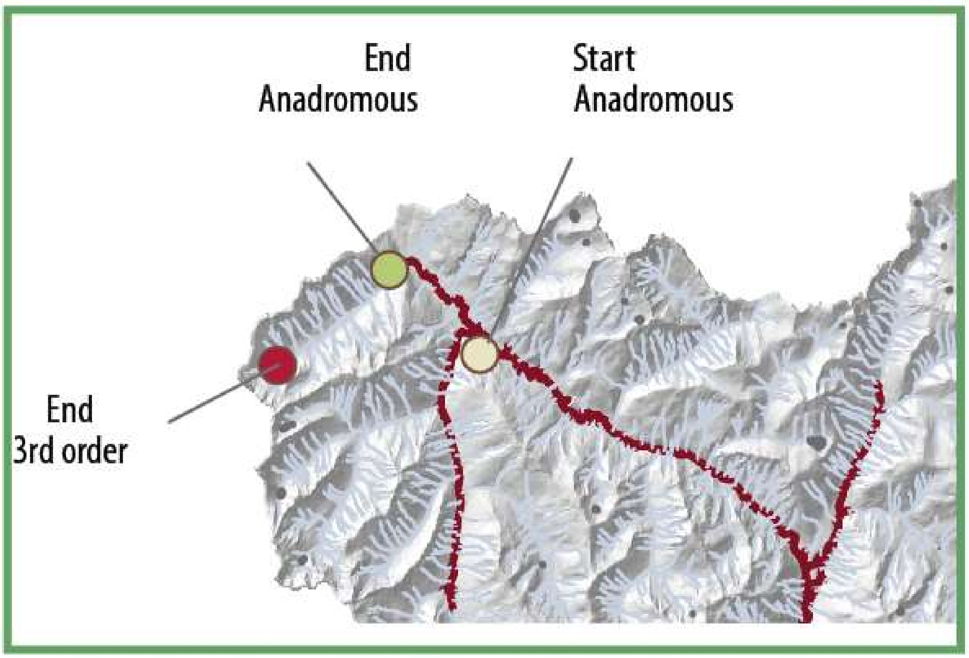
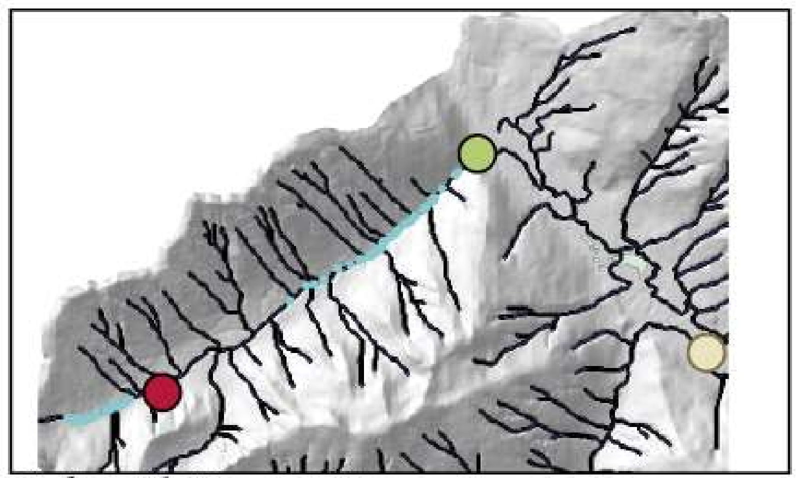


Fig. 1. Potential anadromous fish distribution (in red) of Ferguson Creek

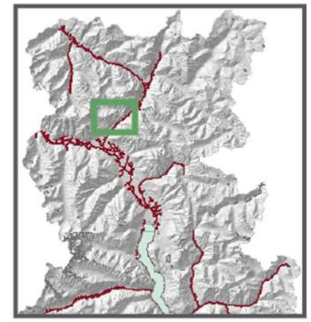


Nodes with Drops ≥ 3.7 m

n = 104; Range = 4.1 m to 85.7 m; first = 8.2 m

Fig. 3. Map of potential barriers ≥ 3.7 m

BC Example ‘end of fish’ distribution



Marmotte Creek

Tributary to the Skagit River

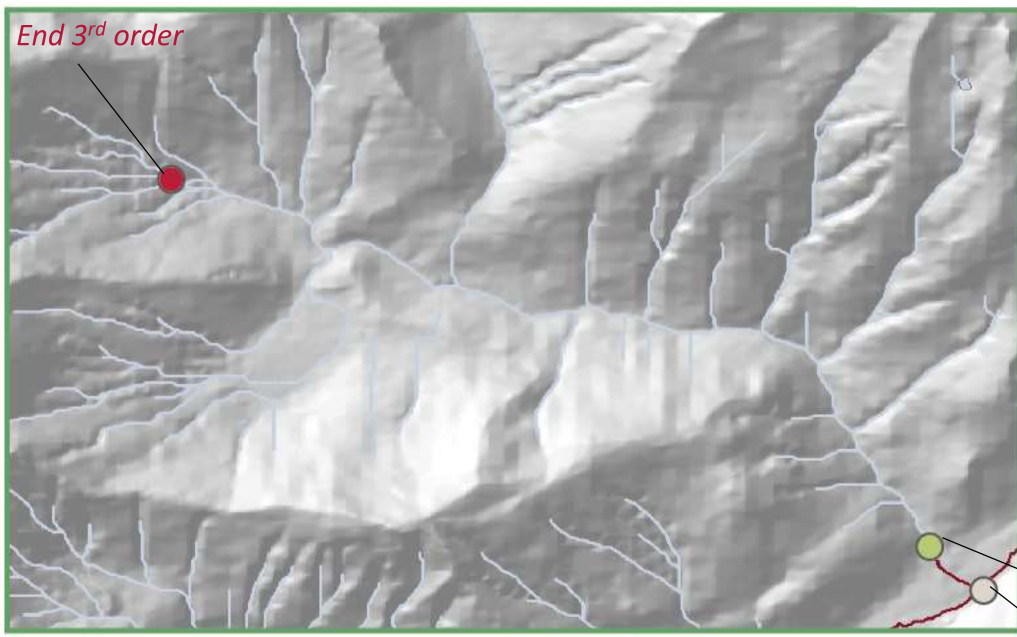
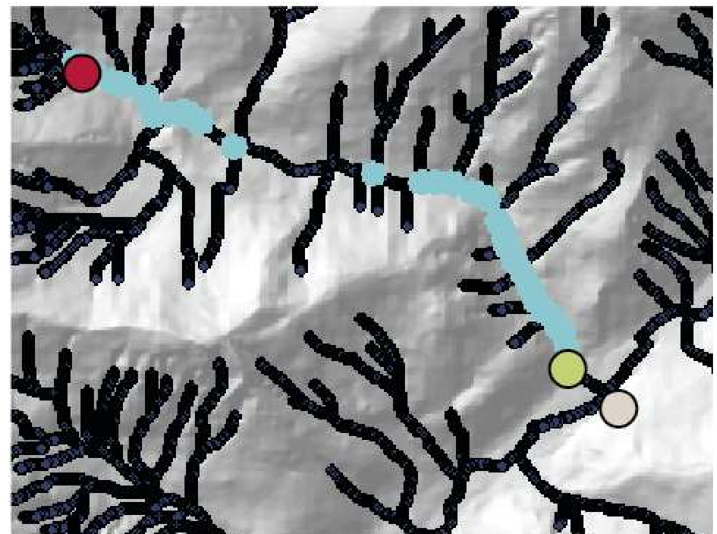


Fig. 1. Potential anadromous fish distribution (in red) of Marmotte Creek.

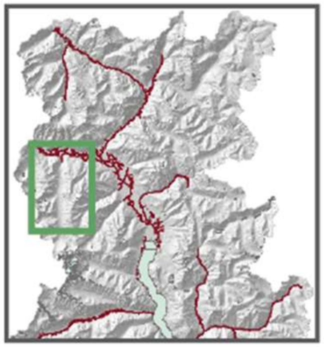


Nodes with Drops ≥ 3.7 m

n = 103; Range = 3.9 m to 22.1; first = 8.5 (n=2)

Fig. 3. Map of potential barriers ≥ 3.7 m

BC Example 'end of fish' distribution



Maselpanik
Tributary to the Klesilkwa River

Fig. 1. Potential anadromous fish distribution (in red) of Maselpanik Creek

Nodes with Drops ≥ 3.7 m
n = 212; Range = 3.8 m to 501.3 m; first = 16.7 m

U.S. Skagit anadromous fish distribution

Table 1. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Big Beaver Creek	Ross to McMillan	14.6	<1
Ruby Creek	Ross to Canyon/Granite Confluence	5.5	2
Canyon Creek	Ruby to Slate Creek	11.9	2
Lightning Creek	Ross to Three Fools	3.5	2
Lightning Creek	Three Fools to Freezeout	8.8	2
Little Beaver Creek	Ross to end 3rd order	24.2	2
Granite Creek	Ruby to “indistinct barrier”	8.6	4
Luna Creek	Big Beaver to end 3rd order	4.5	4
Lightning Creek	Freezeout to Boundary	6.3	4
Three Fools Creek	Lightning to Castle	10.1	4
Castle Creek	Three Fools to Rustle	5.8	9
Canyon Creek	Slate to “barrier falls”	4.2	7
NF Canyon Creek	Canyon to “barrier falls”	1.0	7
East Creek	Granite to end 3rd order	6.9	12
Cabinet Creek	Granite to end 3rd order	3.2	13

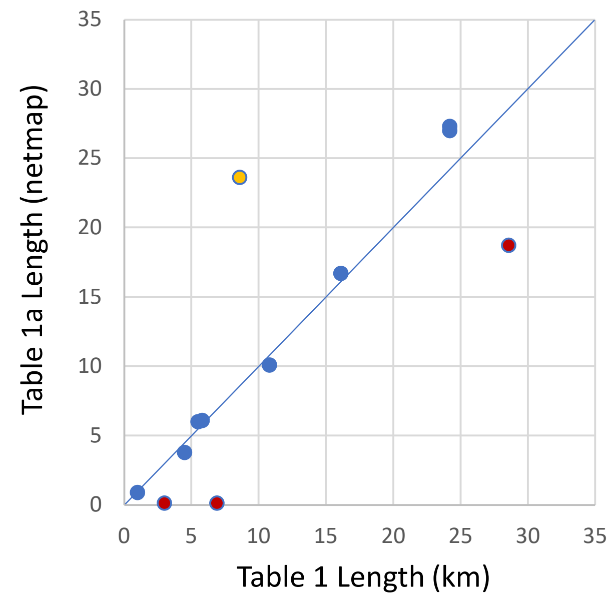


Table 1a. US Washington State streams with accessible habitat to anadromous fish from Ross Reservoir (NPS).

Subbasin	Stream Name	Reach Description	Total Length (km)	Ave. Width m ± SD (range)	Ave. Gradient % ± SD (range)	Ave. Annual Discharge (cms)
US Skagit	Hozomeen Creek	Ross to potential barrier	0.2	5.0 ± 0.01 (x – y)	0.15 ± 0.03 (x – y)	0.4 ± 0.002 (x – y)
Little Beaver	Little Beaver Creek	Ross Lake to end of 3rd order	27.3	12.4 ± 2.4 (6.5 – 16.6)	0.02 ± 0.02 (0.0 – 0.11)	3.4 ± 1.6 (0.8 – 6.1)
Big Beaver	Big Beaver Creek	Ross Lake to Luna Creek	27.0	15.0 ± 2.3 (9.8 – 17.9)	0.01 ± 0.02 (0.0 – 0.13)	5.4 ± 1.6 (1.9 – 7.2)
	McMillan Creek	Big Beaver Creek to potential barrier	8.1	8.2 ± 1.1 (5.5 – 9.6)	0.04 ± 0.03 (0.0 – 0.13)	1.3 ± 0.4 (0.5 – 1.8)
	Luna Creek	Big Beaver to potential barrier	3.8	9.1 ± 0.36 (8.3 – 9.8)	0.02 ± 0.02 (0.0 – 0.07)	1.6 ± 0.1 (1.3 – 1.9)
Lightning	Lightning Creek	Ross Lake to border creek	18.7	11.5 ± 2.8 (8.3 – 16.8)	0.03 ± 0.02 (0.01 – 0.11)	2.9 ± 1.6 (1.3 – 6.3)
	Three Fools Creek	Lightning Creek to Castle Fork Creek	10.8	10.6 ± 1.4 (7.9 – 12.3)	0.04 ± 0.02 (0.0 – 0.10)	2.3 ± 0.7 (1.2 – 3.1)
	Castle Fork	Three Fools Creek to Rustle Creek	6.1	5.8 ± 0.8 (4.6 – 6.7)	0.06 ± 0.02 (0.01 – 0.14)	0.6 ± 0.2 (0.4 – 0.8)

Provisional data subject to change and not for distribution or attribution

U.S. Skagit anadromous fish distribution

Table 1. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Big Beaver Creek	Ross to McMillan	14.6	<1
Ruby Creek	Ross to Canyon/Granite Confluence	5.5	2
Canyon Creek	Ruby to Slate Creek	11.9	2
Lightning Creek	Ross to Three Fools	3.5	2
Lightning Creek	Three Fools to Freezeout	8.8	2
Little Beaver Creek	Ross to end 3rd order	24.2	2
Granite Creek	Ruby to “indistinct barrier”	8.6	4
Luna Creek	Big Beaver to end 3rd order	4.5	4
Lightning Creek	Freezeout to Boundary	6.3	4
Three Fools Creek	Lightning to Castle	10.1	4
Castle Creek	Three Fools to Rustle	5.8	9
Canyon Creek	Slate to “barrier falls”	4.2	7
NF Canyon Creek	Canyon to “barrier falls”	1.0	7
East Creek	Granite to end 3rd order	6.9	12
Cabinet Creek	Granite to end 3rd order	3.2	13

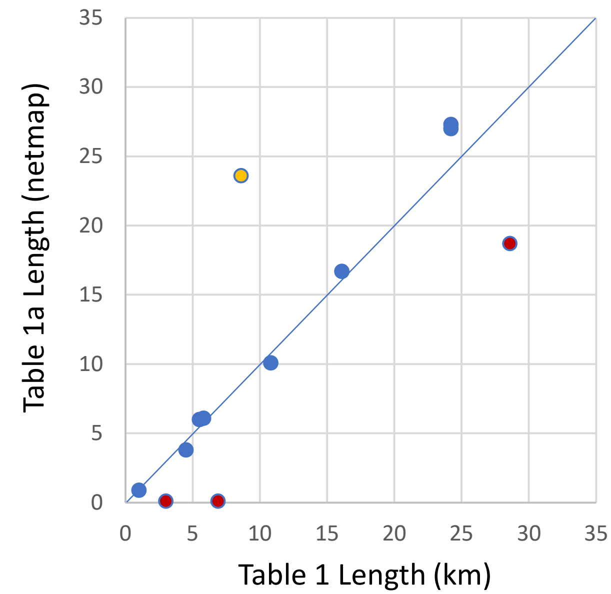


Table 1a. US Washington State streams with accessible habitat to anadromous fish from Ross Reservoir (NPS).

Subbasin	Stream Name	Reach Description	Total Length (km)	Ave. Width m ± SD (range)	Ave. Gradient % ± SD (range)	Ave. Annual Discharge (cms)
US Skagit	Ruby Creek	Ross Lake to Canyon Creek	6.0	16.6 ± 1.1 (18.6 – 22.1)	0.01 ± 0.004 (0.01 – 0.03)	8.8 ± 1.2 (7.8 – 11.6)
	Devil’s Creek	Ross Lake to potential barrier	14.3	7.4 ± 1.5 (3.7 – 9.1)	0.04 ± 0.02 (0.00 – 0.10)	1.1 ± 0.4 (0.2 – 1.6)
Canyon Creek	Canyon Creek	Ruby Creek to potential barrier	16.7	11.7 ± 2.6 (6.2 – 14.4)	0.03 ± 0.02 (0.0 – 0.12)	8.8 ± 1.2 (7.8 – 11.6)
	N.F. Canyon Creek	Canyon Creek to potential barrier	0.9	6.3 ± 0.2 (5.8 – 6.4)	0.09 ± 0.03 (0.06 – 0.15)	0.7 ± 0.4 (0.6 – 0.7)
Granite Creek	Granite Creek	Ruby Creek to potential barrier	23.6	10.6 ± 1.7 (6.5 – 13.4)	0.03 ± 0.02 (0.0 – 0.11)	2.3 ± 0.8 (0.8 – 3.4)
	East Creek	Granite Creek to potential barrier	0.1	-	-	-
	Cabinet Creek	Granite Creek to potential barrier	0	-	-	-
	Slate Creek	Granite Creek to potential barrier	1.0	8.6 ± 0.3 (8.5 – 8.6)	0.06 ± 0.02 (0.03– 0.09)	2.3 ± 0.8 (0.8 – 3.4)
US Skagit	Thunder Creek	Diablo Lake to potential barrier	8.0	20.0 ± 0.5 (19.2 – 20.8)	0.02 ± 0.02 (0.0 – 0.07)	9.2 ± 0.5 (8.5 – 10.1)
US Skagit	Stetattle Creek	Gorge Lake to potential barrier	8.5	10.2 ± 1.7 (6.5 – 12.0)	0.04 ± 0.03 (0.0 – 0.14)	2.1 ± 0.7 (0.8 – 3.0)

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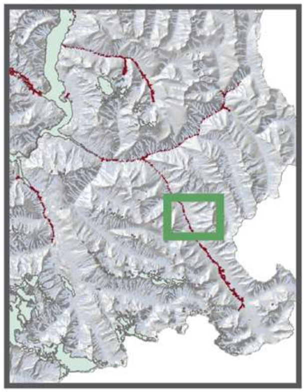
U.S. example 'end of fish' distribution



East Creek
Tributary to Granite Creek

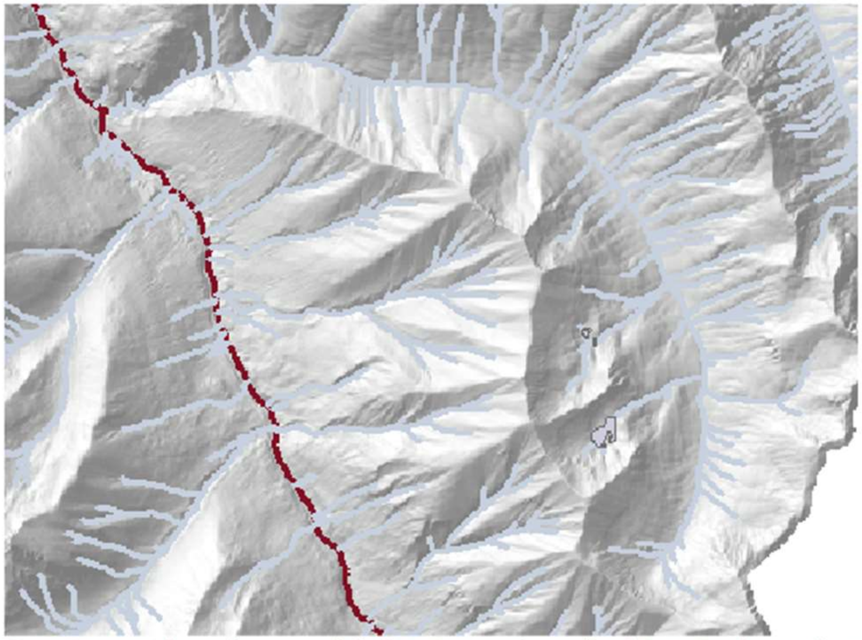


Fig. 1. Potential anadromous fish distribution (in red) of East Creek, a tributary of Granite Creek .

Nodes with Drops ≥ 3.7 m
n = 82; Range = 3.9 m to 54.1; first = 13.1 (n=3)

Fig. 3. Map of potential barriers ≥ 3.7 m

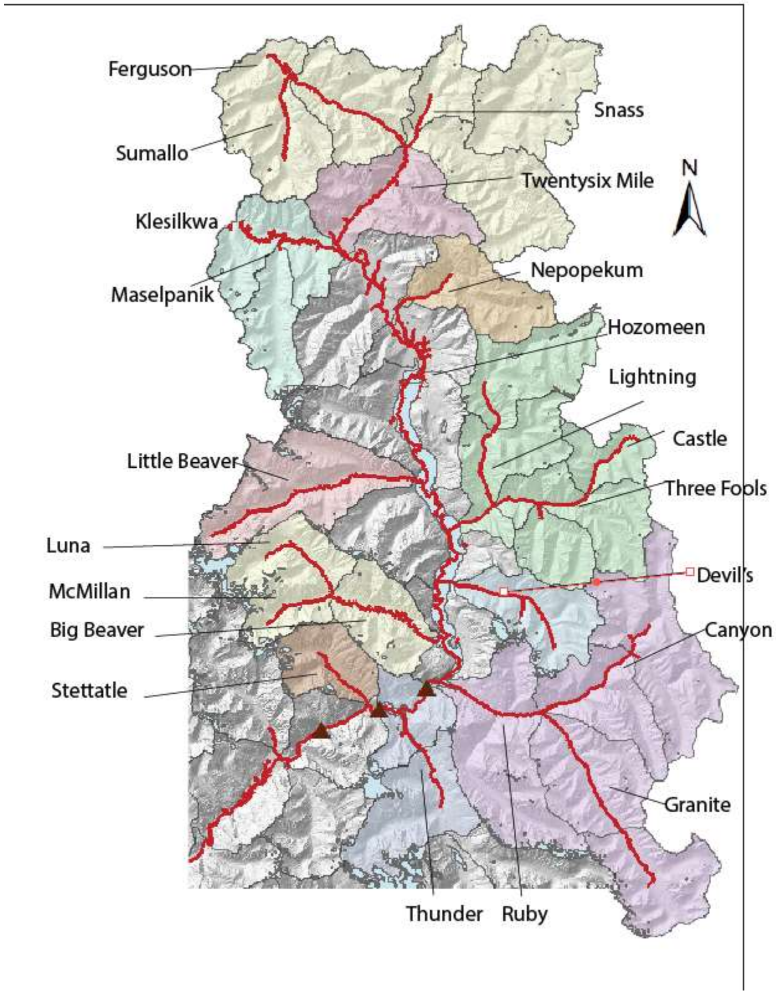
Puget Sound TRT Steelhead IP Model- parameters

		Bankfull Width		
		0–3 m	3–20 m	> 20 m
Gradient	0–0.25%	High	Moderate	Low
	0.25–4.0%	Moderate	High	Moderate
	> 4%	Low	Low	Low

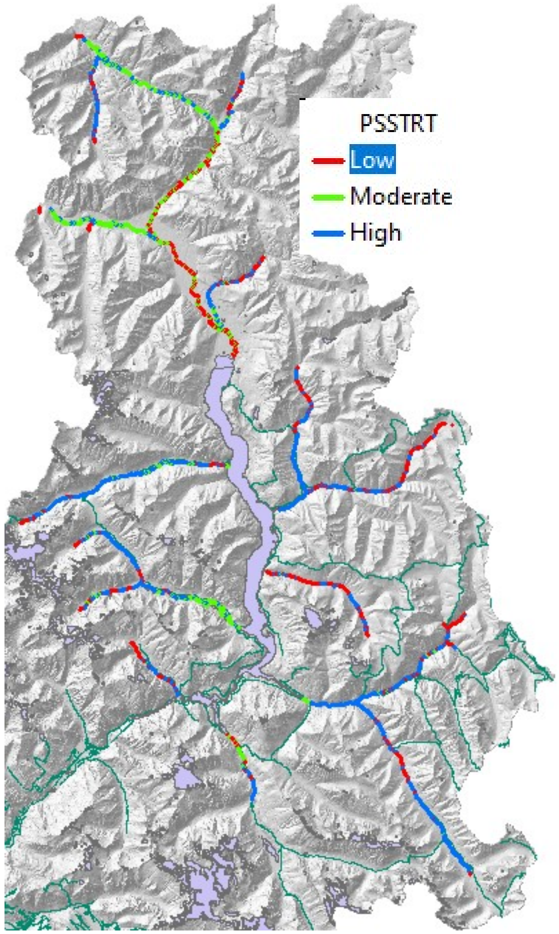
From Hard et al. 2015. Viability Criteria for Puget Sound Steelhead. NOAA Tech Memo

Draft Steelhead IP Results: PS_TRT IP Model

Proposed anadromous fish distribution



PS TRT Steelhead Matrix



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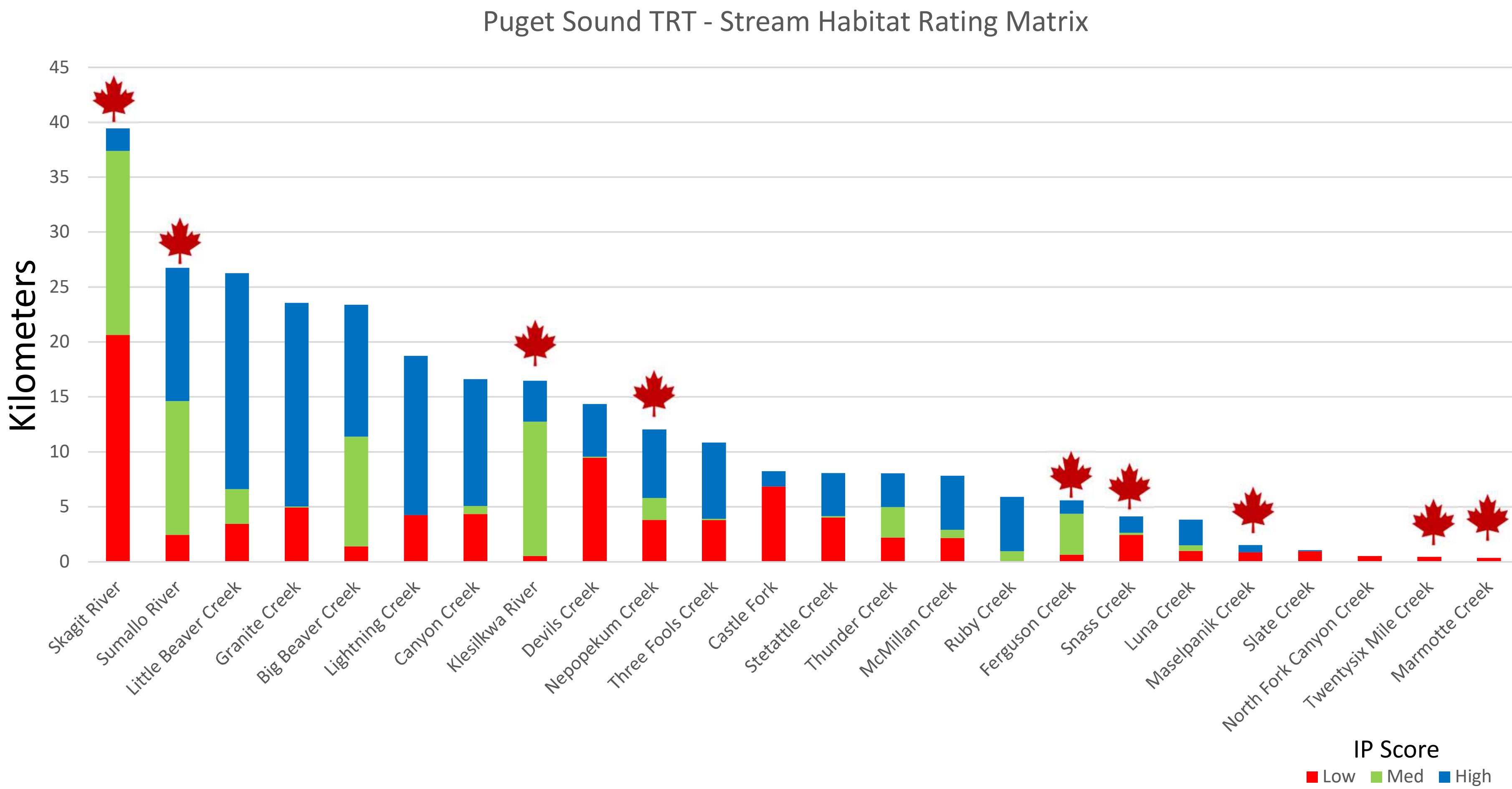
Puget Sound TRT Steelhead IP Model – summary



