RECOLONIZATION POTENTIAL FOR COHO SALMON (*ONCORHYNCHUS KISUTCH*) IN TRIBUTARIES TO THE KLAMATH RIVER AFTER DAM REMOVAL

By

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ABSTRACT

RECOLONIZATION POTENTIAL FOR COHO SALMON (*ONCORHYNCHUS KISUTCH*) IN TRIBUTARIES TO THE KLAMATH RIVER AFTER DAM REMOVAL

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Removal of four major dams on the Klamath River is scheduled to begin in 2023, restoring access to greater than 50 km of historic mainstem habitat for coho salmon. However, mainstem habitat may not be suitable for juvenile coho salmon due to elevated water temperatures and high concentrations of infectious myxospores in the summer and fast water velocities in the winter. Small, cooler tributaries can provide essential habitat for escape from deleterious conditions in the mainstem Klamath River. I used temperature and other physical features of six tributaries to the Klamath River above Iron Gate Dam to assess their capacity to support juvenile coho salmon following dam removal. I applied the Habitat Limiting Factors and Intrinsic Potential models to tributaries above Iron Gate Dam to estimate potential capacity. I also developed an occupancy model using data from reference tributaries below the dam and from other nearby watersheds to estimate the potential distribution of juvenile coho salmon in tributaries above Iron Gate Dam. I found that the six newly accessible tributary streams will provide greater than 26 km of accessible rearing habitat. Most streams had summer temperature suitable for coho salmon, with maximum weekly maximum and maximum weekly average temperatures ranging from 13.2 °C to 24.0°C and 12.0 °C to 20.7 °C respectively. The Habitat Limit Factors model estimated that the streams could support up to 105,000 juvenile coho salmon in the summer, with most of this capacity (66,300 individuals) in Spencer Creek (note that predicted capacity is not a prediction of actual production following dam removal). Four out of the six streams exhibited high intrinsic potential, particularly near their confluences with the Klamath River. In reference streams, coho salmon occupancy ranged from 0.41-0.44 of available habitat. I found that the probability of summertime occupancy by juvenile coho salmon was positively correlated with percent instream cover, surface area, and nearby coho salmon hatchery production. Applying these relationships to the study streams, Scotch, Jenny, Fall, Shovel, and Spencer creeks exhibited 0.48, 0.50, 0.53, 0.46, and 0.61 mean occupancy probability respectively. I also found that Scotch, Jenny, Fall, Shovel, and Spencer creeks contained 26%, 2%, 7%, 2%, and 46% by surface area of suitable spawning gravels for adult coho salmon. Based on model predictions and a large quantity of suitable habitat for coho salmon habitat, Spencer Creek should be prioritized for restoration and protection. While Spencer Creek contains a large quantity of suitable habitat for coho salmon, I identified limited spawning and rearing habitat in Jenny, Fall, and Shovel creeks suggesting a need for habitat restoration.

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INTRODUCTION

Dams affect the dynamic physical and biological nature of rivers at multiple temporal and spatial scales (Rosenberg et al. 1997, Petts and Gurnell 2005, Bejarano et al. 2017). Dams disconnect sediment transport processes, creating sediment-starved waters downstream which promote channel incision, bank erosion, and a decrease in appropriate spawning gravels for anadromous fishes (Kondolf 1997). Large hydroelectric dams alter flow regimes (Kern et al. 2012), increase predation for vulnerable life history stages (Zimmerman 1999), and decrease genetic connectivity (Samarasin et al. 2017). For anadromous species, impassable dams eliminate access to habitat, decreasing their overall abundance (Ugedal et al. 2008).

Dam removal has led to increased abundances of anadromous fishes throughout the Pacific Northwest (McMillan et al. 2019, Allen et al. 2016, Schroeder et al. 2012). Dam removal and active relocation of adult hatchery coho salmon (*Oncorhynchus kisutch*) to small tributaries after the Elwha River dam removals led to rapidly increased instream spawning and naturally-spawned smolt production in previously inaccessible tributaries (McMillan et al. 2019). Dam removal can lead to rapid recolonization by coho salmon even in the absence of re-introduction of adults: coho salmon naturally recolonized reaches above a former dam site on the Little White Salmon River only four years after dam removal (Jezorek and Hardiman 2017).

The Klamath Hydroelectric Project

In the Klamath River basin, Anglo-American mill pond operations blocked anadromous fish passage at the historic town of Klamathon, CA beginning as early as 1889 (Coots 1962). The dams installed as part of the Klamath Hydroelectric Project (KHP) (Table 1 and Figure 1) influenced the Klamath River watershed and its anadromous fisheries starting in 1912. Modern-day Iron Gate Dam (IGD), completed in 1964, currently blocks all fish passage on the Klamath River at 306 river km (RKM) from the ocean (Kramer 2003). Historically, four anadromous fish species, coho salmon, Chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*Oncorhynchus mykiss*), and Pacific lamprey (*Entosphenus tridentatus*), used habitat above the KHP (Hamilton et al. 2005). Early developers of the KHP deemed fish ladders impractical for the height of the dams, so no passage was installed at the KHP dams (Fortune et al. 1966), resulting in extirpation of all anadromous fish above IGD.

Table 1 Klamath River dam characteristics

Dam	Klamath RKM	Date Completed	Fish Ladder	Scheduled for Removal in 2023
Link River	408	1921	X	
Keno	375	1966	X	
J.C. Boyle	362	1958		X
Copco 1	320	1918		X
Copco 2	319	1925		X
Iron Gate	306	1962		X

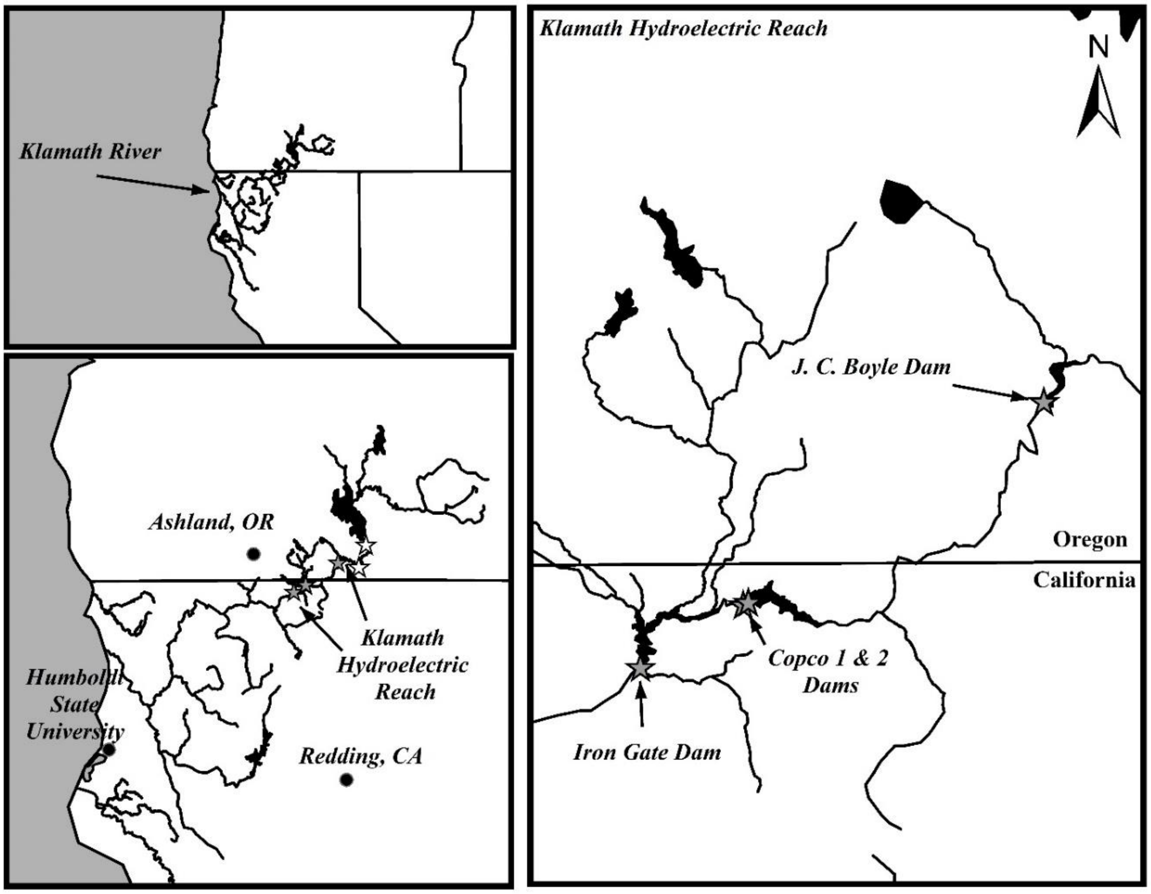


Figure 1. Overview (from upper left moving counterclockwise) of the Klamath River as located on the west coast of the United States, a close-up of the Klamath Hydroelectric Project in relation to the Klamath River Basin (gray stars indicate dams to be removed; white stars indicate dams to be retained with volitional fish passage; black circles indicate major city centers), and a close-up of the Klamath Hydroelectric Project and tributaries (gray stars indicate dams to be removed).

Reintroduction Efforts

Government, private, and tribal agencies have expressed interest in the reintroduction of anadromous fishes to the mid and upper Klamath River since passage was blocked in the late 1800s. A mitigation hatchery was installed on Fall Creek in 1919 and operated through 2003 to produce Chinook salmon (Fortune et al. 1966). However, introduction of anadromous salmon above the KHP dams never came to fruition, despite agreements with the state of Oregon (Fortune et al. 1966). The Bureau of Indian Affairs pursued the reintroduction of anadromous salmon to the mid and upper Klamath watershed in 1940, but this effort failed due to the issues with downstream migrant passage at the Copco dams (Fortune et al. 1966). Pacific Power and Light Company financed a comprehensive feasibility study for the reintroduction of anadromous salmon in the 1960s that investigated the riverine and reservoir conditions in the Klamath River in relation to life history strategies (Fortune et al. 1966). Ultimately, all anadromous salmon reintroduction initiatives were abandoned due to high costs of facilitating fish passage over KHP dams.

In 2001, water rights conflicts between irrigators and the federal government over water withholdings for coho salmon sparked discussions that culminated in the drafting of the Klamath Basin Restoration Agreement (KBRA) (Klamath Basin Restoration Agreement 2010) and the Klamath Hydropower Settlement Agreement (KHSA) (Klamath Hydropower Settlement Agreement 2010). The KBRA was developed in conjunction with the KHSA to solve water rights issues, grant financial support to fisheries restoration projects, update outdated irrigation diversions, and promote new economic opportunities in nearby rural communities (Klamath Basin Restoration Agreement 2010). The KHSA called for the removal of four hydroelectric dams in the KHP (Table 1 and Figure 1) and preservation of certain water rights for irrigators in the upper basin (Klamath Hydropower Settlement Agreement 2010). A congressional block of the KBRA in 2016 led to the amendment of the KHSA, pursuing dam decommissioning through the Federal Energy Regulatory Commission (FERC) (Klamath Hydropower Settlement Agreement 2016). On November 17th 2020, PacifiCorp, the states of California and Oregon, the Karuk and Yurok tribes and the Klamath River Renewal Corporation (KRRC) announced a proposal, the Memorandum of Agreement (MOA), for the states of California and Oregon to become co-licensees along with the KRRC, relinquishing PacifiCorp of obligations associated with dam decommissioning (PacifiCorp et al. 2020). Pending FERC's approval of the MOA, decommissioning of the Iron Gate, Copco I and II, and the J.C. Boyle dams is scheduled to begin in 2023.

Klamath dam decommissioning will restore access to spawning and rearing habitat for coho and Chinook salmon, steelhead, and Pacific lamprey. In this study, I assess the potential for tributary streams above the existing dams to support the production of coho salmon.

Coho Salmon Biology

Coho salmon in North America range from Point Hope, Kotzebue Sound, Alaska to Scott Creek, just north of Davenport, CA. Coho salmon tend to spawn in low-gradient, low-order streams. Juveniles typically rear in freshwater streams for one to two years (most often for one year in California, Quinn 2005) before migrating to sea in spring. During juvenile rearing, coho salmon co-occur most often with steelhead and cutthroat trout (*Oncorhynchus clarkii*), as well as Chinook salmon (Quinn 2005). Coho salmon tend to be the most abundant salmonid in low-order, low gradient streams with a high proportion of pool habitat types, at intermediate elevations and distances upriver (Quinn 2005). Watershed-scale coho salmon smolt production in the Pacific Northwest positively correlates with pool or pond area, average annual runoff, and summer low flow and negatively correlates with the gradient of the stream valley (Sharma and Hilborn 2001).

Despite the large amount of literature emphasizing the importance of instream habitat structure for juvenile coho salmon occupancy (Reeves 1989, Nickelson et al. 1992, Quinn and Peterson 1996, Burnett et al. 2003, Shirvell 1990, Anlauf-Dunn et al. 2014), modern studies also identify the importance of water temperature and food availability for the growth and survival of juvenile coho salmon (Mantua et al. 2010, Lusardi 2020). Coho salmon are the least tolerant of high temperature out of the salmonids occurring on the west coast of North America (Brett 1952). California represents the southernmost extent of the coho salmon’s range, so many populations experience temperatures near their upper thermal tolerance. When juveniles experience temperatures above their preference, multiple deleterious effects arise. Chronic thermal stress causes mortality within hours when temperatures exceed 25.0 °C (Brett 1952). Even below this lethal limit, increases in temperature result in increased vulnerability to disease, advantageous or deleterious changes in behavior and growth, and alterations in life-history. In the Klamath River, the abundance of the myxozoan parasite *Ceratonova shasta* increases with water temperature, indirectly reducing juvenile coho survival

(Chiaramonte et al. 2016). Ultimately, water temperature and prey availability control fish energetics. Recent experiments conducted *in situ* in the Shasta River ascertained that juvenile coho salmon can continue to grow at temperatures well above their recognized thermal range when prey are very abundant (Lusardi et al. 2020).

Coho Salmon in the Klamath River

In the Klamath Basin, coho salmon currently use the mainstem Klamath River, the Trinity, Shasta, Scott, and Salmon rivers, as well as smaller tributaries. Historically, coho salmon distribution extended upstream of IGD, likely to Spencer Creek in Oregon (Hamilton et al. 2005).

Coho salmon abundance continues to precipitously decline in the Klamath River. The coho salmon population between the 1990s and mid 2000s, coho salmon escapement to the Klamath was 52 – 95 percent of historic adult numbers (Moyle et al. 1995, Ackerman et al. 2006). Ackerman et al. (2006) estimated total run sizes in the Klamath River of 1,500 to 19,000 adult coho salmon per year between 2001 and 2004. Anthropogenic disturbances in addition to the dams continue to alter conditions in the Klamath River. Large-scale agriculture, timber harvest, mining operations, channel modifications, water extraction, and overfishing contribute to the decline of Klamath River anadromous fishes (USDI and NMFS 2013).

Water temperatures in the mainstem Klamath River often exceed 25° C in summer, resulting in high use of thermal refugia by adult and juvenile salmonids (Soto

2011). Cold-water refuge habitats in the Klamath River basin below IGD almost exclusively occur at or near the confluence of small, cold-water tributaries with the mainstem Klamath River (Belchik 2003, Deas et al. 2006, Sutton et al. 2007, Soto 2011). A portion of juvenile coho salmon re-distribute and leave natal streams and other rearing areas during periods of poor water quality or high flow events in the Klamath River (Soto 2011). In some cases, juvenile coho salmon in the Klamath River make substantial migrations during summer and winter:

> "*Migrations of sub-yearling coho have been documented to exceed 120 miles in some cases along the mainstem Klamath River, combined with considerable movement upstream into small tributaries with preferred habitats.*" (Soto 2011)

In anticipation of dam removal, my project assessed the physical characteristics of Klamath River tributaries upstream of IGD within the historical upstream distribution of coho salmon (Camp, Fall, Jenny, Scotch, Shovel, and Spencer creeks) and four reference tributaries below the dam and in other river basins (Bogus, Beaver, Lawrence, and Quartz creeks). My project sought to answer the following question through the collection of habitat structure data and the use of three modeling approaches: What is the potential of the six above-dam creeks to support production of coho salmon after dam removal? I focused my research on summer rearing habitat for juvenile coho salmon as it will likely be limiting in relatively warm inland streams. An ancillary objective of this project is to provide the baseline data necessary for later determination of the impact of returning anadromous fishes on resident species richness, abundance, and habitat use in the study streams.

Southern Oregon/Northern California Coast Evolutionarily Significant Unit

Two coho salmon Evolutionarily Significant Units (ESUs) are listed on the federal Endangered Species Act exist in California: Central California Coast (CCC) ESU ranging from Punta Gorda, CA to Aptos Creek, CA; and the Southern Oregon/Northern California Coast (SONCC) ESU ranging from Punta Gorda, CA to Cape Blanco, OR. The SONCC ESU includes coho salmon in the Klamath River watershed. The National Marine Fisheries Service (NMFS) listed the SONCC ESU as “threatened” on May 6, 1997 and on June 28, 2005, after further declines in the stock, opted to include artificially propagated coho salmon from the Iron Gate Fish Hatchery, Trinity River Hatchery, and the Cole M. Rivers Hatchery (NMFS 2014). In a recent study, NMFS suggested that the SONCC ESU will likely move from “threatened” to “endangered” in the near future (Williams et al. 2016).

Study Tributaries

I selected six study tributaries located above the IGD (Figure 2). Land ownership within the study stream watersheds consists of a mix of state, federal and private lands. Local geology consists of porous volcanic formations with cold water springs. Fall, Jenny, Shovel and Spencer creeks flow year-round. Camp and Scotch creeks become de-watered during the dry season in some years. Relatively low summer water temperatures in the study tributaries suggest that the streams could provide cold water refugia for anadromous fishes after dam removal (Hamilton et al. 2011). Water diversions for local municipalities and agriculture exist on many of the study streams, but the extent of diversion is poorly documented.

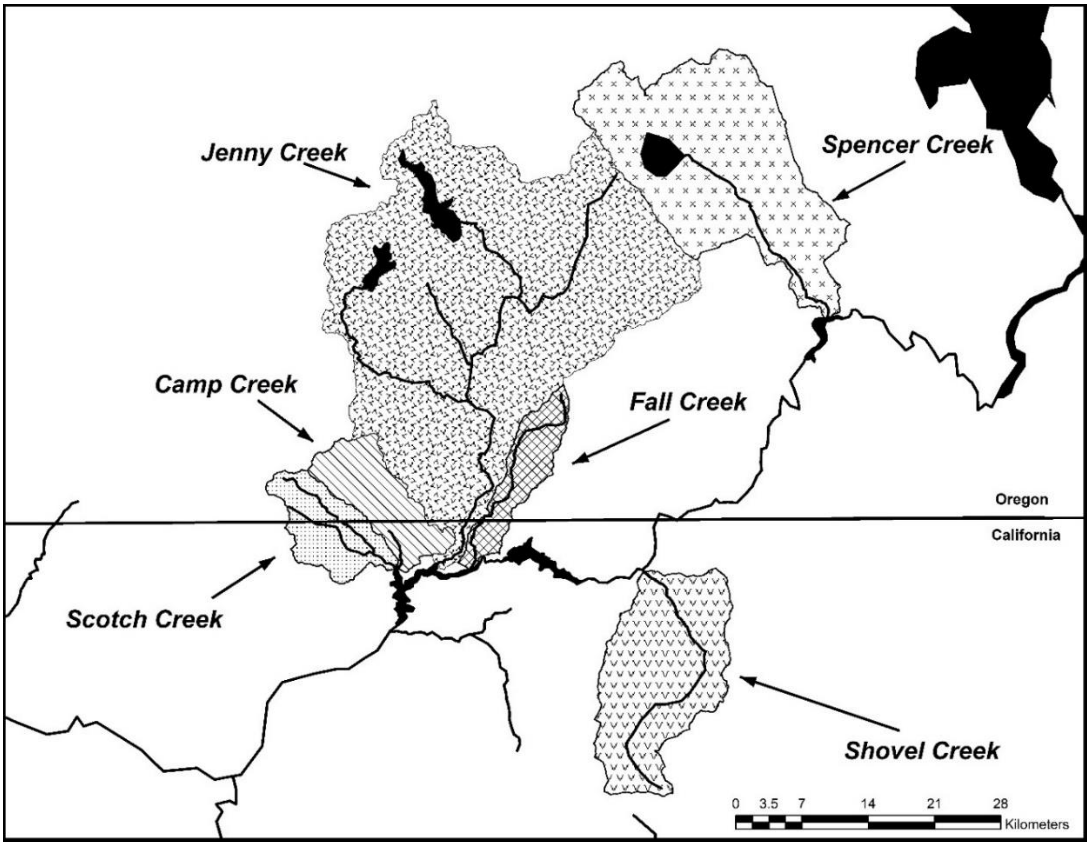


Figure 2 Study tributaries in the KHP reach and accessible post-dam removal. Stream watersheds are differentiated by fill pattern (black dots for Scotch Creek; diagonal lines for Camp Creek; staggered notch marks for Jenny Creek; cross hatched for Fall Creek; “v” shapes for Shovel Creek; “x” shapes for Spencer Creek).

Scotch Creek

Scotch Creek enters the Klamath River from its northern bank at RKM 310. Scotch Creek experiences the lowest estimated discharge of the streams I studied (Figure 3) and is intermittent at the mouth. Few data exist on fish species diversity of Scotch Creek before or after IGD, but personal observations and communications with local private property owners suggest a robust population of rainbow trout throughout the year. Fish rescues conducted by the California Department of Fish and Wildlife (CDFW) in 1961 translocated greater than 44,000 unidentified salmonids from Scotch Creek. A high density of willow cover and a complex braided channel network comprise the lower 0.2 km of Scotch Creek (PacifiCorp 2007). Upstream, the creek consists of moderate gradients, large cobble and small boulder substrates, with no distinct spawning tailouts (PacifiCorp 2007).

Scotch Creek originates near Pilot Rock in Jackson County, Oregon. A series of waterfalls and a bedrock chute, potential barriers to anadromy, occur at Scotch Creek RKM 1 (PacifiCorp 2007). PacifiCorp owns the land downstream of Copco Road; upstream, the CDFW manages the Horseshoe Ranch Wildlife Refuge.

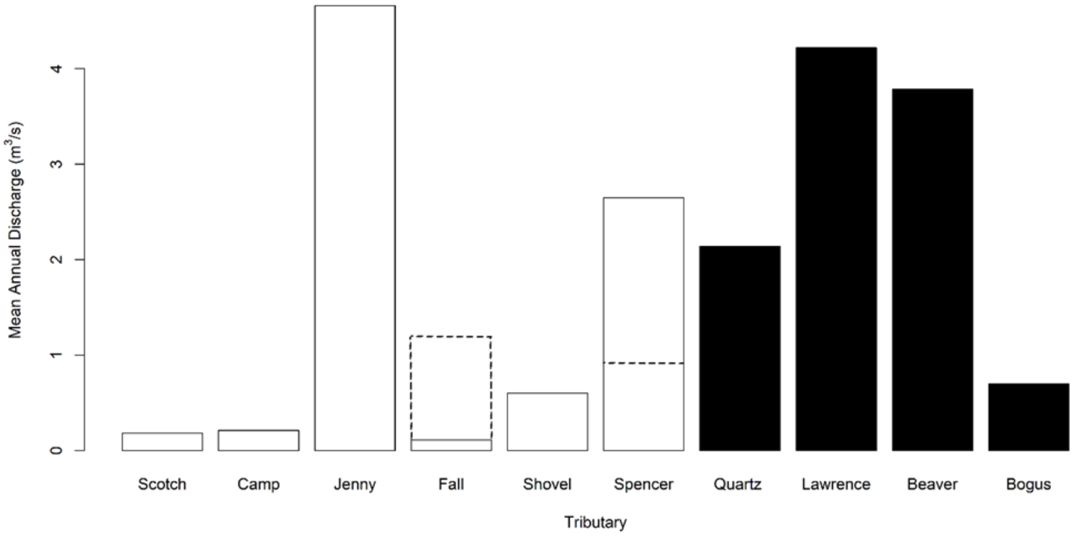


Figure 3 Estimated mean annual discharge in m^3/s for each of the six study tributaries (white bars) and the four reference tributaries (black bars). I calculated discharges for Lawrence and Quartz using the “Cape Blanco” model for ungaged sites of coastal streams in northern California and the Eastern Oregon model for Beaver, Bogus, Camp, Jenny, Fall,

Scotch, Shovel, and Spencer creeks developed by Agrawal et al. 2005. I included Fall Creek discharge from USGS gaging operation from 2003 – 2005 and Spencer Creek discharge from Oregon Water Resources Department gaging operations from 2003 – 2013 (dashed bars) (OWRD 2019).

