# Assessment of ecological risks associated with fish reintroduction and conservation projects


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# Interaction Pathways

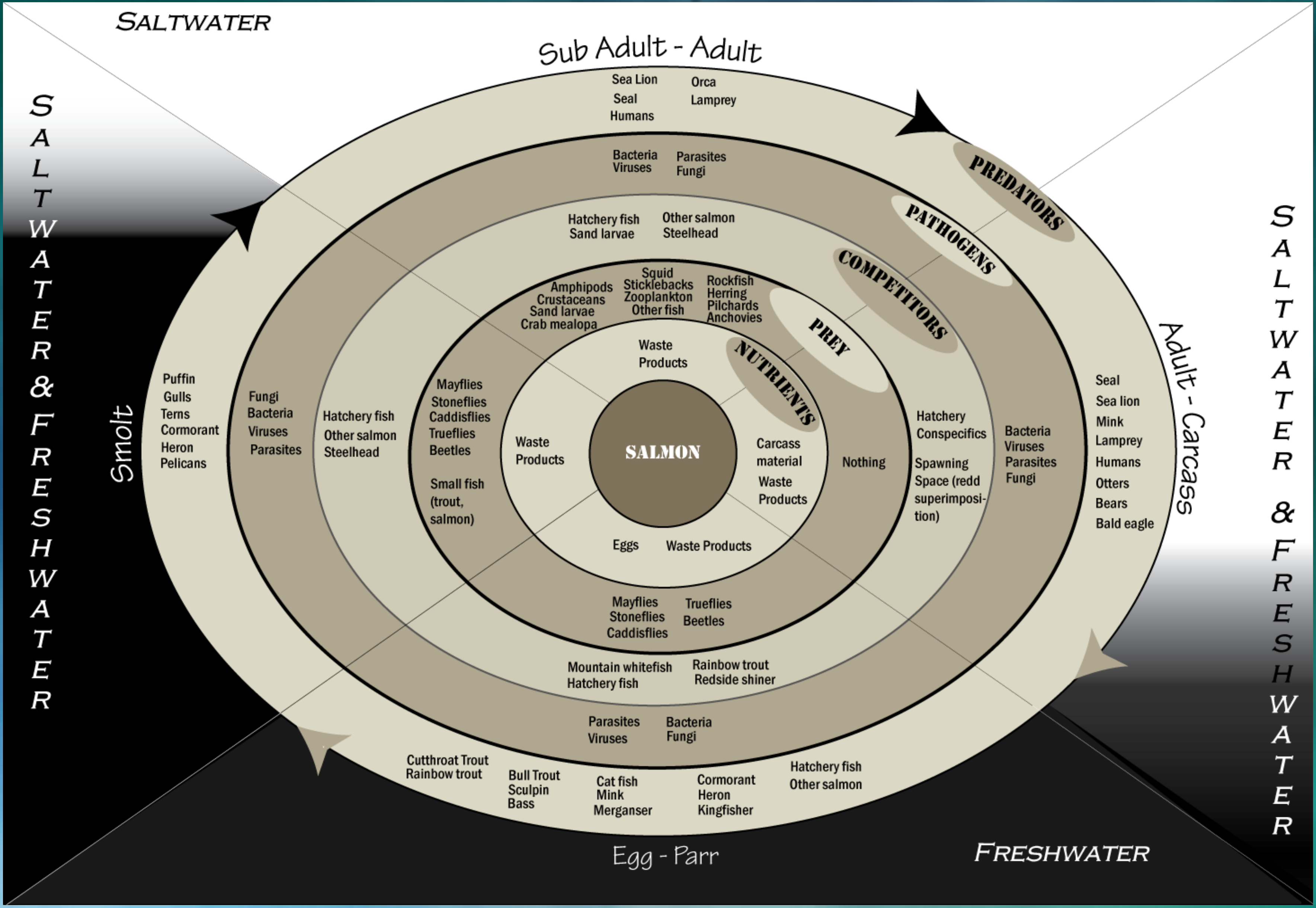


Figure by Todd Pearsons and Molly Kelly

# A Practical Approach for Assessing Ecological Risks Associated with Fish Stocking Programs

By Todd N. Pearsons and Charles W. Hopley

**ABSTRACT**
As wild fish populations continue to decline, fisheries managers are increasingly concerned about how hatchery operations might be contributing to declines of highly valued wild populations. Ecological risk assessments can provide decision makers with critical information about potential effects of stocking. In this paper we describe a practical approach for assessing ecological risks to select nontarget taxa (NTT) associated with fish stocking programs. This approach requires the completion of five tasks: (1) Determine acceptable impacts to NTT (e.g., impact of 10% to a species distribution, abundance, or size structure); (2) determine potential spatial-temporal overlap of NTT life stages with target taxon; (3) determine potential strong ecological interactions; (4) determine ecological risk; and (5) determine scientific uncertainty of ecological risk assessment. These tasks are accomplished by analyzing information gathered from scientists, managers, and policy makers. The result of the assessment is a listing of the ecological risks and associated uncertainties of failing to meet a stated objective for a variety of NTT. We also describe a decision matrix that prescribes various levels of uncertainty resolution, risk minimization strategies, risk containment monitoring, and stocking proposal implementation. Prescriptions reflect the amount of ecological risk and scientific uncertainty. Application of ecological risk assessment concepts to hatchery stocking decisions allows for a balanced approach when evaluating the benefits of hatchery stocking relative to ecological costs to nontarget populations and the economic costs of risk management.