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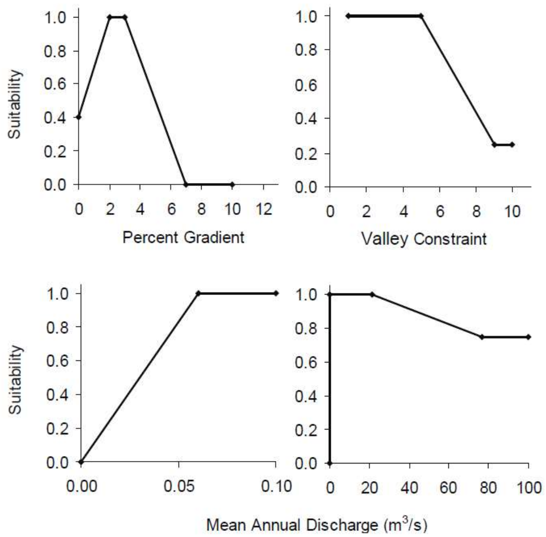
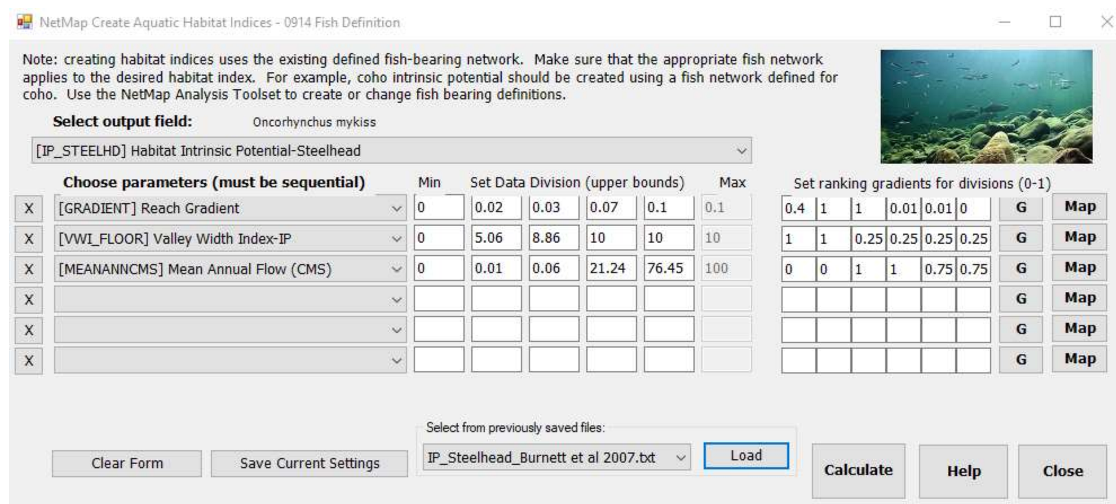
Burnett et al. Steelhead IP Model-Parameters





Gradient: Derived from DEM

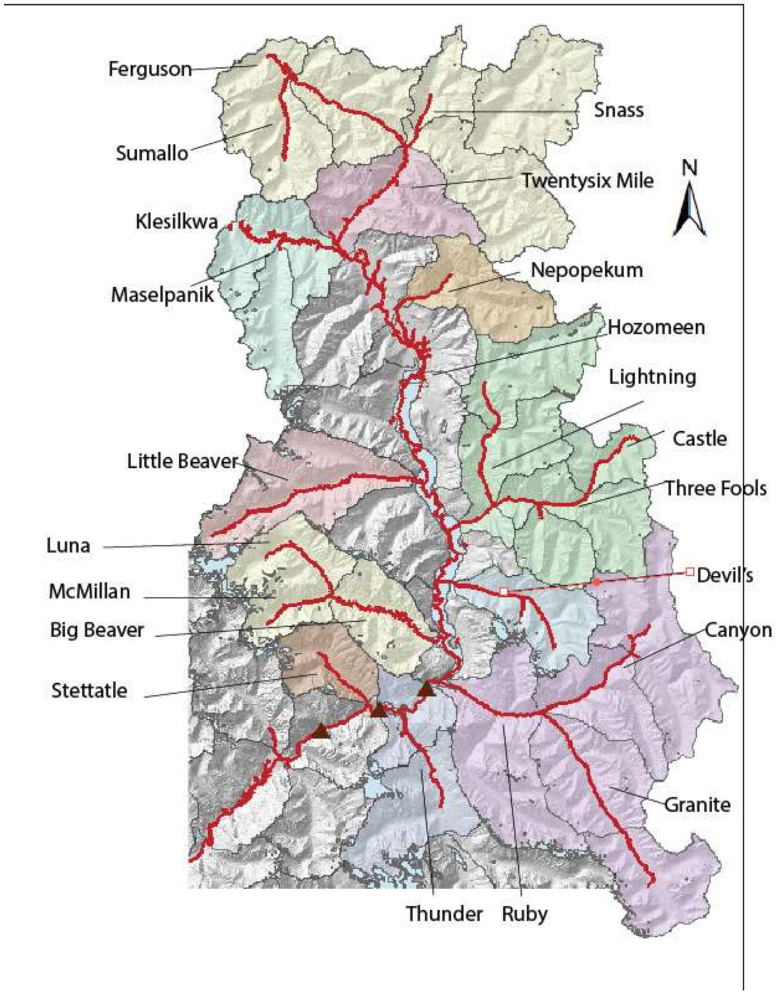
Mean Annual Flow: Calculated from regional regression equation (Kresch 1998): 0.016098234*Watershed Area$^{0.942}$*Mean Ann Precip$^{1.5}$

Valley Width Index: Valley width/bankfull depth.

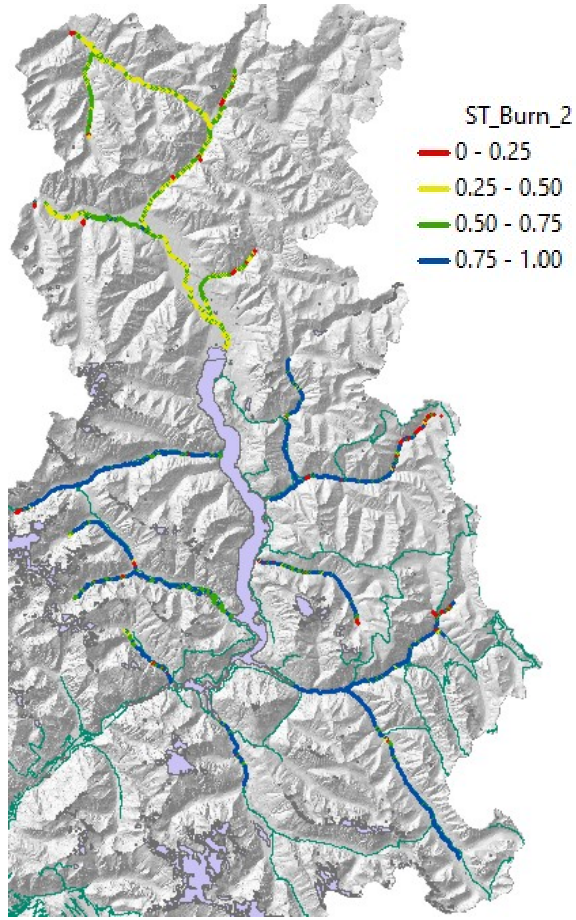
From Burnett et al. 2007. Ecological Applications 17:66-80.

Draft Steelhead IP Results: PS_TRT IP Model

Proposed anadromous fish distribution



Burnett Steelhead IP model



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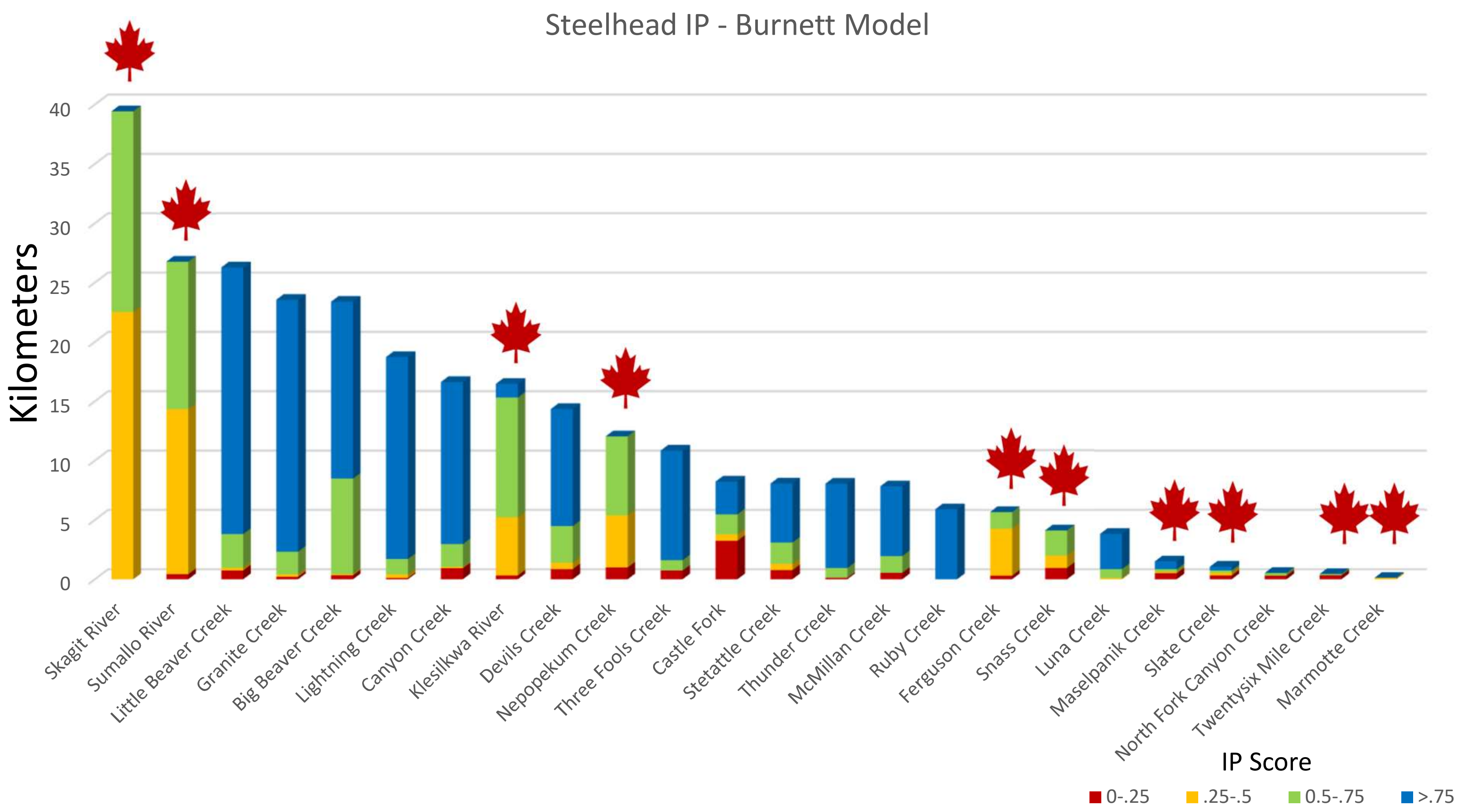
Burnett et al. Steelhead IP Model – summary



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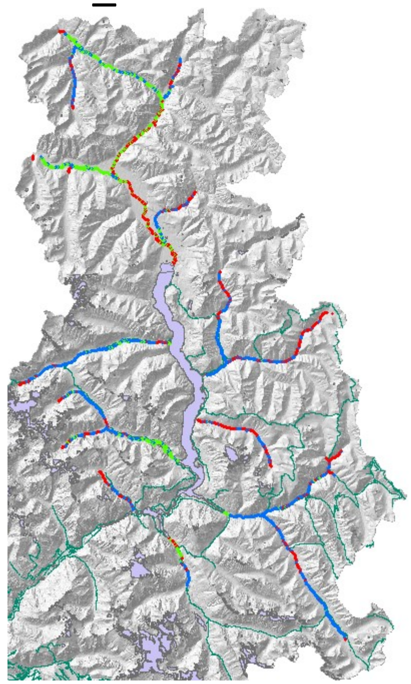
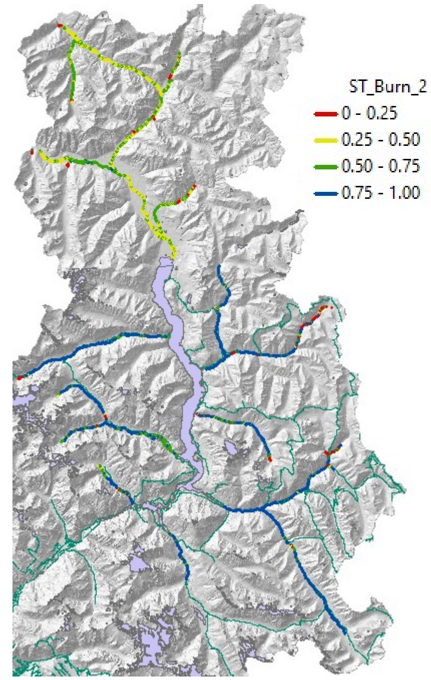
Comparing IP model results

PS_TRT



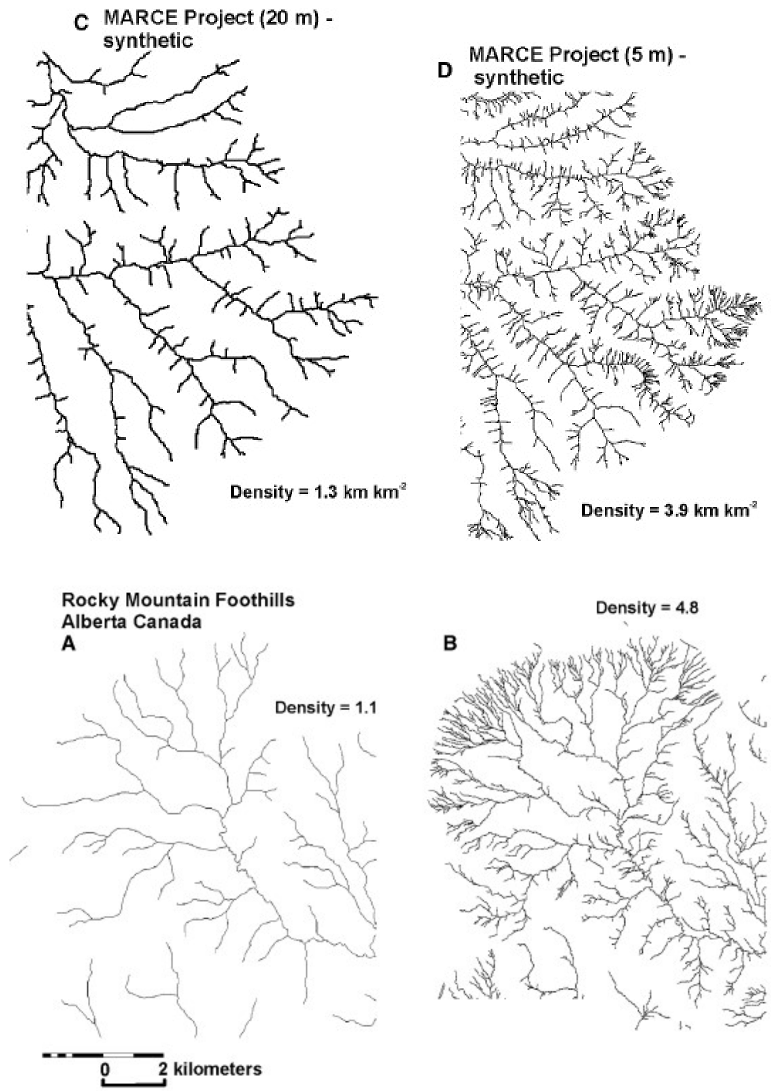
Burnett Steelhead IP model



PS_TRT	Low	Medium	High
	81 km	66 km	136 km
Burnett et al.	0–0.50	0.50–0.75	>0.75
	67 km	76 km	140 km

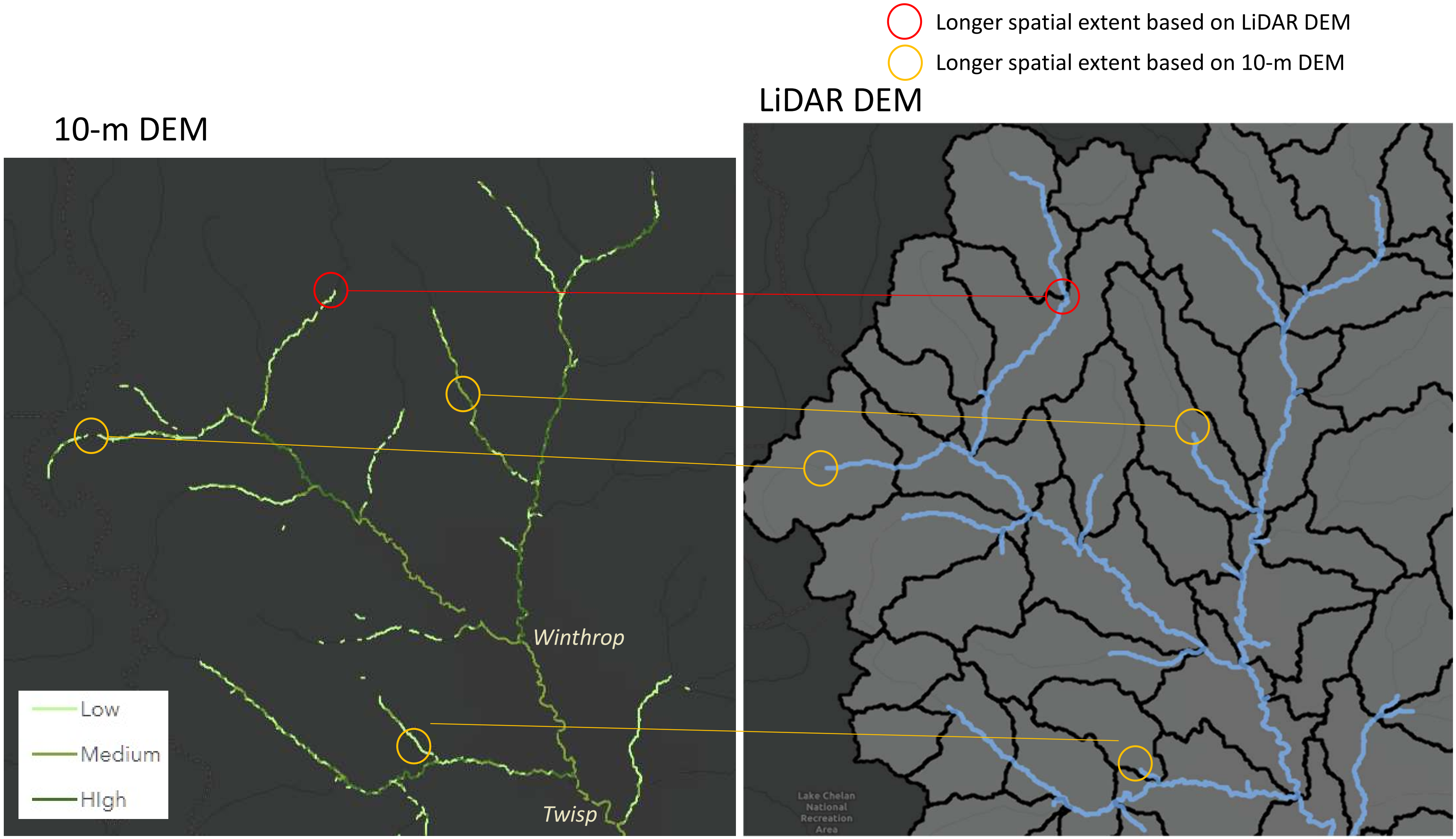
DEM resolution: 20-m, 10-m, and LiDAR-based DEMs

The completeness of synthetic hydrography depends upon the resolution of the DEM and how the DEM was derived. For example, a 90-m DEM (e.g., the length dimensions in x, y coordinate space) provides only a rough approximation of topography and the resulting synthetic river network may have inaccuracies in river network locations and may omit many headwater streams (Zhang and Montgomery 1994; Penas et al. 2011). Although a 30-m DEM provides considerably more topographic detail, limitations may still include a low density of headwater channels (Clarke and Burnett 2003). A 10-m DEM can delineate the majority of the channel network and will support other characterizations, such as aquatic habitats and erosion processes (Burnett et al. 2007; Miller and Burnett 2007; Benda et al. 2007). The upper extent of the



From Benda et al. 2016 Building Virtual Watersheds…Environmental Management 57:722-739

Upper Columbia Spring Chinook Intrinsic Potential



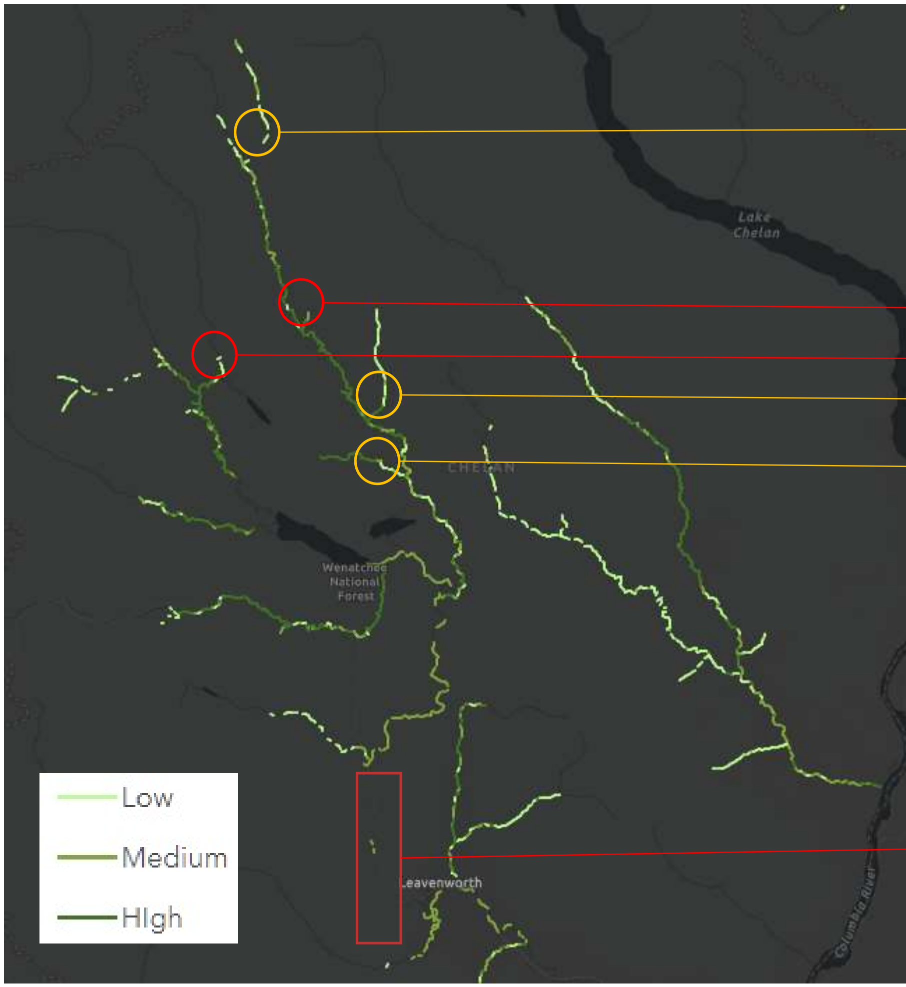
IP results from Upper Columbia

Draft IP results from Upper Columbia
*courtesy Greer Maier

Upper Columbia Spring Chinook Intrinsic Potential

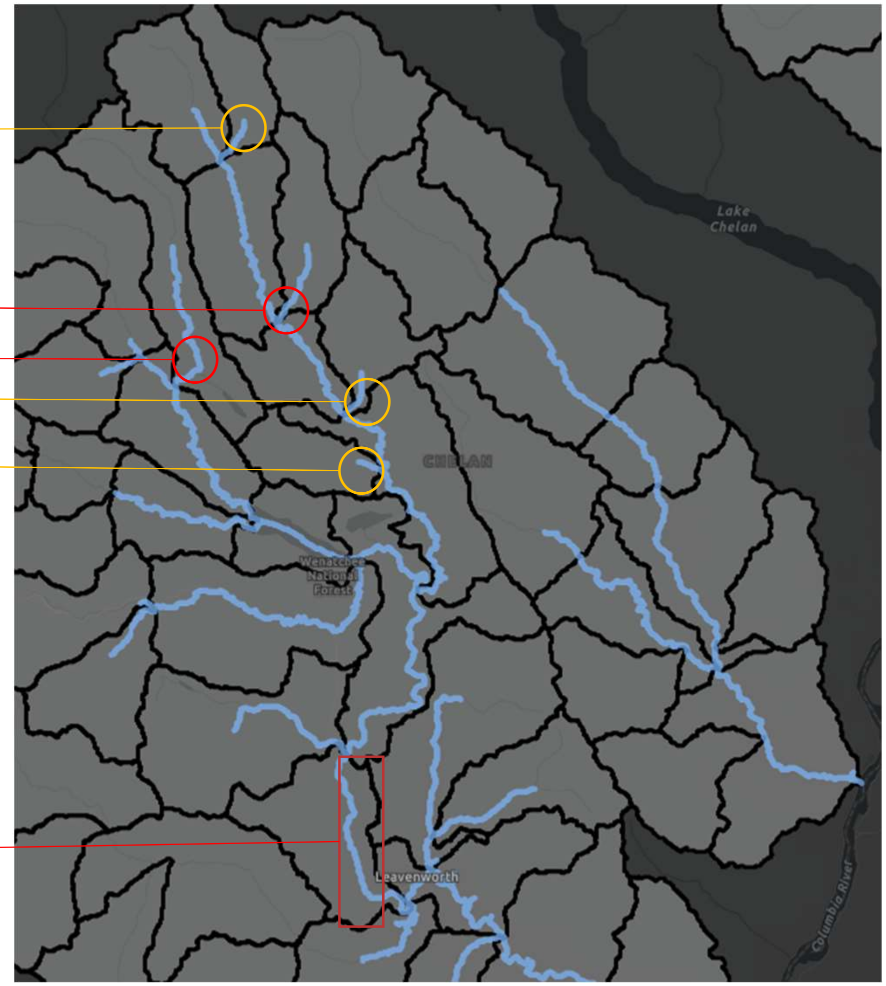
Longer spatial extent based on LiDAR DEM
Longer spatial extent based on 10-m DEM

10-m DEM



IP results from Upper Columbia

1-m DEM



Draft IP results from Upper Columbia
*courtesy Greer Maier

Next steps

- Incorporate hydrography fix in NETMAP to Klesilkwa River
- Complete IP model runs for steelhead, coho, chum, and pink salmon based on existing models
- Workshop:
  - Evaluate IP model results
  - Modify habitat index criteria if needed
  - Develop habitat suitability curves for additional species where existing IP models do not exist (i.e., sockeye, brook trout, brown trout)

Questions?

jduda@usgs.gov

Seattle City Light

MEETING AGENDA

Skagit Hydroelectric Project Relicensing Meeting
FA-07 Tributary & Reservoir Habitat and Food Web Workshop
December 21, 2021, 1:00 pm – 5:00 pm

WebEx Meeting: [LINK HERE]
Password: GpMQqaur632 (47677287 from phones and video systems)

Conference Call: +1-510-338-9438 USA Toll
Access code: 2556 649 1208
(Meeting ID: XafZK9pNb33**)**

MEETING PURPOSE

- Discuss approach to Gorge Lake Food Web modeling.
- Provide an update on proposed data collection under FA-01 and their potential use in the Food Web Study.
- Discuss fish species list for Intrinsic Potential (IP) modeling.