Camp Creek

Camp Creek enters the Klamath River at RKM 310 on its northern bank, just upstream of Scotch Creek. Camp Creek exhibits low estimated mean annual discharge (Figure 3) and is intermittent at the mouth. Before the installation of IGD, Chinook salmon used Camp Creek for spawning (Coots 1953). In 1961, the year prior to IGD construction, CDFW fish rescue efforts yielded translocations of greater than 286,000 salmonids of unknown species from Camp Creek. Dense willow vegetation exists on Camp Creek downstream of Copco Road. The culvert under Copco Road creates a backwater scour pool with large quantities of fines and small gravels just upstream (PacifiCorp 2007). Further upstream, Camp Creek consists of high densities of large woody debris, small braided channels, step-pools, some scour pools and riffle type habitats of moderate gradient (PacifiCorp 2007).

Camp Creek originates just south of the Pacific Crest Trail and within the Cascade-Siskiyou National Monument in Jackson County, Oregon. No data exists as to the presence of potential barriers to fish movements in Camp Creek. Private parties own the majority of land in the Camp Creek watershed with some PacifiCorp property downstream of Copco Road and Bureau of Land Management (BLM) properties in its headwaters. Diversions and water rights on Camp Creek warrant further investigation.

Jenny Creek

Jenny Creek enters the Klamath River on its northern bank at RKM 312. Jenny Creek estimated mean annual discharge is the largest of any of the streams studied based on regression modeling (Figure 3). Prior to construction of IGD, fishing guides targeted coho salmon at the mouth of Jenny Creek with some of the highest success rates in the upper river (Hamilton et al. 2005). The Jenny Creek watershed supports three sensitive species above a series of falls, the Jenny Creek sucker (*Catostomus rimiculus*) a spatially isolated dwarfed Klamath smallscale sucker (Hohler 1981), the redband trout (*Oncorhynchus mykiss newberrii*) and the northwestern pond turtle (*Actinemys marmorata*) (Drehobl et al. 1995). Below the falls, Jenny Creek supports rainbow trout, brown bullhead (*Ameiurus nebulosus*), speckled dace (*Rhinichthys osculus*), marbled sculpin (*Cottus klamathensis*), green sunfish (*Lepomis cyanellus*), Klamath smallscale sucker (*Catostomus rimiculus*), and Klamath River lamprey (*Lampetra similis*).

Jenny Creek originates in Howard Prairie Reservoir in Oregon. Two waterfalls, located 3.2 km upstream of the mouth, restrict upstream fish movements. PacifiCorp owns the lower 1.8 km of the watershed and other private entities and the BLM own the properties upstream, roughly equally by surface area. Up to 0.47 m^3/s is diverted from Spring Creek (a small Jenny Creek tributary stream) to Fall Creek for power generation at the Fall Creek hydroelectric facility (PacifiCorp 2004). Other water diversions may exist upstream of the waterfalls in Jenny Creek. Flow in Jenny Creek is highly influenced by water releases from Hyatt and Howard Prairie reservoirs in Jackson County, Oregon.

Fall Creek

Fall Creek enters the Klamath River on its northern bank at RKM 316. Measured annual discharge averages just over 1 m^3/s in Fall Creek (Figure 3). Measured discharge in Fall Creek is more than predicted from the regression model based on precipitation and watershed area, at least partly because of diversions into and out of the stream from adjacent drainages (State Water Resources Control Board 1966, PacifiCorp 2004). Before the construction of IGD, coho salmon contributed a small but significant proportion of adult spawners and juvenile outmigrants in the stream (Coots 1954, 1957, 1962). Chinook salmon also used Fall Creek as a spawning tributary, producing greater than 350,000 outmigrants in some years (Coots 1954, 1957, 1962). Rainbow trout and marbled sculpin are the only fishes known to currently occupy Fall Creek.

Fall Creek originates in the mountains of southern Jackson County, Oregon. Waterfalls, located 1.6 km upstream of the mouth, block upstream fish movements. Fall Creek receives up to 0.47 m^3/s of water from Spring Creek, a tributary in the Jenny Creek drainage (PacifiCorp 2004). This diversion supports a small hydroelectric facility operated by Pacificorp near where Copco Road crosses Fall Creek. The “run-of-the-river” hydroelectric facility requires a minimum flow of 0.01 m^3/s, maintained by a small diversion dam above Fall Creek falls. The restoration of the Klamath River in 2022 will not include the removal of the Fall Creek Diversion Dam and Powerhouse (Kramer 2003). The city of Yreka operates two additional diversion dams immediately below the waterfall. These dams divert up to 0.42 m^3/s and provide the primary municipal water source for Yreka (State Water Resources Control Board 1966).

Shovel Creek

Shovel Creek enters the Klamath River on its southern bank at RKM 332. The stream's estimated annual discharge averages just over 0.5 m^3/s (Figure 3). Spring-seep sources maintain stable water temperatures year-round (Beyer 1984). Historical accounts document high utilization of Shovel Creek as a spawning tributary, but most accounts only refer to "salmon" in general:

> "*The salmon run up the river and go up Shovel Creek in such numbers as to be almost beyond belief. It is a fact that at narrow points in the river the salmon sometimes crowd each other out upon the bank."* (San Francisco Call, June 27, 1909)

Large abundances of Chinook salmon used habitat at the mouth, including a short distance upstream, of Shovel Creek (Coots 1965). After the construction of IGD, Shovel Creek emerged as an important spawning tributary for rainbow trout (Starcevich et al. 2006). Today, speckled dace, rainbow trout, brown trout (*Salmo trutta*), marbled sculpin, and Klamath River lamprey persist in Shovel Creek.

Shovel Creek originates on the east slope of Willow Creek Mountain. Waterfalls, 3.2 km upstream of the mouth in Shovel Creek, potentially block upstream fish movements. Private properties comprise the majority of land in the Shovel Creek watershed, with approximately twenty percent of the watershed managed by the U.S. Forest Service (Beyyer 1984). PacifiCorp operates three screened diversions on Shovel

Creek: the Lower Shovel Creek Diversion [0.212 m^3/s], the Upper Shovel Creek Diversion [0.071 m^3/s], and the Negro Creek Diversion [0.142 m^3/s] (PacifiCorp 2012).

Spencer Creek

Spencer Creek enters the Klamath River at its northern bank at RKM 369. The stream's measured annual discharge averages just under 1 m^3/s (Figure 3). This is substantially less than predicted from the regression model based on precipitation and watershed area, likely due to numerous irrigation diversions. Hamilton et al. (2005) identify Spencer Creek as the upstream-most extent of historic distribution for coho salmon and Pacific Lamprey in the Klamath River watershed. A pre-KHP account in Spencer Creek suggests staggering abundances of an unknown species of salmon:

> "*Recalled salmon in Spencer Creek, 20 miles below Klamath Falls, so thick that they frightened the horses fording the creek.*" (H. H. Cole 1946)

Today, rainbow trout use Spencer Creek primarily as a spawning tributary (PacifiCorp 2004, Starcevich et al. 2006). Juvenile rainbow trout rear in Spencer Creek year-round (PacifiCorp 2004), but most eventually migrate into the main stem Klamath River to grow before returning to spawn. Speckled dace and Klamath smallscale sucker persist in the stream in addition to rainbow trout.

Spencer Creek originates in the Buck Lake irrigation complex. Potential barriers to upstream fish passage need more investigation. A number of culverts exist throughout the watershed, and temporary unsanctioned recreation dams potentially limit juvenile fish passage during the summer months and prior to winter flows. Land ownership consists of a mix of private holdings, the BLM and the United States Forest Service (USFS). Green

Diamond Resource Company owns a large swath of land in the lower Spencer Creek watershed. The headwaters of Spencer Creek once a physical lake, now consist mainly of irrigation channels and diversions for nearby agriculture. An incomplete understanding of irrigation in the watershed below the Buck Lake irrigation complex deserves future research.

Reference Tributaries

Coho salmon habitat associations are widely documented in the literature. However, relationships between fish populations and their habitat often fail when extrapolated across regions (Fausch et al. 1988). The study streams are near the southern range limit of coho salmon and the warm, arid sites are not typical of coho salmon streams in other regions. Therefore, I collected data from reference streams closer to the study sites to provide input data for a habitat -based occupancy model to predict summer rearing distribution in the study streams. I selected four reference tributaries occupied by juvenile coho salmon during summer months. I selected Beaver and Bogus creeks in the mid-Klamath River watershed based on proximity to the IGD, similarity in geography to the study sites (Figure 4). I included two additional inland reference tributaries outside of the Klamath River watershed (Lawrence and Quartz creeks) with similar estimated mean annual discharge to the study sites (Figure 3 and Figure 4).

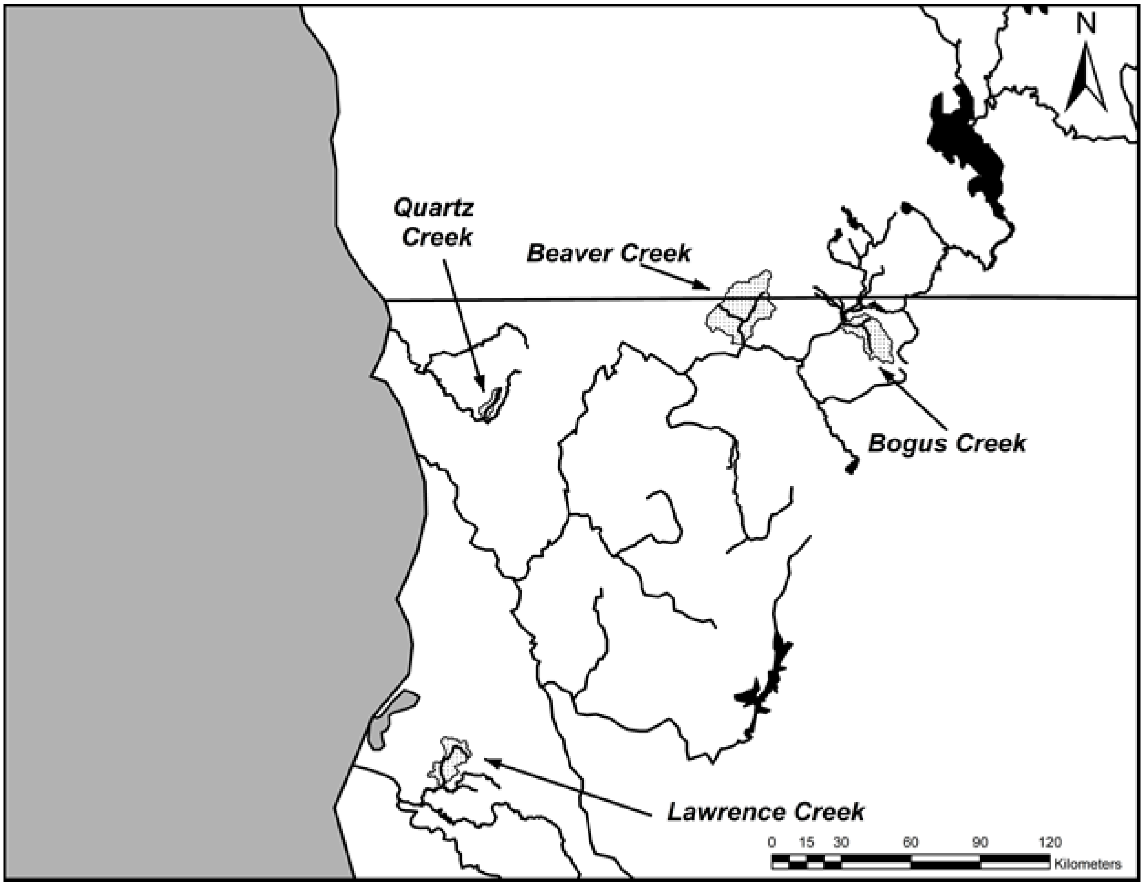


Figure 4 Reference tributaries below the IGD. Bogus and Beaver creeks are tributaries to the Klamath River, while Lawrence Creek is a tributary to the Van Duzen River and Quartz Creek is a tributary to the Smith River. Reference stream watershed boundaries are shown by the dotted fill.

Bogus Creek

Bogus Creek enters the Klamath River on its southern bank at RKM 305 (Figure 4). A fish counting video weir on Bogus Creek operated by CDFW provides high-quality estimates of fish abundance. Bogus Creek, in post-dam history, accounts for a large proportion of the natural spawning Chinook salmon above the Trinity River confluence

(31% during the 1996 to 1998 spawning seasons) (Knechtle and Chesney 2010). Fall-run Chinook salmon return to Bogus Creek between mid-September and early-November. Coho salmon also spawn in Bogus Creek from late-October to early-January (Knechtle and Chesney 2010). Large numbers of stray spawners from the adjacent Iron Gate Fish Hatchery artificially inflate total coho and Chinook salmon abundance in Bogus Creek. Iron Gate hatchery-origin coho salmon comprised 51 percent of Bogus Creek spawning adults from 2004 to 2013 (Knechtle and Chesney 2014). Rainbow trout, Klamath smallscale sucker, speckled dace, Pacific lamprey, Klamath River lamprey, and marbled sculpin persist in Bogus Creek.

Bogus Creek originates in northern Siskiyou County in the mountains just east of Ager, CA. Cascading bedrock features further upstream may limit fish movements. Land within the Bogus Creek watershed consists of private allotments, many used for ranching and agriculture. Water diversions and irrigation return flows in the upper Bogus Creek basin affect discharge and water quality.

Beaver Creek

Beaver Creek enters the Klamath River on its northern bank at RKM 263 (Figure 4). Its estimated discharge averages just under 4 m^3/s (Figure 3). Beaver Creek supports spawning and rearing of coho and Chinook salmon and steelhead. Beaver Creek is also occupied by transient juvenile anadromous and resident salmonid populations from the Klamath River, likely because it maintains cool water temperatures during summer months when Klamath River main stem water temperatures exceed juvenile salmonid thermal tolerances (Sutton et al. 2007).

Beaver Creek originates from Mt. Ashland, OR and nearby mountains. A large concrete dam footing approximately 1.2 km upstream from the confluence with the Klamath River potentially limits upstream fish movements. Lower Beaver Creek, a popular recreational area for nearby landowners in hot summer months, contains a number of temporary dam structures potentially detrimental to upstream fish movements for juveniles during summer. National Forest lands and private inholdings make up the majority of the Beaver Creek watershed. I do not know of any major diversions from Beaver Creek.

Lawrence Creek

Lawrence Creek is in the Eel River watershed. It enters Yager Creek approximately 13.5 km upstream of its confluence with the mainstem Van Duzen River and 46 km upstream of the mouth of the Eel River and the Pacific Ocean (Figure 4). Estimated mean annual discharge averages just over 4 m^3/s in Lawrence Creek (Figure 3). The stream's habitat conditions and lower gradient reaches support a high diversity of anadromous fishes (USEPA 1999). Lawrence Creek is considered a critical spawning tributary for anadromous fishes in the Van Duzen watershed (USEPA 1999). Chinook salmon, coho salmon, and rainbow trout occupy the stream.

Lawrence Creek originates in mountains just south and southeast of Kneeland, CA in Humboldt County. Land ownership consists of primarily private entities. The land use within the Lawrence Creek watershed consists of primarily commercial logging; shrubs and “young” redwood forests dominate the vegetation (USEPA 1999). I do not know of any major water diversions from Lawrence Creek.

Quartz Creek

Quartz Creek enters the South Fork Smith River approximately 39 km upstream of the mouth of the Smith River to the Pacific Ocean (Figure 4). Estimated mean annual discharge averages just over two m^3/s in Quartz Creek (Figure 3). Few data exist on fish species in Quartz Creek, but coho salmon and rainbow trout occupy the stream.

Quartz Creek originates in the mountains of central Del Norte County and approximately 16 km due south of Idlewild, CA. Features restricting upstream movement may exist in Quartz Creek. The stream is located within the Smith River National Recreation Area operated by the USFS and designated as recreational under the Wild and Scenic River system (USDA 1992).

Table 2 Watershed characteristics of streams. Reference tributaries are delineated by the dashed lines.

Watershed	Klamath River Kilometer (km)	Watershed Area (km^2)	Maximum Watershed Elevation (m)	Minimum Watershed Elevation (m)	Change in Elevation (m)	Length of Longest Flow Path (km)	Mean Annual Precipitation (cm)	10-Year Peak Flood (m^3/s)	25-Year Peak Flood (m^3/s)
Scotch Creek	310	47	1761	711	1050	14.5	62	10	14
Camp Creek	310	51	1856	710	1145	14.5	62	11	16
Jenny Creek	312	545	1989	711	1278	53.1	73	78	114
Fall Creek	316	39	1567	710	857	20.9	54	7	10
Shovel Creek	332	132	2384	816	1568	25.7	61	21	30
Spencer Creek	369	221	2493	1158	1335	--	93	16	20
Lawrence Creek (Van Duzen River)	--	109	1133	132	1001	25.7	174	213	275
Quartz Creek (Smith River)	--	29	1609	319	1290	14.5	277	91	114
Beaver Creek (Klamath River)	261	282	2282	540	1746	32.2	96	75	109
Bogus Creek (Klamath River)	305	134	2383	664	1717	29.0	64	22	33

Note: I obtained these data from the USGS StreamSTAT database on October 17, 2018; Dashed box, “- - -“, indicates reference tributaries.

METHODS

Summertime Temperature Variation

I recorded a time-series of thalweg temperature for tributaries above the IGD and Bogus and Beaver creeks using calibrated Onset HOBO Water Temp Pro V2 sensors. I installed the sensors near the tributary confluence with the mainstem Klamath River or reservoir and near the first likely barrier for migrating adult coho salmon. I installed the upstream-most temperature sensors for Bogus and Beaver creeks near the upper extent of the study reach as I did not find definitive barriers to anadromy. To measure temperature during the summertime rearing period, I deployed temperature monitoring sensors mid-June 2018 and mid-May 2019 and retrieved them in late-September 2018 and in late-October 2019. Sensors recorded temperature continuously at 60-minute intervals. In 2018, I deployed 10 temperature sensors and in 2019, I deployed 13 sensors.

To identify potential effects on rearing conditions, I plotted a temperature time-series for each study tributary with reference lines for optimal, suboptimal, cessation of growth, and lethal zones for chronic weeklong exposure to juvenile coho salmon. Konecki et al. (1995) consider temperatures between 7.0 ° and 21.0 °C to be optimal for the growth of juvenile coho salmon. When temperatures exceed the optimal rearing temperature range for salmonids, feeding rate and growth can decline (McCullough et al. 2001). Brett (1952) found that juvenile coho salmon could not withstand chronic exposure to water temperatures greater than 25.0 °C, an upper lethal temperature. Spence et al. (1996) suggest that juvenile coho salmon require water temperatures greater than 4.4 °C, a suboptimal minimum.

Juvenile coho salmon can tolerate temperatures outside the suboptimal or lethal ranges if food is not limited (Lusardi 2020); I therefore chose to use these published temperature requirements and preferences as guidelines rather than hard rules for future coho utilization.

In addition to plotting temperature in reference to the published optimal and suboptimal temperatures for chronic exposure for juvenile coho salmon, I calculated maximum weekly maximum temperature (MWMT) and maximum weekly average temperature (MWAT). Welsh et al. 2001 define MWMT as the “highest average of maximum daily temperatures over any 7-d period” and MWAT as the “highest average of mean daily temperatures over any 7-d period”, assumed to occur during the summer months with high ambient air temperatures. MWMT and MWAT more accurately characterize the temperature regime predictive of juvenile coho presence or absence when compared to other methods of temperature regime characterization (Welsh et al. 2001).

In the Mattole River (a stream on the northern California coast), reaches with MWMT above 18.0 °C or MWAT above 16.7 °C did not contain juvenile coho salmon and all reaches with an MWMT less than 16.3 °C or an MWAT less than 14.5 °C contained juvenile coho salmon (Welsh et al. 2001). I compared MWMT and MWAT values of the study streams to values associated with juvenile coho salmon presence or absence as described by Welsh et al. 2001 in the Mattole River.

Sampling Hierarchy

I defined the habitat and fish sampling hierarchically, smallest to largest in spatial scale as follows: habitat unit as delineated by habitat type, 200-m reach, and study tributary (Figure 5). I divided the streams into 200-m reaches beginning at the stream mouth and terminating at the perceived definitive natural barrier to upstream fish movements.

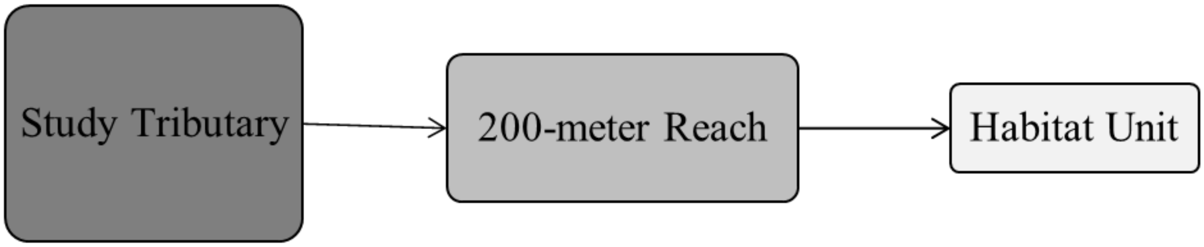


Figure 5 Sampling hierarchy for habitat surveys, electrofishing, and snorkel fish surveys. Field sampling took place at the habitat unit scale.

Barriers to Anadromy

I surveyed study tributaries from their confluence with the mainstem Klamath River and up to the first likely barrier for adult coho salmon migration. I marked locations of barriers on a handheld Garmin GPS unit (+/- 5 m accuracy). Reiser et al. (2006) defined barriers for adult coho salmon by: a maximum jump height of 2.19 m, a sustained velocity of 6.55 m/s (maximum burst velocity) over 1.63 m, or a sustained velocity of 3.23 m/s (maximum prolonged velocity) over 650 m. I conducted habitat sampling during summer months at much lower discharge than expected during the fall and early winter spawning migration. Therefore, I identified barriers and located the uppermost extents of study tributaries at waterfall features exceeding 2.19 m in height or high gradient cascade features predicted to exhibit water velocities exceeding 6.55 m^3/s during fall and winter flows. The barrier falls on Fall Creek are definitive, greatly exceeding these minimum values. For Scotch, Jenny, Shovel, and Spencer creeks, it is possible that coho salmon adults could pass the identified barriers under some flow conditions.

Distribution of non-natal, and downstream in origin, juvenile coho salmon is limited by their ability to move upstream to find suitable rearing areas (Davis and Davis 2011). I assessed potential barriers for non-natal juvenile coho salmon originating downstream during summer low flows between mid-July 2018 and mid-August 2018 and mid-June 2019 and mid-July 2019. Juvenile coho (45-60 mm fork length) cannot jump heights greater than approximately 40 cm or achieve burst swim speeds greater than 1.0 m/s (C. O'Keefe, pers. comm., 2020). Physical measurements of stream habitat features do not classify habitat features as juvenile barriers with high certainty (Davis and Davis 2011). Therefore, I classified high velocity and high gradient features as "potential" barriers to juvenile distribution. I measured waterfall and cascading features using a stadia rod to assess jump height and visually estimated water velocity to assess juvenile passage.