The stocking of fishes into natural water systems has occurred for more than a hundred years, on almost every continent, and in many instances without adequately anticipating or understanding the consequences that stocking could have to other species in the ecosystem. This lack of planning has led to some undesirable outcomes, including species endangerment and extinction (Miller et al. 1989; Nehlsen et al. 1991; Lassuy 1995). New approaches to fish stocking programs could be applied to minimize undesirable impacts to aquatic communities, many of which are already in peril. In this paper, we describe a practical approach to assessing risks of fish stocking programs that can be used to facilitate planning. We have chosen to focus on assessing risks associated with anadromous salmonid stocking programs because anadromous salmonids are among the most targeted group of fishes for stocking and because they are stocked into many waters with nontarget taxa (NTT) that are highly valued or nearing extinction. Although the types of interactions may differ among types of fishes (e.g., bass and salmon) and the types of water they are stocked into (e.g., rivers and lakes), the general principles that we describe should apply to any stocking program.

The stocking of anadromous salmonids has come under increased scrutiny during the past decade in part because of the potential for ecological and genetic impacts that stocked salmonids are believed to have on wild fish (Krueger and May 1991; Waples 1991; White et al. 1995). Genetic risk to wild populations has received considerable attention (Waples and Do 1994; Busack and Currens 1995; Currens and Busack 1995). However, ecological risks have received less attention despite the potential for hatchery fish to affect a greater number of taxa in the ecosystem. For example, genetic risks associated with interbreeding are primarily restricted to a single stock or species. In contrast, ecological risks may extend to many classes of plants and animals such as fishes, birds, mammals, amphibians, trees, and insects.

Anadromous salmonids play key ecological roles in many freshwater systems. Juvenile salmonids prey on other fishes, are preyed on by a variety of vertebrates, and compete for resources with other fishes (Fresh 1997). Adult salmonids contribute marine-derived nutrients to aquatic and terrestrial ecosystems, and

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**Table 1.** Tasks required to perform an ecological risk assessment of a fish stocking program.

Tasks

I. Determine nontarget taxa objectives
  A. Select valued nontarget taxa of concern (NTT)
  B. Determine status of NTT
  C. Determine acceptable impact level (e.g., 10% impact in abundance and distribution)
II. Determine or hypothesize spatial-temporal overlap of target taxa with NTT life stages
  A. Determine Type 1 overlap of target taxa and NTT by life stage
  B. Determine Type 2 overlap of target taxa and NTT by life stage
III. Determine or hypothesize strong ecological interactions
  A. Determine the potential kinds of Type 1 and 2 ecological interactions that might occur
  B. Identify the kinds of interactions that are hypothesized to be strong
IV. Determine ecological risk
  A. Assess ecological risk for each NTT (the probability of failing to meet an objective for a NTT) by summing the positive and negative interactions that might occur
V. Determine scientific uncertainty
  A. Determine the level of scientific uncertainty of risk assessment (standard deviation of risk assessments)

**Table 3.** Levels of precaution associated with different levels of ecological risks and scientific uncertainty.

| | Low risk | High risk |
|---|---|---|
| Low uncertainty | Low | Very high |
| High uncertainty | Medium | High |

**Table 4.** Action items based on levels of precaution (Table 3). All actions assume that the stocking provides a cost-efficient method of providing production benefits and that genetic risks have been deemed acceptable.

| Precaution | Uncertainty resolution | Risk minimization strategies | Risk containment monitoring | Stocking proposal |
|---|---|---|---|---|
| Low | None | None | Low effort | Proceed |
| Medium | Some | Some | Moderate effort | Proceed with caution |
| High | Much | Moderate | High effort | Do not stock unless adequate risk containment measures are in place or uncertainties are resolved. |
| Very high | Little | Extensive | High effort | Do not stock unless adequate risk containment measures are in place |


N. Pearsons

Stocking of fishes into natural water systems has frequently occurred without adequately anticipating or understanding the consequences to nontarget taxa.

**Table 2.** Template for assessing ecological risks to NTT relative to fish stocking programs. We provide an example of one NTT relative to a hypothetical stocking program.

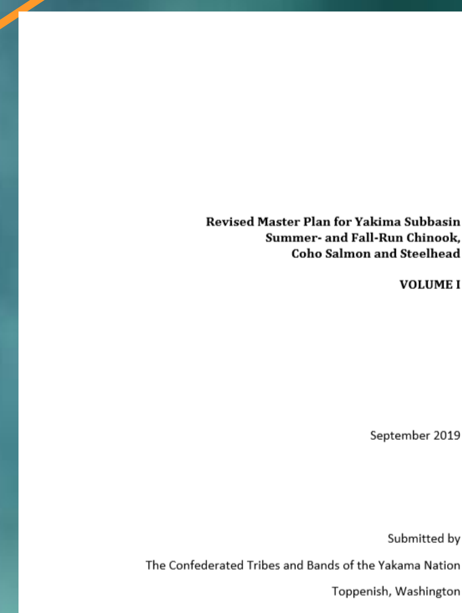
**Proposed Stocking Program:** Target taxon__________ Size at release__________
Date of release__________ Number and location__________

| | | Overlap[a] | | Interaction Strength[b] | | | |
|---|---|---|---|---|---|---|---|
| NTT[c] | Status[d] Impact | Type 1 Life stage | Type 2 Life stage | Type 1 Interaction | Type 2 Interaction | Risk[e] | Uncertainty[f] |
| Example species or stock | D/10% | Fry | All | C, P, B, D, N | C, P, B ,D N, S | 74% | 16% |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