RESOURCES AND MEETING MATERIALS

- NOA Commitments
- Reservoir Work Group Discussion Tracker

AGENDA

1:00 – 1:15 pm [15 mins]	**Introductions** – *Greer Maier (Facilitator, Triangle Associates)* ▪ Roll call introduction. ▪ Review agenda and meeting objectives. ▪ Review meeting context and previous summary and action items
1:15 – 3:15 pm [2 hours]	**Approach to Gorge Lake Food Web modeling**– *Dave Beauchamp (USGS)* ***(I & C)*** NOA Commitment #53 ▪ Discussion on LP interests and objectives. ▪ Application of existing scale, otolith, and fish tissue samples to stable isotope analysis. ▪ Approach to bioenergetics modeling ▪ Evaluating growth potential and relative predation risk of juvenile salmonids. ▪ Discuss path forward for addressing bioenergetics in Gorge Lake.
3:15 – 3:30 pm [15 mins]	**Break**
3:30 – 4:00 pm [30 mins]	**Update on Data Collection Proposed for FA-01 and Linkage to FA-07** – *Jeff Fisher (City Light)* ***(I)*** ▪ Review progress made in Water Quality Work Group discussions. ▪ Benthic macroinvertebrate and drift sampling proposed for FA-01. ▪ Discuss potential use of these data for the Food Web Study.
4:00 – 4:45 pm [45 mins]	**Intrinsic Potential (IP) Modeling Species List** – *Jeff Fisher (City Light)* ***(I & C)*** Current Discussion Topic ▪ Background on current list of proposed species ▪ Discussion on species to be evaluated with IP Modeling.

4:45 – 5:00 pm [15 mins]	**Meeting Wrap-Up–** *Greer Maier (Triangle Associates)* ▪ Review meeting decisions, action items, and discussion topics ▪ Review updated NOA Commitment Matrix and opportunity for comment ▪ Timing and agenda topics for next meeting
5:00 pm	**Meeting Adjourned**

Agenda Topic Goals: I=Information, A=Advise, C=Concurrence

Action Items from 10/25 FA-07 Reservoir Work Group Meeting

Action	**Responsibility**	**Deadline**
LP Action Items		
Ashley Rawhouser (NPS) will provide Gorge Lake reservoir data and samples to David Beauchamp (USGS) to inform future discussion at Work Group or work session meeting.	Ashley Rawhouser/NPS	November/December
Licensing Participants (LPs) will provide Jeff Duda the location of existing known/presumed barriers to compare with modeled barriers and incorporate and include in the Intrinsic Potential (IP) layer and report.	LPs and Jeff Duda/USGS	Ongoing
City Light/Consultant Action Items		
Jeff Duda will incorporate the Triton Environmental Report: Fish and Fish Habitat Inventory of the Canadian Skagit River Watershed (2008) in the IP model report as context for the results.	Jeff Duda/USGS	IP model report
Jeff Duda (USGS) will change the IP model criteria for fish passage barriers to sustained gradient >20% over a distance of 160 meters per WDFW guidelines.	Jeff Duda/USGS	Next model iteration
Facilitation Team Action Items		
Triangle will digitize (PDF) the paper copy of historical master's thesis (1974) data for the Food Web Study and upload it to the Triangle SharePoint site for future use.	Triangle	In process
Triangle will invite Reservoir Work Group members to the November Water Quality meeting to address the need for conversation around FA-01 sampling.	Triangle	Complete

IP Modelling for SCL Upper Skagit salmon Introduction[1]

Species	IP Model	Gradient	Confinement	Discharge[1]	Other
Steelhead	Burnett 2007	Yes	Yes	Yes	
	PSS_TRT	Yes			Bankfull
	Agrawal 2005	Yes	Yes	Yes	
	Waldo et al. 2013	Yes		Yes	
	Cooney and Holzer 2006	Yes	Yes	Yes	Bankfull
Coho	Burnett 2007	Yes	Yes	Yes	
	Agrawal 2005	Yes	Yes	Yes	
	Ramos 2020 (Thesis)				
Chinook	Agrawal	Yes	Yes	Yes	
	Bidlack et al 2014	Yes	No	Yes	Glaciated
	Cooper et al 2020	Yes	Yes	Yes	
	Connor et al. 2015				
	Cooney and Holzer 2006	Yes	Yes	No	
Sockeye	None[2]	Yes	Yes	No	

[1]Modeled mean annual flow based on drainage area

2 Modify provisional Sockeye Salmon IP model using expert opinion and distribution of river spawning Sockeye in Western Washington (e.g., Murdoch et al. 2009).

Citations:

Agrawal, A., 2005. Predicting the potential for historical coho, Chinook and steelhead habitat in Northern California. NOAA Technical Memo

Bidlack, A.L., Benda, L.E., Miewald, T., Reeves, G.H. and McMahan, G., 2014. Identifying suitable habitat for Chinook salmon across a large, glaciated watershed. *Transactions of the American Fisheries Society*, *143*(3), pp.689-699.

Burnett, K.M., Reeves, G.H., Miller, D.J., Clarke, S., Vance-Borland, K. and Christiansen, K., 2007. Distribution of salmon-habitat potential relative to landscape characteristics and implications for conservation. *Ecological Applications*, *17*(1), pp.66-80.

Cooney, T. and Holzer, D., 2006. Appendix C: Interior Columbia basin stream type Chinook salmon and steelhead populations: Habitat intrinsic potential analysis. *Preliminary draft of the viability criteria for the Interior Columbia domain*.

[1] City Light would like to agree on the final list of species to be evaluated with IP and UCM modeling. Please be prepared to discuss the need for inclusion of lamprey and unestablished non-native salmonid species. Please note, production potential analysis for Bull trout and Brook trout (as well as Dolly Varden) in reservoir tributary habitats has been ongoing already as part of the initially authorized food web study. A Bull trout IP model for Montana will be evaluated, or a surrogate from a suite of steelhead IP models.

Cooper, E.J., O'Dowd, A.P., Graham, J.J., Mierau, D.W., Trush, W.J. and Taylor, R., 2020. Salmonid Habitat and Population Capacity Estimates for Steelhead Trout and Chinook Salmon Upstream of Scott Dam in the Eel River, California. *Northwest Science*, *94*(1), pp.70-96.

Connor, E., Lowery, E., Light, S.C., Hartson, R., Tribe, U.S.I., Brocksmith, R. and Council, S.W., Tributary Assessment for Potential Chinook Salmon Rearing Habitat and Recommendations for Prioritizing Habitat Protection and Restoration.

Murdoch AR, Tonseth MA, Miller TL. Migration patterns and spawning distribution of adult hatchery sockeye salmon released as parr from net-pens in Lake Wenatchee, Washington. North American Journal of Fisheries Management. 2009 Apr 1;29(2):447-59.

Ramos, M.M., 2020. Recolonization potential for Coho salmon (*Oncorhynchus kisutch*) in tributaries to the Klamath River after dam removal. M.S. Thesis, Humboldt State University, Arcata, CA.

Waldo, T., Jones, B., and Clark, C. 2011. NOAA-Fisheries Threshold Intrinsic Potential Model Assessment. Appendix in Puget Sound Steelhead Foundations: A Primer for Recovery Planning. WDFW and Puget Sound Partnership.

FA-07 Gorge Reservoir Food Web Workshop

Examine feasibility of supporting introduced anadromous salmonids in Gorge Reservoir

December 21, 2021

Photo: J. Duda

Bioenergetic Constraints on anadromous salmonid Growth & Potential Predation Losses in Gorge Reservoir

USGS Western Fisheries Research Center

Objectives for Gorge Food Web?

- What's the desired role of the reservoir in supporting anadromous salmonids:
  - Migratory corridor only?
  - Rearing habitat?
  - Other?
- What is the **Growth potential** for introduced juvenile anadromous salmonids?
  - Which anadromous salmonid species proposed for Gorge?
- What is the **Potential Predation mortality** for anadromous salmonids migrating or rearing in Gorge Reservoir?
  - Predation imposed by Rainbow trout, Bull Trout & other salmonids

Gorge Food Web feasibility analysis for supporting introduced anadromous salmonids

- Options depend on accessibility & inventory of NOCA fish samples
  - Focus on Rainbow trout as surrogates for juv salmon, but need to account for hatchery effects on age & growth, stable isotopes
  - Only use stable isotopes for fish that have >2x Body Wt at release
  - Screen scale-based size-at-age for hatchery anomalies
  - Use July diets if available to supplement SIA
- Bioenergetics analysis of growth performance & consumption demand under ambient thermal regime & prey availability
  - Use fitted feeding rate to assess probable growth potential for additional anadromous salmonid production
  - Potential predation losses for rearing or migrant salmonids?

Estimating Consumption Demand

Quantify Predation or Potential Competition

Inputs from Sampling/Literature:

Growth:
$W_0 \rightarrow W_t$

Diet proportions by Wt thru time

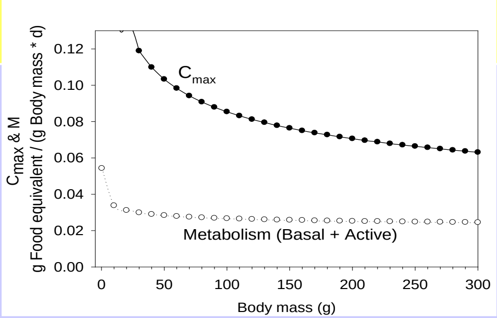
Predator Energy Density (J/g)

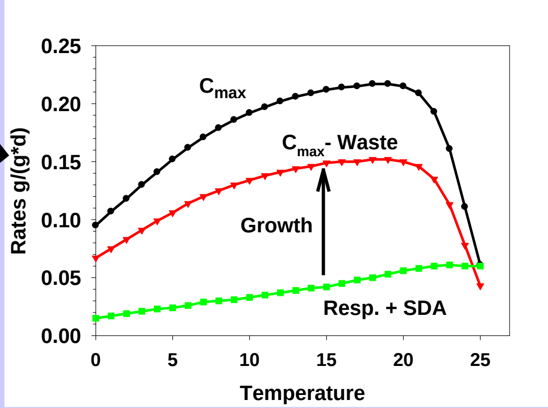
Prey Energy Density (J/g)

Thermal Experience thru time

Bioenergetics Model

$$C = M + W + G$$





How much food must be **Consumed** to satisfy observed **Growth**?

1-Daily Consumption g/d by prey group

2-Feeding Rate %Cmax

Daily time step

Simulation day 0 → day t

Thermal Experience

- **Temperature Logger Data**

- **Temperature Profile Data**
  - **For Deeper reservoir sections if stratification persists**

Diet Composition

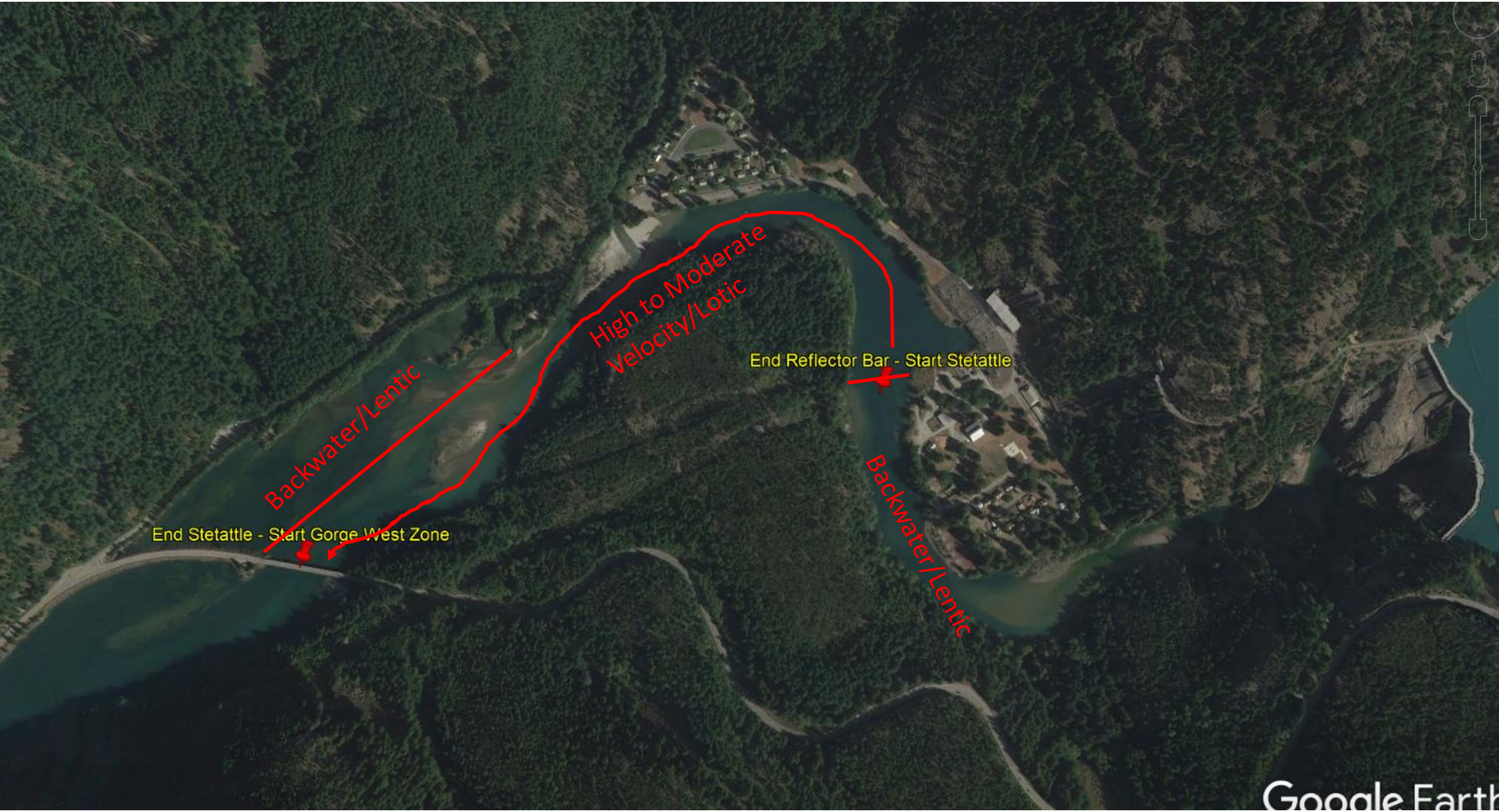
- **July 2021 Diet data provided by NOCA**
  - Provides a snapshot of diet by size & spp during peak growing season
  - Limited to those species & size classes & N sampled
- **Stable Isotope Analysis: tissue samples from same fish samples collected by NOCA July 2021**
  - Compare-contrast prey guilds inferred from SIA to diet:
    - Legacy Effects from hatchery feed in recent releases
    - Longer term diet integration inferred from SIA compared to summer diet data

Growth Inputs

- Use Scales to back-calculate size-at-age at each annulus of salmonids
  - Direct linear relationship for Rainbow trout scales
  - Char sometimes only yield Size- and Age-at-capture
- Incremental Growth (FL at Annulus t to t+1) converted to Weight at annulus for input to Bioenergetics model
  - Model then estimates consumption & growth performance to fit the annual growth estimates (above)

Bioenergetic Model Outputs & Interpretations

- Feeding Rate and Growth Efficiency of juvenile Rainbow trout are indicator for anadromous growth potential in Gorge Reservoir
  - Recommended Minimum Feasibility Thresholds:
    - Feeding rate >50% Cmax would suggest some surplus growth potential available for salmon or steelhead
    - Growth Efficiency > 10%
- Potential Predation Losses from Char & Trout:
  - Biomass of fish prey consumed & numerical equivalents of juvenile salmon lost per predator spp.
  - Basis for predation scenarios for rearing vs migrant salmonids


High to Moderate Velocity/Lotic
End Reflector Bar - Start Stetattle
Backwater/Lentic
End Stetattle - Start Gorge West Zone
Backwater/Lentic
Google Earth


End Stetattle - Start Gorge West Zone
Backwater/Lentic
Moderate Velocity/Lotic
Low Velocity/Lotic

Seattle City Light

MEETING AGENDA

Skagit Hydroelectric Project Relicensing Meeting
Reservoir Work Group Meeting
Tuesday, February 15, 9:00 am – 12:30 pm

Skagit Reservoir Work Group Meeting

WebEx Meeting: LINK
Password: YVrqMUde866 (98776833 from phones and video systems)
Join by phone: +1-510-338-9438 USA Toll
Meeting Number/Access Code: 2551 778 8359

MEETING PURPOSE

- Provide updates on FA-06 study implementation and FA-01 zooplankton sampling
- Present an Initial Study Report (ISR) Preview for FA-03, FA-06 and FA-07
- Finalize approach to bioenergetics modeling in Gorge Lake
- Present draft Intrinsic Potential (IP) modeling results for Chinook, Coho, and Steelhead and discuss approach to IP modeling of Sockeye

RESOURCES

- December 21st FA-07 Meeting Summary
- December 21st FA-07 Proposed Agenda
- Bioenergetics Modeling in Gorge Lake Slide Deck
- Draft results of IP modeling
- NOA Commitments
- Reservoir Work Group Discussion Tracker

AGENDA

Agenda Topic Goals: I=Information, A=Advise, C=Concurrence

9:00 – 9:15 am [15 mins]	**Introductions** – *Greer Maier (Facilitator), Triangle Associates)* • Roll call introduction. • Meeting context, December meeting summary and action items • Review agenda and meeting objectives
9:15 – 9:30 am [15 mins]	**FA-06 - Update and Initial Study Report (ISR) Preview *(I)* –** *Rick Taylor, Expert Panel Member, Erin Settevendemio, HDR (Consultant Team)* ▪ Follow-up from January Work Group meeting ▪ FA-06 Reservoir Native Fish Genetics Study ISR Preview o Refer to the Technical Memo (linked here)
9:30 – 9:50 am [20 mins]	**Initial Study Report (ISR) Previews Cont. *(I)*–** *Jeff Fisher, City Light* • FA-03 Reservoir Fish Stranding and Trapping • FA-07 Reservoir Tributary Habitat Assessment ISR Preview

9:50 – 10:00 am [10 mins]	**FA-01 Zooplankton Sampling Update *(I)* –** *Jeff Fisher, City Light* • Summary of zooplankton sample discussion from January 25 FA-01 WQ workgroup meeting
10:00 – 10:45 am [45 mins]	**Approach to Bioenergetics Modeling in Gorge Lake *(C)* –** *Jeff Fisher, City Light & Dave Beauchamp, USGS (Consultant Team)* • Study context for food web modeling • Update on conversations with LPs since December Work Group meeting • Proposed data collection and modeling approach • Discussion to reach LP/CL concurrence on approach *NOA commitment #53 - "Add Gorge Reservoir to Food Web Study"*
10:45 am – 12:15 pm [90 mins]	**Intrinsic Potential (IP) Modeling *(I & A)*** *– Jeff Duda, U.S. Geological Survey (Consultant Team)* • Study context for IP modeling • Draft IP results for Chinook, Coho, and Steelhead • Approach to IP modeling of Sockeye • Next Steps
12:15 – 12:30 pm [15 mins]	**Action Items and Next Steps–** *Greer Maier, Triangle Associates* • Review concurrence items, action items, and new discussion topics • Next steps and agenda items for next meeting
12:30 pm	**Adjourn**

Action Items from December 21st FA-07 Tributary & Reservoir Habitat Workshop #3

Action	**Responsibility**	**Deadline**
LP Action Items		
Jeff Fisher (City Light) and Dave Beauchamp (USGS) will discuss information requests and data needs related to Eastern Brook Trout in Gorge Lake with Ashley Rawhouser (NPS).	City Light/NPS	Complete
Jeff Fisher (City Light) and Dave Beauchamp (USGS) will discuss information requests and data needs related to rearing capacity in Gorge Lake with Brian Lanouette (USIT).	City Light/USIT	Complete
City Light Action Items		
Work with Dave Beauchamp (USGS) to identify next steps for a discussion on the frequency and seasonality of zooplankton sampling (e.g., FA-01 Water Quality Work Group agenda item).	City Light	Complete
Work with Dave Beauchamp (USGS) to review LP interests discussed at this FA-07 Work Group Meeting to inform Gorge Lake Food Web modeling. Report back to Work Group on changes and next steps.	City Light/Triangle	Complete
Facilitation Team Action Items		
Triangle will clarify and confirm the Reservoir IP Modeling Species List with Reservoir Work Group representatives from NMFS and report back to City Light and the Work Group.	Triangle/NMFS	Complete

Triangle will distribute the historical master's thesis (1974) data and upload it to the Triangle SharePoint site for future use.	Triangle/Dave Beauchamp	Complete

FA-07 Gorge Reservoir Food Web Workshop

Examine feasibility of supporting introduced anadromous salmonids in Gorge Reservoir

February 15, 2022

Photo: *J. Duda*

Bioenergetic Constraints on anadromous salmonid Growth & Potential Predation Losses in Gorge Reservoir

USGS Western Fisheries Research Center

Objectives for Gorge Food Web?

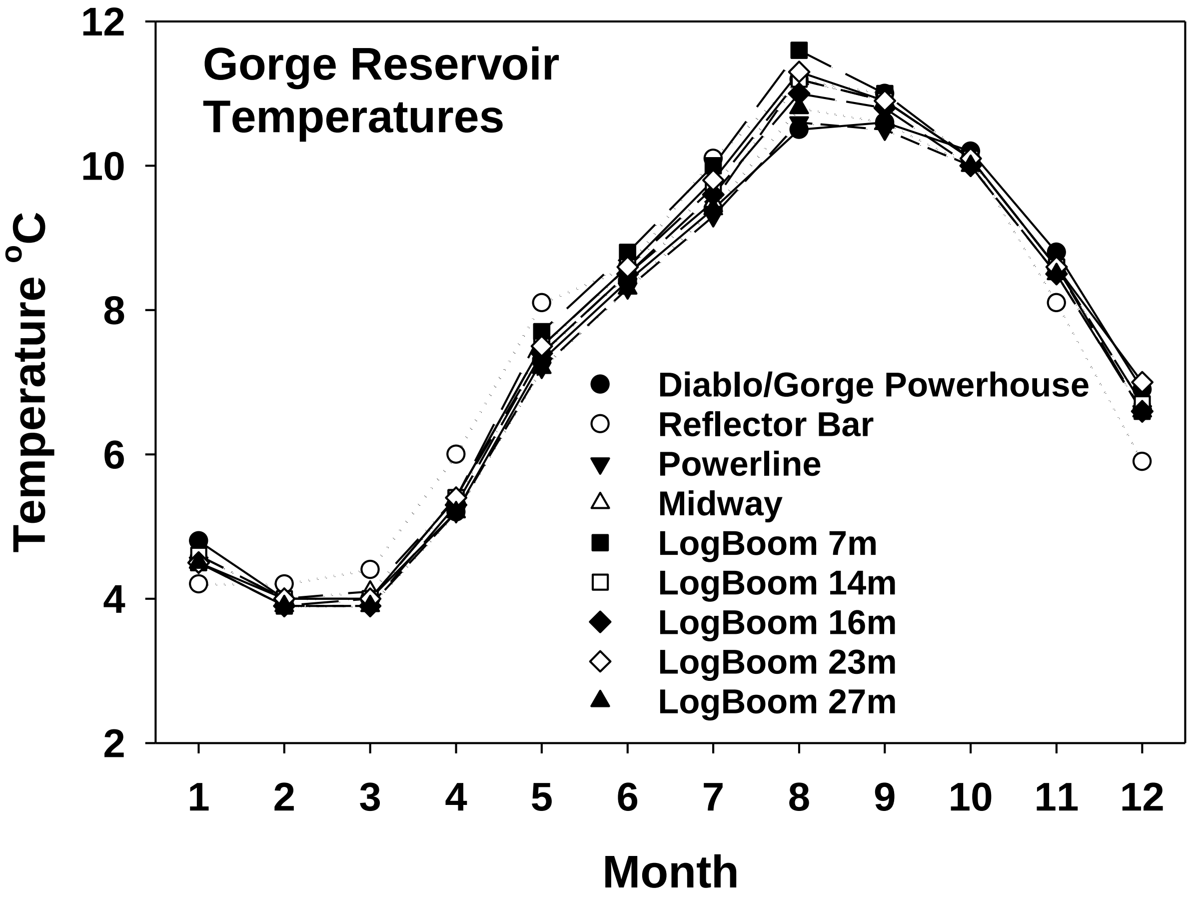
- Role of the reservoir in supporting anadromous salmonids:
  - If Migratory corridor only?
    - Then focus on estimating potential predation losses by native + invasive salmonids
  - Rearing habitat?
    - Support growth to viable smolt size over "normal" duration of freshwater rearing
    - Juveniles that cannot achieve viable smolt size over "normal" growing period either:
      - Remain to grow in Gorge for an additional ≤ year & undergo additional mortality
      - Migrate to an alternative rearing habitat outside Gorge Reservoir
- **Evaluate Growth potential** for introduced juvenile anadromous salmonids using performance of Rainbow trout as surrogates
  - Which anadromous salmonid spp proposed for Gorge?
    - Chinook (ocean- or stream-type)? Steelhead? Coho?
- Potential **Predation mortality** for anadromous salmonids migrating or rearing in Gorge Reservoir
  - Predation imposed by Rainbow, Bull, Brook Trout & other salmonids
  - Predation losses dependent on prey size & duration of residence in habitat

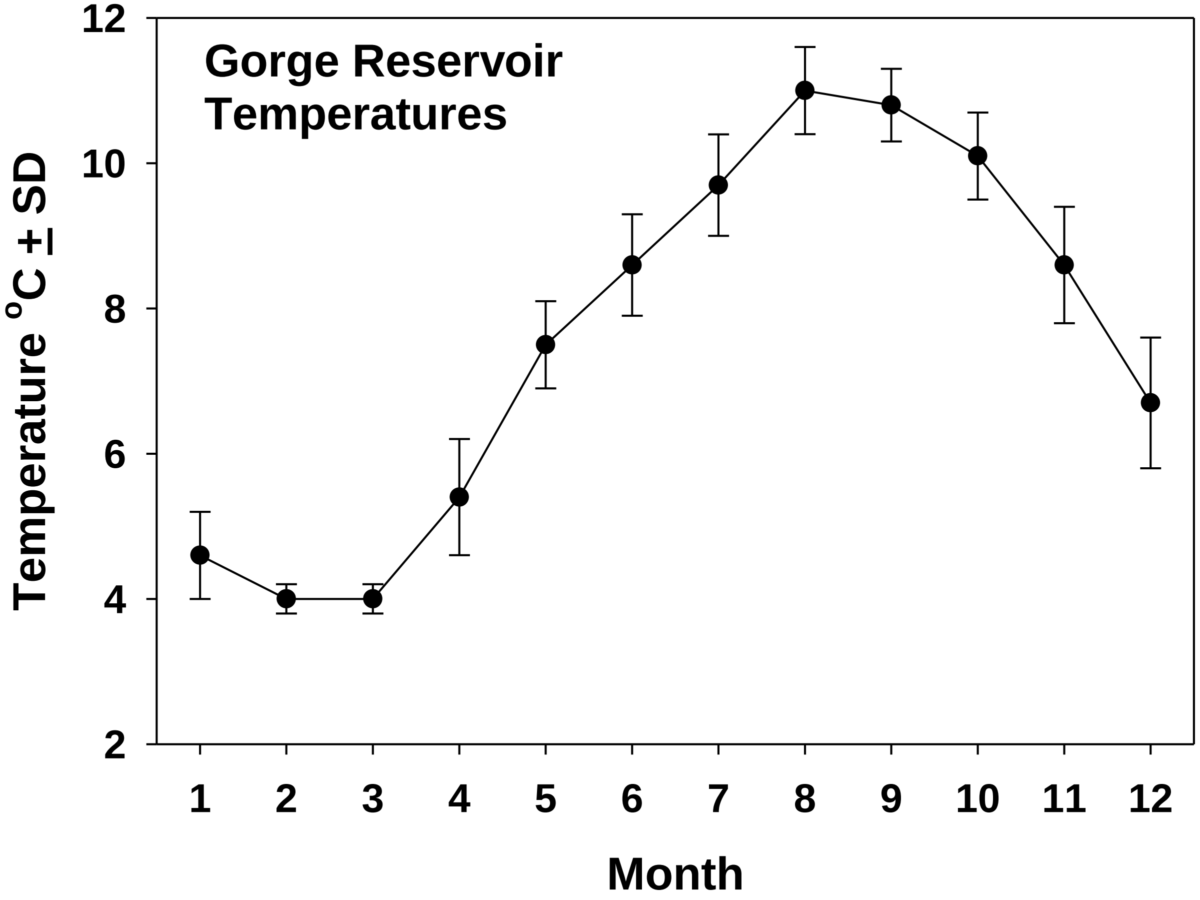
Gorge Food Web feasibility analysis for supporting introduced anadromous salmonids

- Analysis based on fish sampled July 2021: N=123 provided by NOCA
  - Focus on Rainbow trout as surrogates for juv salmon, but need to account for hatchery effects on age & growth, stable isotopes
  - Only use stable isotopes for fish that have >2x Body Wt at release
  - Screen scale-based size-at-age for hatchery anomalies
  - Use July diets to supplement & compare with stable isotope data
    - Spp & sizes involved in piscivory; magnitude of piscivory
    - Confirm or refute prediction of benthic-dominated food web interactions
- Bioenergetics analysis of growth performance & consumption demand under ambient thermal regime & prey availability
  - Use fitted feeding rate to assess probable growth potential for additional anadromous salmonid production
  - Potential predation losses for rearing or migrant salmonids?