Habitat Surveys

A field crew of two to three conducted longitudinal habitat surveys from mid-June 2018 through mid-August 2018 for Beaver, Jenny, Fall, and Shovel creeks and from early-June 2019 through late-July 2019 for Bogus, Scotch, and Spencer creeks. I was unable to perform habitat surveys on Camp Creek due to inaccessible private property. I selected a randomized subset of approximately fifty percent of the available 200-m reaches in each study tributary for habitat surveys (

Table 3). I used a handheld Garmin GPS unit (+/- 5 m accuracy) to mark coordinates of each habitat unit. Due to logistical and time constraints, I selected 15 percent of available reaches on Spencer Creek. Lawrence and Quartz creek data were collected by the CDFW and were not aggregated into 200-m reaches and included only pools.

Table 3 Summer survey lengths and number of reaches from the mouth for each study tributary

Tributary	Year	Study Length (m)	Number of 200 m Reaches	Reaches Selected for Sampling	Total Number of Habitat Units Sampled	Length Surveyed (m)
Scotch Creek	2019	980	5	1,3,5	42	580
Jenny Creek	2018	3300	17	3, 4, 6, 7, 9, 10, 11, 15, 16	133	1500
Fall Creek	2018	1640	9	1[1], 4, 5, 6, 8, 9	88	1150
Shovel Creek	2018	3200	16	2, 3, 4, 5, 9, 11, 15, 16	127	1820
Spencer Creek	2019	21000	105	17, 19, 20, 24, 28, 44, 45, 57, 61, 63, 65, 74, 75, 80, 90, 102	206	3240
Van Duzen River (Lawrence Creek)	2013	--	--	--	30	--
Smith River (Quartz Creek)	2013	--	--	--	44	--
Beaver Creek	2018	1650	9	1 – 9	61	1650
Bogus Creek	2019	2400	12	1, 3, 4, 10, 11, 12	62	1160

Note: 1. Fall Creek reach number one was added to the habitat sampling list due to its large quantity of spawning gravel and potentially disproportionate number of suitable habitat units when compared to the rest of the sampling length; Dashed box, "- - -", indicates reference tributaries.

I developed a habitat survey protocol based on methods described by the USFS (Overton 1997) and the CDFW (Garwood and Ricker 2013, Garwood and Ricker 2017). I modified these survey protocols to provide data required for the HLFM while including methods consistent with CDFW surveys for occupancy modeling. Survey crews walked the length of each reach and recorded the location and size of discrete habitat units defined by breaks in channel width, depth, and morphometrics (runs, riffles, pools). I classified multiple habitat units within one stream cross-section when multiple discrete habitat types described greater than one third of the channel wetted width.

I recorded channel wetted width (m), canopy cover (%), habitat unit length (m), maximum depth (cm), large woody debris, bedrock composition (%), available spawning gravel (m^2), and instream cover area (m^2) for each non-riffle type habitat unit and a subset of riffle-type habitat units (e.g. every second or third). I temporarily marked measured habitat units with colored flagging during the survey period.

Habitat Types

Implementation of the HLFM model required classification of habitat units by type. Following the HLFM methods combined with other protocols, I established fast moving water type classifications as a function of stream gradient, water velocity, and streambed morphology (Overton 1997).

Wetted Width

I measured the wetted width of each habitat unit to the nearest 0.1 m using a tape measure perpendicularly from each bank, where the width appeared to be representative of the entire habitat unit (Overton 1997). I subtracted any unwetted (sand and/or gravel bars) portions of the stream channel.. For larger habitat units and habitat units with highly variable widths, I recorded and averaged multiple measurements. For slow water habitat units, I measured the wetted width at the downstream location where thalweg depth matched the average of the pool maximum depth and tail crest depth.

Depth

I measured depth to the nearest cm with a stadia rod. I took depth measurements at the same location as the unit average wetted width measurement. I measured fast water habitat type depths at one fourth, one half, and three fourths of the stream cross-section. I summed three depth measurements (at 1/4, 1/2, and 3/4 wetted width) and divided by four to account for zero depths at either end of the cross-section (banks).

Residual Pool Depth (Depth for Slow Water Habitats)

I calculated the residual pool depth by subtracting the pool tail crest depth from the maximum pool depth. I measured the tail crest depth at the thalweg of the break in stream channel slope between the pool habitat unit measured and downstream habitat unit to the nearest cm. I located and measured the pool maximum depth by exploration with a stadia rod and recorded to the nearest cm.

Surface Area

I measured the maximum defined habitat unit length to the nearest 0.1 m using a tape measure and multiplied the length by the average wetted width to estimate surface area.

Instream Cover Area

Instream cover area is the area of the habitat unit occupied by cover suitable for fish refuge. I visually estimated instream cover to the nearest 0.25 m^2. Instream cover included but was not limited to: bank undercutting, woody debris, boulder undercutting, root wads, aquatic and overhanging terrestrial vegetation. I included all features 0.25 m^2 or greater in surface area within the wetted channel; I also included features suspended 1.0 m or less above the water's surface.

Canopy Cover

I ocularly estimated canopy cover percentage of habitat units to the nearest 5 percent of their surface area. Canopy cover included all vegetative features directly over the units.

Percent Bedrock

I ocularly estimated the percentage of bedrock relative to the habitat unit surface area to the nearest 5%.

Spawning Gravel

I ocularly estimated all available spawning gravel area in each habitat unit to the nearest 0.25 m^2. Spawning gravel patches less than 0.5 m^2 were not included as available gravels as a patch this size is unsuitable for spawning needs of adult coho salmon. I defined spawning gravel for coho salmon as substrates that had an intermediate axis between 13 and 150 mm (Hassler 1987), composed of less than 15 percent very fine gravel, that occurred in riffle type habitats with water depths greater than or equal to an estimated 15 cm at winter flows (McMahon 1983), located at stream gradients less than or equal to 7% (Agrawal et al. 2005), and substrates that exhibited embeddedness less than 80% (McMahon 1983).

Large Woody Debris Count

I counted and measured the number of large woody debris (LWD) in each habitat units. I included LWD features of 10 cm or greater in maximum diameter and of 1 m or greater in length. I measured LWD diameter at the widest portion of the woody debris unit to the nearest cm. I measured LWD unit length to the nearest 0.1 m. I included suspended LWD features that occurred within 1.0 m above the surface of the habitat unit in the LWD count and measurement. I counted multi-branched large woody debris units as one.

Snorkel Surveys

I selected a randomized subset of habitat units catalogued in the habitat surveys for snorkel surveys. I conducted snorkel surveys from late-June 2018 to mid-September 2018 on Beaver, Shovel, and Fall creeks and from early-June 2019 to early-September 2019 on Bogus, Jenny, Fall, Shovel, and Spencer creeks. At the reference sites, the snorkel surveys provided data on coho salmon habitat utilization for predicting their distribution in the study tributaries. On the study tributaries, the snorkel surveys provided baseline data on fish community composition and habitat use.

We performed snorkel surveys on one half of slow water, glide, run, and low-gradient riffle type habitats. I did not survey high-gradient riffle habitat types due to low detection probability of fish by divers. A survey crew of two to three conducted snorkel surveys for each selected habitat unit. The first surveyor snorkeled and recorded the abundance of resident and anadromous salmonid species by length class provided in

Table 4; additionally, we recorded the abundance of Pacific giant salamander, other amphibian species, and the presence of freshwater bivalves.

I based snorkel surveys on a two-pass method to account for imperfect detection by surveyors. The first diver surveyed the habitat unit from the downstream to upstream end. After a five to ten-minute recovery period, the second diver repeated the survey, utilizing the same approach. Snorkel surveyors did not communicate fish counts between passes to maintain independence.

Table 4 Salmonid assumed age classification by fork length

Age Class	coho salmon	rainbow trout/steelhead	Chinook salmon	brown trout
0^+	≤ 100 mm	≤75 mm	≤ 100 mm	≤ 75 mm
1^+	> 100 mm	> 75 mm	> 100 mm	> 75 mm

Electrofishing

I conducted electrofishing surveys under Institutional Animal Care and Use Committee (IACUC) approval number 17/18.F.80-A (effective May 1, 2018) on Jenny, Fall, and Shovel creeks to provide size structure information and baseline fish community composition. Methods and results of electrofishing surveys are in Appendix C.

Habitat Models

I used three models to estimate coho salmon summertime rearing potential: the Habitat Limiting Factors Model (HLFM), the Intrinsic Potential (IP) model, and a single-season occupancy model. The HLFM approach relies on measuring discrete habitat unit classifications and physical habitat characteristics (Nickelson et al. 1998). The HLFM uses fish-habitat type relationships observed in stream inventories for coastal Oregon (Nickelson et al. 1992). The IP model estimates the stream's "potential" to exhibit habitat features conducive to juvenile coho salmon rearing based on broad-scale landform and hydrological characteristics (Burnett et al. 2003). The single season occupancy model uses the relationship between coho salmon presence-absence and habitat characteristics at the reference sites to estimate the probability that a given site is occupied (Mackenzie et al. 2002, Kery and Schaub 2011). Unlike traditional empirical models of the relationship between distribution and habitat, single season occupancy models account for imperfect detection (Kery and Schaub 2011).

The results of these analyses provided complementary information: the HLFM model predicts the expected abundance of coho salmon under current habitat conditions. The IP model identifies streams which, under ideal conditions, could support large populations of coho salmon (IP model). The occupancy model predicts the distribution of coho salmon within each stream under current conditions using habitat relationships developed within the Klamath Basin and nearby systems. While the models make quantitative predictions, they are meant be used to screen for habitat issues and rank potential hotspots for coho salmon production that might merit protection or restoration. For example, streams that exhibit high IP and a poor HLFM or occupancy prediction may be targets for future habitat restoration efforts. Similarly, within streams that have a low IP, areas of high probability of occupancy or HLFM prediction may be targets for ensuring accessibility for rearing of non-natal juvenile coho salmon.

HLFM Model

Using the HLFM, I estimated each stream's potential juvenile summer rearing capacity using pre-defined habitat specific rearing densities for juvenile coho salmon (Table 5) and surface area of available habitat determined by habitat surveys collected during summer of 2018 and 2019 (Nickelson 1998). Using my estimates of spawning gravel area, I also compared estimated smolt production for each stream based on HLFM spawning capacity (assuming 830 eggs per m2 of spawning gravel and egg to smolt survival of 0.3) and HLFM summer rearing capacity (assuming parr to smolt survival of 0.7) to assess which life stage habitat is more likely to constrain coho salmon populations. I extrapolated HLFM results to habitats not surveyed for each stream assuming that habitat units that I surveyed were representative of the stream in its entirety.

Table 5 Coho salmon habitat specific densities and survival rates (HLFM Version 5.0)

Habitat Type	Summer Juvenile Density (individuals/m^2)
Cascade	0.0
Rapid	0.6
Riffle	1.2
Glide	1.8
Trench pool	1.0
Plunge pool	0.8
Lateral scour pool	1.3
Mid-channel scour pool	1.3
Dammed pool	2.6
Alcove	2.8
Beaver pond	2.6
Backwater pool	5.8

Intrinsic Potential Model

The IP model estimates the potential for stream sections to provide suitable habitat for coho salmon using associations of fish presence and stream geomorphological characteristics (Burnett et al. 2003). Uniquely, IP models do not require direct measurements of stream habitat features. Instead, IP models use general, large-scale landscape attributes favorable to habitat formation to offer an assessment of the potential for a stream to produce suitable habitat at local or regional scales. Management authorities commonly use IP models to direct restoration funds, plan recovery efforts, and to estimate historic ranges of fishes (Agrawal et al. 2005, Busch et al. 2013, NMFS 2014). In application, the intrinsic potential of a habitat unit represents its relative historical potential as pristine habitat or the current habitat potential neglecting anthropogenic disturbances (Sheer et al. 2009).

The IP model assumes that three landscape and hydrological attributes (channel gradient, mean annual discharge, and valley constraint) interact in creating channel morphology (Burnett et al. 2003). The model weights these attributes by pre-developed rating curves to rescale total habitat area based on a proportional suitability index (Figure 6) (Agrawal et al. 2005, Burnett et al. 2007).

To calculate the channel gradient for the IP model, I used 10-m resolution digital elevation models (DEMs) in a geographic information system (GIS). I calculated IP reach breaks with channel gradient calculations as follows (Nagel et al. 2010):

Gradient (%)	Gradient class	Interval spacing (m)
> 7.5	Cascade	160
3 – 7.5	Step-pool	230
1.5 – 3	Plane-bed	540
< 1.5	Pool-riffle	810

I calculated the mean annual stream discharge for Scotch, Camp, Jenny, Fall, Shovel, and Spencer creeks using a multiple linear regression developed for ungaged sites in eastern Oregon (Agrawal et al. 2005):

$$\ln(D) = -15.712 + 1.176\ln(A) + 2.061\ln(P)$$

Where D is discharge in ft^3/s, A is watershed drainage area in acres and P is mean annual precipitation in inches. I calculated the discharge at the bottommost and uppermost points of each stream's IP length and used a linear model to calculate discharge of discrete IP reaches.

I used ten-m resolution digital elevation models (DEMs) in a geographic information system (GIS) to calculate a valley-width index of valley constraint. Valley constraint "reflects the extent to which hill slopes impinge on the channel, and thus the ability of the stream to interact with its floodplain" (Burnett et al. 2007). I calculated the valley width index (*V*) as the ratio of valley-floor width (*VFW*) to active-channel width (*ACW*) for a given stream reach (*k*) (Burnett et al. 2003):

$$V_k = \frac{VFW}{ACW}$$

I calculated the *ACW* using a predefined simple linear regression equation developed from field-based measurements (Burnett et al. 2003):

$$ACW = 2.19108 + 1.32366 * \sqrt{D}$$

Where *D* is the mean annual discharge in ft^3/s.

I calculated valley floor width in a GIS as "estimated as the length of a transect that intersects the valley walls at a specified height above the channel. Since the exact orientation of the valley was unknown, transect orientation varied to find that which provided the minimum length. The height above the channel is specified as 2.5 times estimated bank-full depth, given as a function of drainage area." (Miller 2003). I calculated the bankfull depth (H_{bf}) for each stream using the equation developed by Agrawal et al. (2005):

$$H_{bf} = 0.36 * A^{0.2}$$

Where *A* represents the stream drainage area in km^2. I calculated drainage area for each stream using the United States Geological Survey (USGS) StreamStats version 4.0 online delineation tool (Ries et al. 2017). I calculated *A* at the bottom-most and upper-most points of each stream's IP length and used a linear model to calculate *A* of discrete IP reaches.

I calculated the intrinsic potential score by taking the geometric mean of the three species-specific index scores (Figure 6) for mean annual discharge (m^3/s), channel gradient (%), and valley constraint (Burnett et al. 2003). Shown quantitatively, for a given stream reach k:

$$IP_k = \sqrt[3]{f_D(D_k) * f_G(G_k) * f_V(V_k)}$$

Where *f* represents the conversion of the parameter to the appropriate IP scale (0 to 1); D_k, G_k, and V_k specify the mean annual discharge, channel gradient, and valley constraint respectively of the given stream reach *k* (Burnett et al. 2007). Intrinsic potential scores can range from zero to one. Higher intrinsic potential values indicate a greater potential to produce high quality fish habitat (Burnett et al. 2007). I created maps of IP scores for each reach of the six tributaries above IGD. I also calculated the weighted IP km of each stream by multiplying each IP reach by its calculated IP value and then calculating the sum of all reaches within the stream. The low-risk abundance target is an IP model-driven and density-based estimate for adult escapement assuming no anthropogenic disturbance effects and full restoration of geomorphological processes (NMFS 2014).

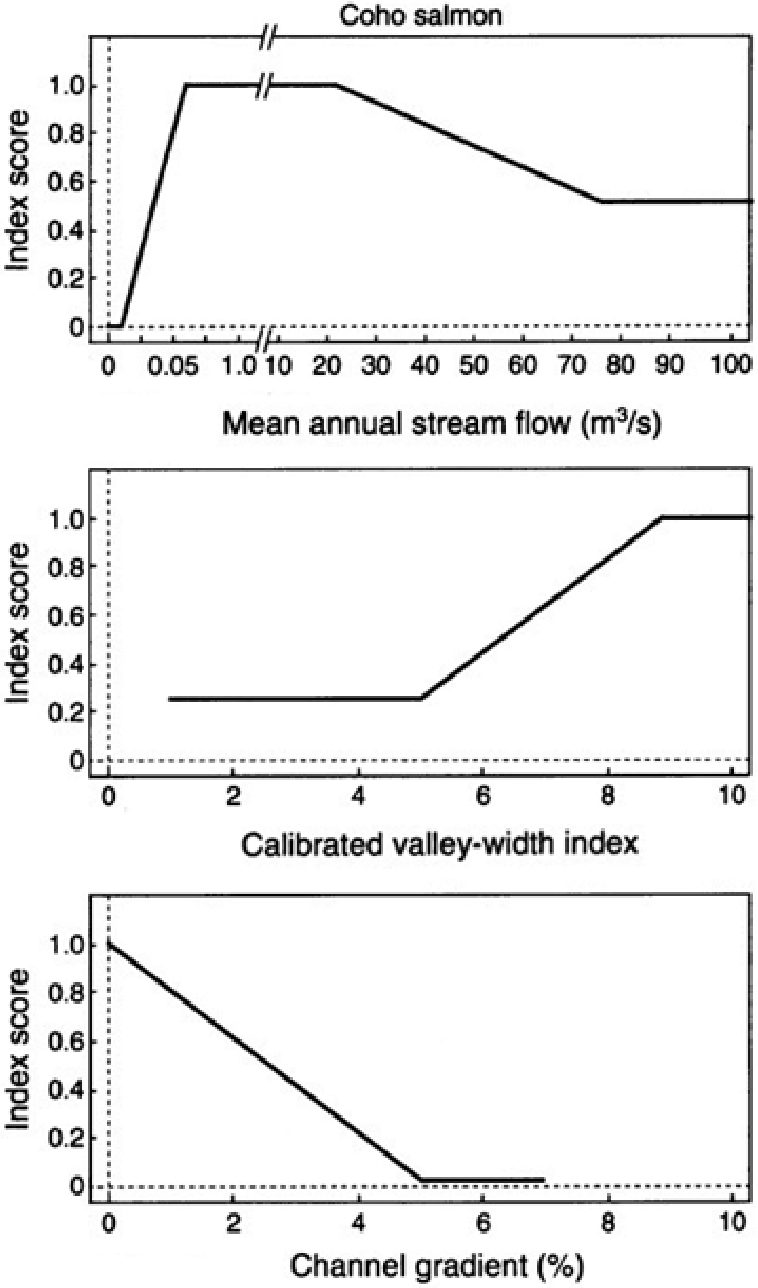


Figure 6 IP index scores for habitat mean annual flow, calibrated valley-width index, and channel gradient for juvenile coho salmon.

Estimation of Occupancy

I used an occupancy analysis approach to predict the small-scale distribution (i.e. habitat selection) of coho salmon in the study streams. Traditional species distribution modeling ignores detection probability, resulting in estimates of "apparent species distribution" rather than real species distribution (Kery and Schaub 2011). Occupancy models are hierarchical logistic-regression models that estimate the probability of occupancy and address issues of imperfect detection (Kery and Schaub 2011). A hierarchical approach helps separate the observational error component from the ecological component (Figure 7). An unoccupied site always results in a nondetection (0); however, an occupied site could result in a detection (1) if the species is present and detected or nondetection (0) if the species is present but not detected. Occupancy models use the frequency of detection (1) and nondections (0) at occupied sites (established over multiple survey occasions) to determine the detection probability.

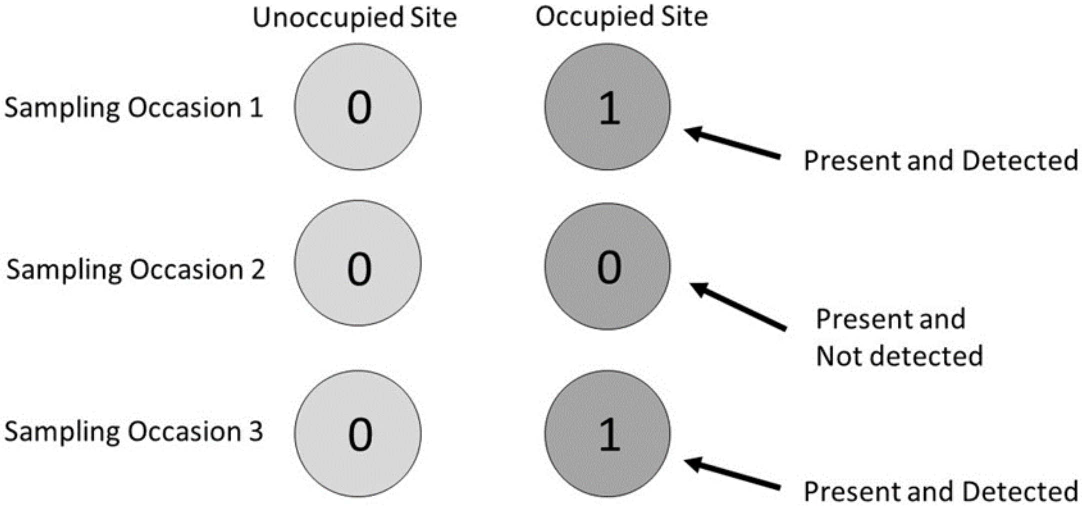


Figure 7 The foundation of occupancy modeling, separating observational error and ecological presence variation.

The ecological component of an occupancy model corresponds to the probability that a site (*i*) is occupied ($\boldsymbol{\Psi_i}$)(i.e. occupancy); the observational component corresponds to the probability of detecting the target species at a site (*i*) on a given survey (*j*) ($\boldsymbol{p_{ij}}$) (i.e. detection probability) given its presence (Kery and Schaub 2011).

The primary assumptions of the occupancy model include (Kery and Schaub 2011):

1. No change to a site's occupancy (Ψ) between surveys (closure).
2. Constant probability of occupancy (Ψ) across all sites (*j*), or if not, appropriately modeled using covariates.
3. Constant probability of detection (*p*) across all sites (*j*), or if not, appropriately modeled using covariates.
4. Independent detection histories of sites.
5. No false-positive detections

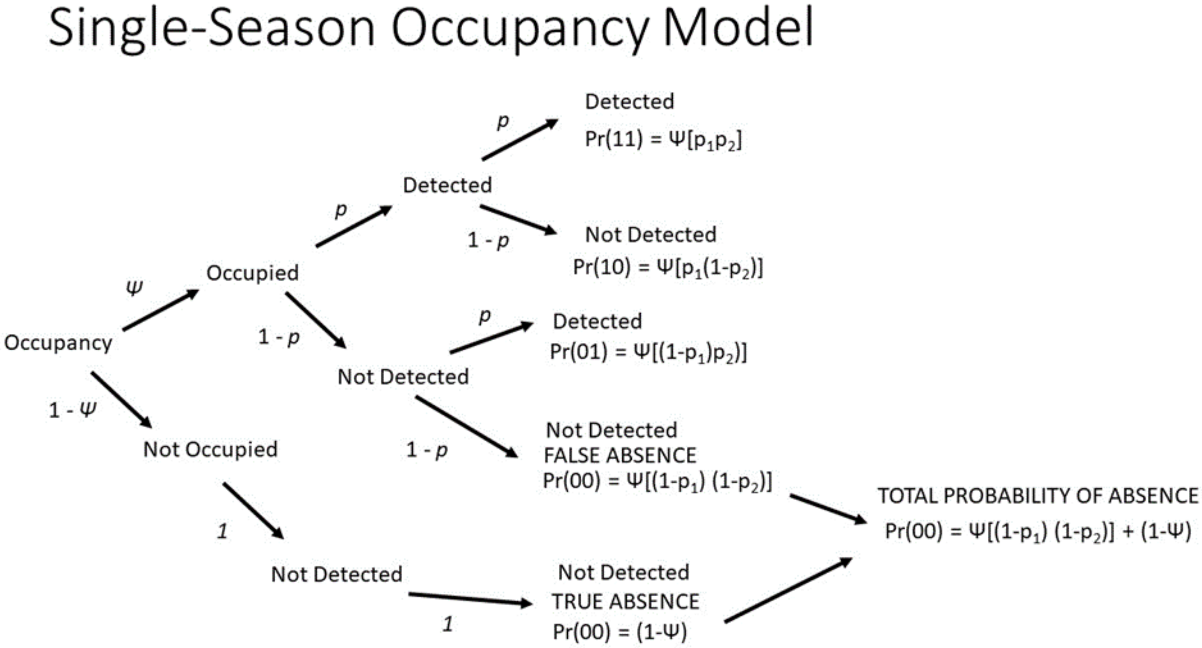


Figure 8 Detailed schematic of all possible outcomes of an occupancy model with two occasions (passes).