[a] *Type 1*: spatial and temporal overlap between released hatchery salmonids, residuals, and returning adults, and NTT.
*Type 2:* spatial and temporal overlap between all life history stages of naturally produced offspring of returning hatchery adults and NTT
*life stage*—fry, parr, smolt, adult (salmonids); age 0, juvenile, adults (other species) or all if overlap occurs for all life stages or none if no overlap occurs.
[b] Ecological interactions that could occur between stocked anadromous salmonids and NTT.
*Negative interactions*
*competition (C)*—the presence of hatchery salmonids limiting the availability of resources that NTT would use in the absence of hatchery salmonids. This occurs when stocked salmonids and NTT use common resources, the supply of which is short (i.e., exploitative or indirect competition); or if the resources are not in short supply, competition occurs when hatchery salmonids limit access of NTT that are seeking a desired resource (i.e., interference or direct competition; Birch 1957).
*predation (P)*—the direct consumption of NTT by hatchery salmonids (direct predation; *Pd*) or the increase in predation by other predator species resulting from the presence of hatchery salmonids (indirect predation; *Pi*). Indirect predation can occur through the following mechanisms: (1) Hatchery salmonids displace NTT from preferred habitat, making NTT more vulnerable to predators; or (2) the increased abundance of hatchery salmonids attracts predators, causes predators to switch prey, or increases population densities of predators, which can increase consumption of NTT, particularly if NTT are preferred.
*behavioral anomalies (B)*—the presence and behavior of hatchery salmonids alter the natural behavior of NTT. For example, migrating hatchery salmonids may cause premature migration of NTT (e.g., pied-piper effect; Hillman and Mullan 1989) or may cause NTT to become less active (McMichael et al., in press).
*pathogenic interactions (D)*—the transfer of a pathogen from hatchery salmonids to NTT (direct pathogenic interaction) or the increased susceptibility of NTT to pathogens (indirect pathogenic interaction).
*nutrient mining (M)*—the carcasses of fish that would normally reproduce naturally are collected for hatchery broodstock and are not distributed back into the natural environment or are distributed inappropriately. This results in a loss of nutrients/food that would ordinarily be available to NTT.
*Beneficial interactions*
*Nutrient enrichment (N)*—increase in nutrients available to NTT because of an increase in marine-derived nutrients from greater salmonid returns (e.g., salmon carcasses).
*Prey (F)*—increased availability of prey for piscivorous NTT.
*Predator swamping (S)*—the survival of NTT is enhanced due to swamping of predators by hatchery fish.
[c] *NTT*—highly valued nontarget taxa.
[d] *Status*: H=healthy, D=depressed, C=critical (or other status descriptors), Impact— acceptable impact level to the NTT (e.g., 10% impact to abundance, distribution, and size structure).
[e] *Risk*: probability (0%–100%) of failing to meet an objective for NTT; 0% corresponds to impossibility of failing, and 100% corresponds to surety that an objective will be exceeded.
[f] *Uncertainty*: scientific uncertainty of risk assessment due to lack of information or variability of ecological interaction outcomes; calculated as the standard deviation of the risks.

# Case Study 1. Coho Salmon Reintroduction in Taneum Creek




**Revised Master Plan for Yakima Subbasin
Summer- and Fall-Run Chinook,
Coho Salmon and Steelhead**

**VOLUME I**

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Submitted by

The Confederated Tribes and Bands of the Yakama Nation

Toppenish, Washington

# Perform the Risk Assessment

**Proposed Stocking Program** (target taxon): Coho- out-of-basin stock

Size at Release: adults

Date of Release:

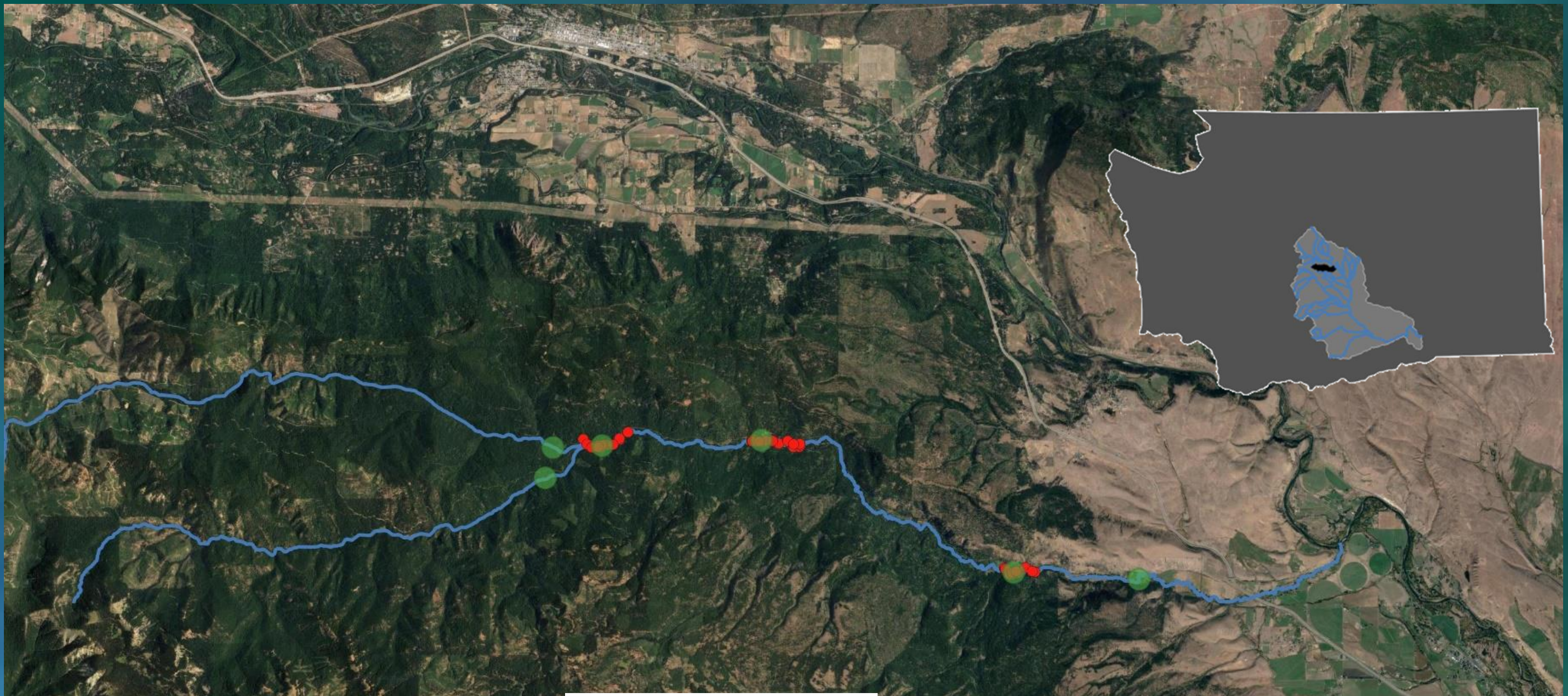
Location & Number: upper Yakima, Tanam Creek, 40 adults