Temperature Data &Thermal Experience

- **Temperature Logger Data**
- **Temperature Profiles 2019-2020**
  - – No significant Stratification; therefore, model as unstratified thermal regime





Diet Composition

- **July 2021 Diet data provided by NOCA**
  - **Provides a snapshot of diet by size & spp during peak growing season**
  - **Limited to the species, size classes & N sampled:**
    - **103 Rainbow trout, 14 Native Char, 6 Brook trout**
- **Stable Isotope Analysis: tissue samples from same fish samples collected by NOCA July 2021**
  - **Compare-contrast prey guilds inferred from SIA to diet:**
    - **Legacy Effects from hatchery feed in recent releases**
    - **Longer term diet integration inferred from SIA compared to summer diet data**

Diet Composition by Species and Size Class

Gorge Reservoir July 2021 (data from: North Cascades National Park)

Species Size Class	N	Redside Shiner	Unid Salmonid	Unid Fish	Daphnia	Amphipod	Snail	Benthos	Immature Insects	Adult Insects	Other
EBT	6	0.00	0.00	0.00	0.00	0.29	0.36	0.00	0.33	0.02	0.00
100-200	3	0.00	0.00	0.00	0.00	0.32	0.06	0.00	0.62	0.01	0.00
200-300	3	0.00	0.00	0.00	0.00	0.27	0.65	0.00	0.04	0.04	0.00
NC	14	0.00	0.07	0.18	0.00	0.25	0.06	0.08	0.13	0.23	0.00
100-200	5	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.07	0.36	0.00
200-300	3	0.00	0.00	0.00	0.00	0.20	0.28	0.36	0.17	0.00	0.00
>300	6	0.00	0.17	0.42	0.00	0.00	0.00	0.00	0.17	0.24	0.00
RBT	103	0.00	0.00	0.00	0.00	0.05	0.07	0.01	0.55	0.29	0.02
100-200	60	0.00	0.00	0.00	0.00	0.07	0.07	0.02	0.50	0.31	0.03
200-300	41	0.00	0.00	0.00	0.00	0.03	0.08	0.00	0.62	0.27	0.00
>300	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.35	0.00
Grand Total	123										

Growth Inputs

- Use Scales or other hard parts as needed to back-calculate size-at-age at each annulus of salmonids
  - Direct linear relationship for Rainbow trout scales
  - Char sometimes only yield Size- and Age-at-capture
- Incremental Growth (FL at Annulus t to t+1) converted to Weight at annulus for input to Bioenergetics model
  - Model estimates consumption, growth performance & efficiency to fit the annual growth increments
  - Enables evaluation of thermal regime, food quantity & quality as opportunities or constraints to production

Bioenergetic Model Outputs & Interpretations

- **Feeding Rate <u>and</u> Growth Efficiency of juvenile <u>Rainbow trout</u> are indicator for anadromous growth potential in Gorge Reservoir**
  - **Recommended Minimum Feasibility Thresholds:**
    - **Feeding rate >50% Cmax would suggest some surplus growth potential available for salmon or steelhead**
    - **Growth Efficiency > 10%**
- **Potential Predation Losses from Char & Trout:**
  - **Biomass of fish prey consumed & numerical equivalents of juvenile salmon lost per predator spp.**
  - **Basis for predation scenarios for rearing vs migrant salmonids**

Background Material

Estimating Consumption Demand

Quantify Predation or Potential Competition

Inputs from Sampling/Literature:

Growth:
$W_0 \rightarrow W_t$

Diet proportions by Wt thru time

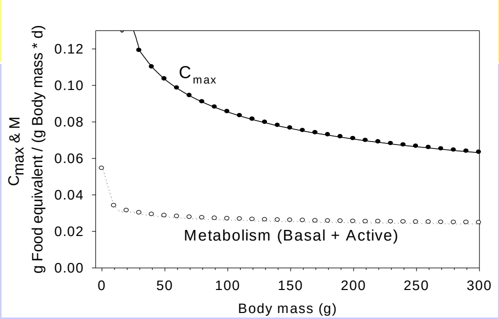
Predator Energy Density (J/g)

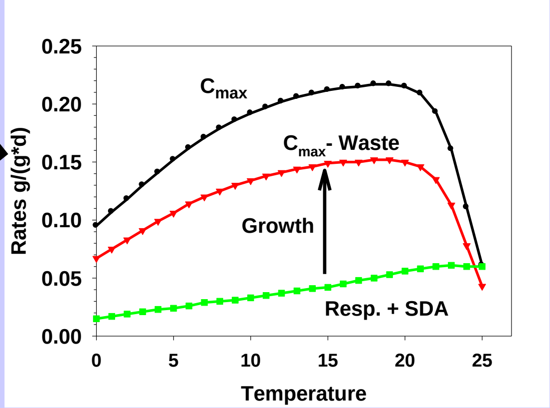
Prey Energy Density (J/g)

Thermal Experience thru time

Bioenergetics Model

$$C = M + W + G$$





How much food must be **Consumed** to satisfy observed **Growth**?

1-Daily Consumption g/d by prey group

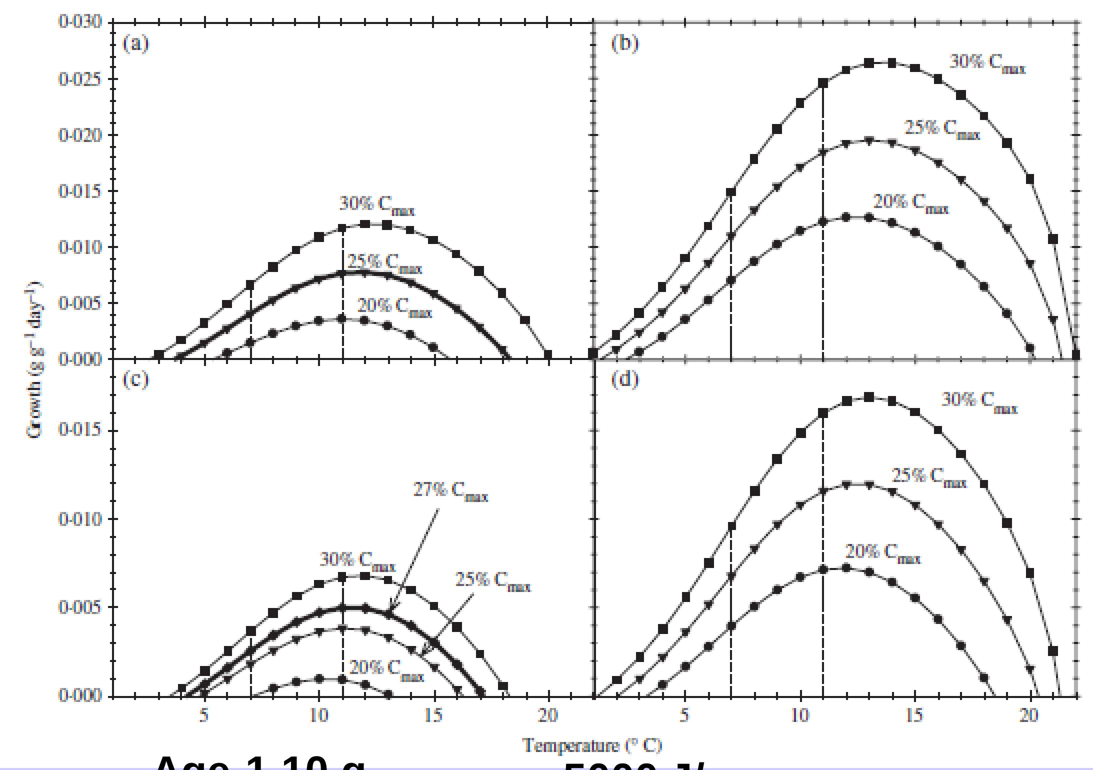
2-Feeding Rate %Cmax

Daily time step

Simulation day 0 → day t

ta &Thermal Experience

2020

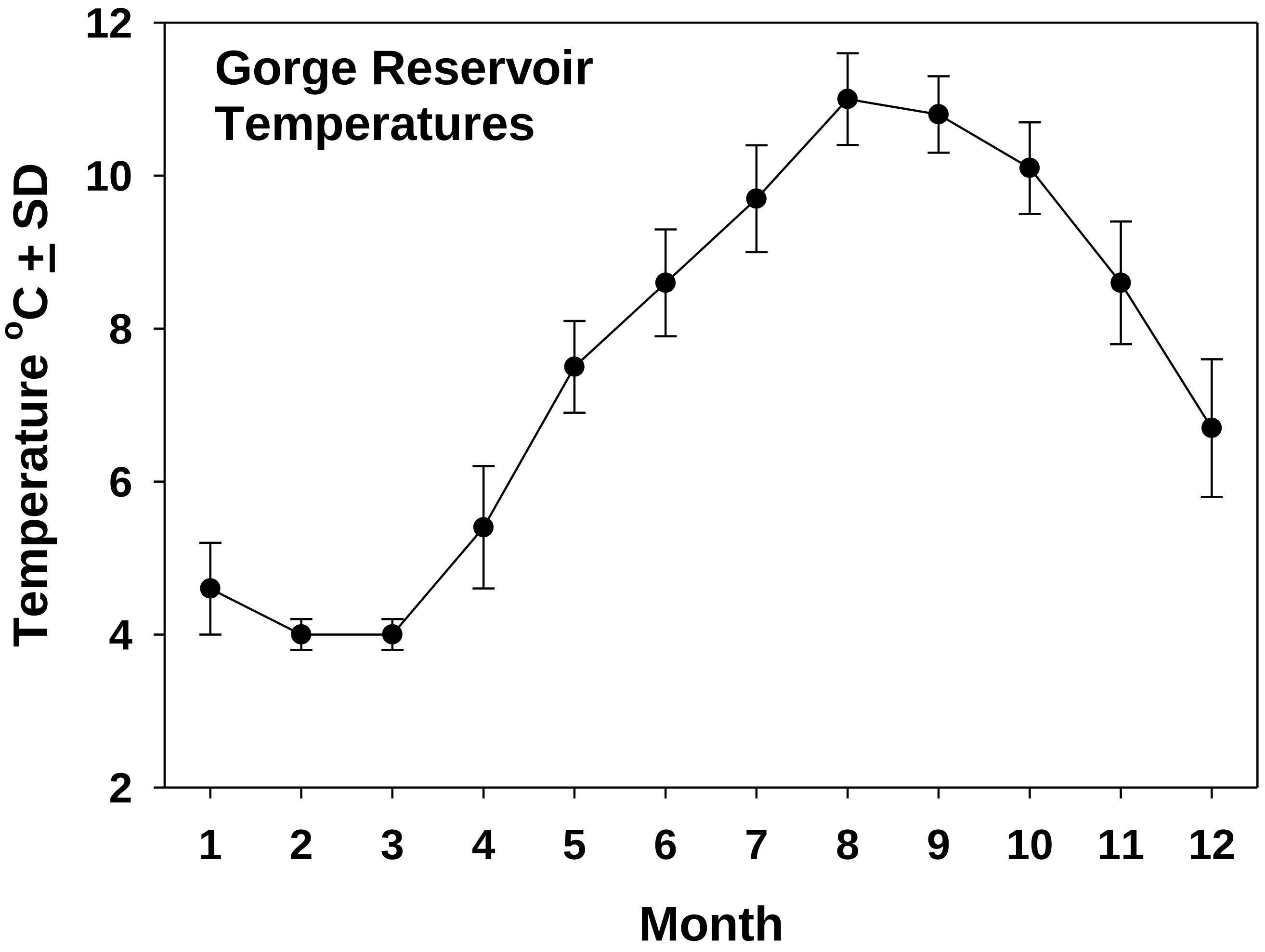


Age-1 10 g
3300 J/g diet

5000 J/g

Age-2 30 g
3300 J/g diet

5000 J/g



Thompson & Beauchamp 2016 JFB

Diet Composition by Species and Size Class

Gorge Reservoir July 2021 (data from: North Cascades National Park)

Species Size Class	N	Redside Shiner	Unid Salmonid	Unid Fish	Daphnia	Amphipod	Snail	Benthos	Immature Insects	Adult Insects	Other
EBT	6	0.00	0.00	0.00	0.00	0.29	0.36	0.00	0.33	0.02	0.00
100-200	3	0.00	0.00	0.00	0.00	0.32	0.06	0.00	0.62	0.01	0.00
200-300	3	0.00	0.00	0.00	0.00	0.27	0.65	0.00	0.04	0.04	0.00
NC	14	0.00	0.07	0.18	0.00	0.25	0.06	0.08	0.13	0.23	0.00
100-200	5	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.07	0.36	0.00
200-300	3	0.00	0.00	0.00	0.00	0.20	0.28	0.36	0.17	0.00	0.00
>300	6	0.00	0.17	0.42	0.00	0.00	0.00	0.00	0.17	0.24	0.00
RBT	103	0.00	0.00	0.00	0.00	0.05	0.07	0.01	0.55	0.29	0.02
100-200	60	0.00	0.00	0.00	0.00	0.07	0.07	0.02	0.50	0.31	0.03
200-300	41	0.00	0.00	0.00	0.00	0.03	0.08	0.00	0.62	0.27	0.00
>300	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.35	0.00
Grand Total	123										

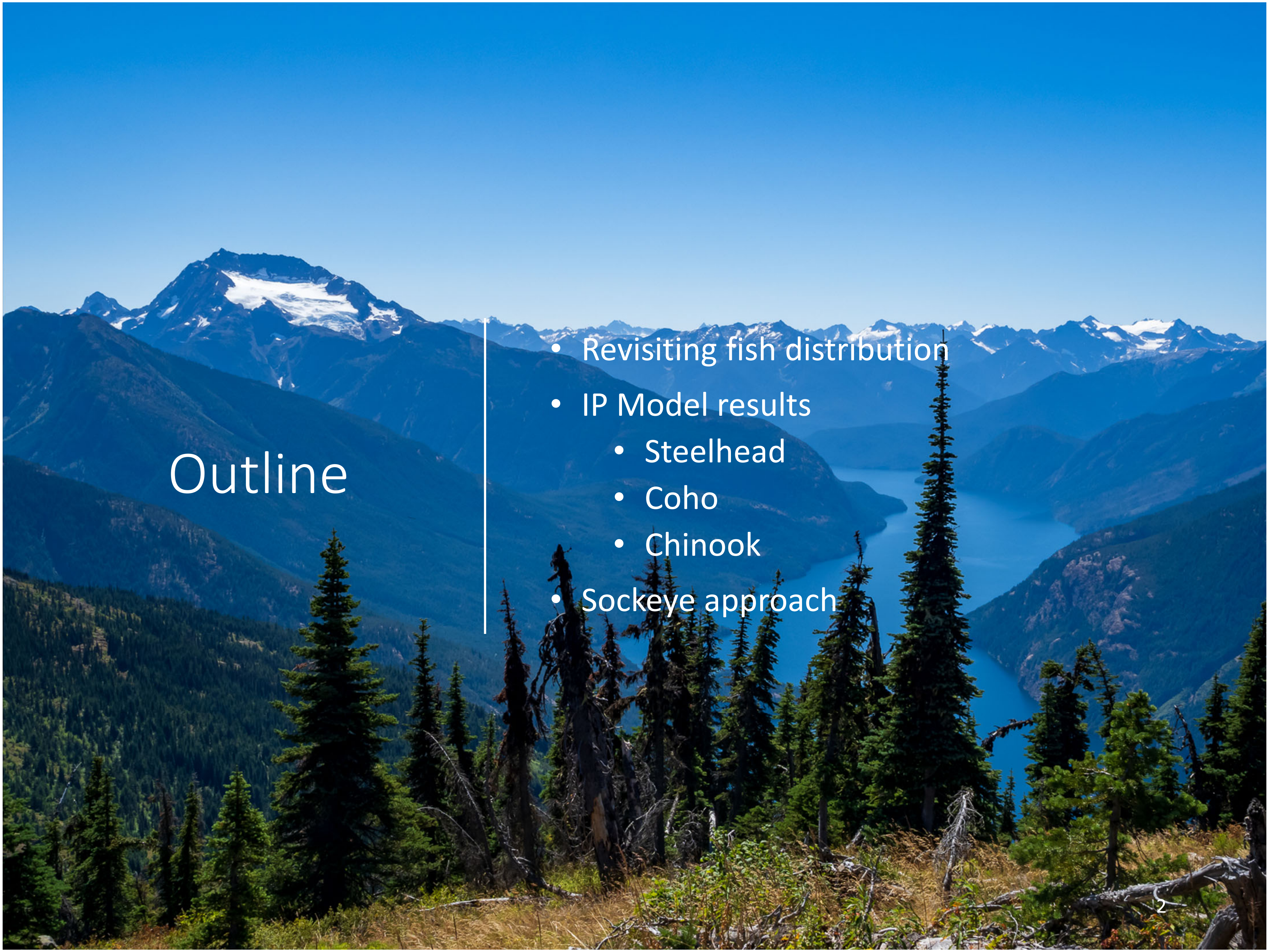
2A-Intrinsic Potential (IP) modeling with NetMap-*An assessment of habitat suitability for salmonids across selected tributaries upstream of the Skagit River dams*

Jeff Duda, Jill Hardiman

U.S. Geological Survey, Western Fisheries Research Center

Jeff Fisher

Seattle City Light



Outline

- Revisiting fish distribution
- IP Model results
  - Steelhead
  - Coho
  - Chinook
- Sockeye approach

Analysis Steps

1. Create potential anadromous fish distribution for tributaries upstream of Skagit Dams
2. Assess potential natural barriers based on Gradient thresholds and node elevation drops
3. Assess fish distribution with IP models applied to streams of interest (i.e., Tables 1 and 2 in Study Plan).

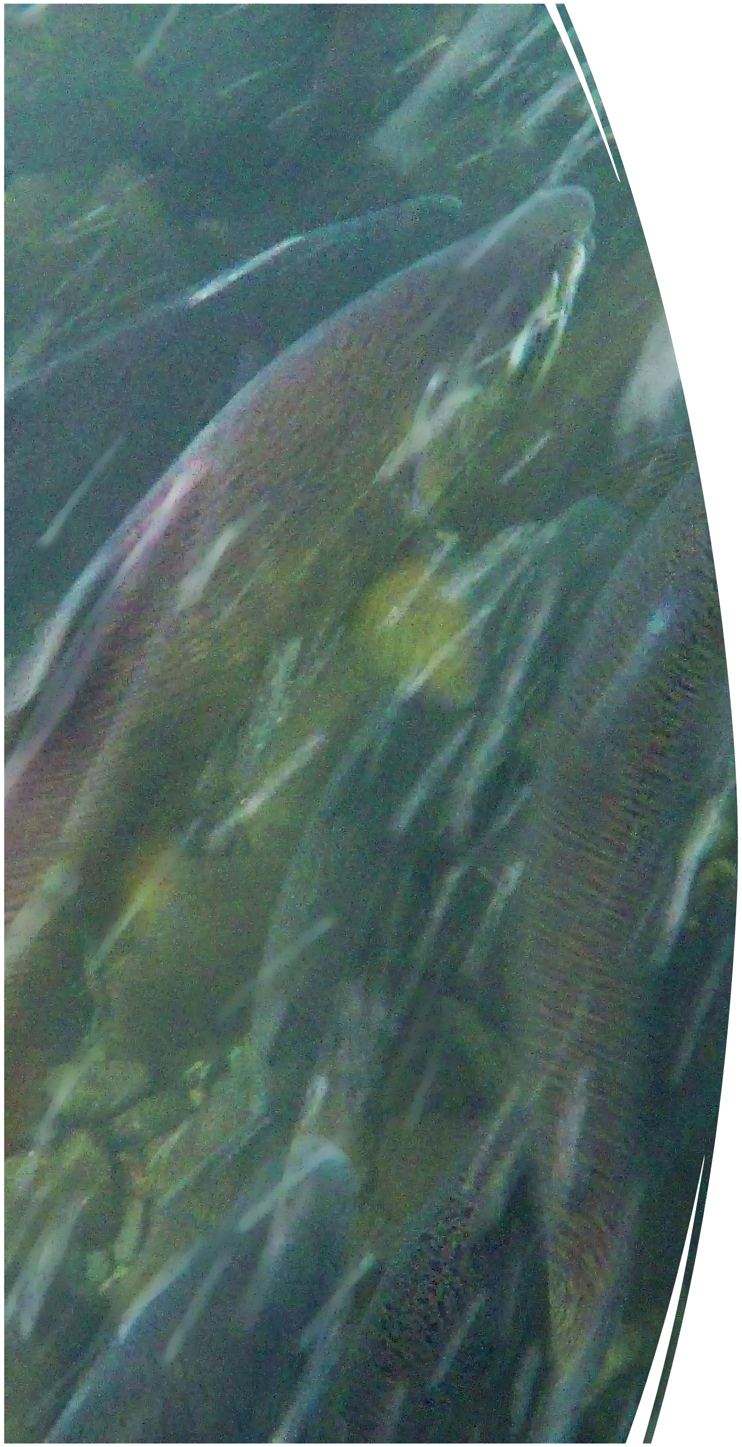
Provide results to KFS team to help guide their work on production capacity estimates.

Table 1. Canadian streams with accessible habitat to fish from Ross Reservoir (NPS, used with permission)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Skagit River	Ross to Klesilkwa	17.5	<1
	Klesilkwa to barrier falls near Snass	17.1	<1
Klesilkwa River	Skagit to Silverhope divide	14.3	<1
Sumallo River	Skagit to Ferguson	16.6	<1
Ferguson Creek	Sumallo R. to HWY3	3.9	2
Nepopekum Creek	Skagit to start of canyon	2.7	3
Nepopekum Creek	Start of Canyon to Poland cr.	9.3	5
Sumallo River	Ferguson to end 3rd order	12.1	5
Maselpanik Creek	Klesilkwa to end 3rd order	12.2	6
Snass Creek	Skagit R. to Dry Lake	3.9	6
Ferguson Creek	Hwy 3 to end 3rd order	3.7	9
Klesilkwa River	Silverhope Divide to end 3rd order	3.7	10
Twentysix Mile Creek	Skagit River to end 3rd order	5.8	11
Marmotte Creek	Marmotte Creek to end 3rd order	4.3	12

Table 2. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS, used with permission)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Big Beaver Creek	Ross to McMillan	14.6	<1
Ruby Creek	Ross to Canyon/Granite Confluence	5.5	2
Canyon Creek	Ruby to Slate Creek	11.9	2
Lightning Creek	Ross to Three Fools	3.5	2
Lightning Creek	Three Fools to Freezeout	8.8	2
Little Beaver Creek	Ross to end 3rd order	24.2	2
Granite Creek	Ruby to "indistinct barrier"	8.6	4
Luna Creek	Big Beaver to end 3rd order	4.5	4
Lightning Creek	Freezeout to Boundary	6.3	4
Three Fools Creek	Lightning to Castle	10.1	4
Castle Creek	Three Fools to Rustle	5.8	9
Canyon Creek	Slate to "barrier falls"	4.2	7
NF Canyon Creek	Canyon to "barrier falls"	1.0	7
East Creek	Granite to end 3rd order	6.9	12
Cabinet Creek	Granite to end 3rd order	3.2	13

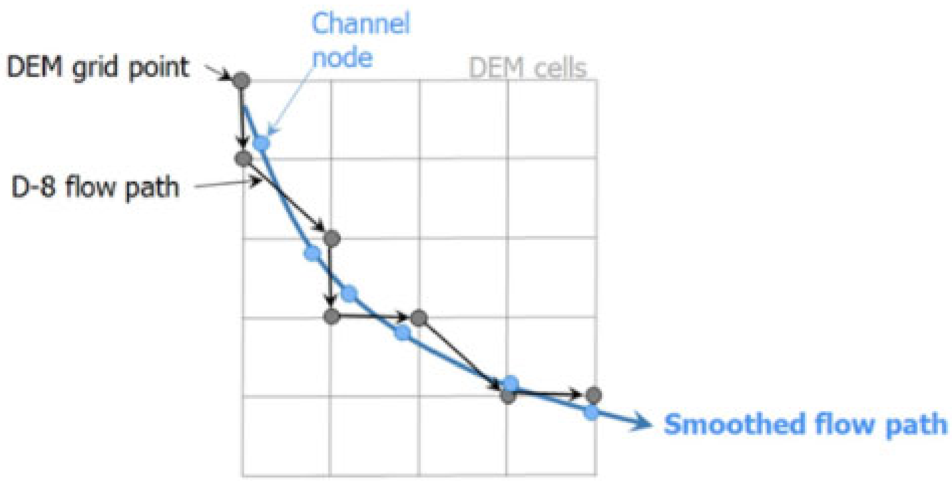


Creating potential anadromous fish distribution

- Use NETMAP virtual watershed and analysis tools to create ArcGIS stream layers
- Create ‘end of anadromy’ fish distribution based on simple rule-based criteria