Fitting the Occupancy Model

I fit an occupancy model using program PRESENCE version 12.39 using data from the four reference tributaries (Figure 4), where juvenile coho salmon currently occur, to predict their distribution at the study sites above the IGD (Figure 2). Data from Lawrence and Quartz creeks consisted of pool type habitat units that fit characteristics defined by the CDFW’s 2013 field protocol (Garwood and Ricker 2013). In the Klamath Basin reference sites, I expanded the CDFW’s 2013 field protocol and sampled all habitat unit types in Beaver and Bogus creeks.

The literature suggests that temperature strongly affects the presence/absence of juvenile coho salmon (Welsh et al. 2001). However, I did not have temperature data available for the CDFW reference streams. For the Klamath Basin reference sites, examination of potential temperature effects was confounded by a large effect of proximity to the Iron Gate Fish Hatchery: Bogus Creek, adjacent to the hatchery, had consistently warmer water temperatures (when compared to the rest of the dataset). I therefore did not include temperature as a predictor in the occupancy model.

I selected a subset of habitat characteristics to include as potential predictors in the occupancy model based on a priori hypotheses. I hypothesized that detection probability varies with depth. Literature suggests that depth affects the ability of a diver to detect fish presence (Albanese et al. 2011). I hypothesized that occupancy of juvenile coho salmon at the habitat-unit scale varies with: percent instream cover, surface area, HLFM value, and a categorical hatchery effect. Juvenile coho salmon use instream cover structures such as large woody debris jams, boulder, and undercuts to minimize energy expenditures while maintaining advantageous drift feeding position (Mundie 1969, Fausch 1993). Surface area, a quantification of available space for juvenile coho salmon, logically increases with an increase in juvenile coho salmon occurrence. I included HLFM value as it is used as an estimate of juvenile coho salmon capacity based on data collected in Oregon coastal streams (Nickelson et al. 1992). Streams in close proximity to hatcheries exhibit an exponential decay relationship with abundance of hatchery salmonids with distance from hatchery (Brenner et al. 2012); I therefore included a hatchery categorical effect to account for inflated juvenile coho salmon abundances in Bogus Creek. I tested all potential covariates for collinearity using the variance inflation factor method. No collinearity issues existed. I standardized covariates using the z-score method prior to model fitting for scaling.

I used Akaike's Information Criterion (AIC) for model selection. I performed the model selection in two phases, first for the detection component and second for the occupancy component. During model selection for the detection component, I used the null model for the occupancy component. During model selection for the occupancy component, I kept the detection component fixed at the best detection model. I did not include any interactions among the potential predictors

Occupancy Model Validation

Once I found the most parsimonious ("best") model, I performed a cross validation analysis to test the utility of the model for predicting coho salmon distribution at sites that are not included in the model input. For model validation, I removed Lawrence and Quartz creeks from the dataset and re-ran the occupancy analysis using the covariates from the "best" model and the input data for Beaver and Bogus creeks. I used similar cross validation using Lawrence and Quartz creeks as input to predict occupancy in Beaver and Bogus creeks. However, for this analysis, I evaluated the accuracy of model predictions separately for Beaver and Bogus, because the input data set did not contain a categorical predictor category representing the hatchery effect in Bogus Creek.

To perform the cross-validation, I assigned each occupancy prediction to "correct" or "incorrect". Model predictions were classified as correct if the model predicted occupancy probability of >0.5 and the unit was occupied or if the model predicted occupancy probability of <0.5 and the unit was unoccupied.

Occupancy Model Implementation

I used the occupancy model from the full reference site data set to predict coho salmon distribution in the study tributaries above the dams. I created a fine-scale map of discrete habitat units and their associated occupancy probability for each of the six study tributaries.

RESULTS

I conducted surveys on 13.4 km of stream habitat and detailed habitat measurements in 740 total habitat units. I conducted snorkel counts of fish abundance in 81 habitat units in reference streams, with 94 additional units from CDFW surveys. Here, I present the results for the IP model in Beaver (average IP of 0.68) and Bogus (average IP of 0.56) creeks for reference, the overall occupancy model, followed by detailed results for all data types organized by stream, and finally a summary and comparison of results across the study streams.

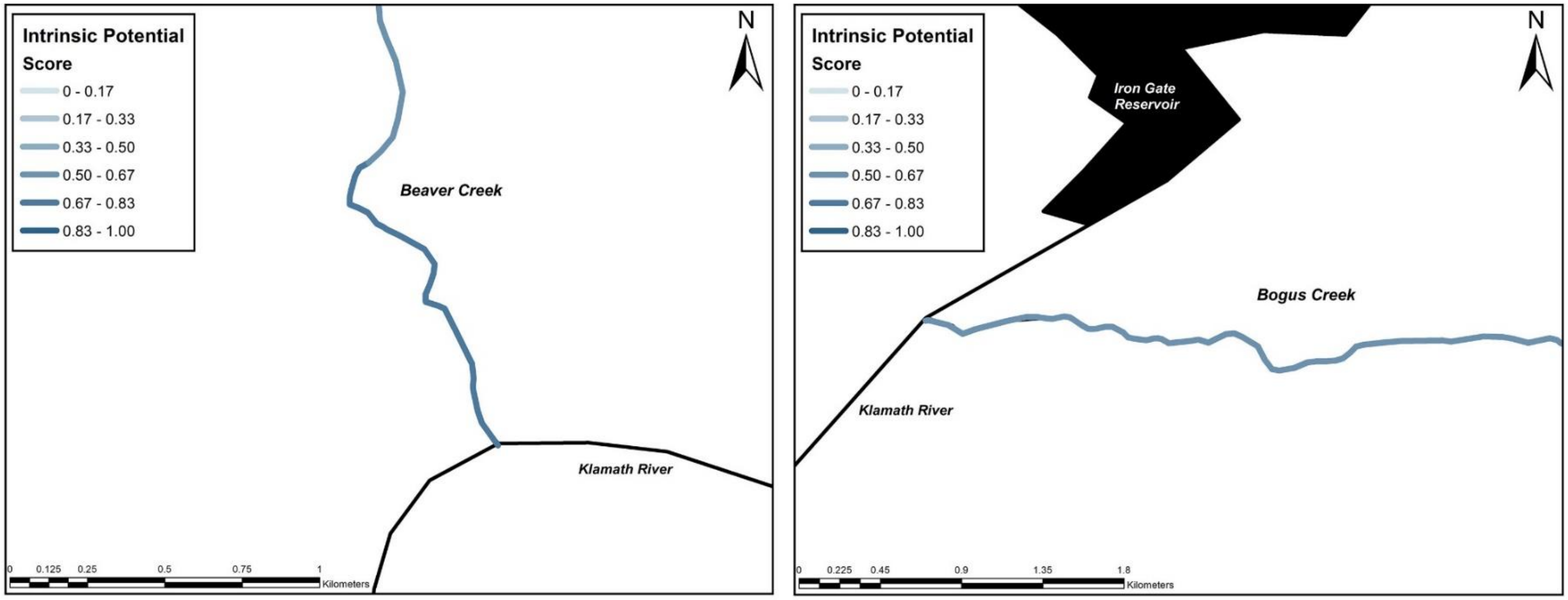


Figure 9 IP of Beaver Creek (left) and Bogus Creek (right) calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

Juvenile coho salmon utilize the lower reaches of Beaver and Bogus creeks, I provided the IP model results (Figure 9) for known juvenile hotspots to make inference on streams that I assessed above the dams on the Klamath River.

Occupancy Model Results

Model selection

I analyzed data collected in habitat and snorkel surveys in Bogus (n = 40), Beaver (n = 41), Lawrence (n = 30), and Quartz (n = 64) creeks in an occupancy model. The model that incorporated depth as a coefficient for detection probability performed significantly better than the “null” model based on AIC (Table 6).

Two models that I fit resulted in similar AIC scores: Ψ(Hatchery + SA + Cover), p(Depth) with an AIC of 362.78 and Ψ(Hatchery + SA + Cover + HLFM), p(Depth) with an AIC of 363.57 . Literature suggests that all models within a delta AIC of 2.0 deserve consideration as potentially the “best” model. In an effort towards parsimony, I selected the Ψ(Hatchery + SA + Cover), p(Depth) as the final model. The final model’s depth coefficient was positively correlated to detection probability (Figure 10 and Table 7). An increase in surface area and percent instream cover increased occupancy probability in the final model (Figure 11and Figure 12 and Table 7). Hatchery presence also increased occupancy probability (Figure 13 and Table 7).

Table 6 Comparison of candidate occupancy models with classification success rates calculated for models with delta AICs less than 5.0, including ψ(.), p(.) and ψ(.), p(Depth)

Model	AIC	ΔAIC	AICw	Number of Parameters	Classification Success for Lawrence and Quartz (%)	Classification Success for Beaver and Bogus (%)
Ψ(Hatchery + SA + Cover), p(Depth)	**362.78**	**0.00**	**0.49**	**6**	**70**	**46**
Ψ(Hatchery + SA + Cover + HLFM), p(Depth)	363.57	0.79	0.33	7	53	41
Ψ(Hatchery + SA + HLFM), p(Depth)	365.76	2.98	0.11	6	53	46
Ψ(Hatchery + SA), p(Depth)	366.72	3.94	0.07	5	72	44
Ψ(Hatchery + Cover + HLFM), p(Depth)	382.70	19.92	0.00	6	--	--
Ψ(Hatchery + HLFM), p(Depth)	382.75	19.97	0.00	5	--	--
Ψ(SA + Cover), p(Depth)	384.26	21.48	0.00	5	--	--
Ψ(Hatchery + Cover), p(Depth)	385.44	22.66	0.00	5	--	--
Ψ(Hatchery), p(Depth)	387.36	24.58	0.00	4	--	--
Ψ(SA), p(Depth)	388.05	25.27	0.00	4	--	--
Ψ(SA + HLFM), p(Depth)	389.02	26.24	0.00	5	--	--
Ψ(Cover), p(Depth)	397.74	34.94	0.00	4	--	--
ψ(.), p(Depth)	399.73	36.95	0.00	3	53	64
Ψ(HLFM), p(Depth)	401.72	38.94	0.00	4	--	--
ψ(.), p(.)	406.95	44.17	0.00	2	53	64

Note: **bold** – indicates the final model selected; “---” indicates the the delta AIC = 2.0 cutoff.

Table 7 Untransformed estimates of coefficients for covariates in the final model

Covariate	Occupancy Parameter	Estimate	Standard Error
Intercept	ψ	-0.002144	0.242666
Hatchery	ψ	2.391419	0.680389
Surface Area	ψ	0.804202	0.209174
Instream Cover	ψ	0.707827	0.350237
Intercept	p	1.164748	0.251162
Depth	p	0.535837	0.223483

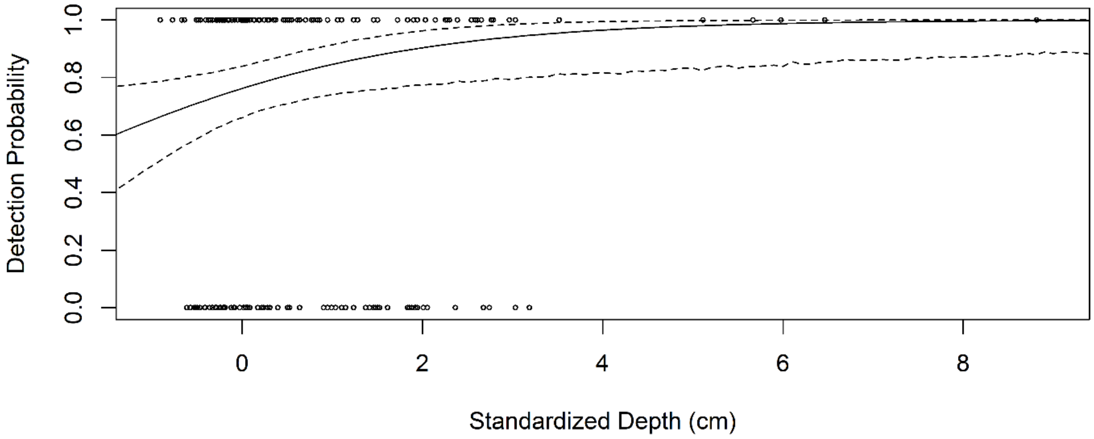


Figure 10 Effect of standardized depth on detection probability for the “best” model structure. The solid back line indicates the covariate coefficient estimate, the open circles indicate observed data, and the dashed lines indicate the 95% confidence interval.

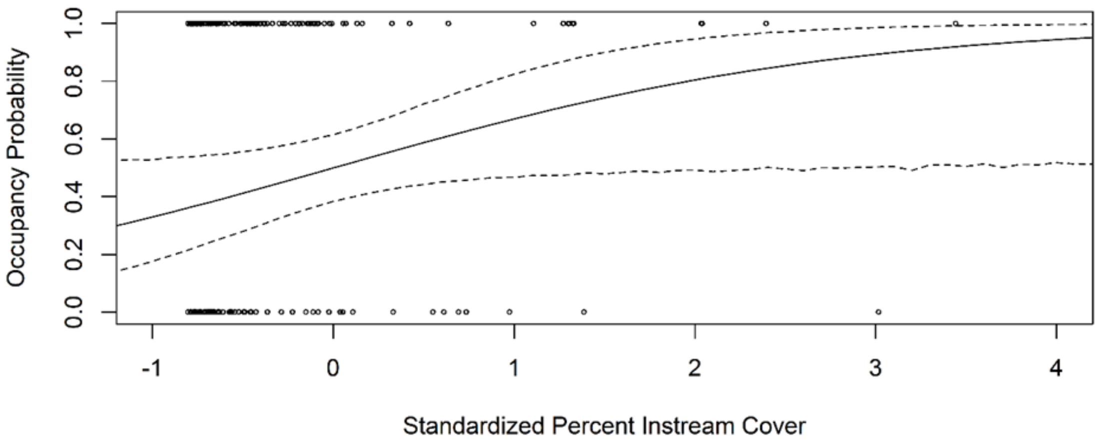


Figure 11 Effect of standardized percent instream cover on occupancy probability for the final model structure. The solid back line indicates the covariate coefficient estimate, the open circles indicate observed data, and the dashed lines indicate the 95% confidence interval.

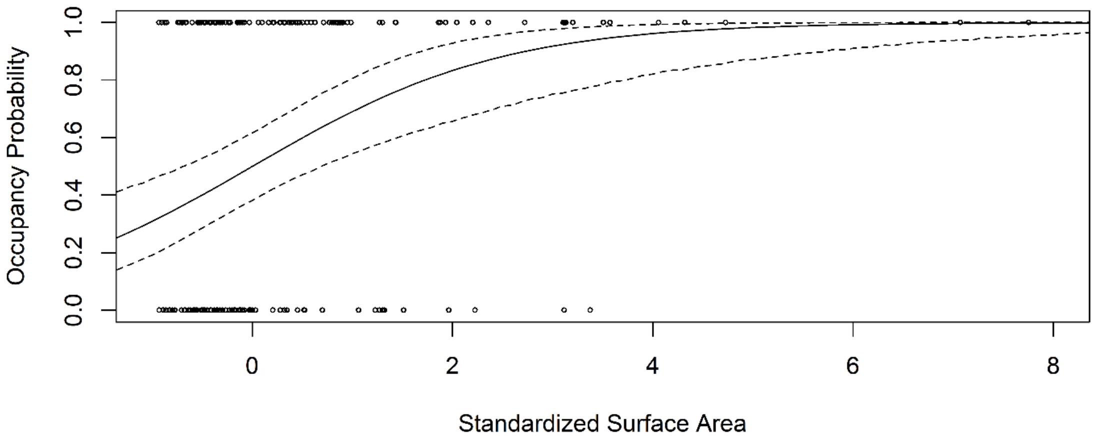


Figure 12 Effect of standardized m^2 of surface area on occupancy probability for the final model structure. The solid back line indicates the covariate coefficient estimate, the open circles indicate observed data, and the dashed lines indicate the 95% confidence interval.

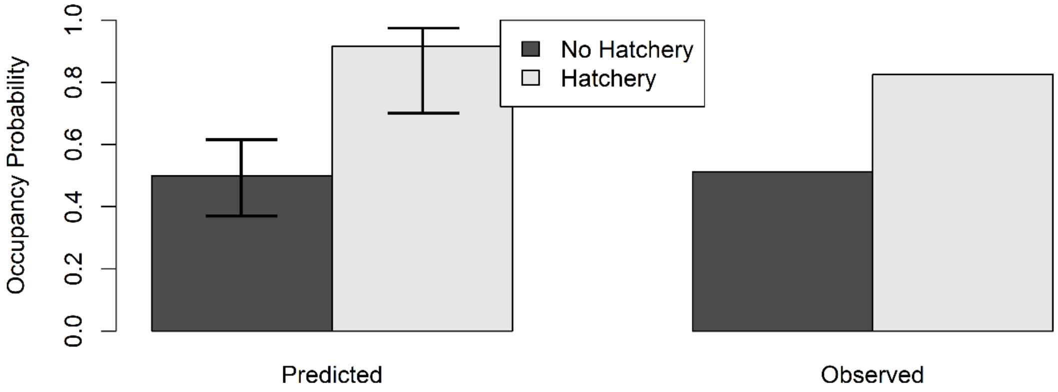


Figure 13 Effect of hatchery presence on occupancy probability for the final model structure (left) and observed proportions of habitat units occupied (right). The vertical lines with ticks indicate the 95% confidence interval.

Occupancy model validation

The final model refit using solely Bogus and Beaver creek data correctly predicted coho occupancy in Quartz and Lawrence creeks 70% of the time (Table 6). The final model refit using solely Quartz and Lawrence creek data correctly predicted coho occupancy in Beaver Creek 66% of the time. When predicting occupancy probability in Bogus Creek (hatchery influenced) the streams predicted correct occupancy assignments 25% of the time. Many units that the model predicted would be unoccupied were occupied in Bogus Creek, likely due to the much higher overall densities of coho salmon in Bogus Creek.

Predictions for Sites above IGD

I fit the final occupancy model to discrete habitat unit data collected on streams above the IGD. I included the “null” hatchery effect, assuming no hatcheries in the vicinity of the streams. I plotted occupancy probabilities in relation to the upstream distance from the stream's confluence with a reservoir or mainstem Klamath River. Specific occupancy predictions for each stream are presented in the "results by stream" section below.

Results by Stream

Scotch Creek

A large fire occurred within the Scotch Creek watershed from July 5 to July 21, 2018. In 2019, pervasive dewatering occurred in Scotch Creek throughout the summer. During watered periods, temperatures in Scotch Creek remained within the range recommended for juvenile coho rearing (Figure 14). In 2019, Scotch Creek MWMT was 17.2 °C and 16.6 °C in the lower and upper locations respectively when watered; and MWAT was 16.6 °C and 15.0 °C in the lower and upper locations respectively when watered.

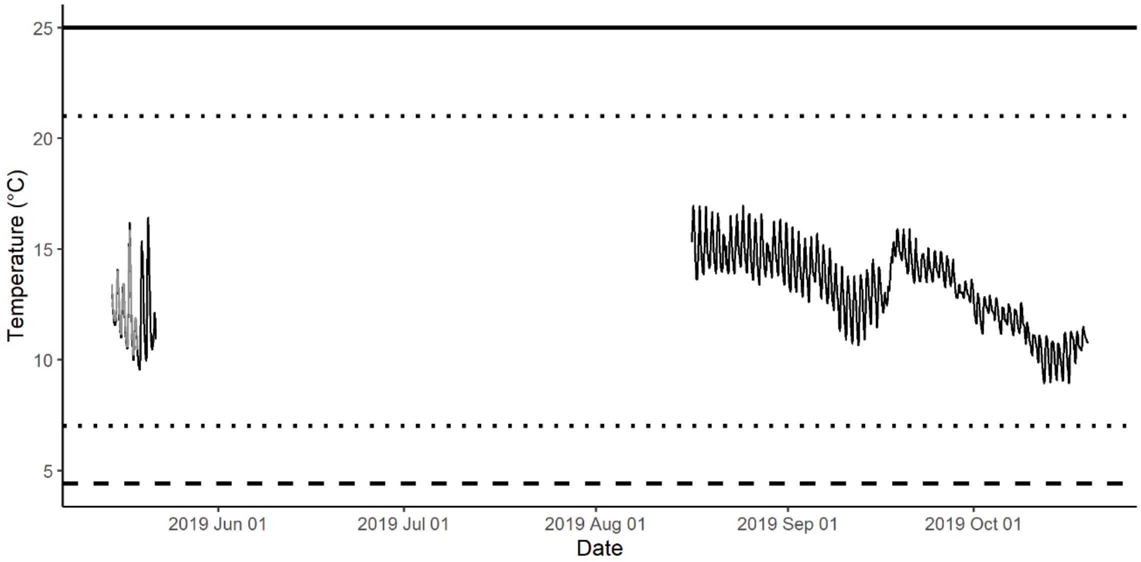


Figure 14 2019 summer temperature variation of Scotch Creek. The black line indicates the upstream temperature and the gray line downstream temperature. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minima of 4.4 °C (Horizontal dashed line), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line). Gaps in black and gray lines indicate periods of dewatering.

Pervasive dewatering observed throughout the summer limits available habitat for juvenile coho salmon in Scotch Creek. When watered, a series of waterfalls 1 km upstream (Figure 15 and Figure 16) will restrict upstream movements of juvenile coho salmon and potentially limit upstream migration by adult coho salmon.

Figure 15 Lower of two waterfalls located in Scotch Creek that will potentially prevent upstream movements of coho salmon.

Figure 16 Upper of two waterfalls that will potentially limit upstream coho salmon movements in Scotch Creek.

I did not conduct snorkel surveys or electrofish Scotch Creek during the summers of 2018 and 2019 due to extensive dewatering, but I observed juvenile rainbow trout throughout the stream and up to the potential barrier falls during habitat surveys. Multiple disconnected small pools retained juvenile rainbow trout during dewatering events of 2019.

Scotch Creek Modeling Results

The HLFM predicts maximum summer rearing capacity for Scotch Creek of less than 2,600 juvenile coho salmon and less than 1,800 smolt outmigrants, contingent on the stream remaining perennial. Based on available spawning gravel and the HLFM, Scotch Creek had the ability to sustain less than 205 coho salmon redds, less than 512,500 coho salmon eggs, and produce less than 153,750 coho salmon smolts. Summertime rearing habitat capacity was much lower than HLFM predicted coho salmon smolt outmigrants based on spawning gravels available.

Scotch Creek consisted of low stream gradients with the majority of 0 – 3% stream gradients concentrated near the stream mouth and below the potential barrier falls (Figure 17). Scotch Creek consisted of a high proportion of reaches with high IP scores when compared to downstream tributaries known to support juvenile coho (i.e. Beaver Creek with an average IP of 0.68 and Bogus Creek with an average IP of 0.56) ; and, like stream gradient, contained high IP scored reaches concentrated near the confluence with the Klamath River (Figure 17). Scotch Creek had approximately 1.7 IP km, which would require approximately 67 adult coho salmon to meet the density-based spawner abundance target (Williams et al. 2008).