| | |
|---|---|
| c | competition |
| p | predation on ntt |
| b | behavioral |
| d | disease |
| m | removing nutrients from dead spawners |
| n | increase nutrients from more spawners |
| f | food for ntt |
| s | swamp predators |
| 3 | strong pos |
| -3 | (-strong neg) |

| | | Overlap | | Interaction Strength | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NTT | Status/accepted Impact | Type 1 Life Stage | Type 2 Life Stage | Type 1 Interaction | | | | | | | | SCORE | Type 2 Interaction | | | | | | | | SCORE | Risk | Uncertainty |
| | | | | C | P | B | D | M | N | F | S | | C | P | B | D | M | N | F | S | | | |
| Spring chinook | D / 10% | | fry,parr,smolt | | | | | | | | | | C | P | | D | | N | | S | | | |
| | | | | | | | | | | | | | -2 | 0 | | -1 | | 1 | | 1 | -1 | 7 | evaluated as t2 interaction |
| Steelhead | C / 0% | | fry,parr,smolt | | | | | | | | | | C | P | B | D | | N | | S | | | |
| | | | | | | | | | | | | | -2 | -1 | -1 | -1 | | 1 | | 1 | -3 | 17 | |
| trib rbt | H / 40% | | all | | | | | | | | | | C | P | B | D | | N | F | S | | | |
| | | | | | | | | | | | | | -2 | -1 | -2 | -1 | | 1 | 1 | 1 | -3 | 14 | |
| trib cut | H / 40% | | all | | | | | | | | | | C | P | B | | | N | F | S | | | |
| | | | | | | | | | | | | | -3 | 0 | 0 | | | 1 | 1 | 0 | -1 | 6 | |

# Experimental Reintroduction

# Record Observations

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## Evaluation of Rainbow Trout Abundance, Biomass, and Condition Following Coho Salmon Reintroduction in Taneum Creek, Washington


### Abstract

Reintroducing fish to previously occupied habitats appears promising for recovery of extirpated fish populations in cold water systems. Uncertainty still exists surrounding the ecological effects of reintroductions however, particularly when they involve historically sympatric taxa. We initiated a study to estimate any potential impacts to rainbow/steelhead trout (*Oncorhynchus mykiss*) that may arise from reintroducing coho salmon (*O. kisutch*) in Taneum Creek, Washington, following their extirpation approximately 100 years ago. Prior to reintroducing coho salmon into Taneum Creek, we conducted a formal risk assessment to predict potential impacts to rainbow trout that might result from restoring coho salmon natural production in this stream. Following the assessment, adult coho salmon were released to spawn naturally in experimental reaches in Taneum Creek during a five year period, 2008–2012. Rainbow trout abundance, average size, condition, and growth were not reduced in our experimental reaches relative to control locations following the reintroduction of coho salmon; a result predicted from our ecological risk assessment. Our findings validate the utility of the ecological risk assessment for predicting and reducing undesirable effects of reintroductions involving historically sympatric salmonids.



**Keywords:** Coho salmon, rainbow trout, ecological interactions, Yakima Basin, salmon reintroduction


### Introduction

Substantially declining numbers of anadromous salmon throughout the Pacific Northwest during much of the last century prompted the development of large scale hatchery and reintroduction programs across the region. The historical abundance of coho salmon (*Oncorhynchus kisutch*) in the Yakima River basin has been estimated to be as high as 100 000 adults returning annually but runs were significantly reduced following hydropower development and extremely high harvest rates in the Columbia River in the early and middle of the last century (Bosch et al. 2007, Galbreth et al. 2014). Consequently, coho salmon were extirpated from the Yakima basin by the 1980s (Yakama Nation 1997, Bosch et al. 2007, Galbreth et al. 2014) and natural recolonization following the extirpation was minimal. Therefore, a study to determine the feasibility of reintroducing coho salmon in the Yakima basin was developed in the mid-1990s using donor populations from the lower reaches of the Columbia River (Dunnigan 1999, Dunnigan et al. 2002, Bosch et al. 2007, Galbreth et al. 2014). Taneum Creek in central Washington State was identified as a prime candidate to initiate coho salmon reintroduction (Hubble et al. 2004).

Both the resident (rainbow trout) and anadromous (steelhead trout) life history forms of *O. mykiss* also reside in Taneum Creek (Temple et al. 2015). While the anadromous form, steelhead trout, are listed as a threatened species under the Endangered Species Act in the Yakima River basin, the resident life history form, commonly known as rainbow trout, are not listed and are currently managed as a sport fishery under the jurisdiction of the state (NMFS 2009). Thus an obvious concern was whether the coho salmon reintroduction would unintentionally reduce the abundance, size, growth, condition, or biomass of the threatened form of *O. mykiss* in Taneum Creek. The uncertainty associated with ecological interactions, as in this

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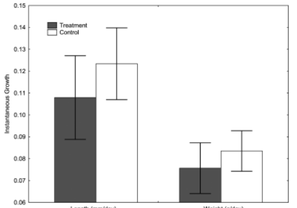



Figure 2. Instantaneous growth in length (mm FL/day) and weight (g/day) of rainbow trout recaptured containing PIT tags. Error bars represent the 95% confidence interval.

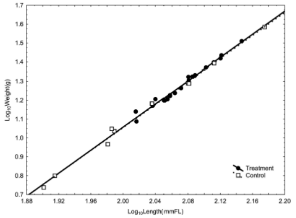



Figure 3. Log transformed average length (fork length; FL, mm) weight (g) relationship of rainbow trout in treatment and control index monitoring sites during the period coho salmon natural production was being re-established (2008–2012) in Taneum Creek, Washington.