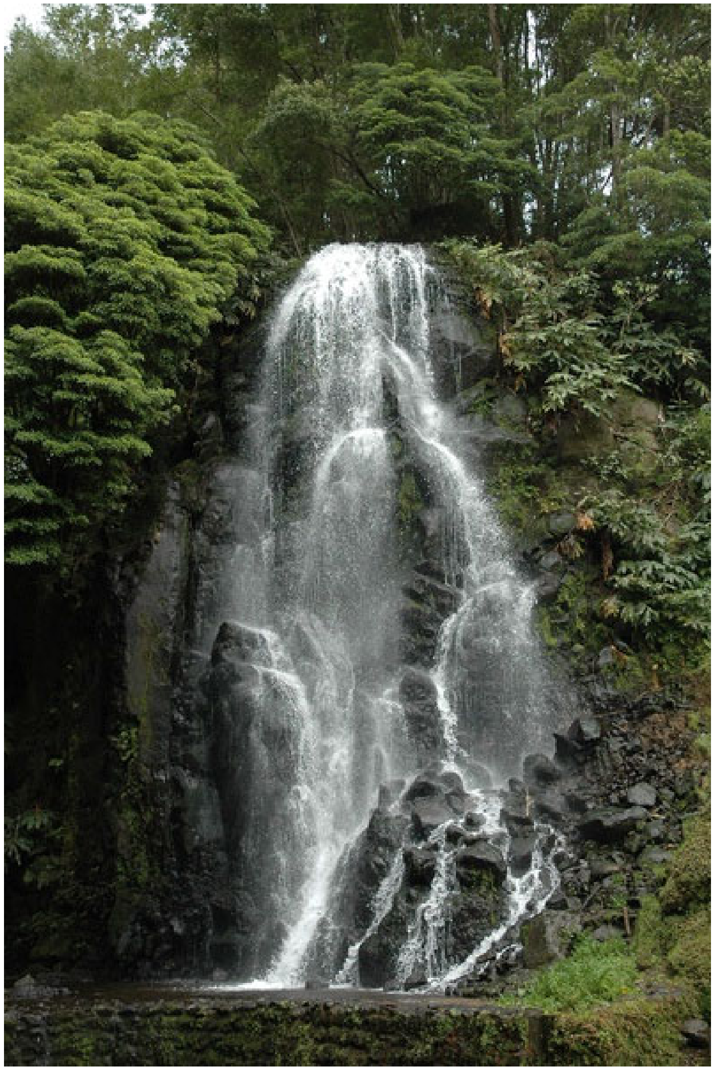
Basics of NETMAP

- Channel nodes based on smoothed flow paths based on the D-8 flow path (i.e., the flow direction based from each cell based on its 8 neighbors towards the steepest downslope neighbor).
- Channel nodes linked to adjacent upstream and downstream nodes in the channel network.
- Each node has a flow length and attributes (e.g., elevation, drop)
- Data attributes can be assigned to reaches derived solely from the DEM

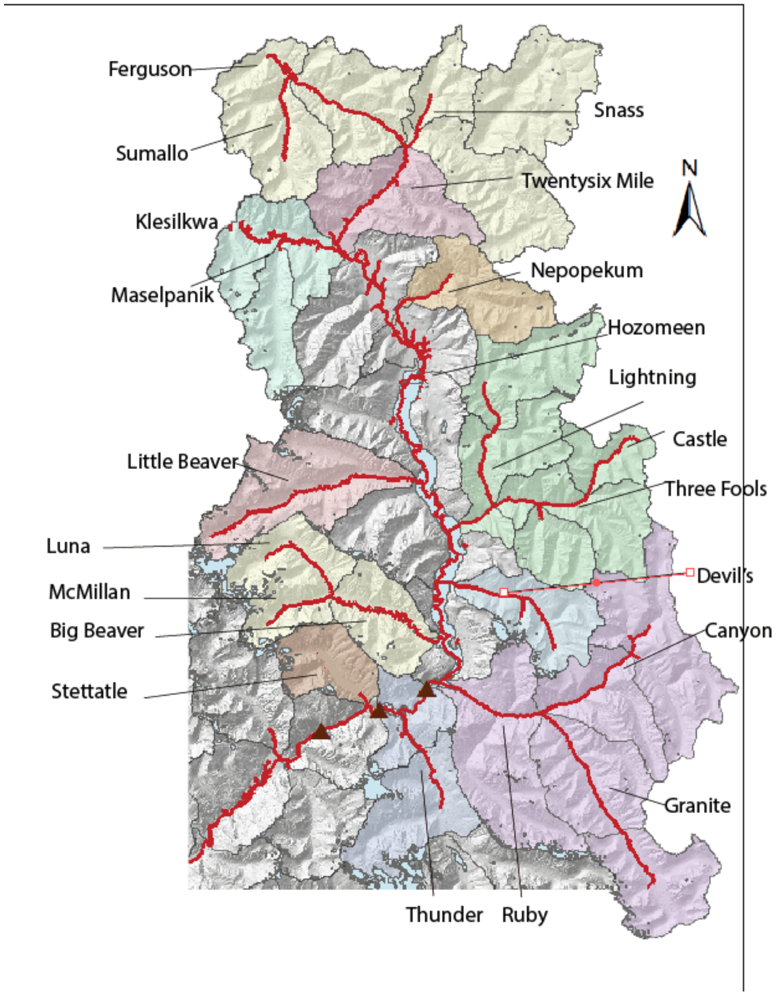


Identifying potential natural barriers

- Natural fish passage barrier assessment estimated from reach gradient and node drops.
- Gradient: Gradient assessed at window of 160 m. All reaches with average gradient < 0.20 included.
- Node Drop: Node value >3.7 m in height



Anadromous fish distribution



Proposed potential anadromous fish distribution based on reaches with Gradient ≤ 0.20 and Node Drop ≤ 3.7 m *

*Some nodes > 3.7 m bypassed in order to extend distribution upstream.
*Most removed nodes with drops < 10 m single, isolated nodes.

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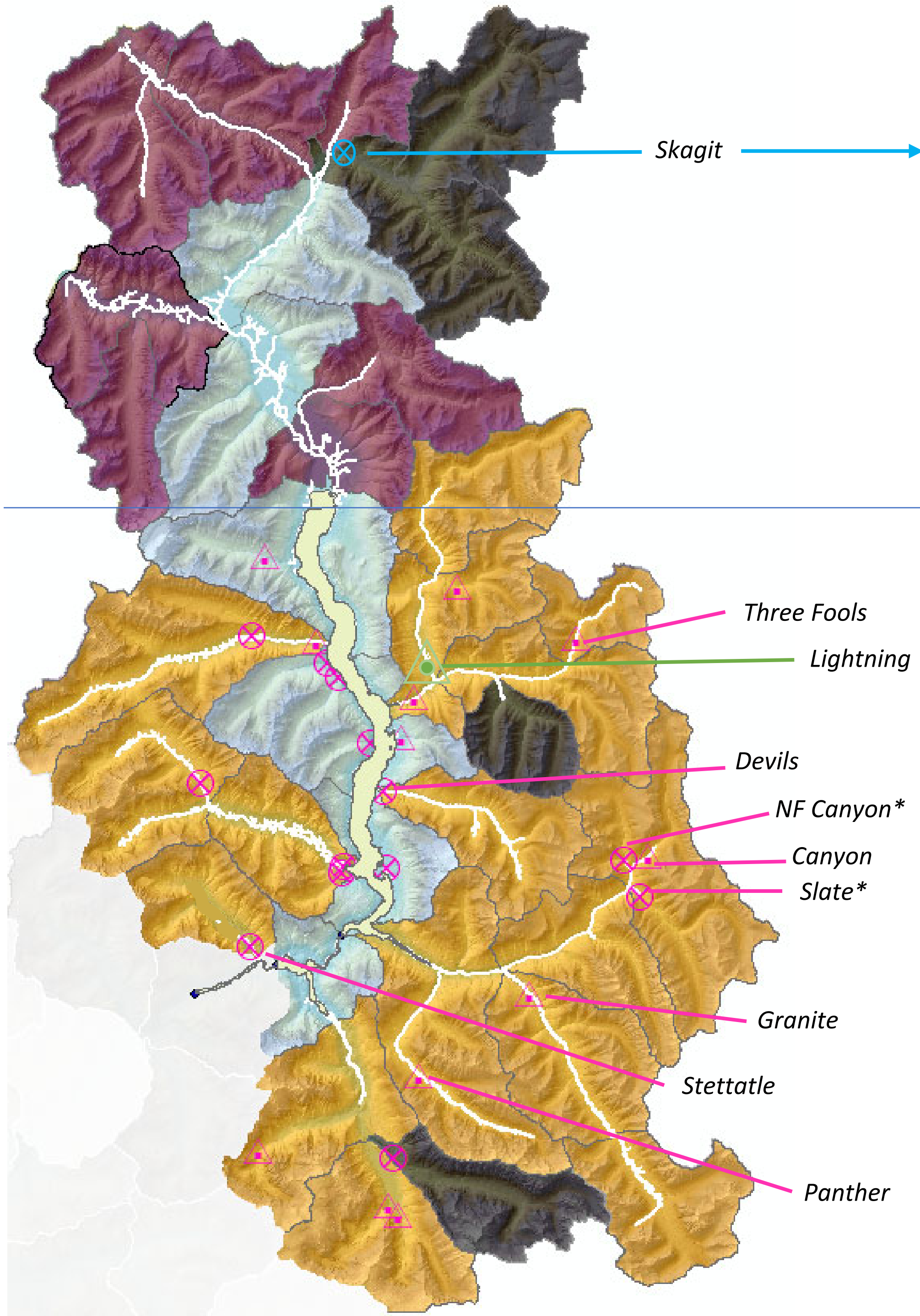

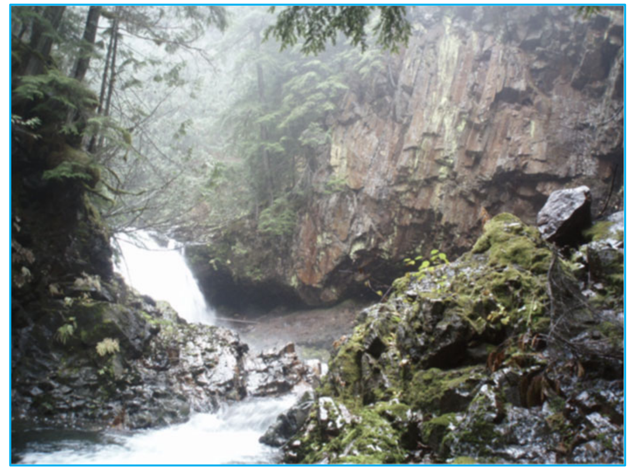

Triton Report

Falls

Seattle City Light data

Falls

Cascade

USGS 2019 Survey

Cascade

BC Upper Skagit anadromous fish distribution

Table 1. British Columbia streams with accessible habitat to fish from Ross Reservoir (NPS)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Skagit River	Ross to Klesilkwa	17.6	<1
	Klesilkwa to barrier falls near Snass	17.1	<1
Klesilkwa	Skagit to Silverhope divide	14.3	<1
Sumallo	Skagit to Ferguson	16.6	<1
Ferguson Creek	Sumallo R. to HWY3	3.9	2
Nepopekum Creek	Skagit to start of canyon	2.7	3
Nepopekum Creek	Start of Canyon to Poland cr.	9.3	5
Sumallo River	Ferguson to end 3rd order	12.1	5
Maselpanik Creek	Klesilkwa to end 3rd order	12.2	6
Snass Creek	Skagit R. to Dry Lake	3.7	6
Ferguson Creek	Hwy 3 to end 3rd order	3.7	9
Klesilkwa	Silverhope Divide to end 3rd order	3.7	10
Twentysix Mile Creek	Skagit River to end 3rd order	5.8	11
Marmotte Creek	Marmotte Creek to end 3rd order	4.3	12

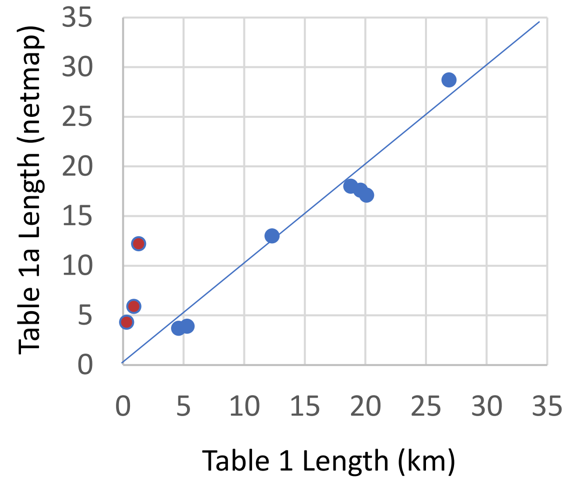

Table 1a. British Columbia streams with accessible habitat to anadromous fish from Ross Reservoir (NPS).

Subbasin	Stream Name	Reach Description	Total Length (km)	Ave. Width m ± SD (range)	Ave. Gradient % ± SD (range)	Ave. Annual Discharge (cms)
BC Skagit	Skagit Mainstem	Ross to Klesilkwa	19.6	25.7 ± 3.6	0.005 ± 0.016	16.6 ± 7/6
	Skagit Mainstem	Klesilkwa to barrier	20.1	20.0 ± 2.2	0.007 ± 0.008	9.4 ± 2.1
	Nepopekum Creek	Skagit to potential barrier (8.6 m drop)	12.3	8.7 ± 0.2	0.03 ± 0.03	1.5 ± 0.1
	Snass Creek	Snass to potential barrier (14.6 m drop)	4.6	6.7 ± 0.8	0.05 ± 0.03	0.8 ± 0.2
	Twentysix Mile Creek	Skagit to potential barrier (10.0 m drop)	0.9	6.3 ± 0.03	0.10 ± 0.03	0.7 ± 0.01
	Marmotte Creek	Skagit to potential barrier (8.6 m drop)	0.3	4.8 ± 0.01	0.07 ± 0.01	0.4 ± 0.001
Klesilkwa	Klesilkwa River	Skagit to Silverhope	18.8	10.9 ± 2.7	0.01 ± 0.02	2.6 ± 1.4
	Maselpanik Creek	Klesilkwa to potential barrier (16.7 m drop)	1.3	10.4 ± 0.2	0.05 ± 0.03	2.2 ± 0.1
Sumallo	Sumallo River	Skagit to potential barrier (14.6 m drop)	26.9	11.0 ± 2.7	0.01 ± 0.02	2.6 ± 1.3
	Ferguson Creek	Sumallo to potential barrier (8.2 m drop)	5.3	5.6 ± 0.7	0.01 ± 0.02	0.5 ± 0.1

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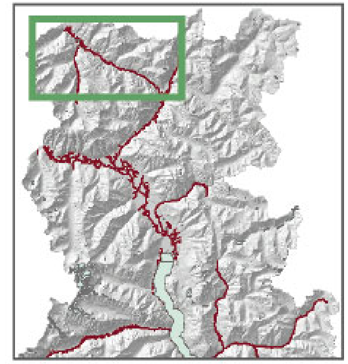
BC Example 'end of fish' distribution



Ferguson Creek

Tributary of the Sumallo River

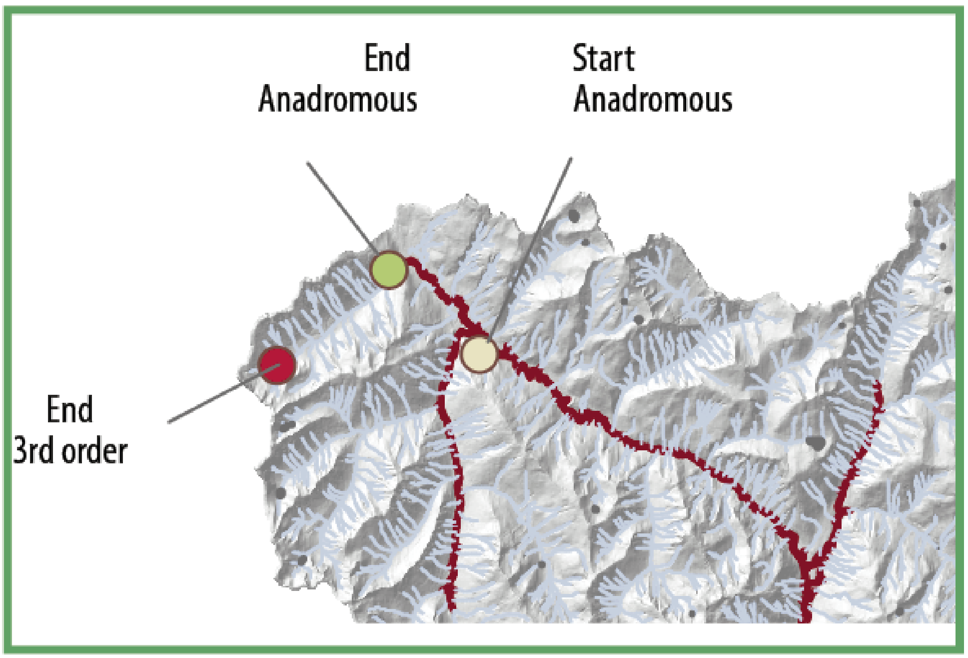
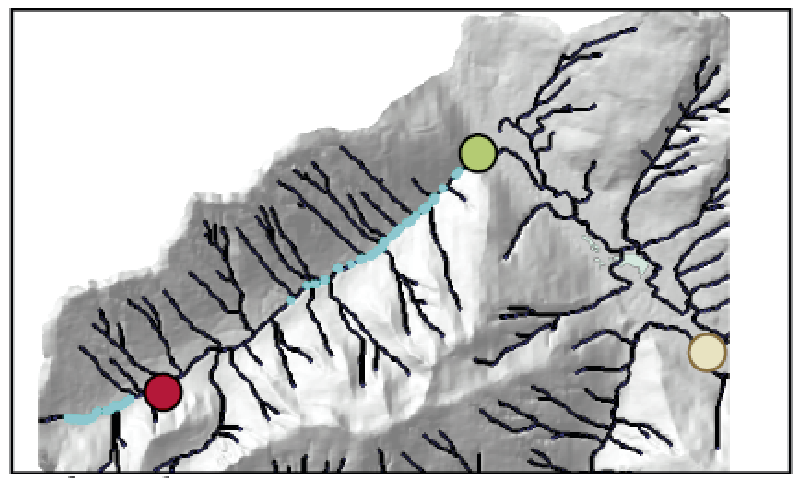


Fig. 1. Potential anadromous fish distribution (in red) of Ferguson Creek

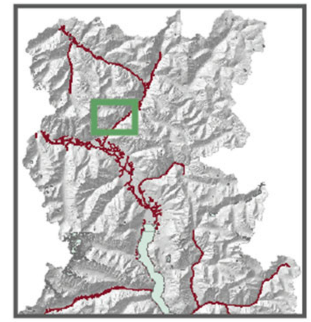


Nodes with Drops ≥ 3.7 m

n = 104; Range = 4.1 m to 85.7 m; first = 8.2 m

Fig. 3. Map of potential barriers ≥ 3.7 m

BC Example ‘end of fish’ distribution



Marmotte Creek
Tributary to the Skagit River

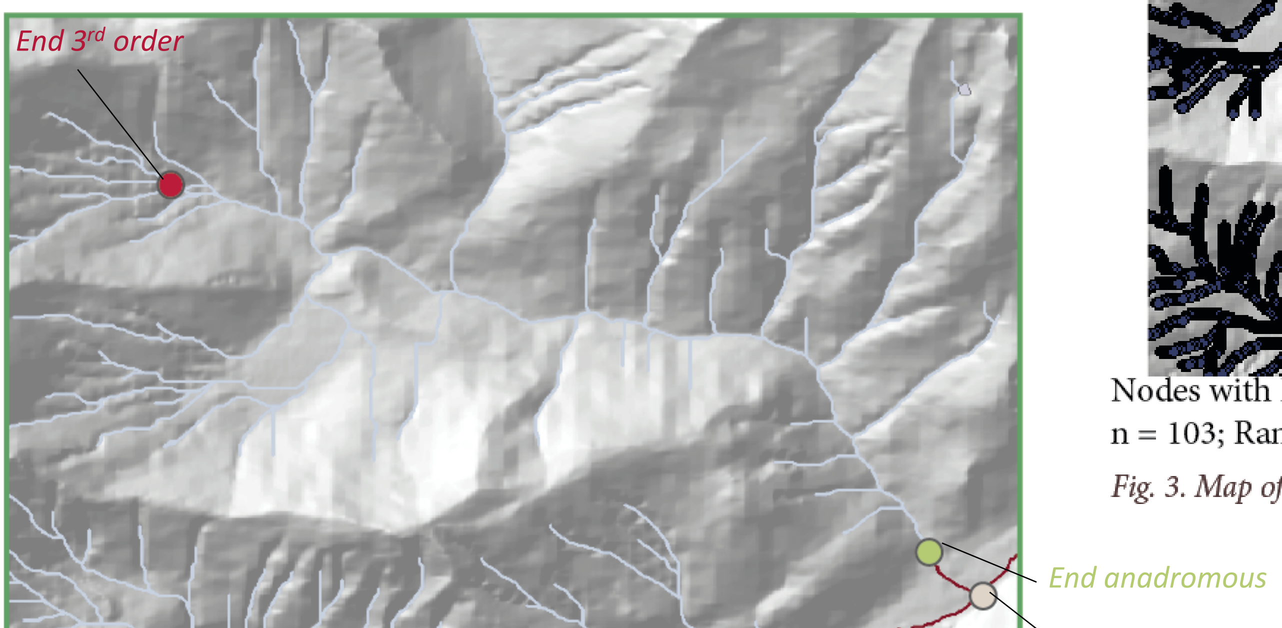
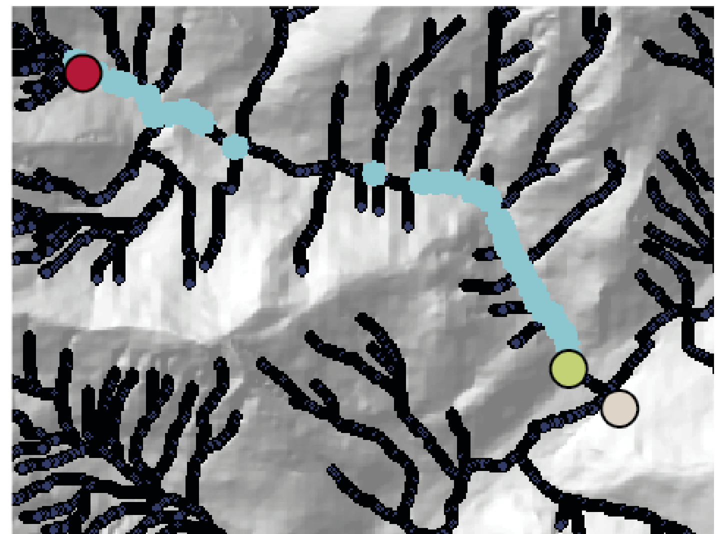


Fig. 1. Potential anadromous fish distribution (in red) of Marmotte Creek.



Nodes with Drops ≥ 3.7 m
n = 103; Range = 3.9 m to 22.1; first = 8.5 (n=2)

Fig. 3. Map of potential barriers ≥ 3.7 m

U.S. Skagit anadromous fish distribution

Table 1. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Big Beaver Creek	Ross to McMillan	14.6	<1
Ruby Creek	Ross to Canyon/Granite Confluence	5.5	2
Canyon Creek	Ruby to Slate Creek	11.9	2
Lightning Creek	Ross to Three Fools	3.5	2
Lightning Creek	Three Fools to Freezeout	8.8	2
Little Beaver Creek	Ross to end 3rd order	24.2	2
Granite Creek	Ruby to “indistinct barrier”	8.6	4
Luna Creek	Big Beaver to end 3rd order	4.5	4
Lightning Creek	Freezeout to Boundary	6.3	4
Three Fools Creek	Lightning to Castle	10.1	4
Castle Creek	Three Fools to Rustle	5.8	9
Canyon Creek	Slate to “barrier falls”	4.2	7
NF Canyon Creek	Canyon to “barrier falls”	1.0	7
East Creek	Granite to end 3rd order	6.9	12
Cabinet Creek	Granite to end 3rd order	3.2	13

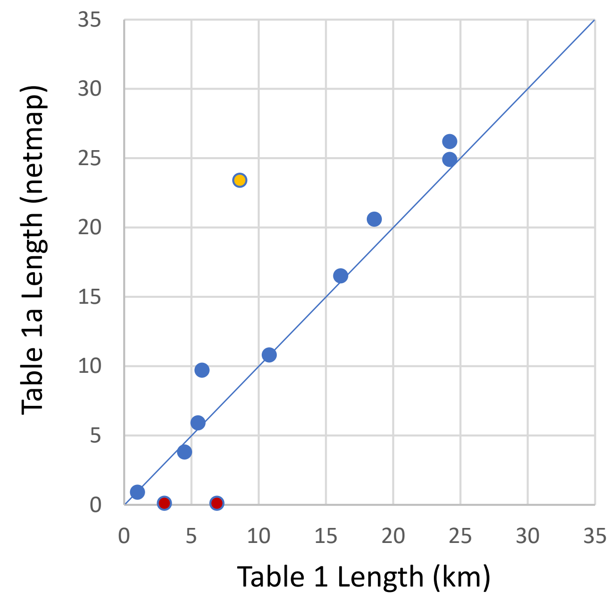


Table 1a. US Washington State streams with accessible habitat to anadromous fish from Ross Reservoir (NPS).

Subbasin	Stream Name	Reach Description	Total Length (km)	Ave. Width m ± SD (range)	Ave. Gradient % ± SD (range)	Ave. Annual Discharge (cms)
US Skagit	Hozomeen Creek	Ross to potential barrier (52 m)	0.1	4.9	0.03	0.4
Little Beaver	Little Beaver Creek	Ross Lake to end of 3rd order	26.2	11.9 ± 2.7	0.02 ± 0.02	3.1 ± 1.4
Big Beaver	Big Beaver Creek	Ross Lake to Luna Creek	24.9	14.1 ± 2.7	0.01 ± 0.02	4.4 ± 1.5
	McMillan Creek	Big Beaver Creek to potential barrier	8.1	8.1 ± 1.1	0.04 ± 0.03	1.3 ± 0.3
	Luna Creek	Big Beaver to potential barrier	3.8	8.9 ± 0.34	0.03 ± 0.02	1.5 ± 0.1
Lightning	Lightning Creek	Ross Lake to border creek	20.6	11.2 ± 2.9	0.03 ± 0.02	2.8 ± 1.7
	Three Fools Creek	Lightning Creek to Castle Fork Creek	10.8	10.6 ± 1.6	0.04 ± 0.02	2.3 ± 0.7
	Castle Fork	Three Fools Creek to Rustle Creek	9.7	4.8 ± 1.4	0.07 ± 0.03	0.4 ± 0.3

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U.S. Skagit anadromous fish distribution

Table 1. Washington State streams with accessible habitat to fish from Ross Reservoir (NPS)

Stream/River Name	Reach Description	Length (KM)	Gradient (%)
Big Beaver Creek	Ross to McMillan	14.6	<1
Ruby Creek	Ross to Canyon/Granite Confluence	5.5	2
Canyon Creek	Ruby to Slate Creek	11.9	2
Lightning Creek	Ross to Three Fools	3.5	2
Lightning Creek	Three Fools to Freezeout	8.8	2
Little Beaver Creek	Ross to end 3rd order	24.2	2
Granite Creek	Ruby to "indistinct barrier"	8.6	4
Luna Creek	Big Beaver to end 3rd order	4.5	4
Lightning Creek	Freezeout to Boundary	6.3	4
Three Fools Creek	Lightning to Castle	10.1	4
Castle Creek	Three Fools to Rustle	5.8	9
Canyon Creek	Slate to "barrier falls"	4.2	7
NF Canyon Creek	Canyon to "barrier falls"	1.0	7
East Creek	Granite to end 3rd order	6.9	12
Cabinet Creek	Granite to end 3rd order	3.2	13

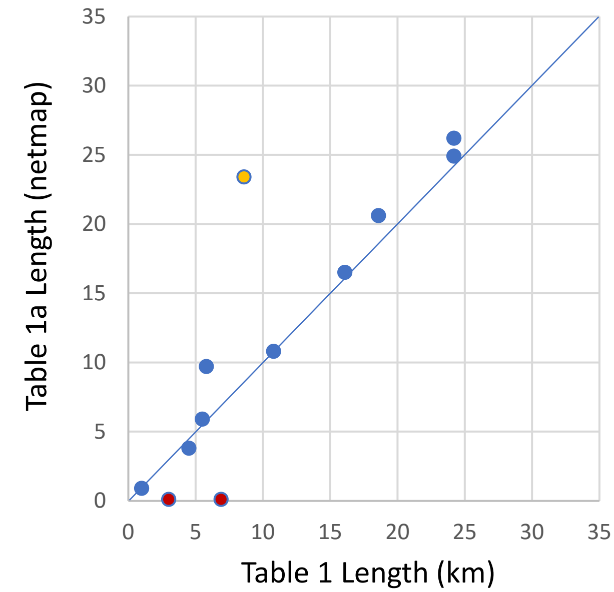

Table 1a. US Washington State streams with accessible habitat to anadromous fish from Ross Reservoir (NPS).