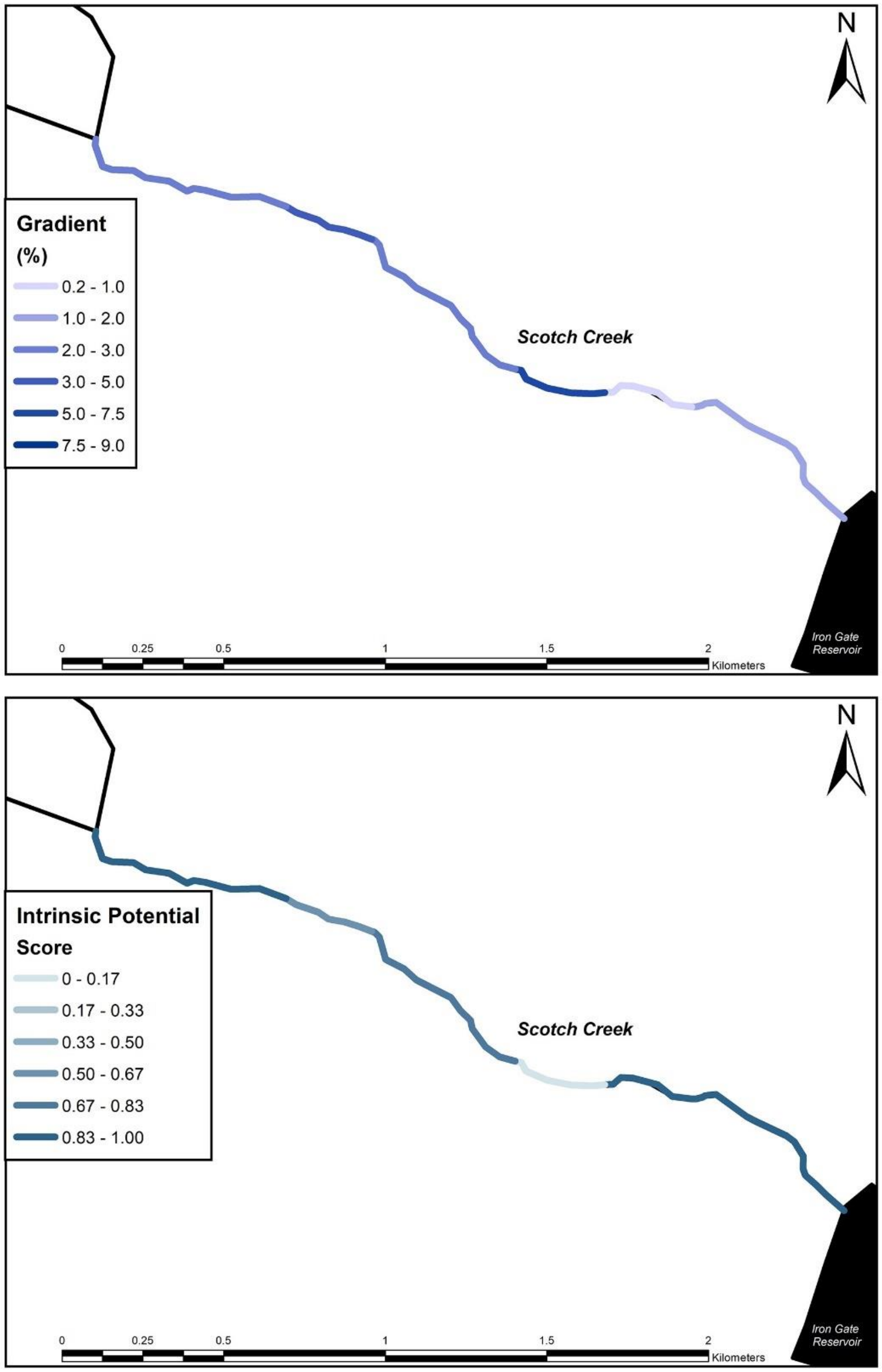


Figure 17 Stream gradient (top) and IP (bottom) of Scotch Creek calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

My occupancy model predicted that less than 37% of Scotch Creek will be occupied by juvenile coho salmon, equivalent to roughly 1110 m^2 of habitat. Habitat units in Scotch Creek had occupancy probabilities ranging from 0.0 to 0.8 with a large proportion between 0.25 and 0.55 (Figure 18). A cluster of high occupancy probability habitat units extended from approximately 80 to 170 m upstream (Figure 18).

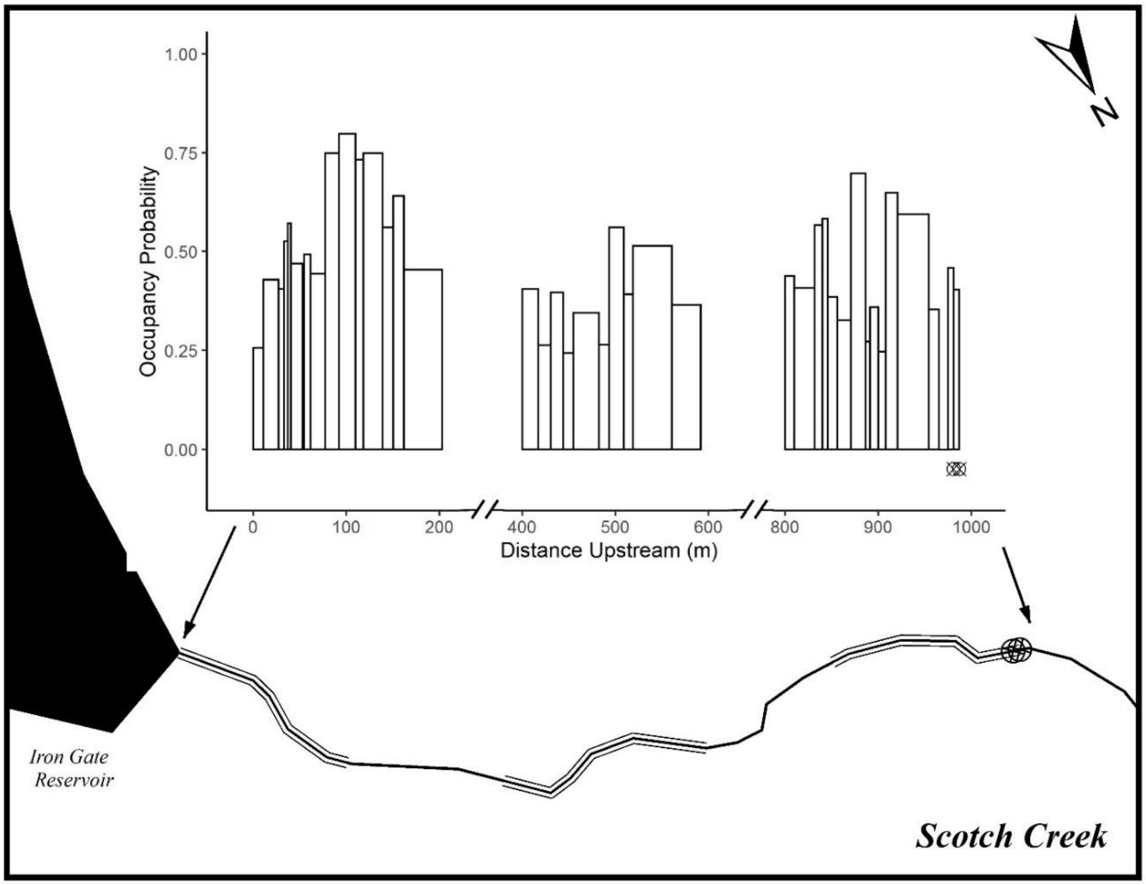


Figure 18 Occupancy probability for habitat units surveyed in the summer of 2019 in Scotch Creek moving upstream. The width of the occupancy bars correspond to the habitat unit length. Circles with “x” symbols in the middle indicate potential barriers to juvenile coho movements and adult coho. Triple line stream lengths indicate surveyed lengths and correspond to the occupancy plot. Missing boxes indicate unsurveyed habitat units. “-/ /-“ are omitted lengths that I did not survey.

Camp Creek

A large fire occurred within the Camp Creek watershed from July 5 to July 21, 2018. I observed significant dewatering of Camp Creek at the Copco Rd. bridge crossing in late July 2019. During watered periods, temperatures in lower Camp Creek remained within the range recommended for juvenile coho rearing (Figure 19). In 2019, Camp Creek MWMT was 17.0 °C and MWAT was 14.6 °C in the lower location when watered

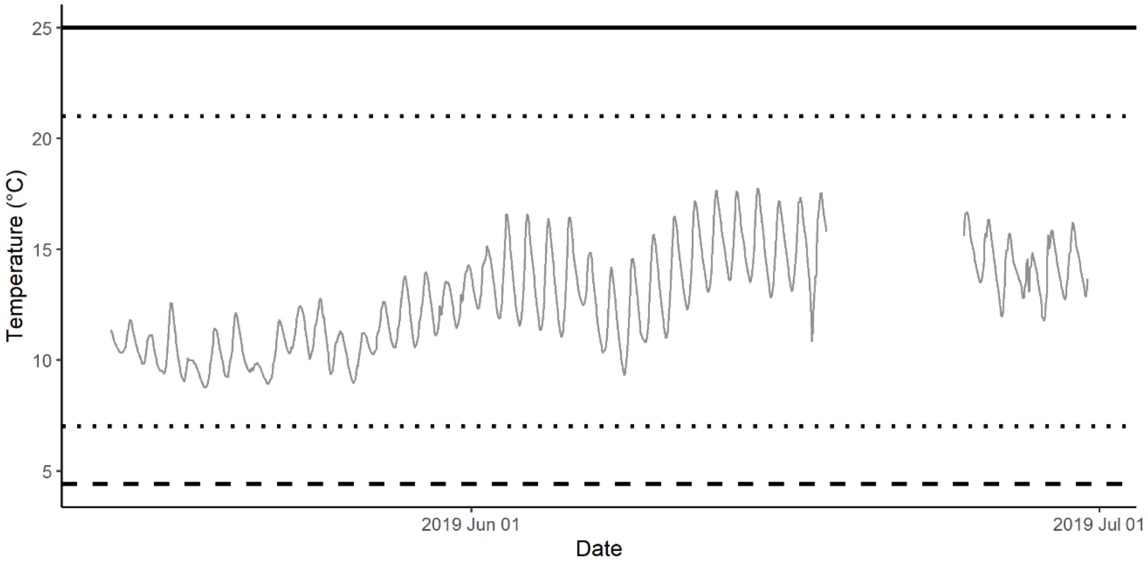


Figure 19 2019 summertime temperature variation of Camp Creek. The gray line indicates the lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line). Gaps in the gray line indicate periods of dewatering.

I did not assess potential barriers to fish movements nor conduct habitat surveys on Camp Creek due to private property access issues. Additionally, I did not conduct snorkel surveys or electrofish Camp Creek, so I could not apply the HLFM or occupancy models to Camp Creek.

Camp Creek IP Modeling Results

Lower Camp Creek consisted of primarily stream gradients less than 5% (Figure 20). Camp Creek contained a high proportion of reaches with high IP scores when compared to downstream tributaries known to support juvenile coho (i.e. Beaver Creek with an average IP of 0.68 and Bogus Creek with an average IP of 0.56); and contained high-IP reaches near the confluence with the Klamath River (Figure 20). Assuming no upstream migration barriers, Camp Creek had approximately 1.6 IP km, which would require approximately 65 adult coho salmon to meet the density-based spawner abundance target (Williams et al. 2008).

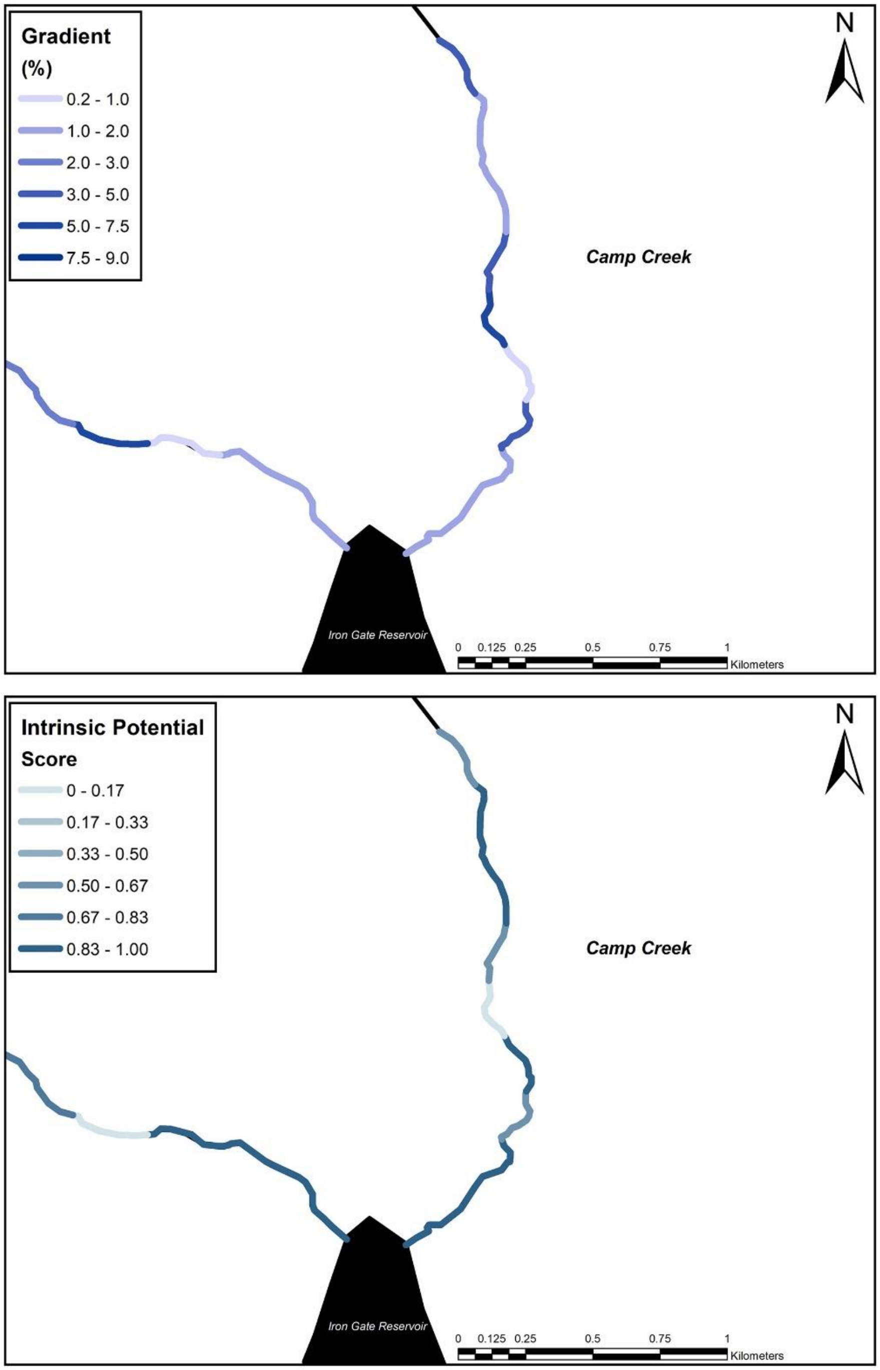


Figure 20 . Stream gradient (top) and IP (bottom) of Camp Creek calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

Jenny Creek

During mid-July to mid-August 2018 and 2019, Jenny Creek exhibited elevated temperatures exceeding values associated with optimal rearing temperatures for juvenile coho salmon (Figure 21Figure 22). In 2018, the upper Jenny Creek temperature sensor failed and no data are available. In 2019, upper Jenny Creek temperature exhibited lower diel variation than lower Jenny Creek despite tracking approximately the same daily mean value. From 2018 to 2019, lower Jenny Creek MWMT was 22.2 °C and MWAT was 20.7 °C. In 2019, upper Jenny Creek MWMT was 20.8 °C and MWAT was 19.8 °C.

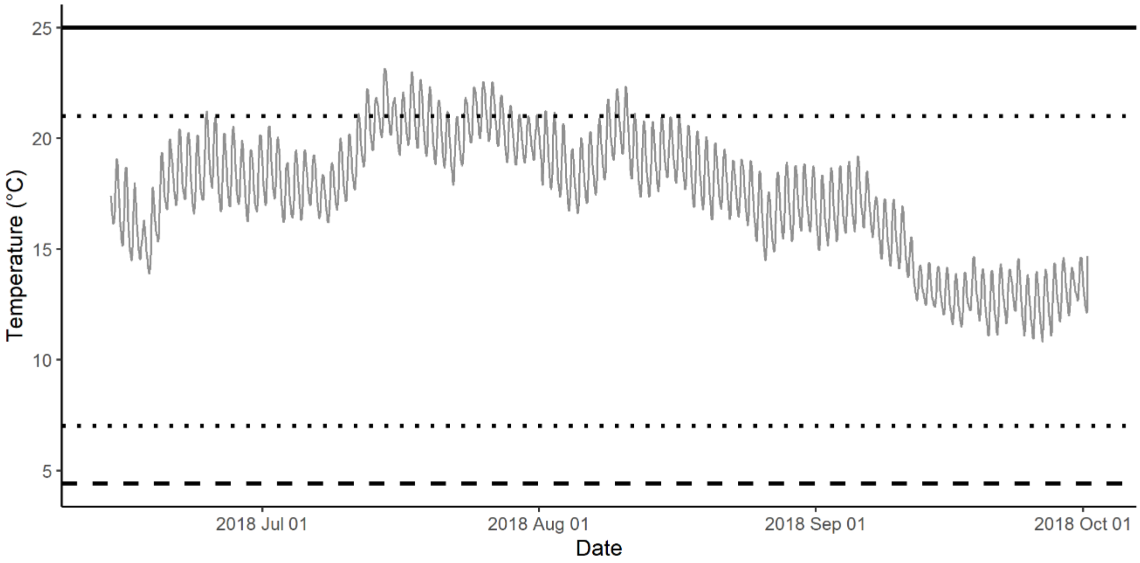


Figure 21 2018 summertime temperature variation of Jenny Creek. The gray line indicates the lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

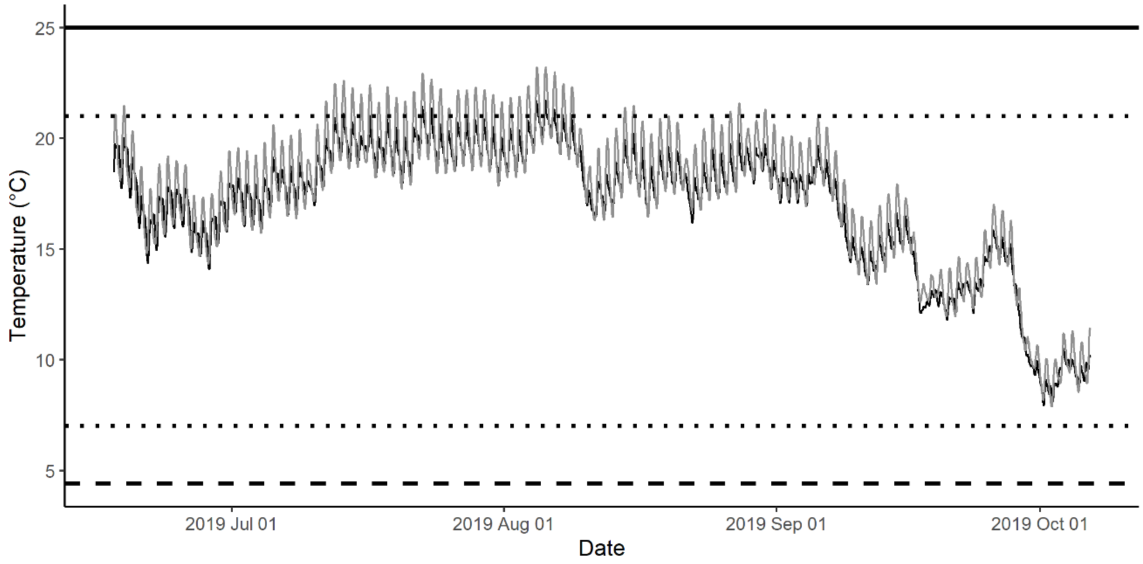


Figure 22 2019 summertime temperature variation of Jenny Creek. The black line indicates the upper temperature location and gray line indicates lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

I surveyed habitat and assessed potential barriers to upstream fish movement in Jenny Creek from July 31 to August 8, 2018. Two large, high gradient cascade features located 914 and 2600-m upstream (Figure 23), a concrete dam (Figure 24) located 1700-m upstream, a complex waterfall and slide feature (Figure 25) located 1908-m upstream, and a landslide located 2900-m upstream in Jenny Creek will potentially restrict upstream movements of juvenile and adult coho salmon.

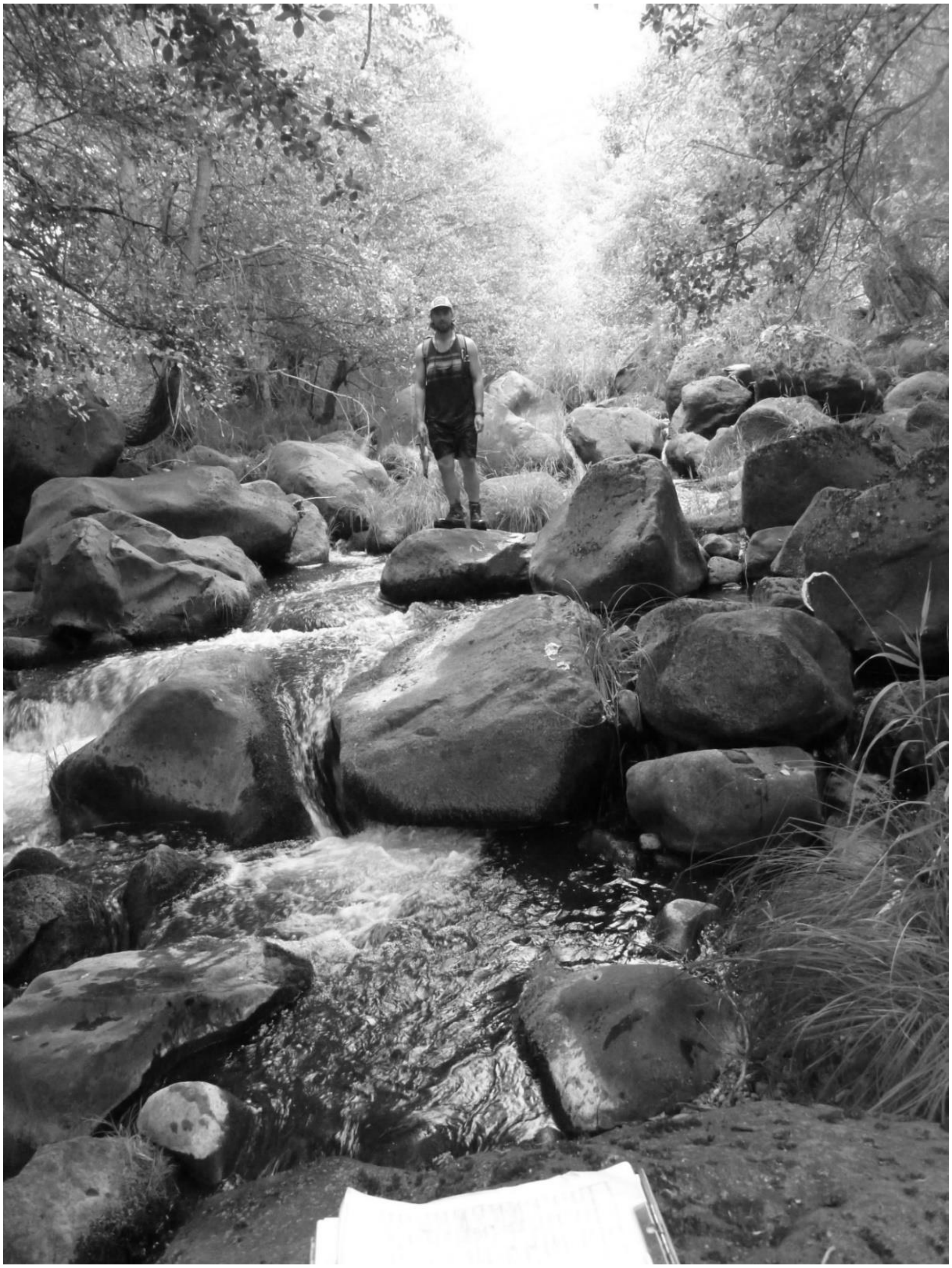


Figure 23 High gradient cascade feature with large boulder substrate in Jenny Creek, 2600 stream m from the confluence with the Klamath River.