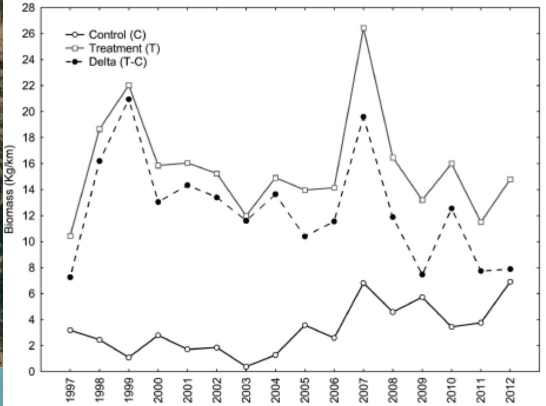



Figure 4. Average biomass (kg/km) of rainbow trout in treatment (T) and control (C) sites from 1997–2012. Annual delta biomass (kg/km) values (T-C) are associated with the dashed line. Adult coho salmon reintroduction began in 2007.

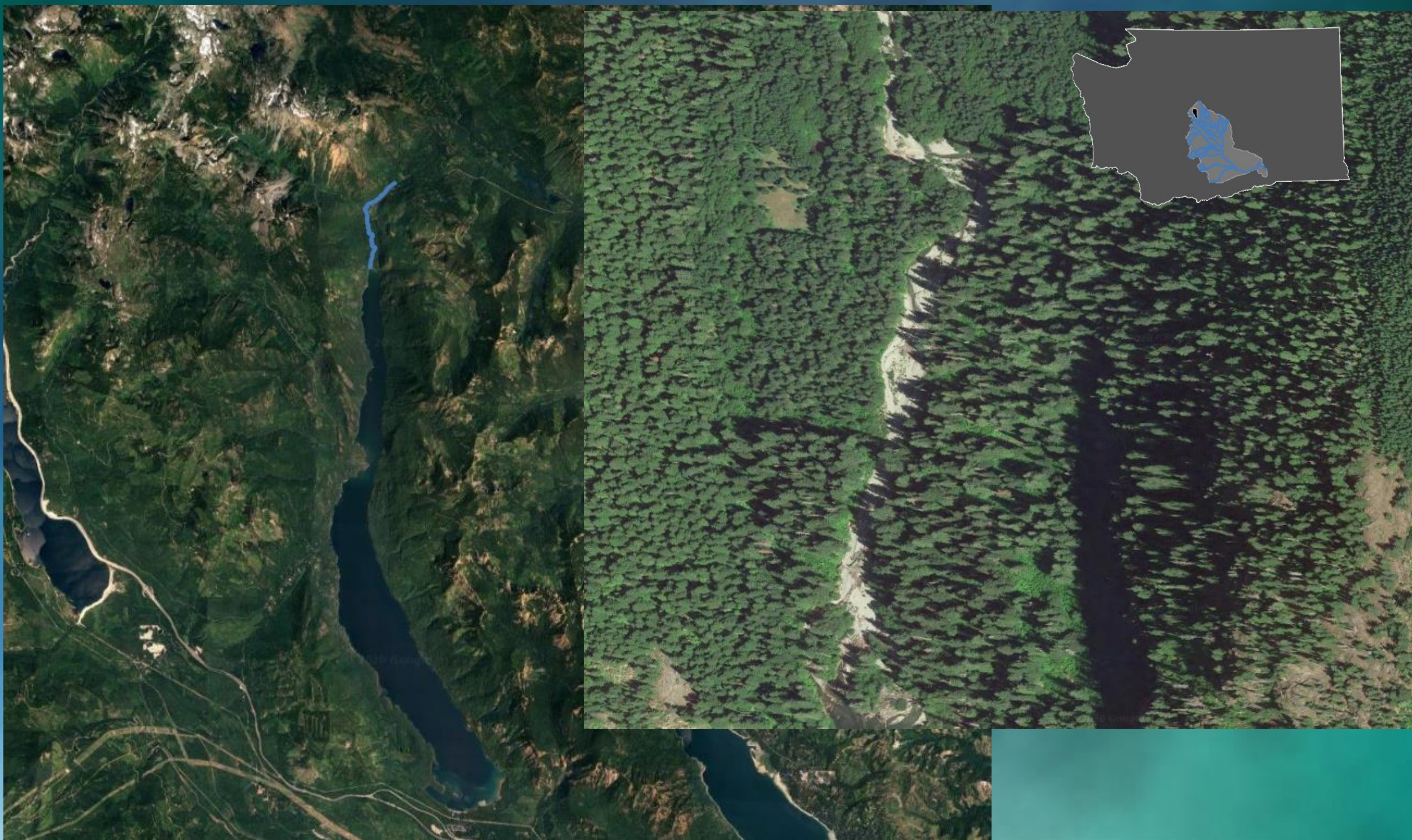
# Case Study 1. Take Home Message

- Observations were consistent with our expectations

The relatively benign ecological interactions that we observed after 5 years of stocking in our monitoring sites in Taneum Creek were consistent with our expectations. The risk and uncertainty scores summarized following the risk assessment and the predicted outcome revealed a general agreement that the ecological risk of stocking was low with a low degree of uncertainty among the panel members. This result was manifested in our experiment and validated the utility of the risk assessment process (Pearsons and Hopley 1999) by emphasizing that pre-implementation planning is useful to predict post-implementation results

(Temple and Pearsons 2012). This is useful for providing insight on likely ecological outcomes from reintroduction efforts. Our Taneum Creek reintroduction can be viewed as a pilot study used to assess the risks and benefits of tributary scale coho salmon reintroduction prior to full implementation (Anderson et al. 2014) in the Yakima basin. Our results indicate that careful pre-implementation planning through the ecological risk assessment will often eliminate undesirable effects of artificial stocking that have potential to manifest during the early implementation of reintroduction programs.