Subbasin	Stream Name	Reach Description	Total Length (km)	Ave. Width m ± SD (range)	Ave. Gradient % ± SD (range)	Ave. Annual Discharge (cms)
US Skagit	Ruby Creek	Ross Lake to Canyon Creek	5.9	19.9 ± 1.4	0.02 ± 0.00	9.2 ± 1.4
	Devil's Creek	Ross Lake to potential barrier	14.4	7.4 ± 1.6	0.05 ± 0.02	1.1 ± 0.4
Canyon Creek	Canyon Creek	Ruby Creek to potential barrier	16.5	11.7 ± 2.7	0.03 ± 0.02	3.0 ± 1.3
	N.F. Canyon Creek	Canyon Creek to potential barrier	0.9	6.4 ± 0.2	0.09 ± 0.02	0.7 ± 0.0
Granite Creek	Granite Creek	Ruby Creek to potential barrier	23.4	10.5 ± 1.7	0.03 ± 0.02	2.3 ± 0.8
	East Creek	Granite Creek to potential barrier	0.1	-	-	-
	Cabinet Creek	Granite Creek to potential barrier	0	-	-	-
	Slate Creek	Granite Creek to potential barrier	1.1	8.6 ± 0.05	0.07 ± 0.01	1.4 ± 0.02
US Skagit	Thunder Creek	Diablo Lake to potential barrier	8.0	19.8 ± 0.5	0.02 ± 0.02	9.1 ± 0.5
US Skagit	Stetattle Creek	Gorge Lake to potential barrier	1.7	11.8 ± 0.8	0.04 ± 0.02	2.9 ± 0.05

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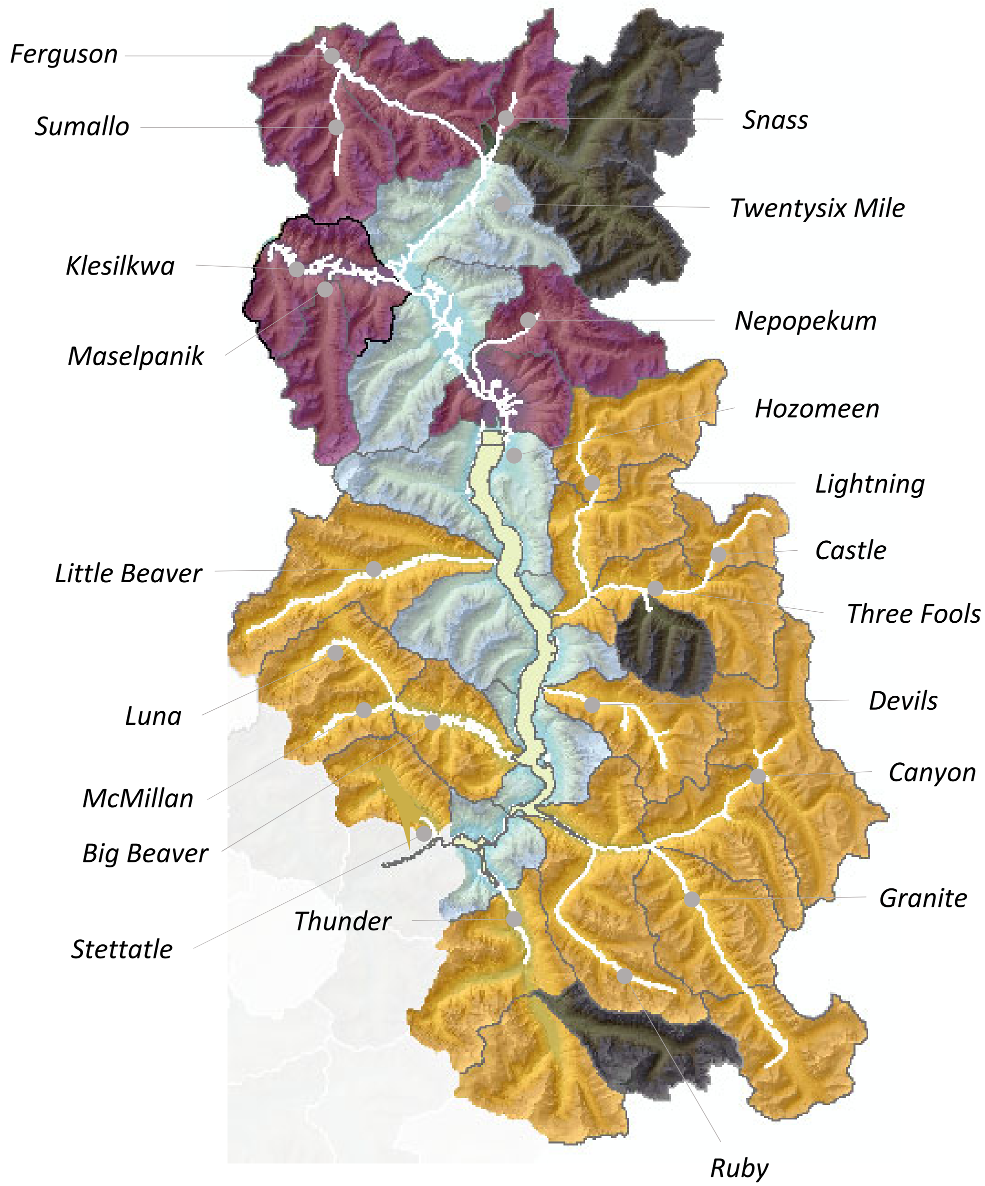
Next steps

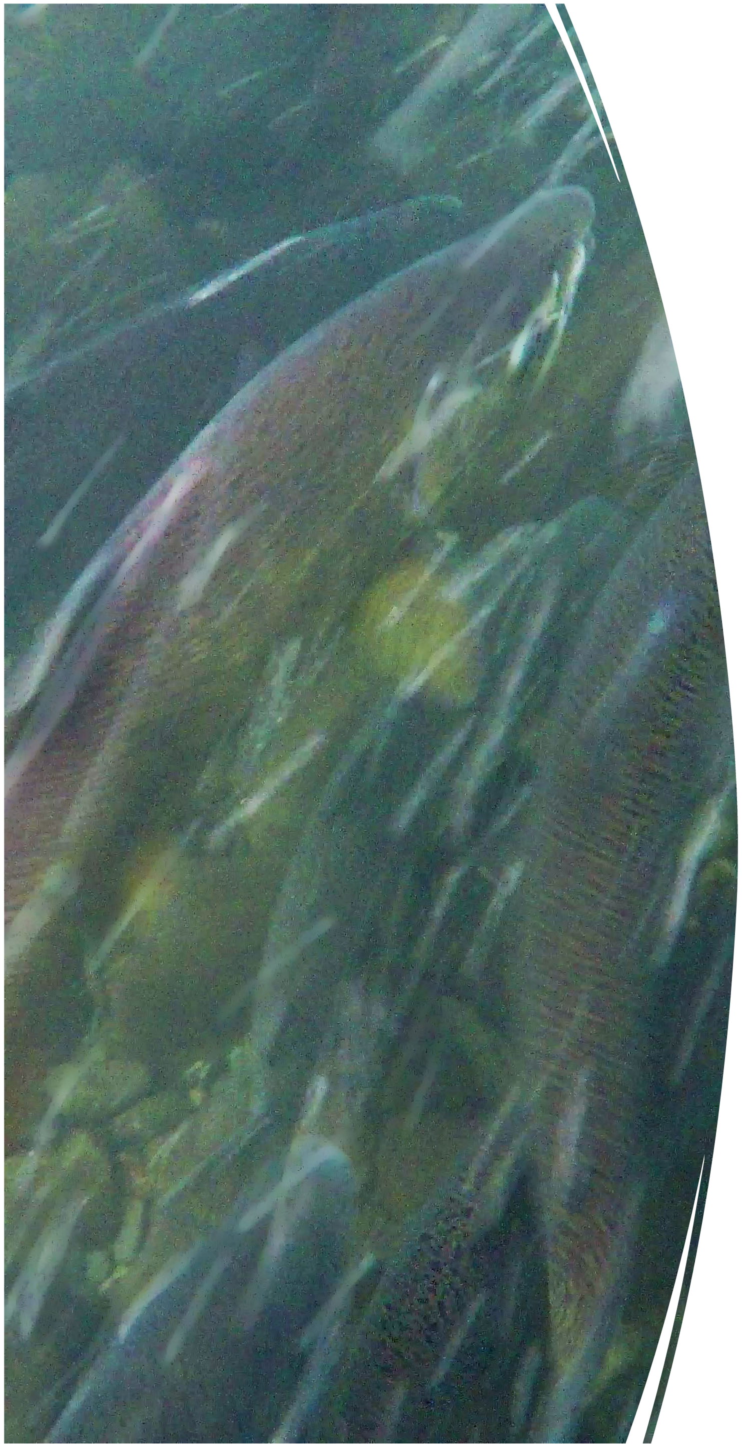
- Incorporate hydrography fix in NETMAP to Klesilkwa River
- Complete IP model runs for steelhead, coho, Chinook based on existing models
- Workshop:
  - Evaluate IP model results
  - Modify habitat index criteria if needed
  - Develop habitat suitability curves for additional species where existing IP models do not exist (i.e., sockeye)

Existing salmon IP Models

Model	Species	Region	Life stage
Burnett et al.	Steelhead	Oregon Coast	Rearing
Agrawal et al.	Steelhead	California	Rearing
Puget Sound TRT	Steelhead	Puget Sound	Spawning/Rearing
Cooney&Holzer	Steelhead	Interior Columbia	Spawning/Rearing
Connor et al.	Chinook	Skagit	Spawning
Busch et al.	Chinook	Lower Columbia	Spawning/Rearing
Cooney&Holzer	Chinook	Interior Columbia	Spawning/Rearing
Burnett	Coho	Oregon Coast	Rearing
Agrawal et al	Coho	California	Rearing
Romey	Coho	Alaska	Rearing

Potential fish bearing streams for salmon introduction





Coho IP

Coho IP: Model inputs

Burnett

Parameter	Data Divisions (habitat envelope)					IP Ranking for divisions				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Gradient (%)	0	5	7	10	>10	1	.01	.01	0	0
VWI	1	5	7	10	>10	.25	.25	1	1	1
Flow (cms)	0	.01	.06	21	>21	0	0	1	1	.5

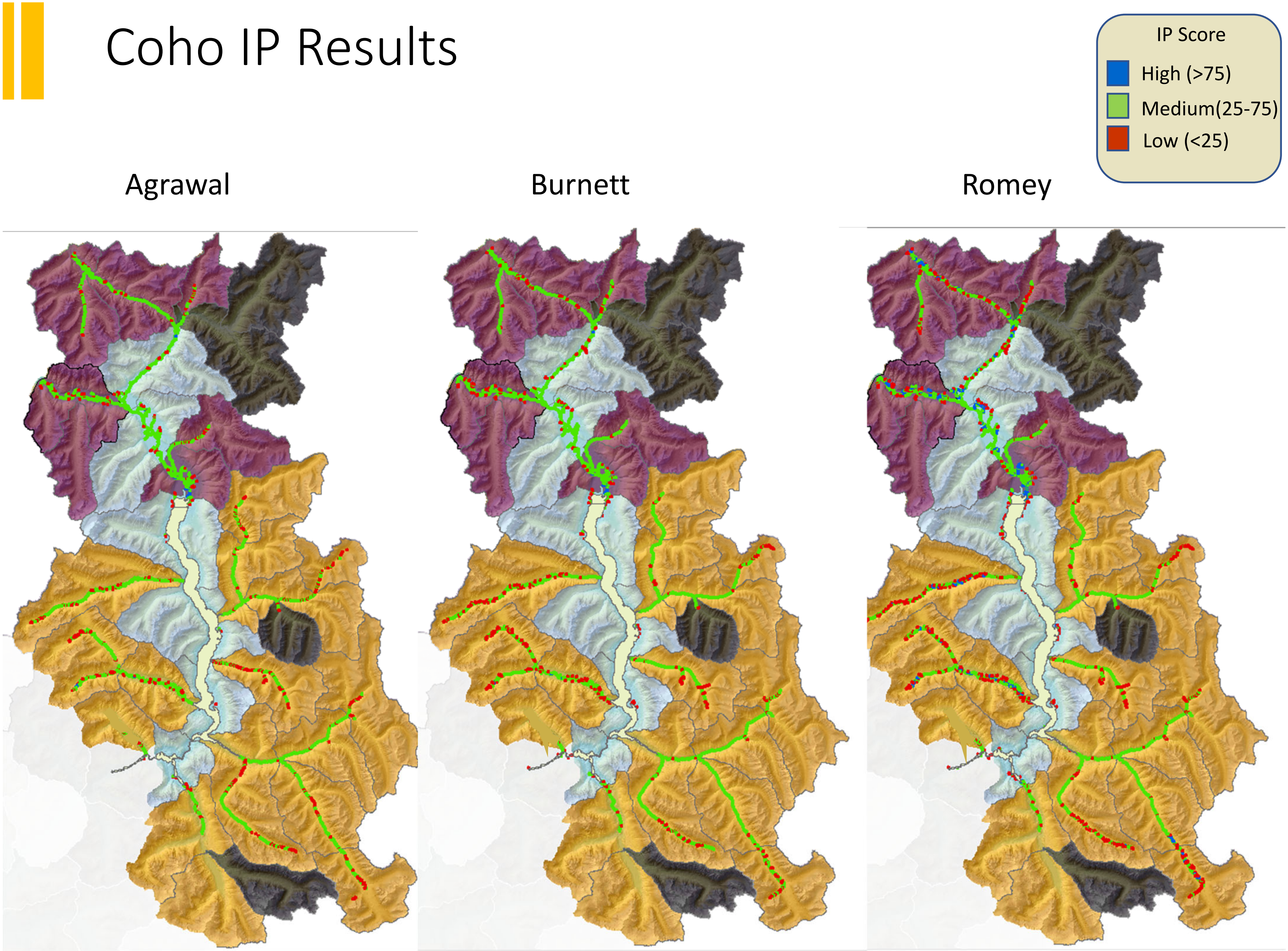
Romey

Parameter	Data Divisions (habitat envelope)					IP Ranking for divisions				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Gradient (%)	0	.15	2.5	7	>10	1	1	1	.01	.01
VWI	1	3	5.25	22	>40	.35	.35	1	1	.55
Flow (cms)	0	.025	5	10	>15	0	1	1	.65	.65

Agrawal

Parameter	Data Divisions (habitat envelope)					IP Ranking for divisions				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Gradient (%)	0	5	7	10	>10	.4	1	1	.01	0
VWI	0	5	9	10	>10	1	1	.25	.25	.25
Flow (cms)	0	.01	.06	21	>21	0	0	1	.5	.5

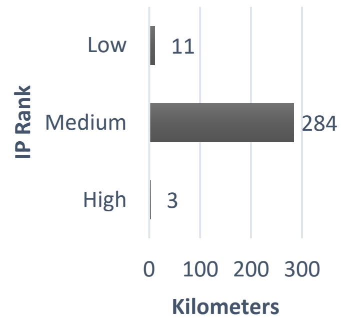
Coho IP Results



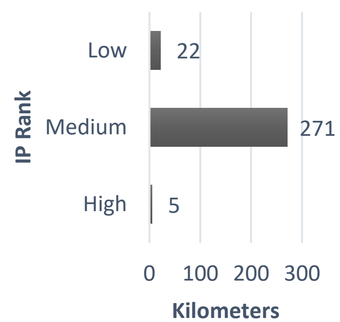
Coho IP – Core Tribs

Agrawal

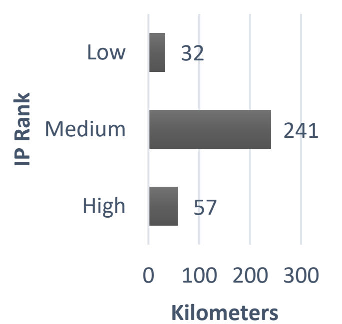
Table 1 & 2 Tribs

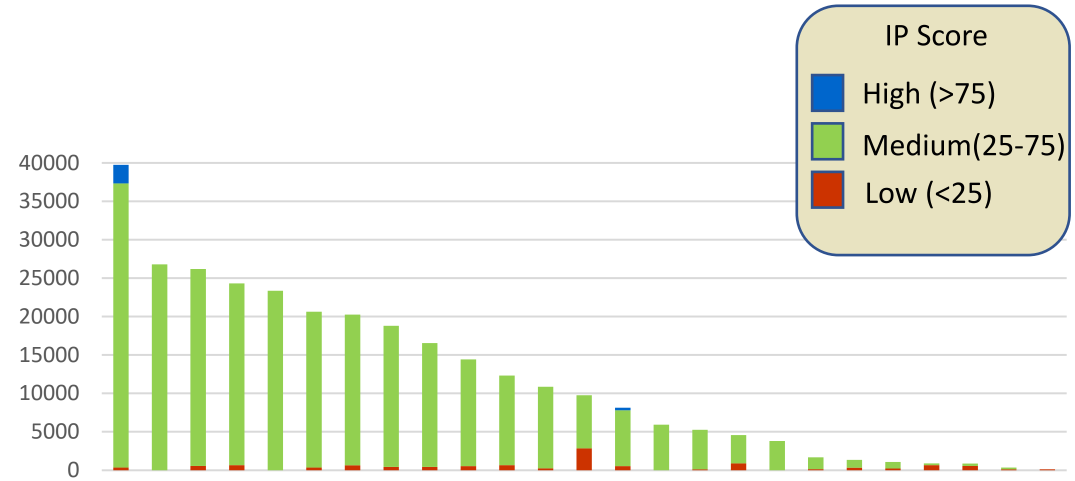


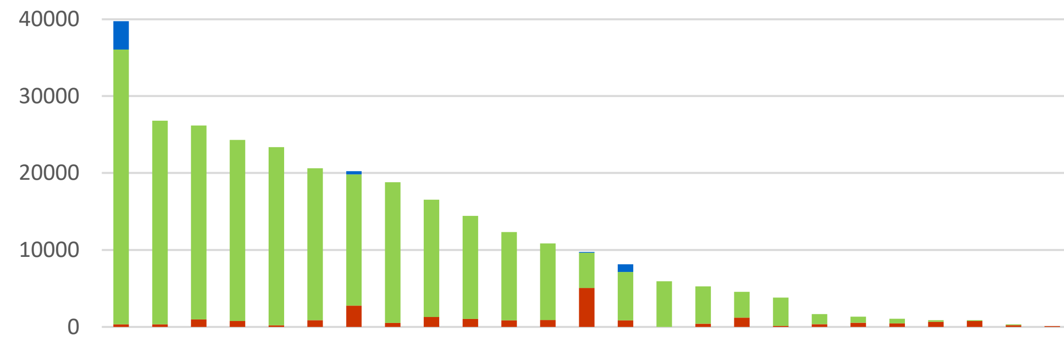
Romey

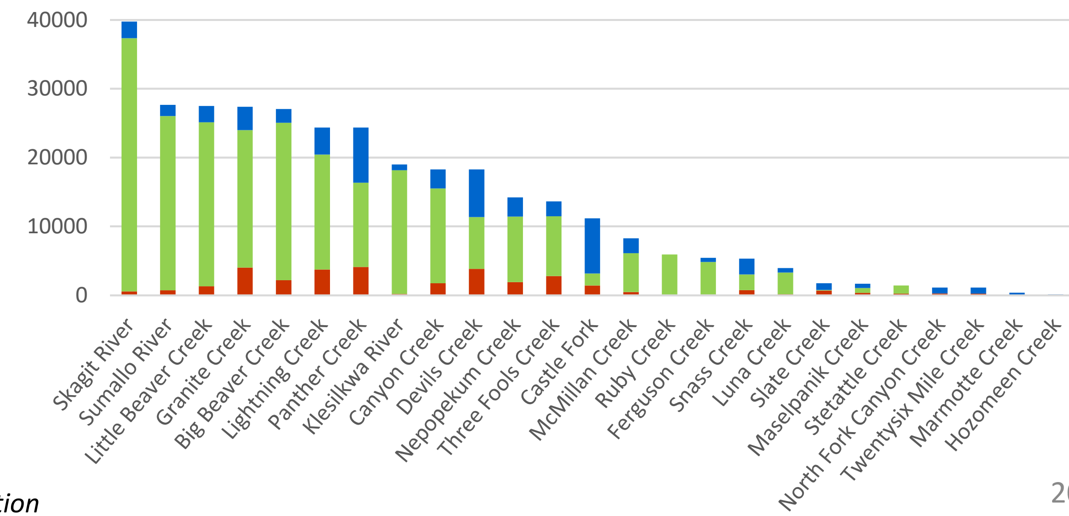


Burnett









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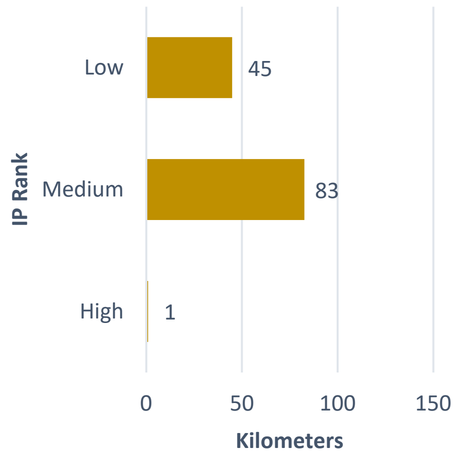
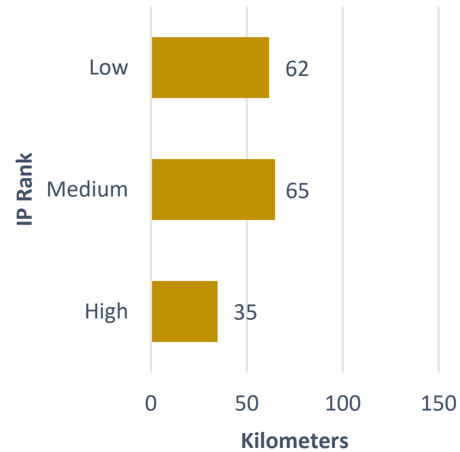
Coho IP – Other reaches

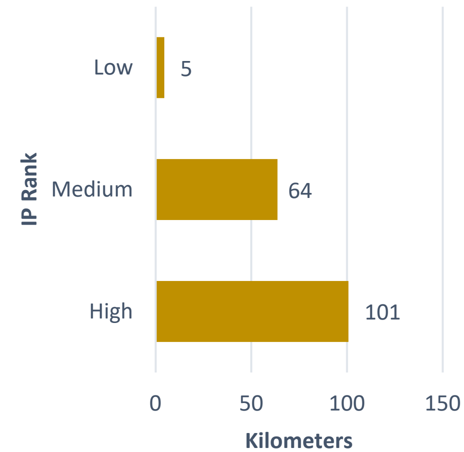
Agrawal



Romey



Burnett



Tributary	Low	Med.	High
Unnamed	39.3	69.5	1.0
Thunder Creek	0.0	8.0	0.0
Cinnamon Creek	0.1	1.7	0.0
North Fork Devils Creek	1.3	0.0	0.0
25 Tribs <1.0 km	4.2	3.4	0.0
Total	**45**	**83**	**1**

Tributary	Low	Med.	High
Unnamed	54.5	52.9	34.7
Thunder Creek	0.1	7.9	0.0
Cinnamon Creek	0.2	1.6	0.0
North Fork Devils Creek	1.3	0.0	0.0
25 Tribs <1.0 km	5	2	0
Total	**62**	**65**	**35**

Tributary	Low	Med.	High
Unnamed	1.4	54.4	90.4
Thunder Creek	1.7	7.2	0.8
Cinnamon Creek	0.3	1.1	0.7
N.F. Devils Creek	0.2	0.0	1.3
Silver Creek	0.3	0.2	0.7
25 Tribs <1.0 km	1	0.7	7.0
Total	**1**	**64**	**101**

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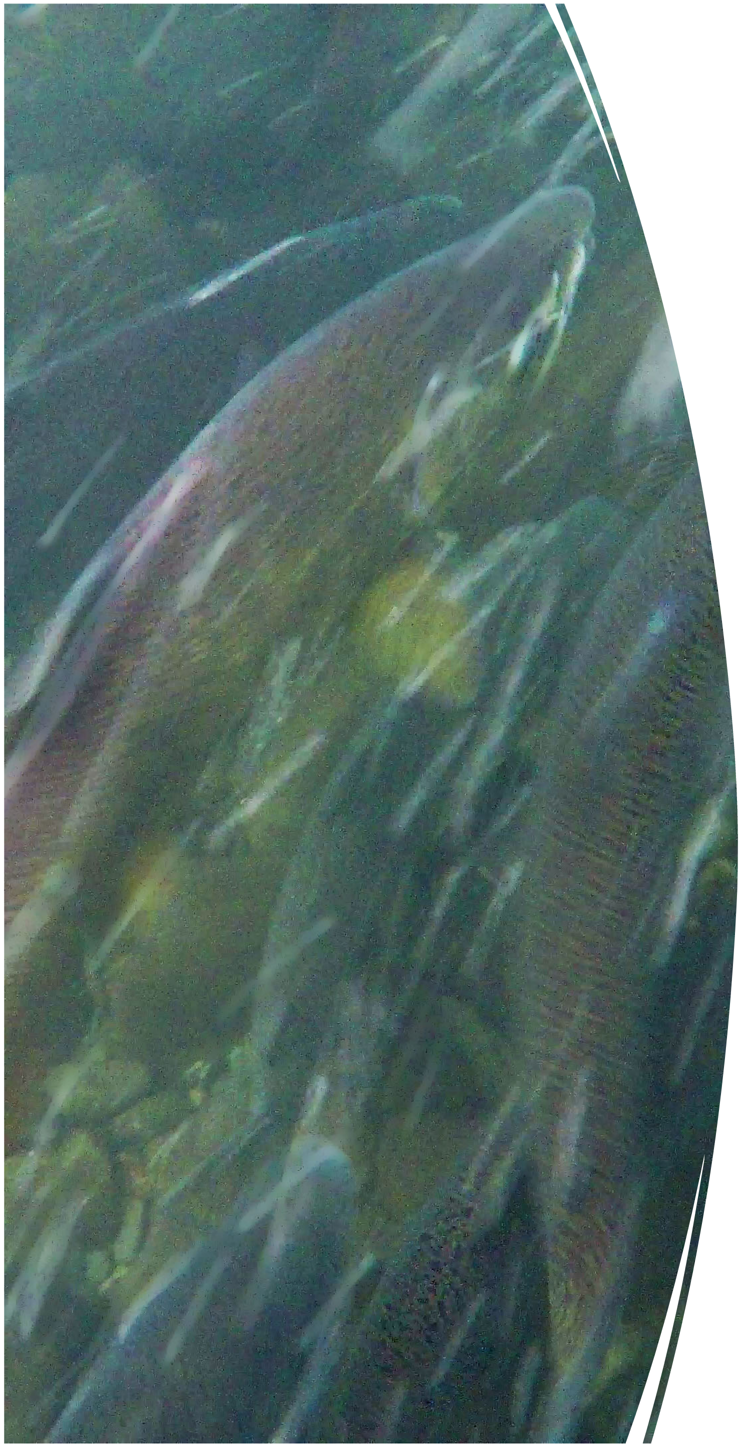