Figure 24 Dam structure in Jenny Creek, 1700 stream m from the confluence with the Klamath River, will potentially restrict fish movements upstream.

Figure 25 Complex bedrock feature, 1908 stream m from the confluence with the Klamath River, with shallow sheet flow on the right and a deep plunge pool on the left.

I snorkel surveyed Jenny Creek from June 24 to July 1, 2019. I observed rainbow trout at a rate of 0.9 individuals per m, and 0.3 individuals per m for age class 0+ and age class 1+ respectively (Appendix A). I also observed Klamath smallscale sucker, speckled dace, and marbled sculpin in Jenny Creek. Electrofishing occurred in Jenny Creek on August 19, 2019. Additional fish species documented while electrofishing included green sunfish, and brown bullhead.

Jenny Creek Modeling Results

The HLFM predicted a maximum capacity of 18,100 summer juvenile coho salmon and 12,700 smolt outmigrants. Based on available spawning gravel and the HLFM, Jenny Creek had the ability to sustain less than 51 coho salmon redds, less than 127,500 coho salmon eggs, and produce less than 38,250 coho salmon smolts. Summertime rearing habitat capacity was much lower than HLFM predicted coho salmon smolt outmigrants based on spawning gravels available in Jenny Creek.

Jenny Creek contained a high proportion of reaches exceeding 3% gradient with the majority of low gradient reaches (less than 5%) located in the lower two thirds of the stream (Figure 26). Jenny Creek reaches predominantly scored low IP values when compared to downstream tributaries known to support juvenile coho (i.e. Beaver Creek with an average IP of 0.68 and Bogus Creek with an average IP of 0.56). Only two reaches, one at the stream mouth and the other approximately two km upstream, expressed IP greater than 0.5 (Figure 26). Jenny Creek had approximately 1.3 IP km, which would require approximately 52 adult coho salmon spawners to meet the density-based spawner abundance target (Williams et al. 2008).

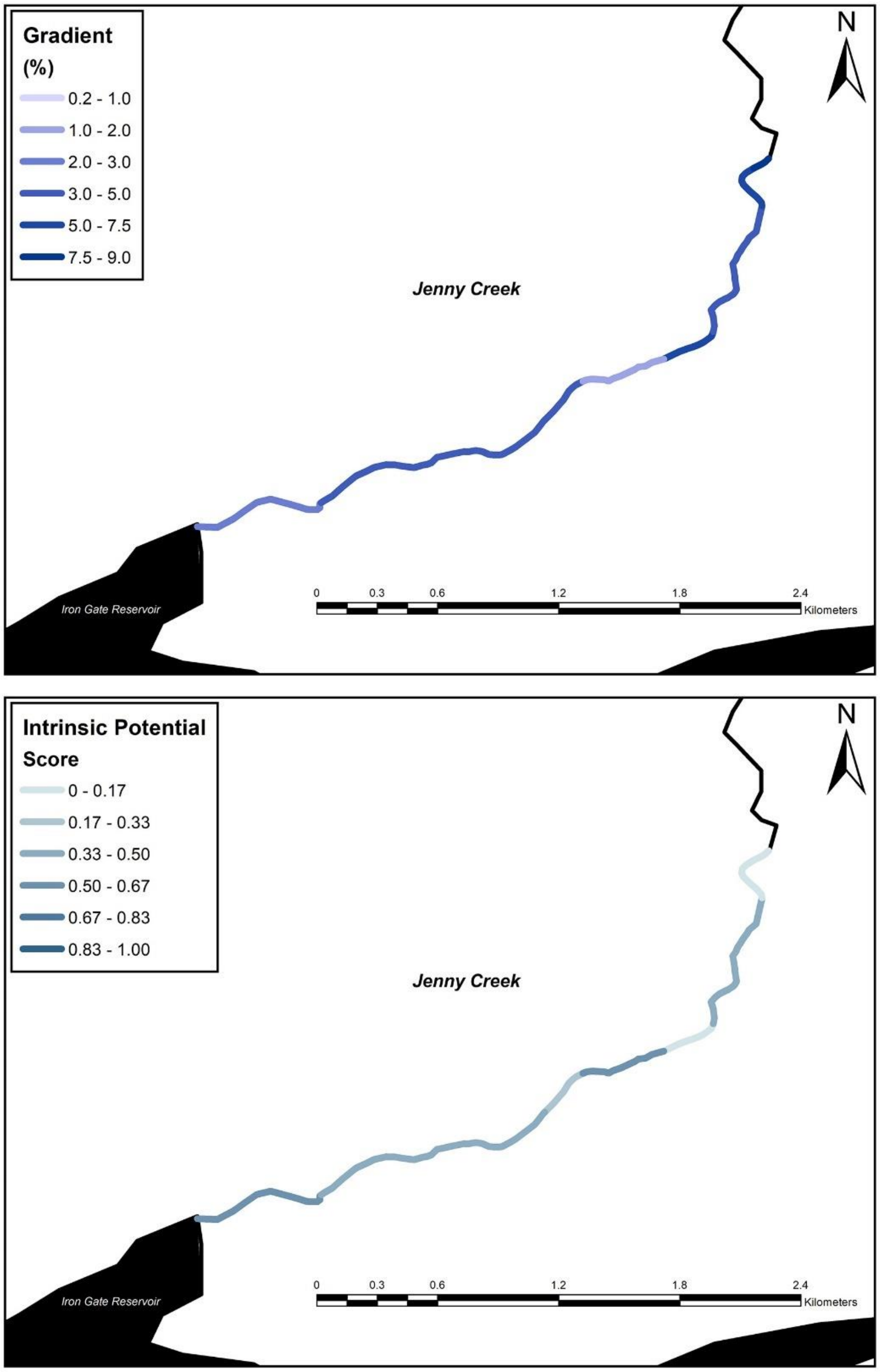


Figure 26 Stream gradient (top) and IP (bottom) of Jenny Creek calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

My occupancy model predicted that less than 47% of Jenny Creek will be occupied by juvenile coho salmon in the summer, equivalent to roughly 10,500 m^2 of habitat. Characteristics of habitat units in Jenny Creek resulted in occupancy probabilities ranging from 0.0 to 0.8 (Figure 27). Non-HGR type habitat units from 550 to 800 m upstream, 1000 to 1100 m upstream, 1208 to 1300 m upstream, and 1500 to 1640 m upstream exhibited higher occupancy probabilities (up to 0.88) (Figure 27).

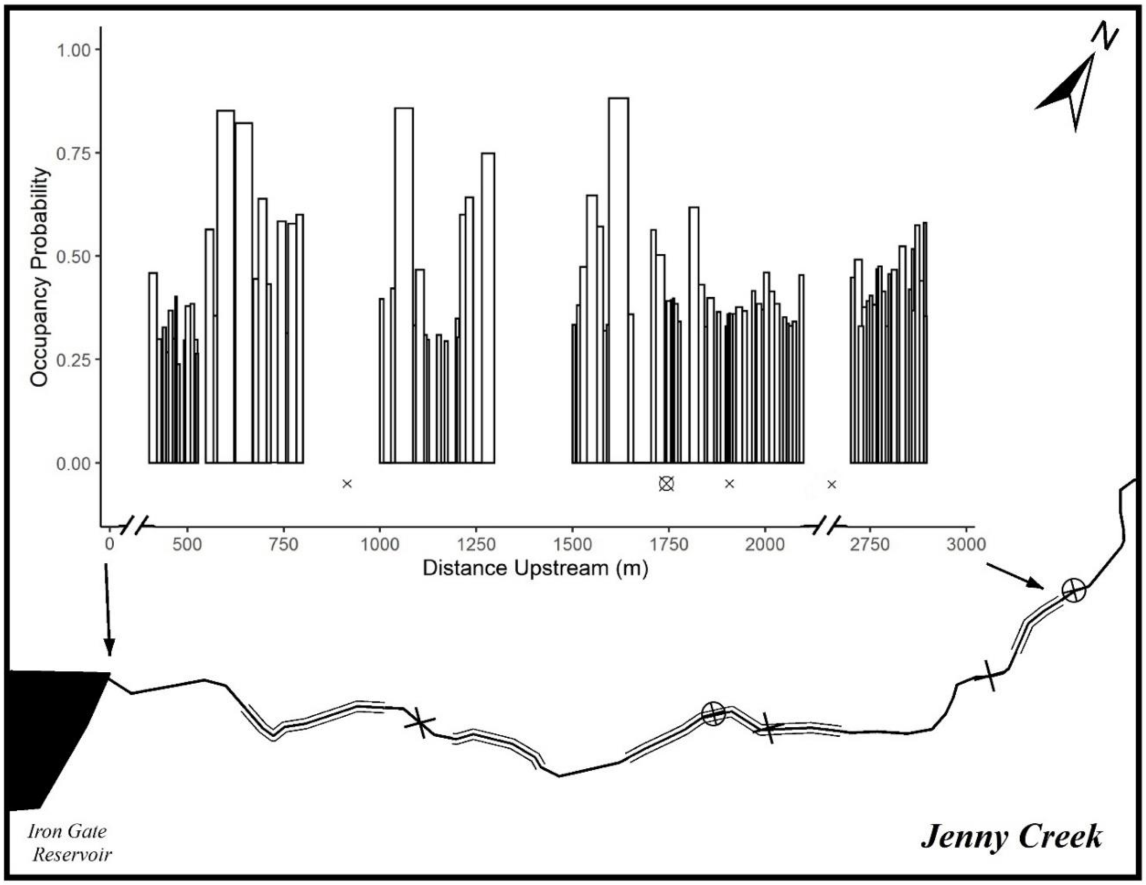


Figure 27 Occupancy probability for habitat units surveyed in the summer of 2019 in Jenny Creek moving upstream. The width of the occupancy bars correspond to the habitat unit length. “X” symbols indicate potential barriers to juvenile coho salmon movement and circles with “x” symbols in the middle indicate potential barriers to juvenile and adult coho salmon movements. Triple line stream lengths indicate surveyed lengths and correspond to the occupancy plot. Missing boxes indicate habitat units that were not surveyed. “-/ /-“ indicate omitted lengths that I did not survey.

Fall Creek

Fall Creek had water temperatures within the recommended range for juvenile coho rearing in 2018 and 2019 with little difference in temperatures at the upper and lower locations (Figure 28 and Figure 29). From 2018 to 2019, Fall Creek had an MWMT of 17.1 °C and 16.6 °C in the lower and upper locations respectively; and an MWAT of 16.6 °C and 15.1 °C in the lower and upper locations respectively.

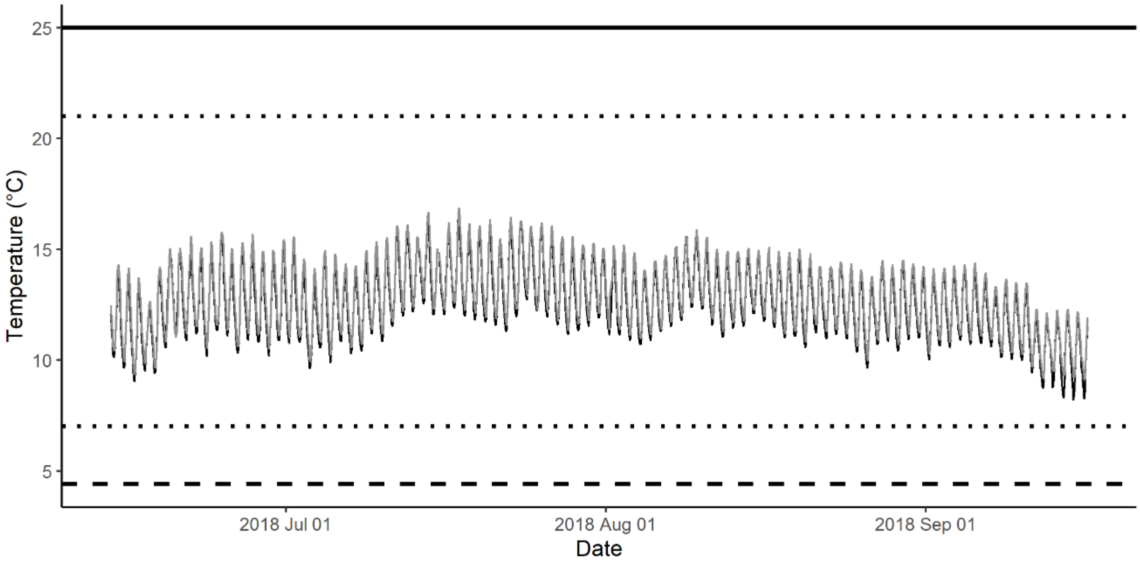


Figure 28 2018 summertime temperature variation of Fall Creek. The black line indicates the upper temperature location and gray line indicates lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

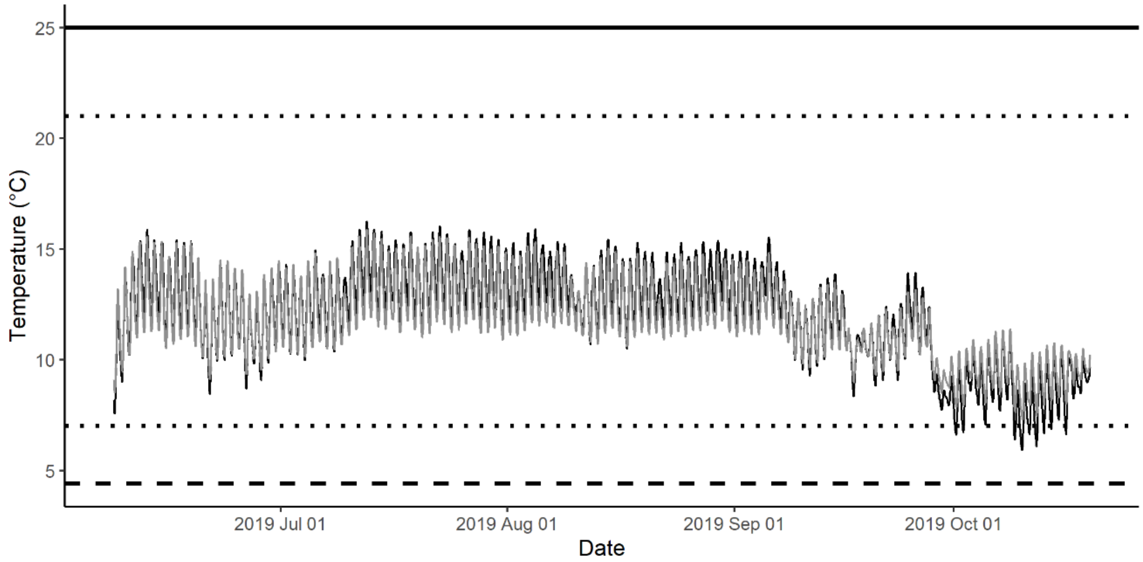


Figure 29 2019 summertime temperature variation of Fall Creek. The black line indicates the upper temperature location and gray line indicates lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

I surveyed habitat and assessed potential barriers to upstream fish movement in Fall Creek from August 14 to August 15, 2018. The falls and diversion dams at the upstream boundary of the survey area are a definitive barrier for coho salmon. A perched culvert (40 m upstream) will potentially restrict upstream movements by adult and juvenile coho salmon. Fall Creek included a large proportion of high velocity habitat features (Figure 30) that will potentially limit or prevent upstream movements by juvenile coho salmon.

Figure 30 High velocity feature within Fall Creek.

I snorkel surveyed Fall Creek from September 15 to September 16, 2018. I observed rainbow trout at a rate of 0.2 individuals per 1 m, and 0.1 individuals per 1 m for age class 0+ and age class 1+ respectively (Appendix A).

Fall Creek Model Results

The HLFM predicted a maximum capacity of 4,700 summer juvenile coho salmon and 3,300 smolt outmigrants for Fall Creek. Based on available spawning gravel and the HLFM, Fall Creek had the ability to sustain less than 92 coho salmon redds, less than 230,000 coho salmon eggs, and produce less than 69,000 coho salmon smolt. Summertime rearing habitat capacity was much lower than HLFM predicted coho salmon smolt outmigrants based on spawning gravels available in Fall Creek and full habitat utilization.

A majority of Fall Creek reaches had average stream gradients less than 5% (Figure 31). The second uppermost reach, adjacent and extending downstream and upstream of the Fall Creek Hatchery site, exhibited an average gradient less than 1%. The majority of reaches in the stream displayed low IP value when compared to downstream tributaries known to support juvenile coho (i.e. Beaver Creek with an average IP of 0.68 and Bogus Creek with an average IP of 0.56); the lowermost reach and the low gradient reach adjacent to the hatchery site exhibited higher IP scores (0.50 to 0.83). Fall Creek had approximately 0.9 IP km, which would require approximately 37 adult coho salmon spawners to meet the density-based spawner abundance target (Williams et al. 2008).

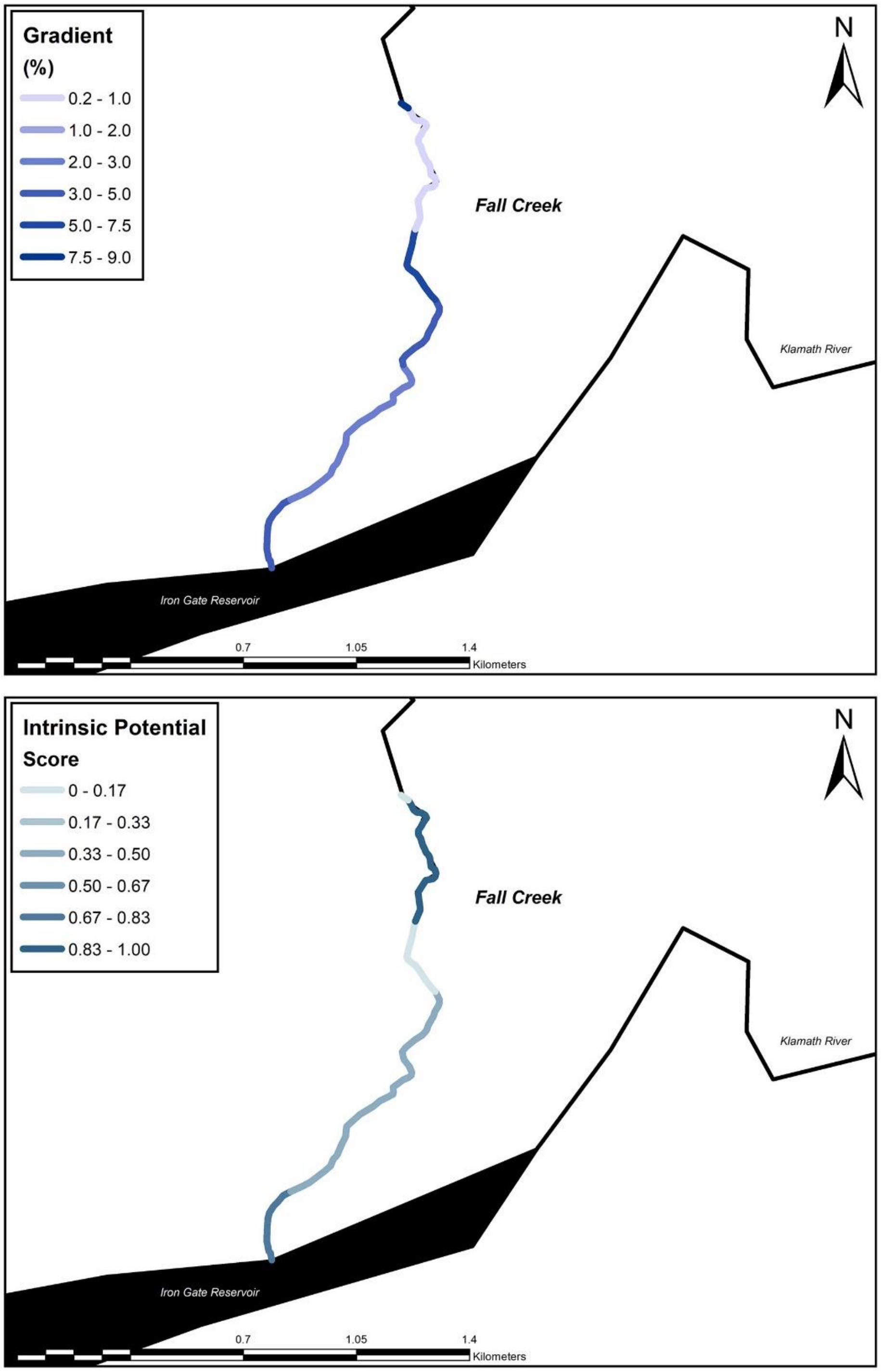


Figure 31 Stream gradient (top) and IP (bottom) of Fall Creek calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

My occupancy model predicted that less than 53% of Fall Creek will be occupied by juvenile coho salmon in the summer, equivalent to roughly 4,300 m^2 of habitat. Fall Creek consisted of predominantly low occupancy probability habitat units (below 0.5) with a large number of HGR habitat units of 0.0 occupancy probability located from 800 to 1150 m upstream (Figure 32). A swath of habitat units concentrated between 600 and 800 m upstream, as well as 1400 to 1750 m upstream exhibit high probability of occupancy (greater than 0.5) in Fall Creek (Figure 32).

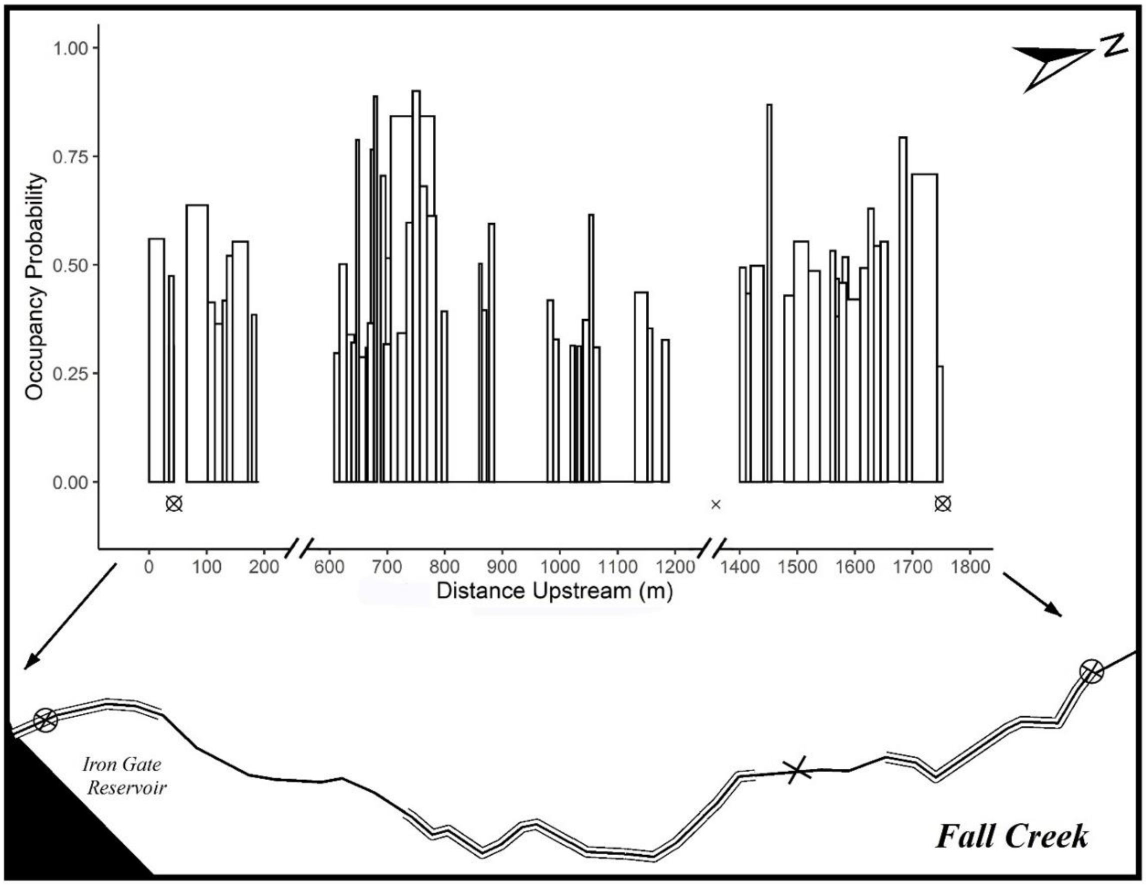


Figure 32 Occupancy probability for habitat units surveyed in the summer of 2018 in Fall Creek moving upstream. The width of the occupancy bars correspond to the habitat unit length. “X” symbols indicate potential barriers to juvenile coho salmon movement and circles with “x” symbols in the middle indicate potential barriers to juvenile and adult coho salmon movements. Triple line stream lengths indicate surveyed lengths and correspond to the occupancy plot. Missing boxes indicate habitat units that were not surveyed. “-/ /-“ indicates omitted lengths that I did not survey.