# Case Study 2. Bull Trout Salvage & Translocation into Taneum Creek



# Case Study 2. Bull Trout Salvage & Translocation into Taneum Creek

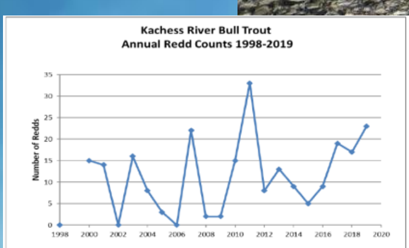
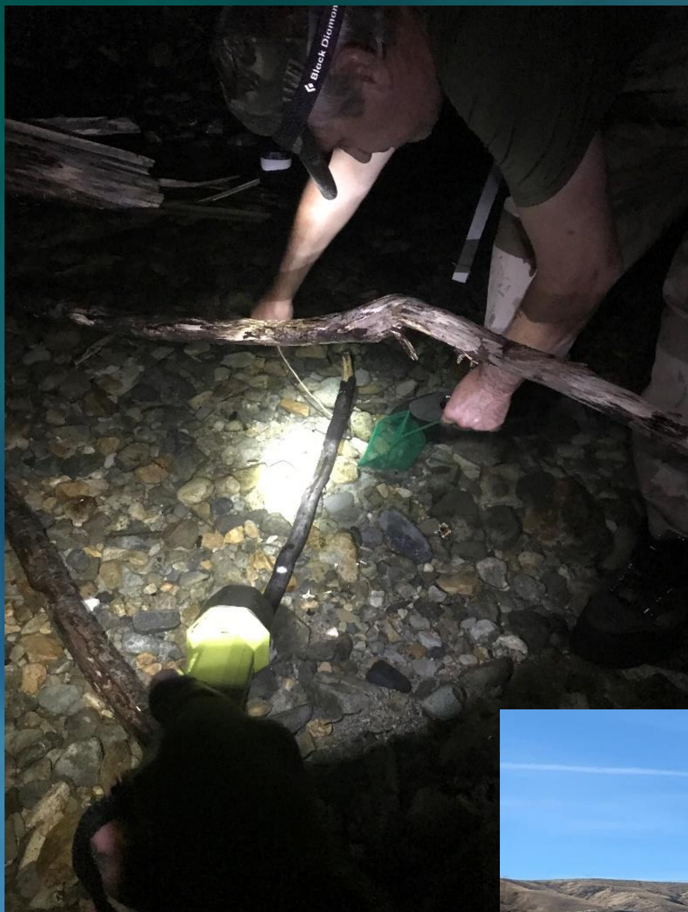