Chinook IP

Chinook IP: Model inputs

Connor

Parameter	Data Divisions (habitat envelope)					IP Ranking for divisions				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Gradient (%)	0	2	4	7	>7	.7	.7	1	.75	.05
Width (m)	0	3	9.1	24.4	>24.4	0	0	.25	.6	1
Basin Elev. (m)	0	610	1219	>1219		0.1	.1	.65	1	

Busch

Parameter	Data Divisions (habitat envelope)					IP Ranking for divisions				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Width	0	4	15	20		0	0	.5	1	
Gradient	0	2	4	7	20	1	1	.05	.05	0
VWI	0	1	8.9	20		0	.01	.25	1	

Cooney & Holzer

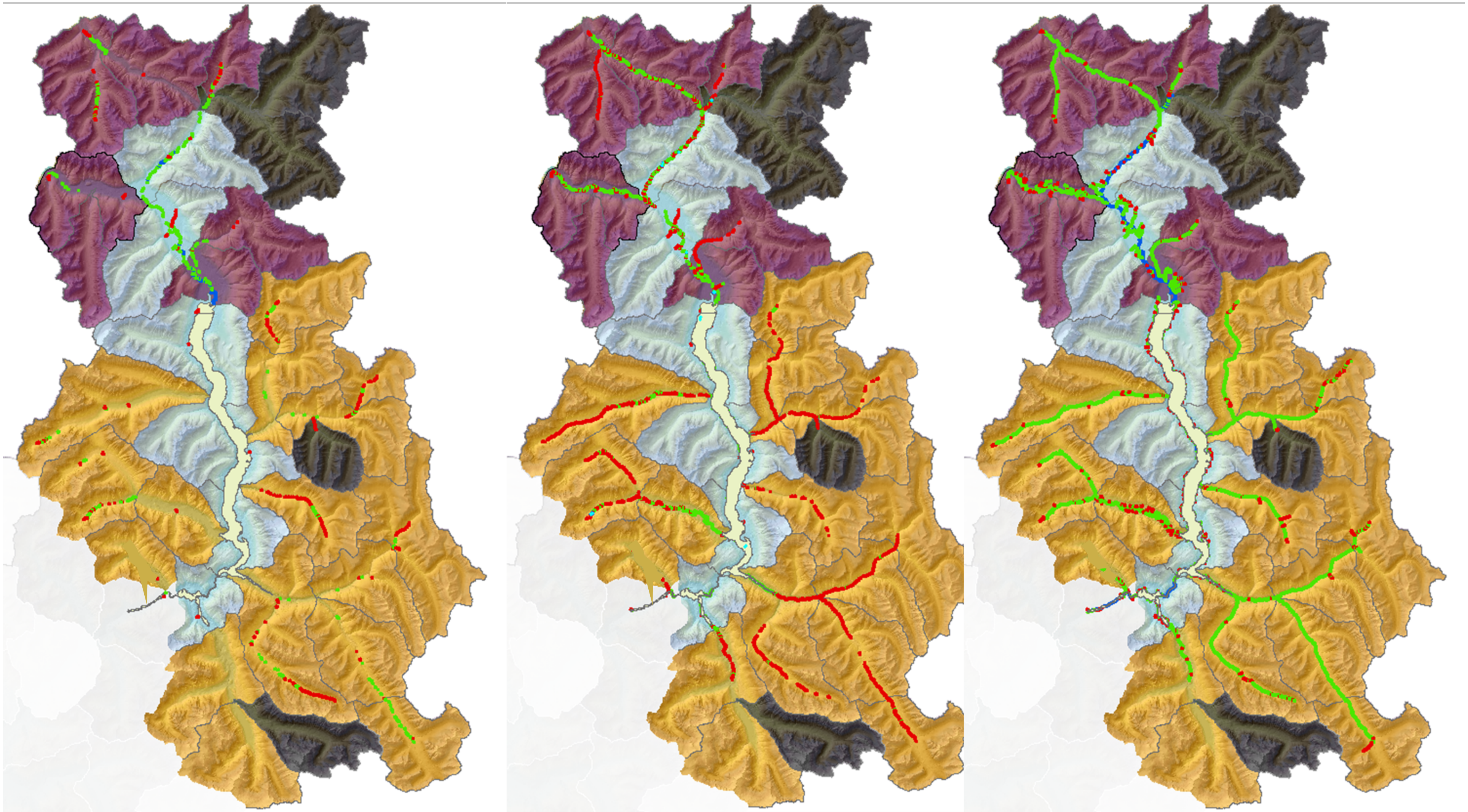
Width (m)	Gradient (%)	Valley Width Ratio		
		<4	4–20	>20
<3.7	>0	0	0	0
3.7–25	<0.5	Med.	High	High
3.7–25	0.5–1.5	Low	Med.	High
3.7–25	1.5–4	Low	Low	Med.
3.7–25	4–7	0	Low	Low
3.7–25	>7	0	0	0
25–50	0–0.5	0	Med.	Med.
25–50	>4	Low	Med.	Med.
>50	>0	0	0	0

Chinook IP Results

IP Score

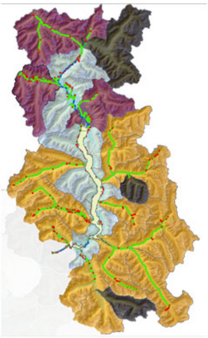
- High (>75)
- Medium(25-75)
- Low (<25)

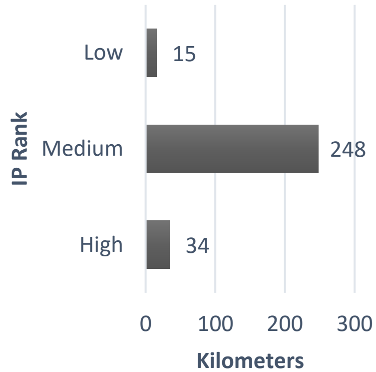
Busch | Cooney & Holzer | Connor

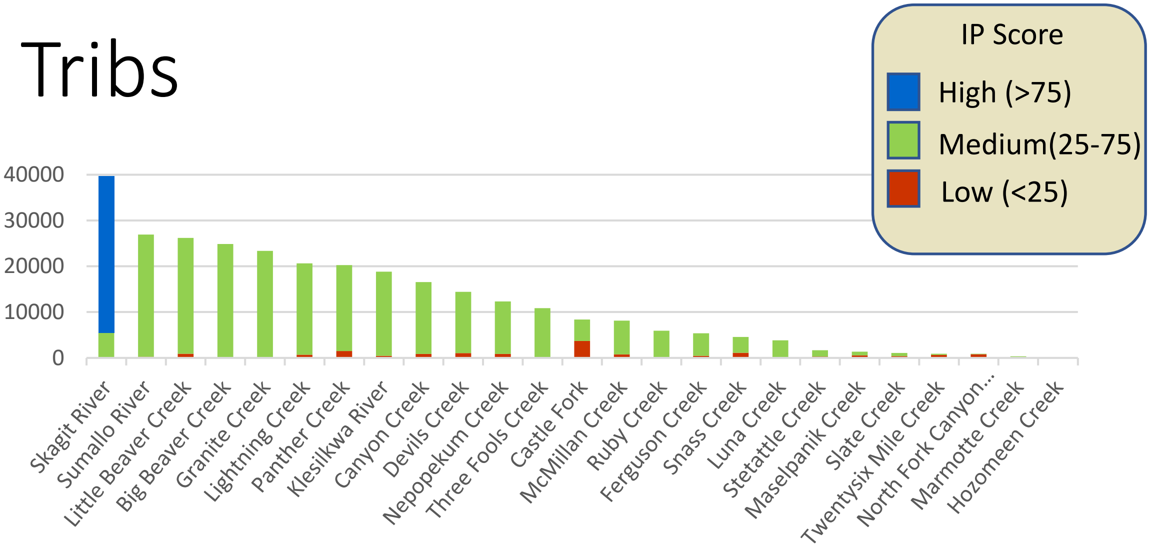


Chinook IP – Core Tribs

Connor







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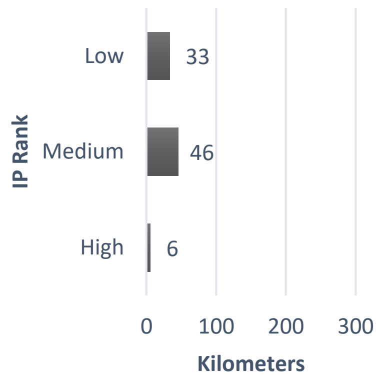
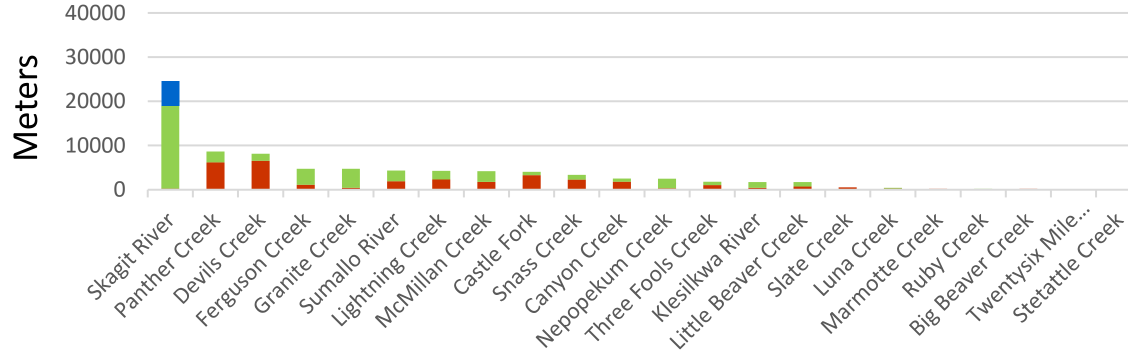
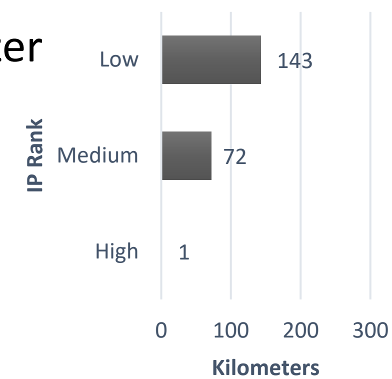
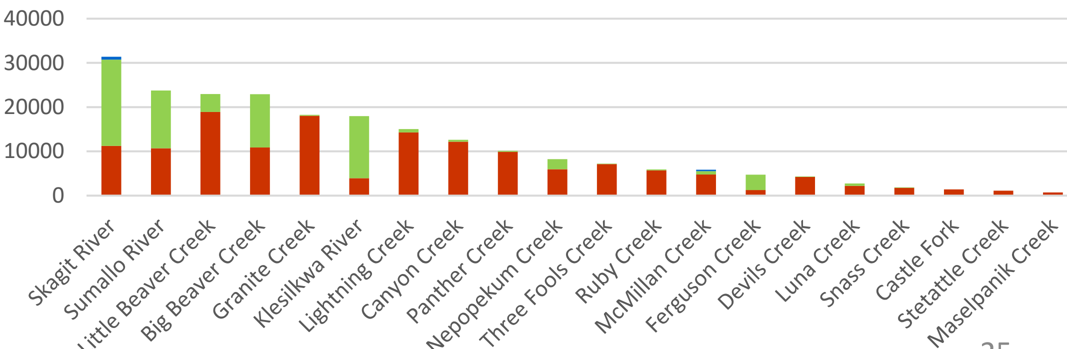




Cooney & Holzer





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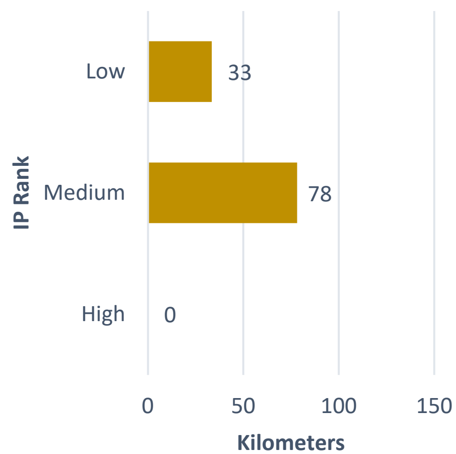
Chinook IP – other reaches

Connor



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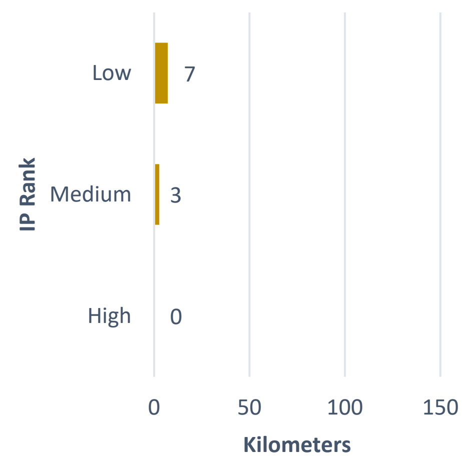
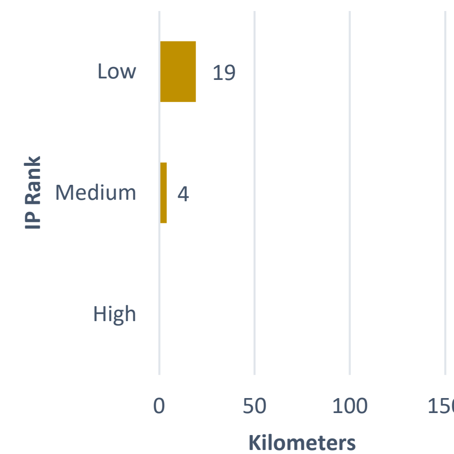


Cooney & Holzer



Tributary	Low	Med.	High
None	27.2	66.2	0
Thunder Creek	0.0	8.0	0
Cinnamon Creek	0.2	1.6	0
North Fork Devils Creek	1.3	0.0	0
22 tribs<1.0 km	4.7	2.4	0
Total	**33**	**78**	**0**

Tributary	Low	Med.	High
Unnamed	3.9	2.5	0
Cinnamon Creek	1.5	0.1	0
9 Tribs <1.0 km	3.0	0.0	0.0
Total	**8**	**3**	**0**

Tributary	Low	Med.	High
Unnamed	6.1	2.2	0
Thunder Creek	5.5	1.5	0
Ruby Creek	5.7	0.2	0
6 Tribs <1.0 km	1.9	0.0	0.0
Total	**19**	**4**	**0**

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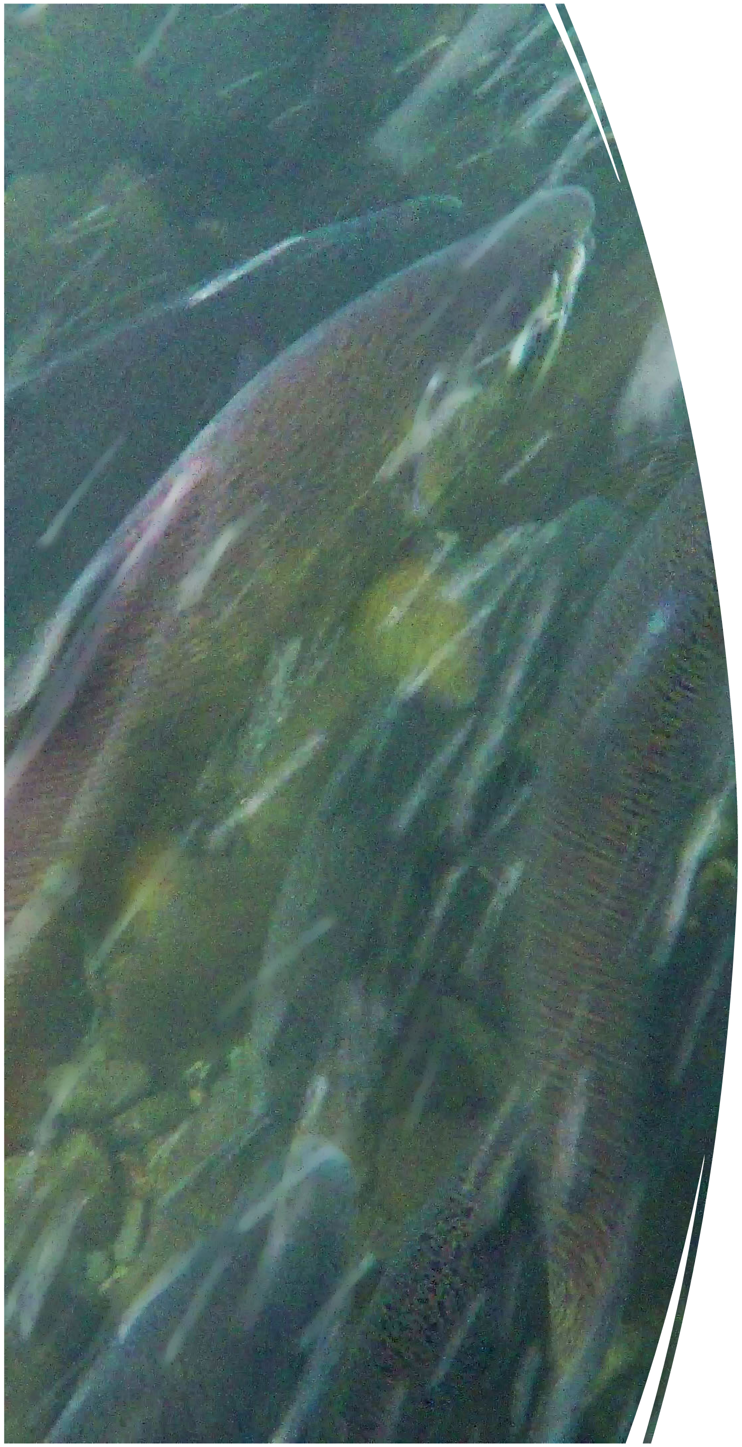


Steelhead IP

Steelhead IP: Model inputs

Burnett

Parameter	Data Divisions (habitat envelope)					IP Ranking for divisions				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Gradient (%)	0	2	3	7	10	.4	1	1	.01	0
VWI	0	5	9	10	>10	1	1	.25	.25	.25
Flow (cms)	0	.01	.06	21	>21	0	0	1	.75	.75

Cooney & Holzer

Bankfull (m)	Gradient (%)	Valley Width Ratio		
		<u><4</u>	<u>4–20</u>	<u>>20</u>
<3.8	>0	0	0	0
3.8–25	<0.5	0	Med.	Med.
3.8–25	0.5–4	Low	High	High
3.8–25	4–7	0	Low	Low
3.8–25	>7	0	0	0
25–50	0–4	0	0	0
25–50	>4	Low	Med.	Med.
>50	>0	0	Low	Low

Agrawal

Parameter	Data Divisions (habitat envelope)				IP Ranking for divisions			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Gradient	0	2	7	12	.4	1	1	0
VWI	1	4	7	9	0	.8	1	.25
Flow (cms)	0	.04	.09	20	0	1	1	.75

PS-TRT

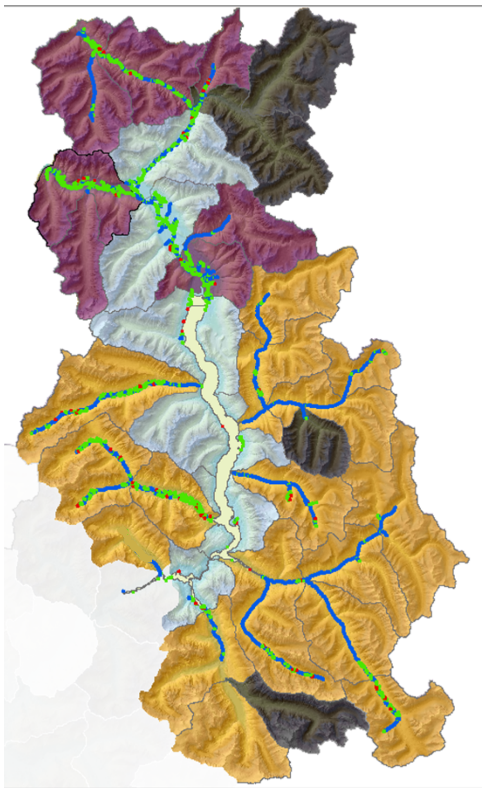
Gradient (%)	Bankfull (m)		
	<u><3</u>	<u>3–20</u>	<u>>20</u>
<0.25	High	Med.	Low
0.25–4	Med.	High	Mod.
>4	Low	Low	Low

Steelhead IP Results

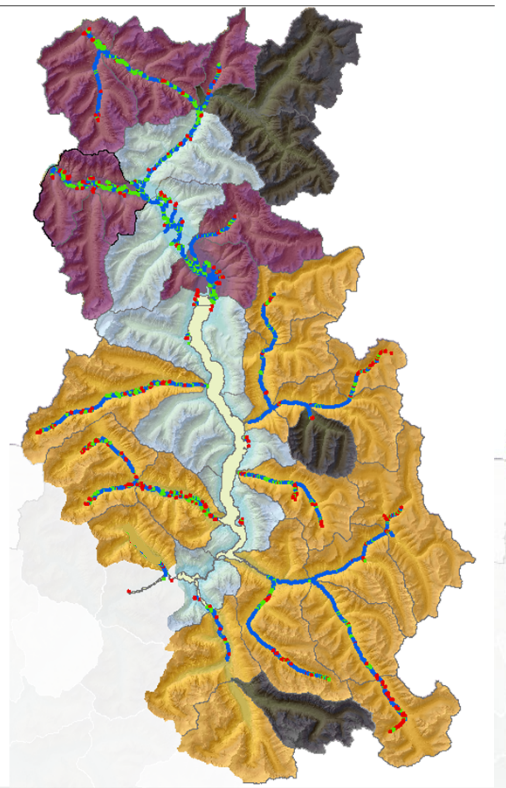
IP Score

- High (>75)
- Medium(25-75)
- Low (<25)

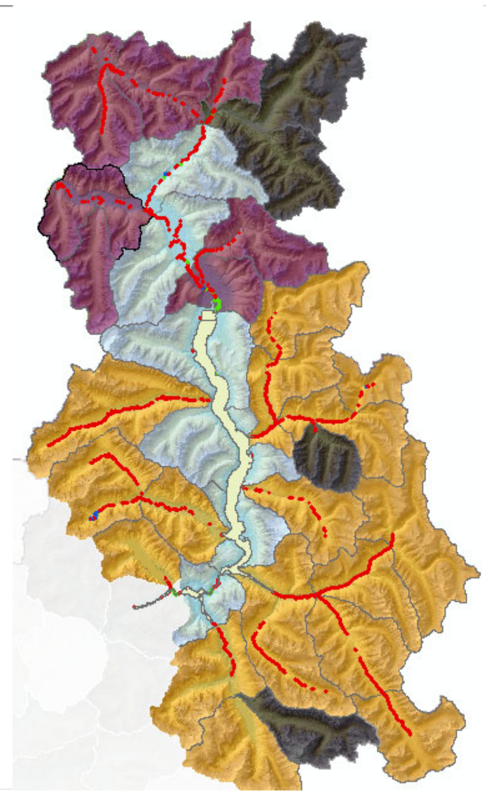
Agrawal



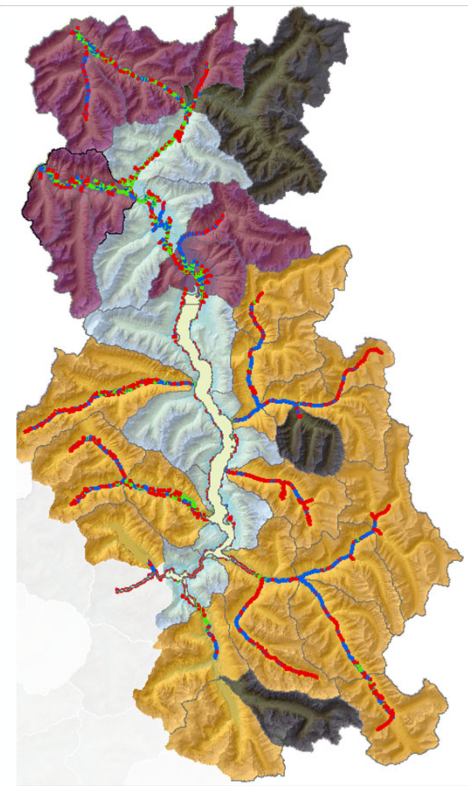
Burnett



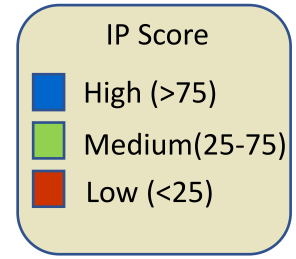
Coney & Holzer



PS_TRT



Steelhead IP – Core Tribs



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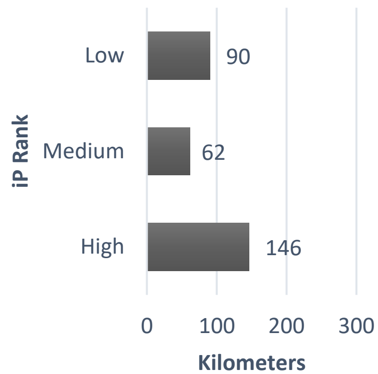

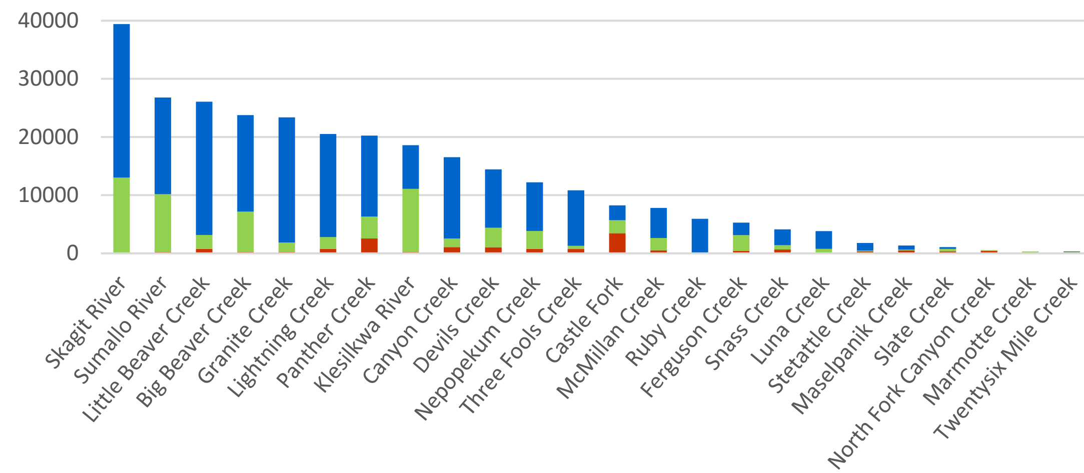

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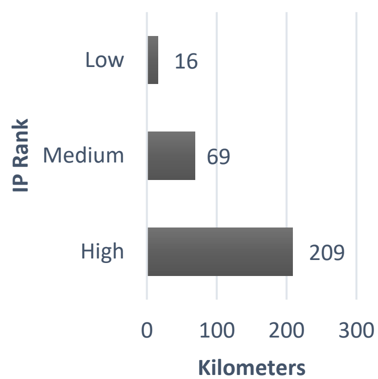