Shovel Creek

Lower Shovel Creek had water temperatures within the recommended range for juvenile coho salmon rearing during 2018 and 2019 (Figure 33Figure 34). Upper Shovel Creek showed both lower diel variation and a lower mean daily temperature than the lower temperature location for 2018 and 2019 (Figure 33Figure 34). From 2018 to 2019, Shovel Creek had an MWMT of 15.4 °C and 13.2 °C in the lower and upper locations respectively; and an MWAT of 13.7 °C and 12.1 °C in the lower and upper locations respectively.

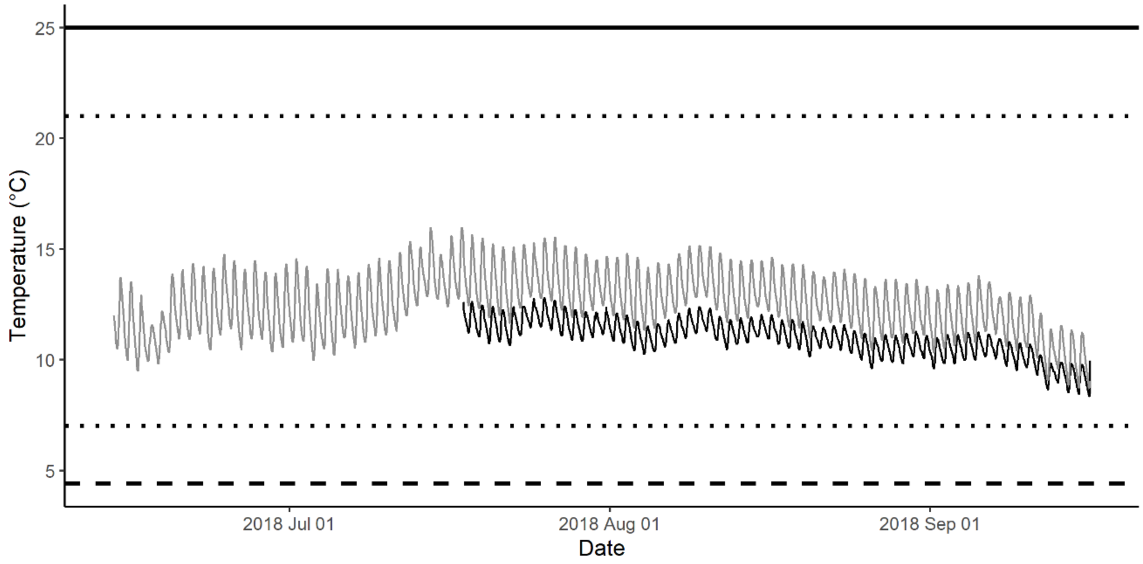


Figure 33 2018 summertime temperature variation of Shovel Creek. The black line indicates the upper temperature location and gray line indicates lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

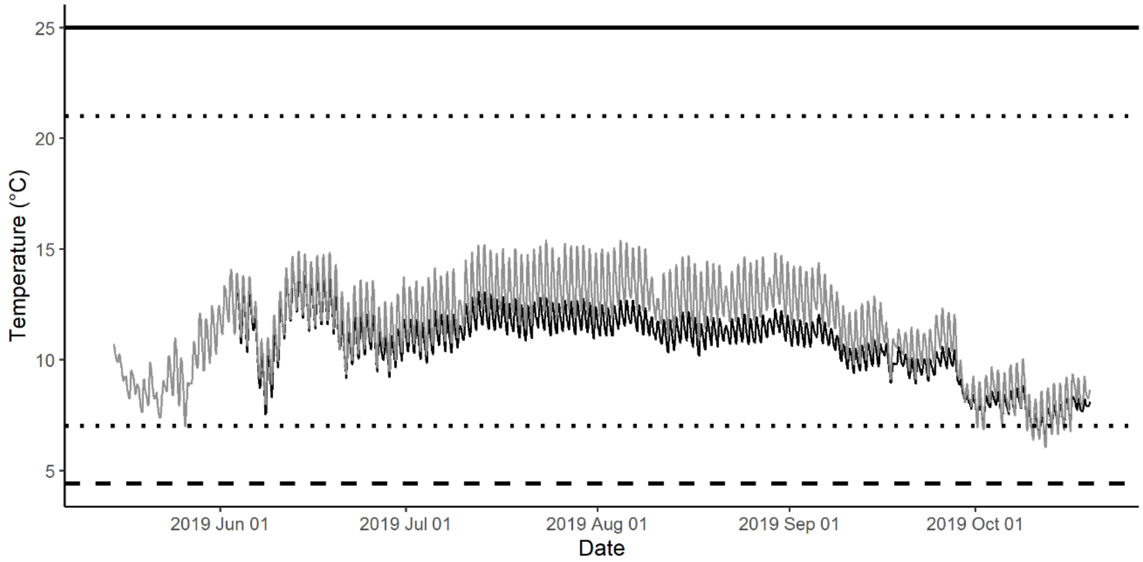


Figure 34 2019 summertime temperature variation of Shovel Creek. The black line indicates the upper temperature location and gray line indicates lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

I surveyed habitat and assessed potential barriers to upstream fish movement in Shovel Creek from July 16 to July 26, 2018. A diversion dam located 2.2 km upstream on Shovel Creek may constrict or prohibit juvenile coho salmon movements upstream. The stream becomes steep and constrained upstream of 3200 m from the confluence with the Klamath River. I did not assess potential barriers or habitat between 3200 m and the waterfalls at 4700 m upstream.

I snorkel surveyed Shovel Creek from July 20 to July 27, 2018. I observed rainbow trout at a rate of 2.5 individuals per 1 m, and 0.1 individuals per 1 m for age class 0+ and 1+ respectively (Appendix A). I also observed juvenile and adult brown trout in the stream. Electrofishing occurred in Shovel Creek on August 6, 2019. Additional fish species documented while electrofishing included Klamath River lamprey, and marbled sculpin.

Shovel Creek Modeling Results

The HLFM predicted a capacity of less than 13,300 summer juvenile coho salmon and 9,300 smolt outmigrants for Shovel Creek. Based on available spawning gravel and the HLFM, Shovel Creek had the ability to sustain less than 23 coho salmon redds, less than 57,500 coho salmon eggs, and produce less than 17,250 coho salmon smolt. Summertime rearing habitat capacity was lower than HLFM predicted coho salmon smolt outmigrants based on spawning gravels available in Shovel Creek and full habitat utilization.

Shovel Creek holds a large concentration of low gradient habitats (less than 3%) in the lower 2600 m of stream with higher gradients (3-7.5%) upstream (Figure 35). A large quantity of reaches exhibited high IP value (when compared to tributaries downstream of IGD with coho present) from the confluence with the Klamath River extending 2600 m upstream (Figure 35). Calculated IP values continued to decrease moving upstream of 2600 m (Figure 35). Shovel Creek had approximately 2.75 IP km, which would require approximately 111 adult coho salmon spawners to meet the density-based spawner abundance target (Williams et al. 2008).

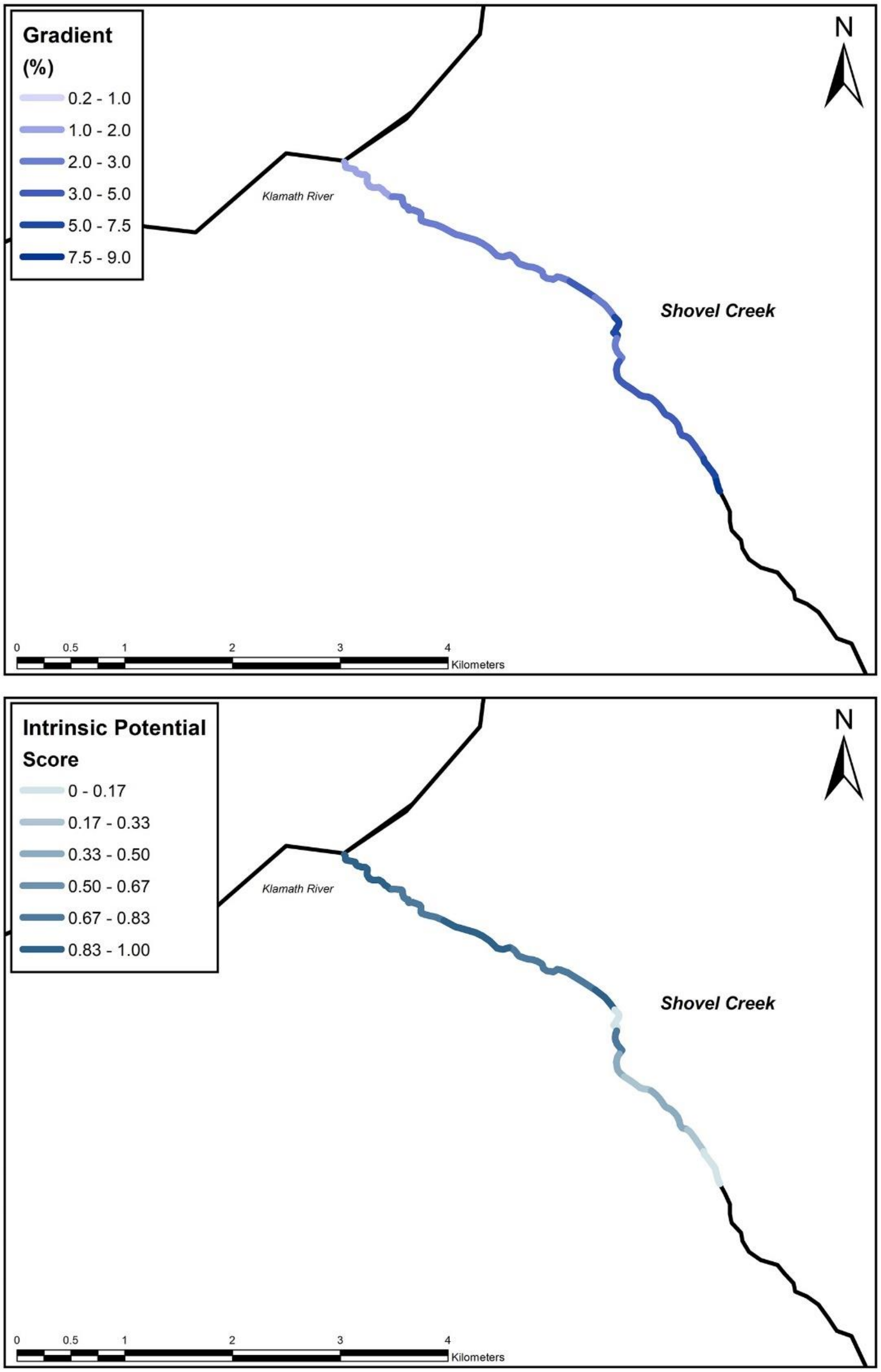


Figure 35 Stream gradient (top) and IP (bottom) of Shovel Creek calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

My occupancy model predicted that less than 37% of Shovel Creek will be occupied by juvenile coho salmon in the summer, equivalent to roughly 9,750 m^2 of habitat. Shovel Creek consisted of a large length of sites with relatively low (< 0.4) occupancy probabilities (Figure 36); I calculated some higher occupancy probabilities (> 0.75) for habitat units between 1600 and 2200 m upstream (Figure 36).

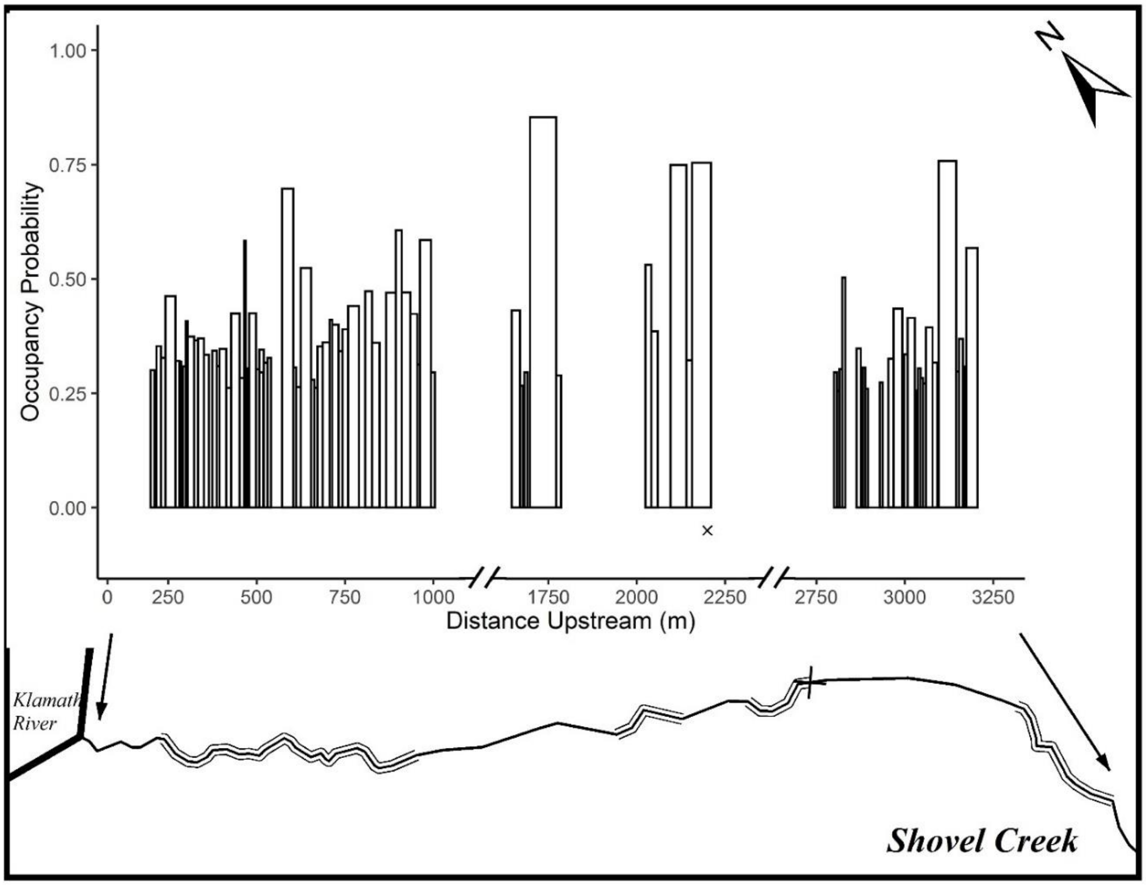


Figure 36 Occupancy probability for habitat units surveyed in the summer of 2018 in Shovel Creek moving upstream. The width of the occupancy bars correspond to the habitat unit length. "X" symbols indicate potential barriers to juvenile coho salmon movement. Triple line stream lengths indicate surveyed lengths and correspond to the occupancy plot. Missing boxes indicate habitat units that were not surveyed. "-/ /-" indicates omitted lengths that I did not survey.

Spencer Creek

Throughout the summer months of 2019, lower Spencer Creek had elevated water temperatures nearing and exceeding values associated with optimal rearing for juvenile coho salmon (Figure 37); however, the same location also maintained values associated with the recommended range for juvenile coho rearing and high growth during nighttime hours (Figure 37). The lower middle temperature location in Spencer Creek had lower water temperatures mostly within values associated with juvenile coho salmon rearing and high growth rates, with much lower diel temperature variations (2-3 °C on average) (Figure 37). The upper middle temperature location in the stream became dewatered from early June through late July 2019. The upper middle location in Jenny Creek maintained water temperatures within and just outside of the recommended range for juvenile coho salmon rearing when data were available (Figure 38); this location also had high diel temperature variation, oftentimes exceeding 10 °C (Figure 38). The upper temperature location in Spencer Creek followed the same approximate water temperature trajectory as the upper middle location with a much lower diel variation during summer months (approximately 5 °C) (Figure 38). In 2019, Spencer Creek had an MWMT of 23.7 °C, 18.5 °C, 16.7 °C, and 23.9 °C in the lower, lower middle, upper middle (when data were available), and upper locations respectively; and an MWAT of 19.2 °C, 17.2 °C, 15.2 °C, and 17.4 °C in the lower, lower middle, upper middle (when data were available), and upper locations respectively.

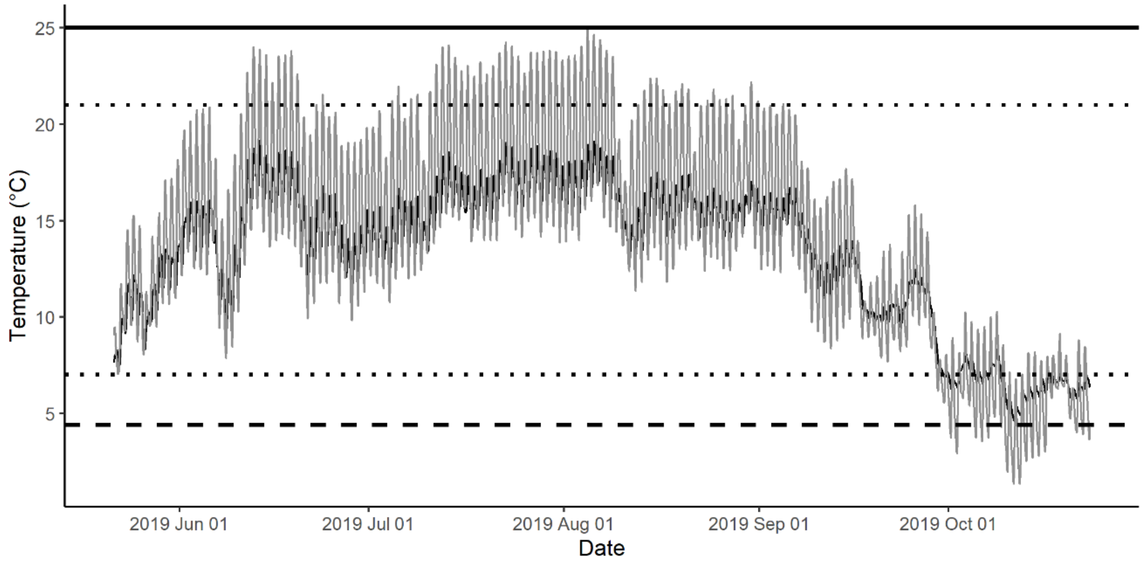


Figure 37 2019 summertime temperature variation of Spencer Creek. The black line indicates the lower middle temperature location and gray line indicates lower temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line).

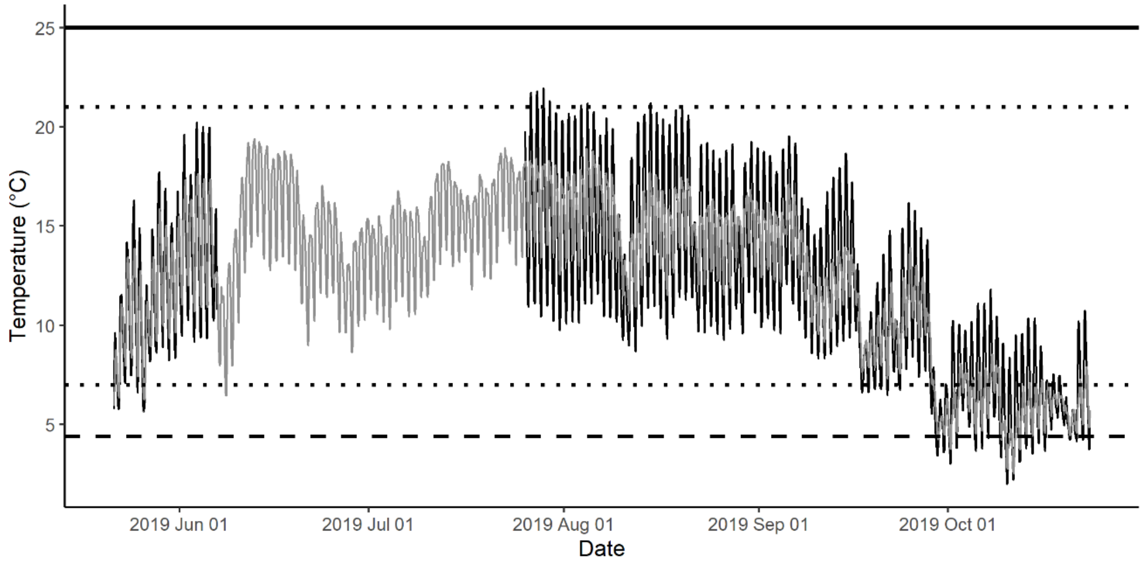


Figure 38 2019 summertime temperature variation of Spencer Creek. The black line indicates the upper middle temperature location and gray line indicates upper temperature location. Recommended summertime rearing temperature for juvenile coho salmon is 7 – 21 °C (horizontal lines with black squares), cessation of growth occurs at a minimum of 4.4 °C (Horizontal dashed lines), and the Upper Lethal Temperature (ULT) occurs at 25.0°C (solid black line). The gap in the black line was a period in which the temperature probe became dewatered due to poor location.

I surveyed habitat and assessed potential barriers to upstream fish movement in Spencer Creek from July 22 to July 25, 2019. I did not observe any potential barriers to upstream fish movements in the habitats surveyed. I expect Buck Lake Irrigation Complex, will be the terminus of upstream movements of juvenile and adult coho salmon.

I snorkel surveyed Spencer Creek from September 9, through September 12, 2019. I observed rainbow trout at a rate of 0.9 individuals per 1 m, and 0.3 individuals per 1 m for age class 0+ and age class 1+ respectively (Appendix A). I also observed speckled dace, Klamath smallscale sucker, and Klamath River lamprey. I did not electrofish Spencer Creek.

<u>Spencer Creek Modeling Results</u>

The HLFM predicted a capacity less than 66,300 summer juvenile coho salmon and 46,400 smolt outmigrants for Spencer Creek. Based on available spawning gravel and the HLFM, Spencer Creek had the ability to sustain less than 18,000 coho salmon redds, less than 44,980,000 coho salmon eggs, and produce less than 13,4950,000 coho salmon smolt. Summertime rearing habitat capacity was far lower than HLFM predicted coho salmon smolt outmigrants based on spawning gravels available in Spencer Creek and full habitat utilization.

Spencer Creek contained a large number of reaches with stream gradients between 0 and 2% (Figure 39). The stream contained an abundance of reaches with high IP scores (greater than 0.67); And, like stream gradient, high IP reaches occurred near the confluence with the Klamath River and extended 13,800 m upstream (Figure 39). Spencer Creek had approximately 13.1 IP km, which would require approximately 526 adult coho salmon spawners to meet the density-based spawner abundance target (Williams et al. 2008).