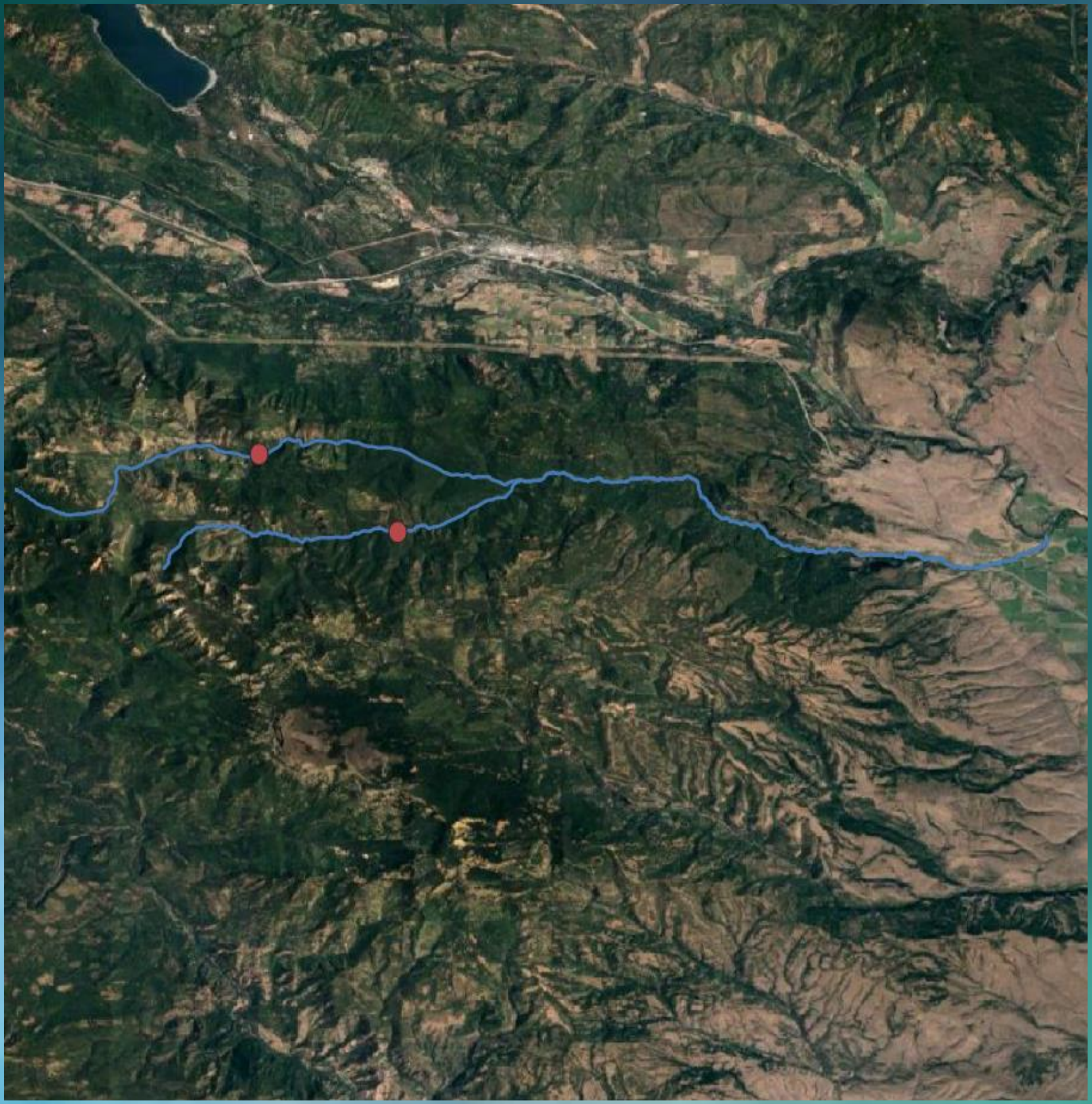

**Figure 16. Bull Trout redd counts in the upper Kachess River (Kittitas County) 1998 through 2019.**

# Stranded Fish Collections



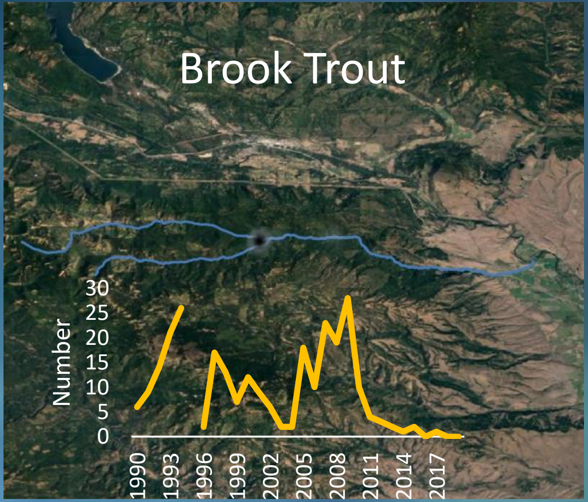
Transport to Facility for Rearing

# Proposed Translocation Sites

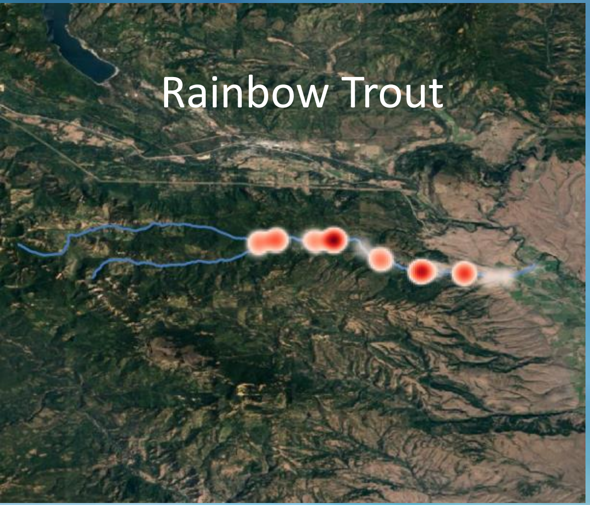


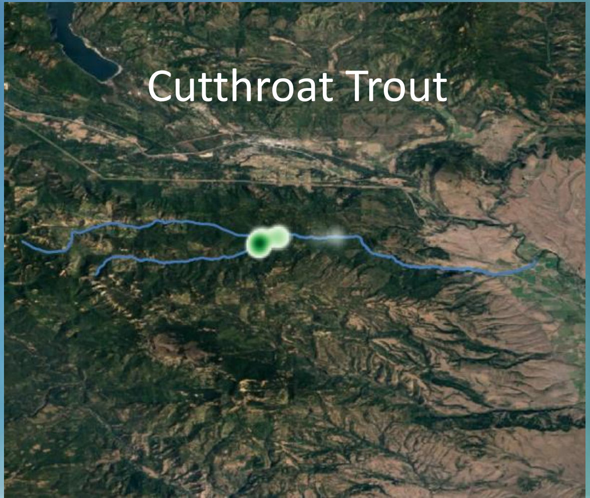
# Review Existing Information for Recipient Stream