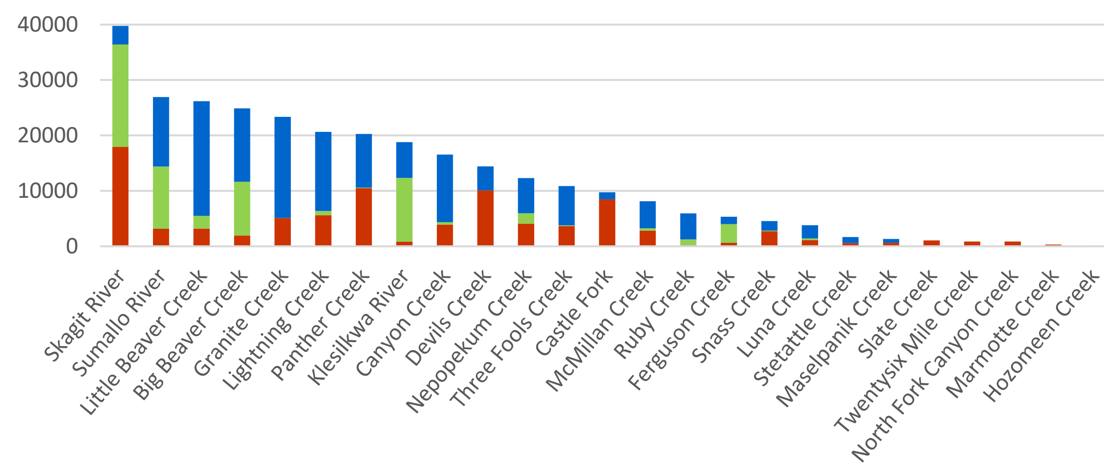

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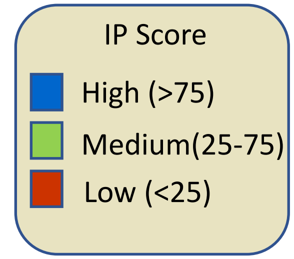
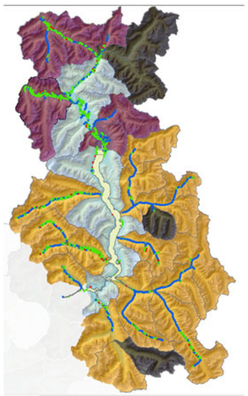
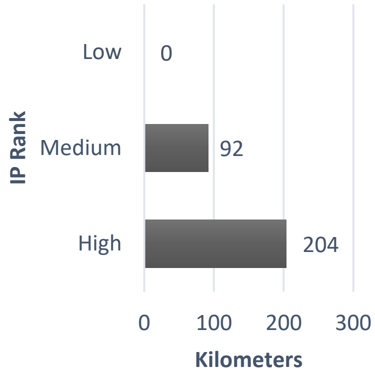
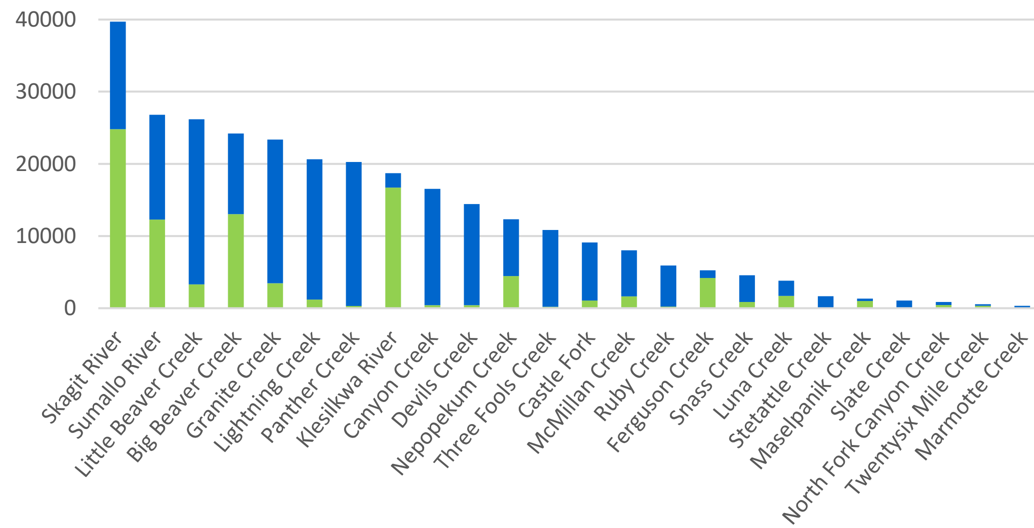
Steelhead IP – Core Tribs (continued)



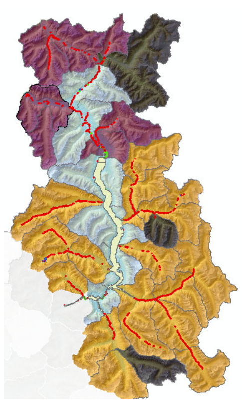
Agrawal

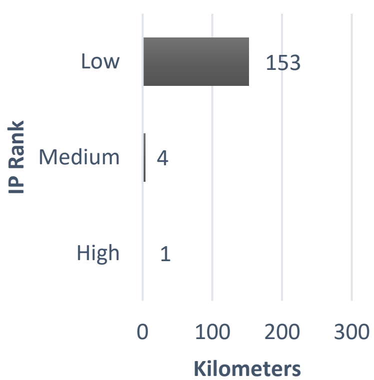


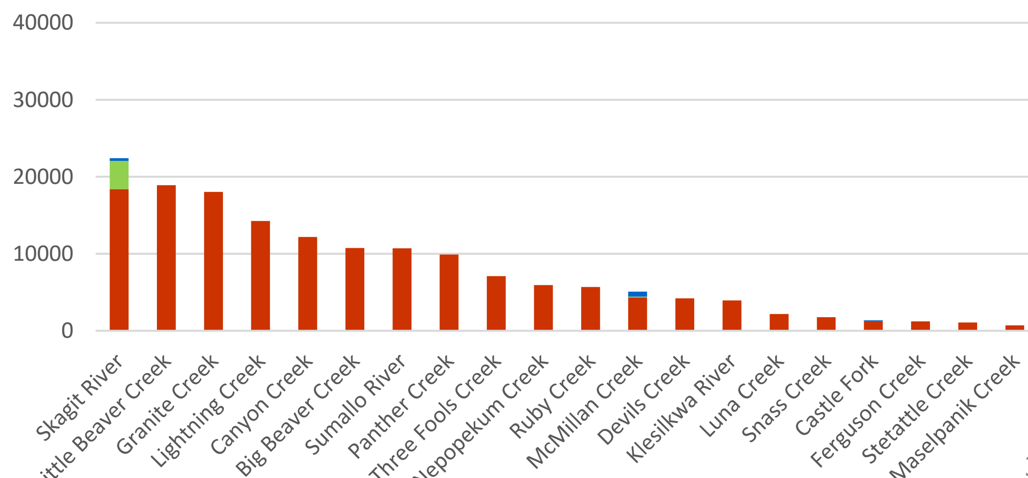




Coney & Holzer







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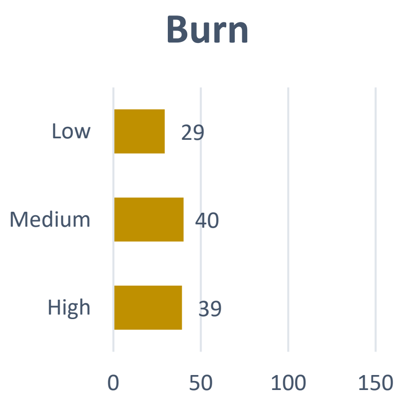
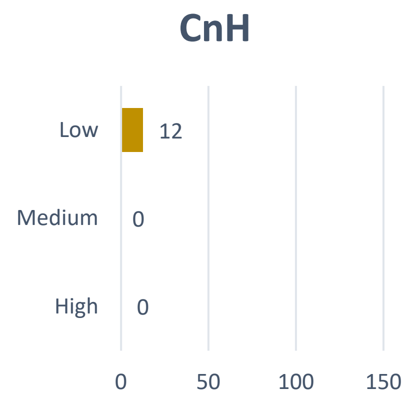
Steelhead IP – other reaches

Burnett



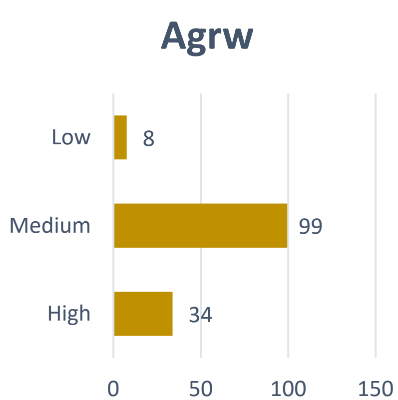
Tributary	Low	Med.	High
None	25.8	38.5	28.9
Thunder Creek	0.0	0.5	7.4
Cinnamon Creek	0.2	0.1	1.5
21 Tribs <1.0 km	3.3	1.0	1.3
Total	**29**	**40**	**39**

Cooney & Holzer



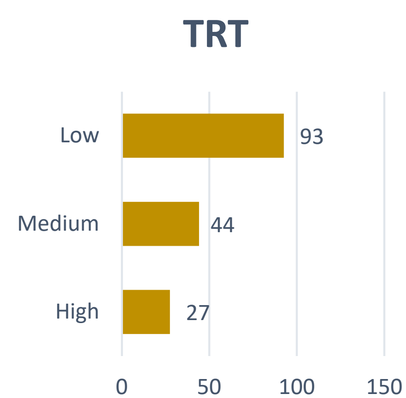
Tributary	Low	Med.	High
Thunder Creek	5.5	0.0	0.0
None	5.0	0.0	0.0
6 Tribs <1.0 km)	1.9	0.0	0.0
Total	**12**	**0**	**0**

Agrawal



Tributary	Low	Med.	High
None	7.4	93.9	22.7
Thunder Creek	0.0	1.1	6.9
Cinnamon Creek	0.0	0.0	1.8
22 Tribs <1.0 km	0.0	4.5	2.4
Total	**7**	**99**	**34**

PS-TRT



Tributary	Low	Med.	High
None	81.7	41.4	22.3
Thunder Creek	1.7	2.8	3.4
Cinnamon Creek	1.0	0.0	0.9
North Fork Devils Creek	1.3	0.0	0.0
25 Tribs <1.0 km	6.9	0.0	0.9
Total	**93**	**44**	**27**

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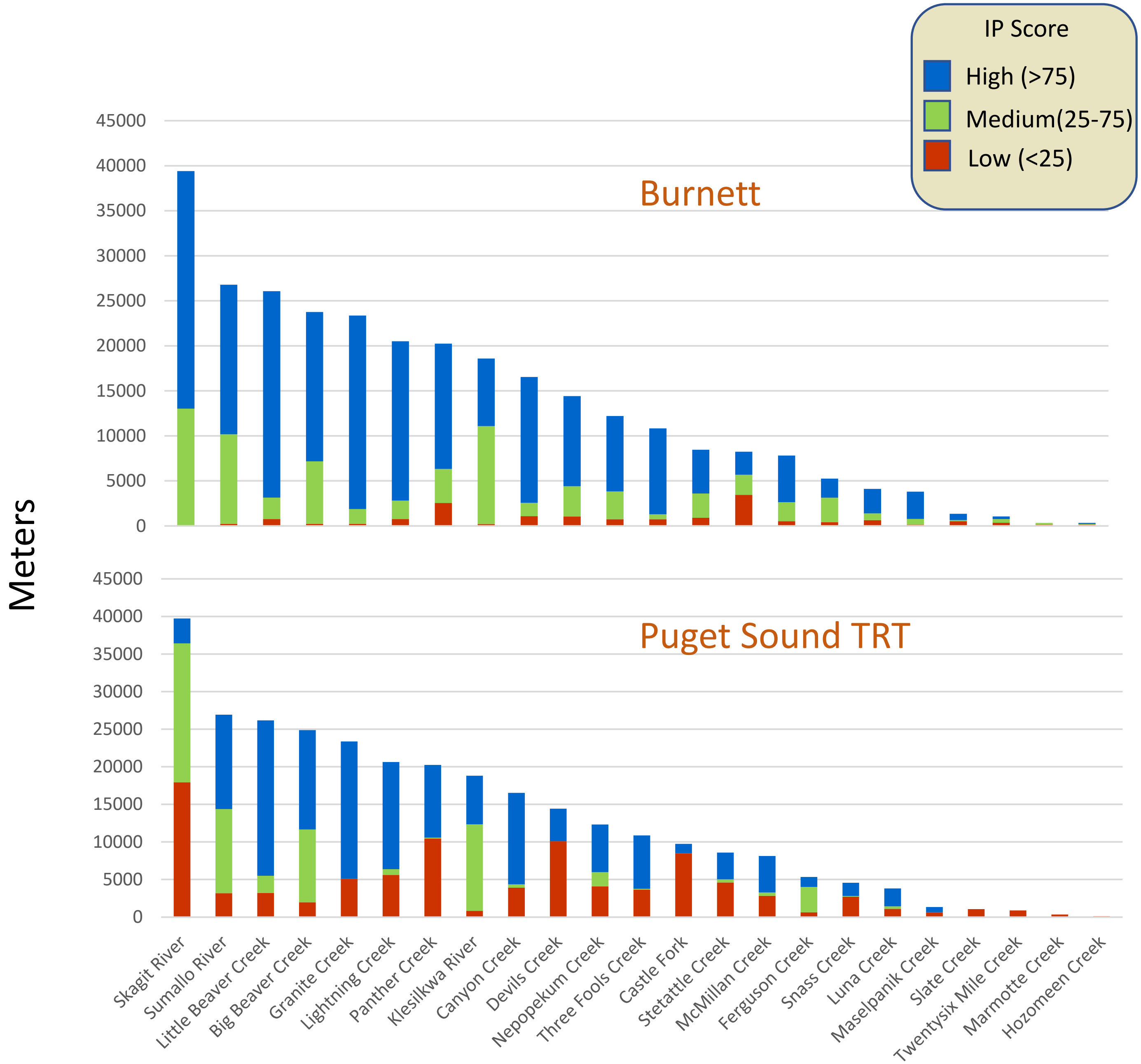
Steelhead IP Model comparison



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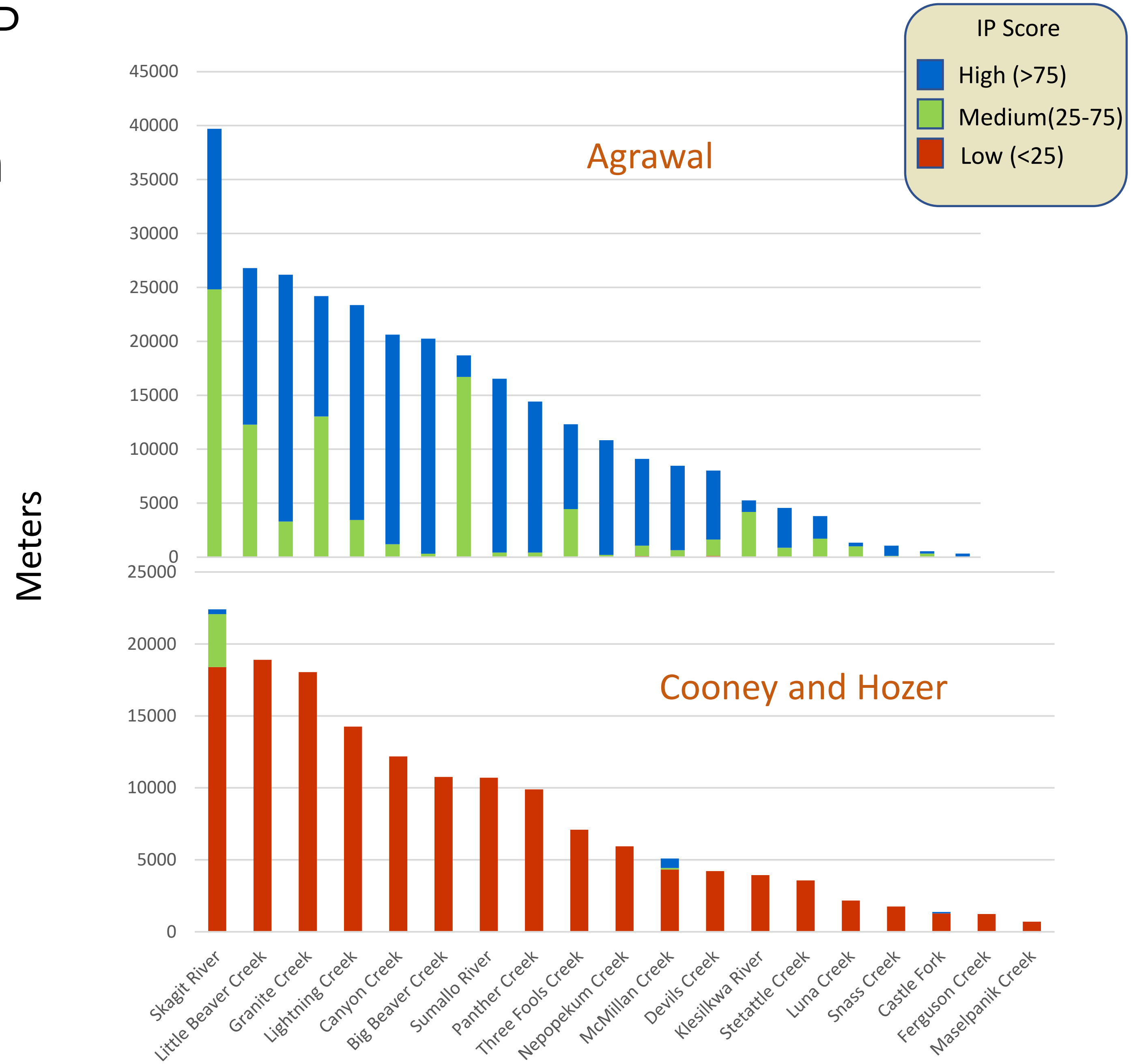
Steelhead IP Model comparison



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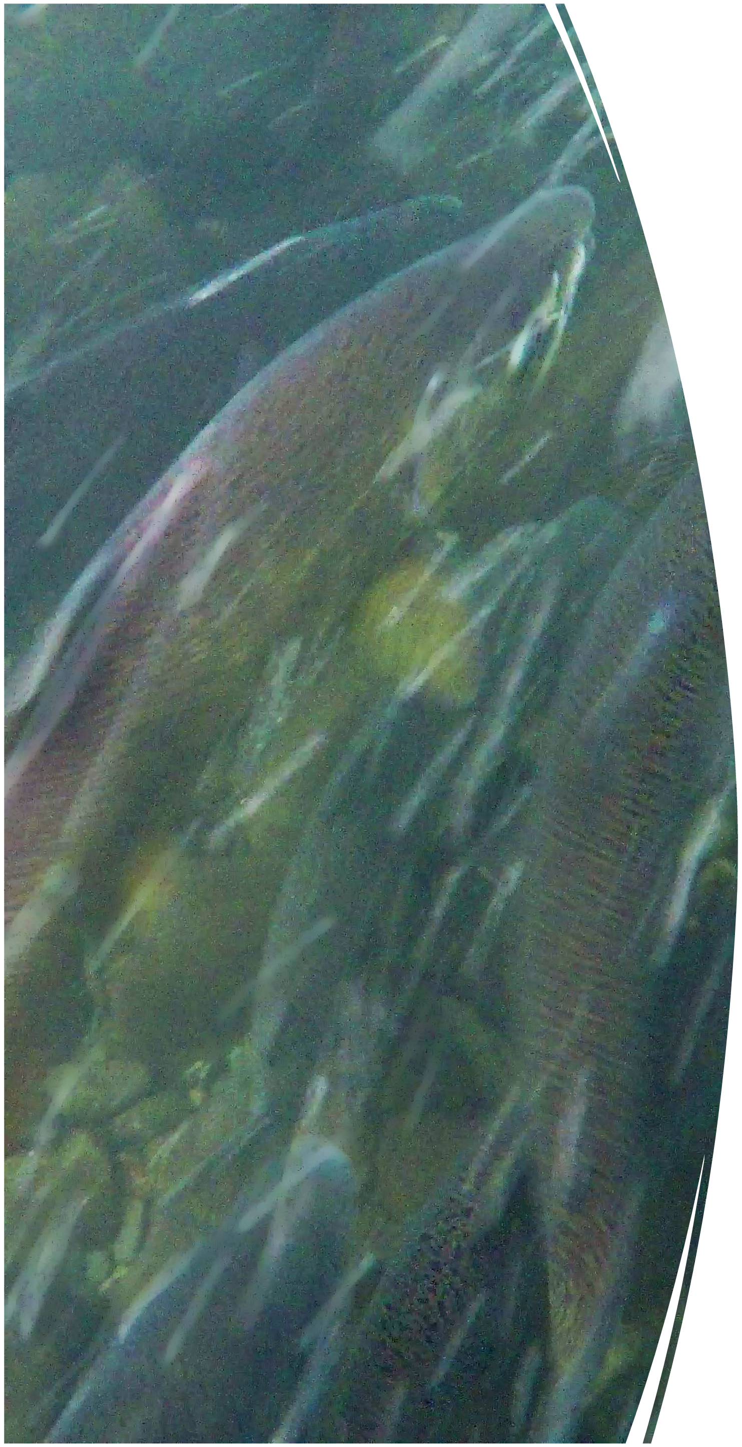
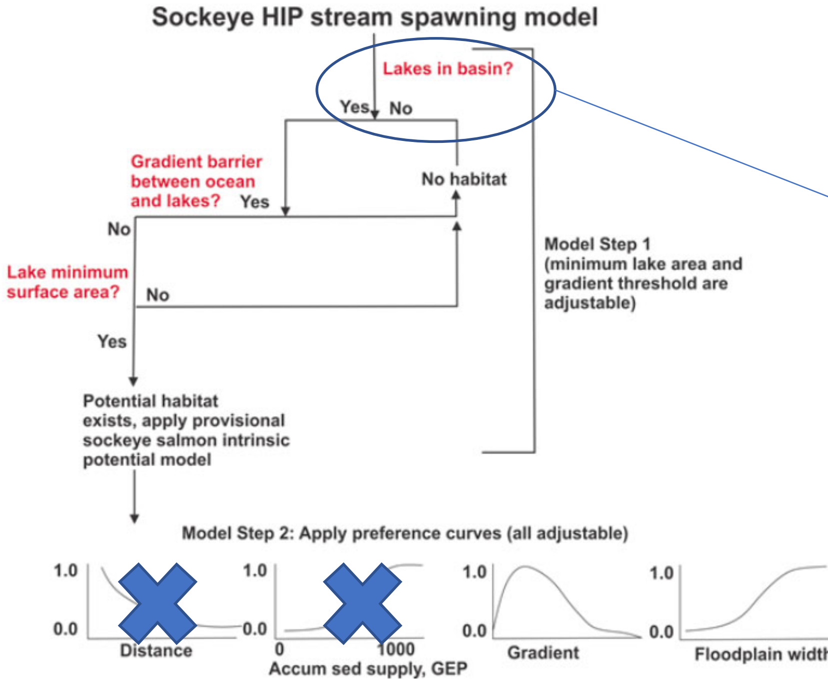
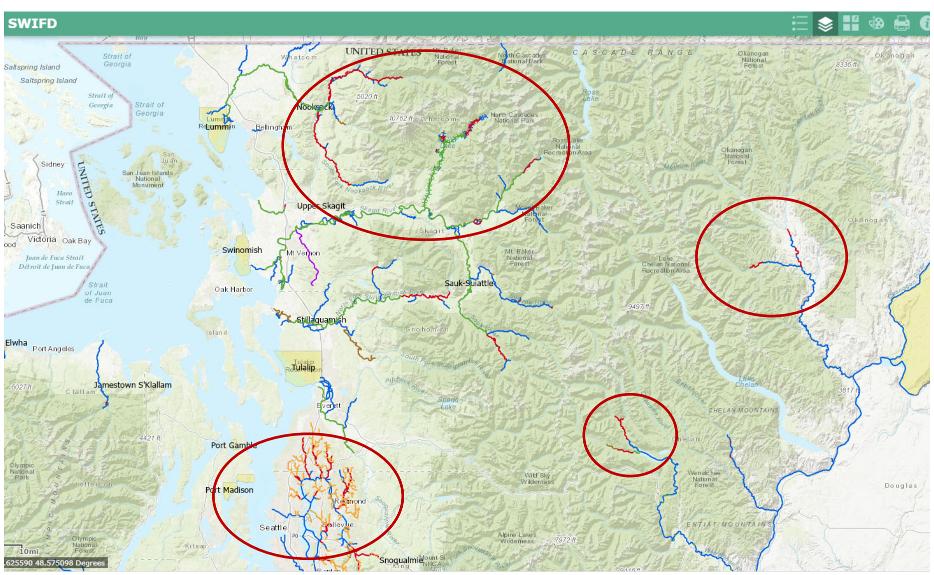


Sockeye IP

Sockeye IP Model 1: Kenai Peninsula, AK



For upper Skagit: Assume all core tributaries that drain into reservoirs



Hypothetical, need contemporary data from stream spawning sockeye populations (e.g., see map)

Parameter	**Data Divisions (habitat envelope)**					**IP Ranking for divisions**				
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*
Gradient	0	2	4	7	12	1	1	.05	.05	0
VWI	0	1	5	9	20	0	.01	.25	.75	1

Sockeye IP Model 2: Mat-Su Basin, AK

Table 5. Sockeye salmon rearing habitat intrinsic potential ranking criteria.

Ranking	Criteria
No potential	Streams upstream of barriers; streams > 2% gradient; streams < 0.5 cms mean annual flow values; streams that are both not wetlands and not glacially influences
Negligible	Wetland streams
Low	Glacially influenced streams
Moderate	Lakes > 1.5 km^2
High	Judd, Larson, and Chelatna Lakes

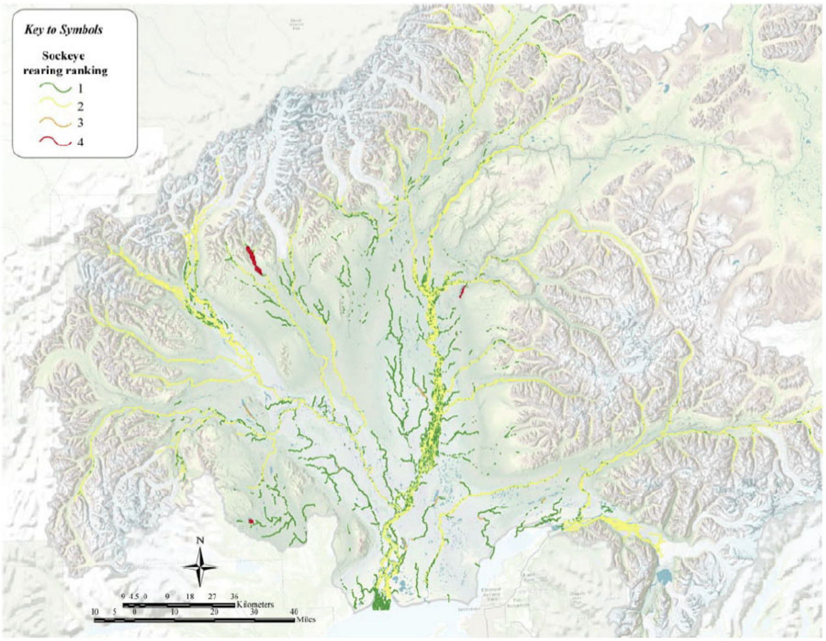


Figure 15. Stream reach intrinsic potential ranking for juvenile sockeye salmon in summer. 1

From: Woll, C. 2018. Landscape scale mapping of Pacific salmon and their freshwater habitats in the Mat-Su Basin. The Nature Conservancy.

Questions?

jduda@usgs.gov