- NTT Distribution, Size Structure, Abundance



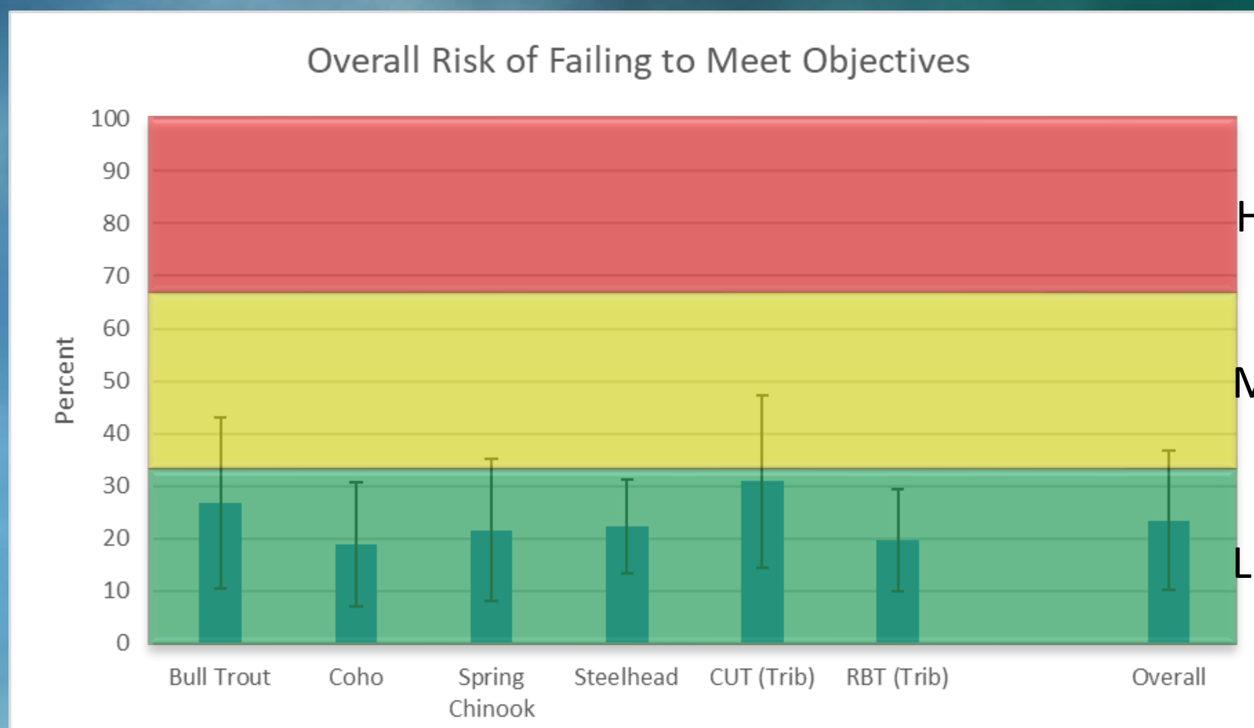



| Contestant | Taxa | Type I Risk Score | Type II Risk Score | Overall Risk Score |
|---|---|---|---|---|
| Gabe | Spring chinook | 0 | 0 | 0 |
| Gabe | Steelhead | -3 | -2 | 24 |
| Gabe | trib rbt | -3 | -2 | 24 |
| Gabe | trib cut | -3 | 2 | 6 |
| Gabe | Coho | -2 | 1 | 7 |
| Gabe | Bull Trout | -5 | -4 | 38 |
| Russ | Spring chinook | 0 | -1 | 33 |
| Russ | Steelhead | -2 | 0 | 11 |
| Russ | trib rbt | -2 | -1 | 13 |
| Russ | trib cut | -5 | -3 | 38 |
| Russ | Coho | -3 | -2 | 17 |
| Russ | Bull Trout | -2 | -5 | 33 |
| Zack | Spring chinook | 0 | 0 | 0 |
| Zack | Steelhead | -1 | -2 | 33 |
| Zack | trib rbt | -1 | -2 | 33 |
| Zack | trib cut | -4 | -5 | 50 |
| Zack | Coho | -1 | -3 | 33 |
| Zack | Bull Trout | -5 | -6 | 61 |
| Zack | Bull Trout | -3 | -6 | 15 |
| Todd | Spring chinook | -1 | -2 | 33 |
| Todd | Steelhead | -3 | 0 | 14 |
| Todd | trib rbt | -3 | -1 | 33 |
| Todd | trib cut | -4 | -1 | 33 |
| Todd | Coho | -2 | -1 | 25 |
| Todd | Bull Trout | -3 | -2 | 33 |
| William | Spring chinook | -1 | -1 | 33 |
| William | Steelhead | -1 | -1 | 11 |
| William | trib rbt | 0 | -1 | 7 |
| William | trib cut | -2 | -3 | 28 |
| William | Coho | -2 | -2 | 33 |
| William | Bull Trout | -1 | -4 | 28 |
| Scott | Spring chinook | -1 | -1 | 17 |
| Scott | Steelhead | -2 | -3 | 33 |
| Scott | trib rbt | -1 | -2 | 17 |
| Scott | trib cut | -3 | -4 | 39 |
| Scott | Coho | -2 | -3 | 33 |
| Scott | Bull Trout | -4 | -4 | 33 |
| Tim | Spring chinook | -1 | -1 | 33 |
| Tim | Steelhead | -2 | -1 | 20 |
| Tim | trib rbt | -2 | -1 | 20 |
| Tim | trib cut | -2 | -2 | 33 |
| Tim | Coho | -1 | 0 | 11 |
| Tim | Bull Trout | -2 | -1 | 20 |
| Marc | Spring chinook | 0 | -1 | 17 |
| Marc | Steelhead | -1 | -4 | 33 |
| Marc | trib rbt | -1 | -3 | 19 |
| Marc | trib cut | -1 | -1 | 13 |
| Marc | Coho | -1 | -3 | 15 |
| Marc | Bull Trout | 0 | -1 | 8 |
| Connor | Spring chinook | 0 | 1 | 17 |
| Connor | Steelhead | -4 | -3 | 26 |
| Connor | trib rbt | -4 | -3 | 26 |
| Connor | trib cut | -8 | -7 | 56 |
| Connor | Coho | -4 | 0 | 15 |
| Connor | Bull Trout | -4 | -3 | 26 |
| Jason | Spring chinook | -1 | -2 | 33 |
| Jason | Steelhead | -2 | 0 | 17 |
| Jason | trib rbt | 0 | -1 | 5 |
| Jason | trib cut | -1 | -1 | 13 |
| Jason | Coho | 0 | 0 | 0 |
| Jason | Bull Trout | 0 | 0 | 0 |
| | | | Overall Risk Score | 23 |
| | | | Standard Deviation in Scores | 13 |

# Conduct the Assessment

| Row Labels | Average of Overall Risk Score | StdDev of Overall Risk Score |
|---|---|---|
| Bull Trout | 26.77272727 | 16.30546478 |
| Coho | 18.86666667 | 11.72335434 |
| Spring chinook | 21.6 | 13.52528496 |
| Steelhead | 22.18095238 | 8.925288285 |
| trib cut | 30.85555556 | 16.36802815 |
| trib rbt | 19.68095238 | 9.66376139 |
| Grand Total | 23.38264377 | 13.28076032 |



# Case Study 2. Summary

- Assessment scores generally attributed low risk to NTT associated with translocating Bull Trout to Taneum Creek
- Our team recommends adopting some level of monitoring to verify we meet our expectations, particularly for NTT with high conservation/ stewardship value (Steelhead and Bull Trout)

# Take Home

- Manipulating fish populations through artificial production, reintroductions, or even conservation action is not with out ecological risk
- Assessing risks that may result from stocking is prudent and responsible
- Conducting a formal risk assessment will guide implementation actions that utilize an appropriate level of caution….But….
- * Recommend adaptively managing to respond quickly and appropriately to unforeseen results

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