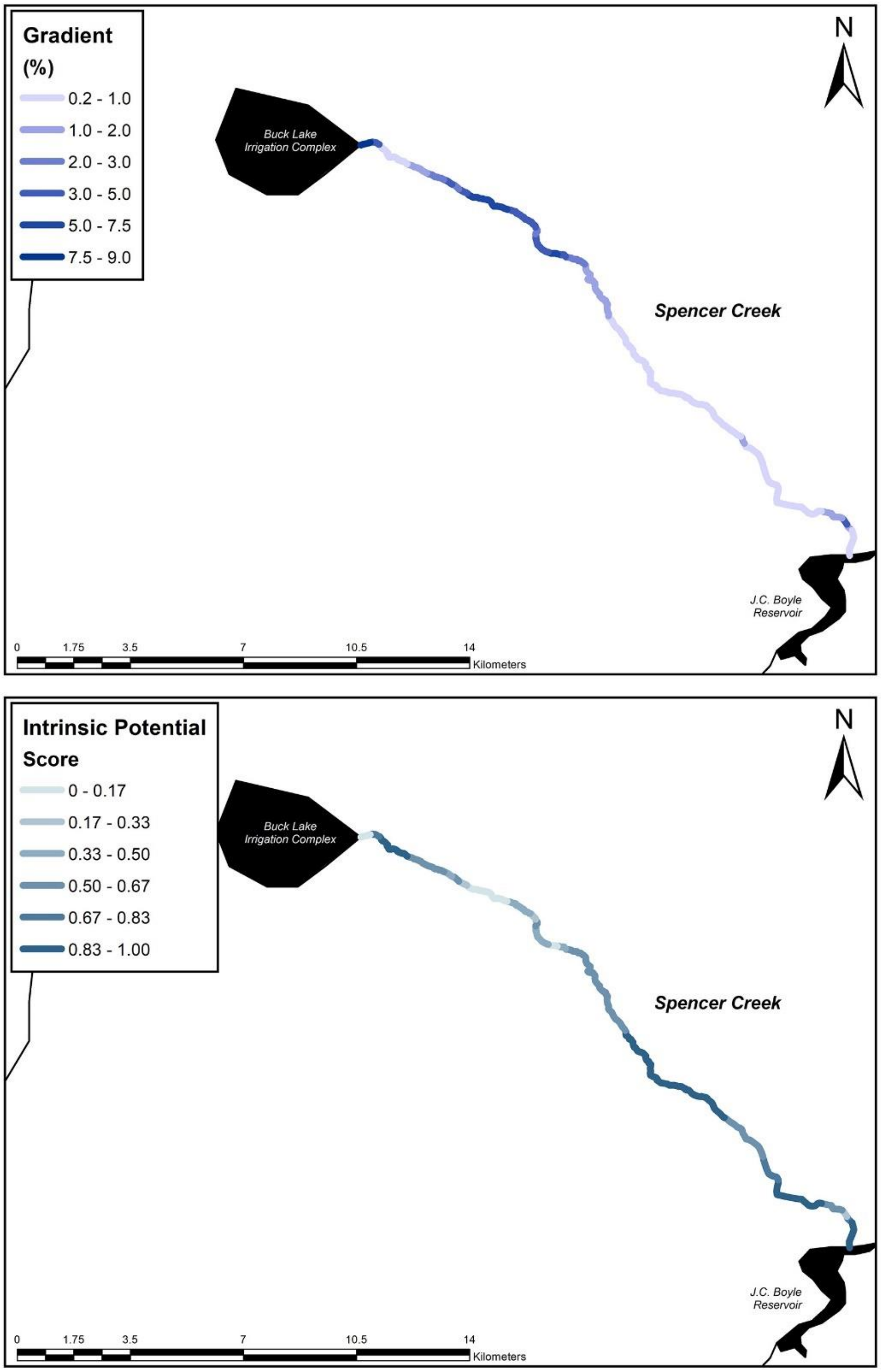


Figure 39 Stream gradient (top) and IP (bottom) of Spencer Creek calculated in a GIS using U.S. Geological USGS 10 m resolution DEMs and National Hydrography Dataset Plus High Resolution (NHDPlus HR).

My occupancy model predicted that less than 70% of Spencer Creek will be occupied by juvenile coho salmon in the summer, equivalent to roughly 70,300 m^2 of habitat. Spencer Creek consists of a swath of habitat units with occupancy probabilities greater than 0.5 located from 3,300 to 12,800 m upstream and 18,100 to 20,700 m upstream (Figure 40). Of streams surveyed, Spencer Creek contains the highest average occupancy probability (Figure 40).

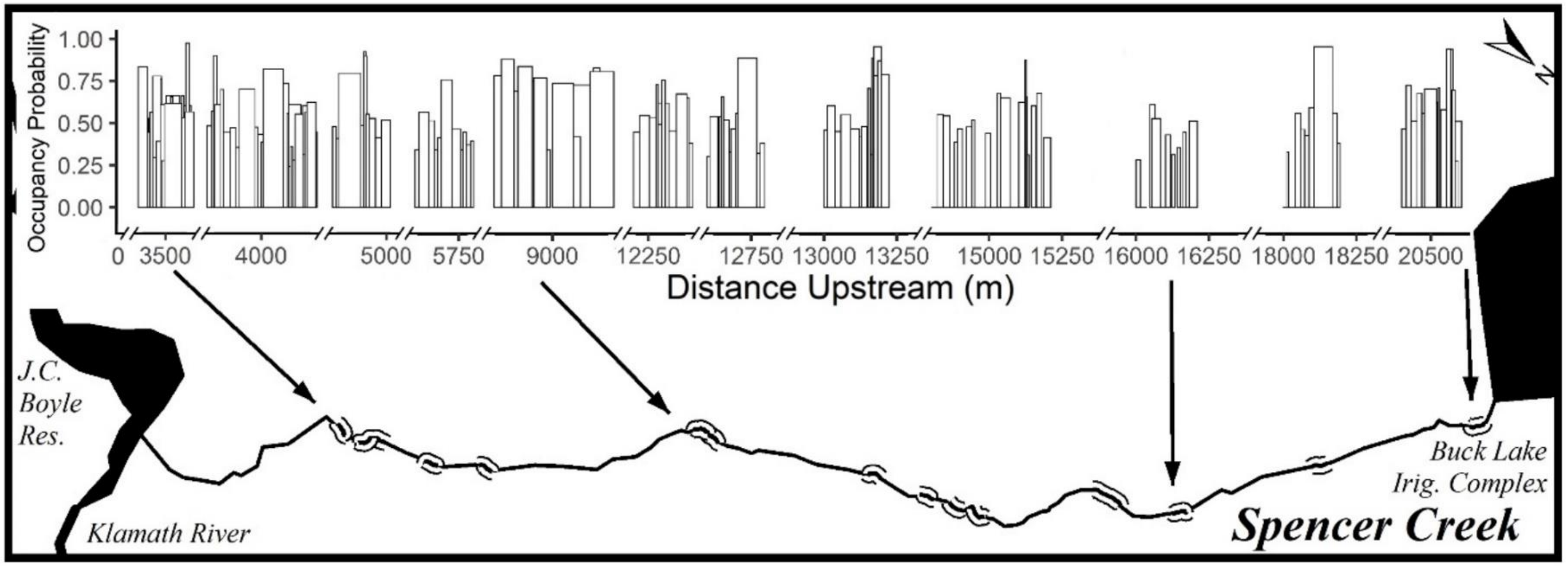


Figure 40 Occupancy probability for habitat units surveyed in the summer of 2019 in Spencer Creek moving upstream. The width of the occupancy bars correspond to the habitat unit length. Triple line stream lengths indicate surveyed lengths and correspond to the occupancy plot. Missing boxes indicate habitat units that were not surveyed. "-/ /-" indicates omitted lengths that I did not survey.

Stream Results Summary

Flow disconnection occurs in Scotch Creek in summer months. Water temperatures in Scotch Creek reflect intermediate suitability, high HLFM capacity, high IP, and intermediate occupancy probability (Table 8). Camp Creek water temperatures are intermediate in suitability and the stream contains a large number of high IP habitat near the confluence with Iron Gate Reservoir (Table 8). High water temperatures, low HLFM capacity estimates, low IP, and intermediate occupancy probability in Jenny Creek indicates low suitability for summertime rearing of juvenile coho salmon (Table 8). Despite high water temperature suitability, Fall Creek lacks substantial suitable habitat based on HLFM, IP, and occupancy probability (Table 8). Shovel Creek can be summarized by high water temperature suitability, intermediate juvenile coho HLFM capacity, high IP in lower reaches, and intermediate occupancy probability (Table 8). Despite Spencer Creek water temperatures, intermediate to low in suitability, the stream exhibited a large HLFM capacity, high IP, and intermediate-high occupancy probability (Table 8).

Table 8 Overall summary of results for streams above IGD.

Stream	Scotch Creek	Camp Creek	Jenny Creek	Fall Creek	Shovel Creek	Spencer Creek
MWMT (°C)	16.6 – 17.1	17.1	20.8 – 22.2	15.6 – 16.2	13.2 – 15.4	16.7 – 23.7
MWMT Suitability (Welsh et al. 2001)	Intermediate	Intermediate	Low	High - Intermediate	High	Intermediate - Low
MWAT (°C)	15.1 – 16.6	14.6	19.8 – 20.7	13.8 – 14.0	12.1 – 13.7	15.2 – 19.2
MWAT Suitability (Welsh et al. 2001)	Intermediate	Intermediate	Low	High	High	Intermediate - Low
Accessible Habitat (km)	1.0[1]	2.2[1,2]	3.3[3]	1.6[4]	4.7[5]	20.5
HLFM Juvenile Coho Salmon Summer Rearing Capacity	2,600	--	18,100	4,700	13,300	66,300
HLFM Redd Capacity	205	--	51	92	23	17,993
HLFM Egg Capacity	512,500	--	127,500	230,00	57,500	44,982,500
IP (km)	1.7	1.6	1.3	0.9	2.8	13.1
IP Coho Salmon Spawner Escapement Target	67	65	52	37	111	526

Stream	Scotch Creek	Camp Creek	Jenny Creek	Fall Creek	Shovel Creek	Spencer Creek
Average Occupancy Probability	0.48	--	0.50	0.53	0.46	0.61
Summertime Habitat Predicted to be Occupied by Juvenile Coho Salmon (%)	37	--	47	53	37	70

Note: MWMT and MWAT of study and reference streams in comparison to values associated with juvenile coho salmon presence or absence in the Mattole River in Welsh et al. 2001 (suitability: High = MWMT and MWAT less than 16.3 °C and 14.5 °C respectively; Intermediate = MWMT greater than 16.3 °C but less than 18.0 °C and MWAT greater than 14.5 °C but less than 16.7 °C; Low = MWMT and MWAT greater than 18.0 °C and 16.7 °C respectively).

1. I estimate that habitat in Camp and Scotch creeks will extend approximately 1.8 km further after reservoir drawdown (not included in total accessible habitat).
2. Camp Creek was not assessed for potential barriers, and accessible habitat limit is an approximation based on large boulder features apparent in aerial photography;
3. Accessible habitat includes habitat above four identified potential barriers in Jenny Creek;
4. Accessible habitat includes habitat above the lower culvert and high velocity sections in Fall Creek;
5. Accessible habitat includes habitat above the small dam structure in Shovel Creek.

DISCUSSION

I gained valuable insights into the potential for coho salmon recolonization in tributaries to the Klamath River after dam decommissioning. I found that coho salmon will gain access to greater than 26.1 km of tributary habitat within Scotch, Camp, Jenny, Fall, Shovel, and Spencer creeks in addition to approximately 48 km of mainstem habitat after the dam removal project. I also identified the existence and locations of potential human-built upstream passage barriers blocking access to approximately 5.9 km of additional combined habitat in Jenny, Fall and Shovel creeks.

I identified differences in thermal regimes between study streams. Scotch, Camp, Fall creeks and portions of Spencer Creek maintained water temperatures within the recommended range for juvenile coho rearing. Jenny Creek and portions of Spencer Creek had mid-summer fluctuations above published recommended rearing temperatures. I found that Shovel and Fall creeks predominately sustained lower water temperatures within recommended rearing temperatures for juvenile coho salmon. In addition to providing rearing habitat in the study tributaries, inputs of cool water from these streams may provide important refuge sites at the confluence with the warmer mainstem Klamath River following dam removal.

Based on available spawning gravel, the HLFM predicted that Scotch, Jenny, Fall, Shovel, and Spencer creeks had the capacity to support a maximum of 18,177 coho salmon redds that could produce less than 13,770,000 coho salmon smolts. Despite a large capacity based on spawning area, I estimated a total juvenile coho salmon summertime rearing capacity of 105,000 individuals and a subsequent estimate of 73,500 spring smolt outmigrants for Scotch, Jenny, Fall, Shovel, and Spencer creeks. This suggests that summertime rearing habitat in the five tributaries will limit coho salmon smolt recruitment rather than suitable spawning gravels. Note that these are capacity estimate and not predictions of actual production from these tributaries after coho salmon recolonization.

I found differences in the spatial distribution of suitable stream gradient and suitable IP values of study streams. Many streams exhibited high IP suitability and the majority of streams contained elevated concentrations of high IP valued reaches near stream mouths to the Klamath River. Scotch, Camp, Jenny, Fall, Shovel, and Spencer creeks will contribute approximately 21.4 IP km of tributary habitat after dam removal. For the coho salmon populations in these streams to have low extinction risk, the IP abundance targets for adult coho salmon in Scotch, Camp, Jenny, Fall, Shovel, and Spencer creeks were 67, 65, 52, 37, 111, and 526 individuals respectively.

I found that snorkel survey detection probability of juvenile coho salmon positively correlated with an increase in depth and that occupancy probability positively correlated with: percent instream cover, surface area, and nearby coho salmon hatchery production. Interestingly, a planned coho salmon mitigation hatchery on Fall Creek after dam removal may provide an opportunity to test the hatchery effect in my occupancy model. I fit the same final occupancy model to Fall Creek with the nearby hatchery effect. With a hatchery occupancy model predicted that 100% of Fall Creek (non-HGR type habitats) would be occupied by juvenile coho salmon in the summer if there is a hatchery effect similar to that in Bogus Creek.

Range Expansion

A large majority of coho salmon in the Klamath River originate from the Iron Gate Fish Hatchery (Ackerman et al. 2006). Downstream of IGD, coho salmon use the Shasta and Scott rivers as well as numerous small tributaries to the mainstem upper Klamath River (Seiad Valley and upstream) including: Bogus, Little Bogus, Cottonwood, Humbug, Beaver, Horse, Grider, and Seiad creeks. In total, these streams provide a large proportion of total habitat for wild spawning coho salmon in the upper Klamath River watershed (NMFS 2014). Considering small tributaries alone, the restoration of fish passage to habitats located above IGD will increase total available habitat for coho salmon (excluding the Scott and Shasta rivers) in the upper Klamath River by roughly 20%.

Tributary Relationships with the Mainstem Klamath River

While study tributaries will provide substantial summertime spawning and rearing habitat for coho salmon, an estimated 48 km of mainstem habitat from IGD to Spencer Creek (historical limit to coho salmon extent) constituting 8% of the entire Klamath River basin will provide large habitat gains for coho salmon pioneers. Additionally, areas of Scotch, Camp, Jenny, Fall, and other small tributaries currently underwater from reservoir flooding, and not assessed in my analysis, may provide a significant quantity of potentially high-quality rearing and (or) spawning habitat for coho salmon. I estimate that habitat in Camp and Scotch creeks will extend approximately 1.8 km (combined) further after reservoir drawdown.

We should also consider the potential for tributary streams to serve as thermal refugia for non-natal juvenile coho salmon and their abilities to support additional individuals from the main-stem Klamath River. It is not clear what the water temperatures and conditions of the Klamath River will be after dam removal. High water temperatures (> 20°C) during summer months are predicted for the areas of the Klamath River at the current sites of IGD and Copco dam after removal (Perry et al. 2011); however, studies indicate cold groundwater seeps are located under present day Iron Gate Reservoir and throughout mainstem habitat above IGD (NMFS 2013). The physiological unsuitability of habitat in the mainstem Klamath River could cause juvenile coho salmon to move across the landscape and into tributary habitats including intermittent streams (Huey 1991, Wigington Jr. et al. 2006)). The study streams may provide important summer rearing habitat for non-natal juvenile coho salmon originating from spawning in the mainstem or Spencer Creek, where HLFM predicts that spawning capacity greatly exceeds rearing capacity.

Additional juvenile coho salmon displacements and movements will occur during high winter flows. Juvenile coho salmon may seek refuge from high flow events in slower water backwater pools and side-channels in or associated with study streams above IGD. In the mid-Klamath River, juvenile coho salmon seek side-channel habitat features in response to high flow events (Witmore 2014). Non-natal wintertime rearing habitats in the mid-Klamath are important for the growth and retention of juvenile coho salmon (Witmore 2014). While I did not evaluate winter habitat capacity, the IP and gradient analysis does show that many of the study tributaries have low-gradient habitat near the confluence with the Klamath River that have potential to provide slow-water habitat in the winter months.

Water Temperature and Bioenergetics

High food availability can offset deleterious water temperature conditions in some circumstances (Brewitt et al. 2017). Recent studies identified populations of juvenile coho salmon thriving in water temperatures much higher than past rearing temperature standards, challenging historical understandings of temperature suitability. Bisson et al. (1988) measured high juvenile coho salmon summertime production in streams affected by the 1980 Mount St. Helens eruption despite elevated water temperatures (up to 29.5 °C), little instream cover, and few pool type habitats. The authors suggest that nitrogenous volcanic blast inputs (in an otherwise nitrogen-limited system), high juvenile coho salmon growth rates, elevated primary production, and an increase in riparian vegetation contributed to coho salmon production. Osterback et al. (2018) found positive growth rates for juvenile coho salmon occupying a freshwater lagoon in CA with daily mean water temperatures greater than 20 °C. In-situ enclosure experiments conducted by Lusardi et al. (2020) identified the highest absolute growth rate of juvenile coho salmon in the Shasta River occurs at an MWMT of 21.1°C and that growth remains positive up to an MWMT of 24.0 °C (highest value tested) when invertebrate densities range between

44,000 and 59,000 individuals/m^2 despite reduced overall survival. Hypotheses proposed to explain these phenomena include local population adaptations, acclimations, and high concentrations of invertebrate prey (Bisson et al. 1988, Osterback et al. 2018, Lusardi 2020). At my reference sites on Klamath River tributaries, both Beaver and Bogus creeks contained large numbers of juvenile coho salmon despite having low temperature suitability. I hypothesize that this occurred because these sites, while warm, were the coolest locations available and were occupied by fish seeking refuge from the warmer Klamath River main stem.

Researchers consider the mainstem Klamath River highly productive, sustaining greater than 43,000 macroinvertebrates/m^2 of stream bottom or 5,600 kg/ha near Hornbrook, CA (Needham and Needham 1967). High densities of invertebrate prey may offset some deleterious effects of high temperature after dam removal. Juvenile coho salmon do not currently appear to be utilizing these high energy yet warm water habitats in the mainstem Klamath River below IGD, typically crowding into cold water habitats around tributary mouths in summer months. The abundance, species composition, and concentration of invertebrates is unknown in the study streams. Additionally, if higher temperature tolerance is in fact a function of local population adaptation or acclimation, juvenile coho salmon in the Shasta and Scott rivers may be suited to and ready to colonize warmer water conditions experienced in Jenny Creek and portions of Spencer Creek.

Qualifications and Pitfalls of Modeling Approaches

Modern modeling approaches continue to increase in their capacity to explain ecological phenomena. Model structure and the decision to include certain covariates and not others should be based on sound ecological theory and hypotheses (Faraway 2015).

When considering the identification of what makes beneficial juvenile coho salmon habitat it is important to discern the difference between a requirement (conditions that permit an individual to survive and grow, a “need”) and a preference (what a fish behaviorally selects when it has a choice, a “want”). Key in differentiating between the two is the idea of habitat selection. A fish will select habitat based on a range of habitats available to them (a preference); whereas, if a fish is introduced to a singular habitat without other options, this habitat may or may not provide characteristics (food, shelter, velocity escapes, water temperatures or dissolved oxygen) that are needed for the fish’s survival based on fitness trade-offs (a requirement). When testing the relationship between habitat characteristics and fish distribution and abundance in the field, it is difficult to discern habitat requirements from habitat preferences, because the spatial distribution of individuals reflects both (Rosenfeld et al. 2003). Many models assume that observations of habitat preference are indicative of habitat requirements. For my modeling of summertime rearing potential above the dams, I used three approaches based on this assumption. I applied two models that assume relationships between habitat capacity and habitat characteristics based at least in part on observed habitat associations and one model where I explicitly use observations of juvenile coho salmon distribution in relation to habitat at reference sites to predict their distribution above the dams.

The HLFM model that I implemented provides estimates of habitat capacity for different life stages of coho salmon in coastal Oregon streams. These estimates are not predictions of actual production from these habitats. Actual production would only approach the capacity estimates for a particular life stage in cases of no density-dependent constraints (e.g. unlimited capacity) at all other life stages and very high productivity (density-independent survival) at all life stages. These conditions will not be met for the study sites and actual production for coho salmon will be much less than the estimated capacity. However, the capacity estimates do provide a means to assess differences across sites (Reeves et al. 1989). Additionally, it is not clear how transferable the HLFM is to more interior streams in the Klamath basin (Reeves 1989).

The IP modeling approach assumes that historic coho salmon abundances and distributions reflect the intrinsic habitat potential of a given watershed (Williams et al. 2008). Additionally, the IP model extrapolates historic coho salmon-geomorphological associations in coastal Oregon rivers to other systems. Is the association of stream flow, valley width, and channel gradient with juvenile coho salmon in coastal systems maintained in more interior streams (such as the Klamath River)? Additionally, the three geomorphological associations with coho salmon may fail to capture small discrete habitats that disproportionately promote (such as cold water habitat at the mouth of Tom Martin Creek in the mid-Klamath River watershed) or discourage (such as extreme summer low discharges) growth and utilization by juvenile coho salmon.

High confidence bounds in my occupancy model covariate plots indicates unexplained variation in the data. The occupancy model structure that I selected was based on literature accounts of summertime juvenile coho salmon occupancy associations with habitat structure. Are there other variables that explain summertime juvenile coho salmon occupancy? Additionally, occupancy models assume no false-positive detections; turbidity and/or basic fish identification may have caused an unknown quantity of false detections in the data.

Portfolio Effect in the Klamath Basin

Resilience of the aggregate upper Klamath Basin coho population could increase as a result of dam removal. The portfolio effect describes the importance of heterogenous life history strategies of sockeye salmon in maintaining species-level viability under a changing climate (Schindler et al. 2010). High resiliency of the entire Bristol Bay, AK sockeye salmon fishery results from variation in adult sockeye salmon run-timing amongst different drainages. Much like diversifying a stock portfolio to reduce volatility, a dampening effect occurs despite annual variation of specific sockeye salmon components of the larger, and more stable, Bristol Bay sockeye salmon fishery (Schindler et al. 2010).

The upper Klamath River coho salmon population is understudied. Good estimates of current coho salmon abundance and juvenile production for each tributary in the upper Klamath River do not exist outside of Bogus Creek and the Scott and Shasta Rivers. Furthermore, documentation of unique adult coho salmon run timing nor juvenile coho salmon entry date for different tributary streams does not exist in the upper basin. However, unique survival tactics associated with high mainstem water temperatures have been documented in the lower watershed (Belchik 2003, Deas et al. 2006, Sutton et al. 2007, Soto 2011).

Prior to the installation of the KHP, coho salmon in the upper Klamath River could have expressed a high diversity of life histories (stabilizing portfolio effect), due to the unique conditions in the study streams. In the future, coho salmon pioneers encountering new conditions above current IGD may express novel life-history strategies to exploit unique and favorable habitats within the KHP reach. Additionally, landscape heterogeneity can be viewed through a similar portfolio effect lens; habitat heterogeneity reduces the threat of physical conditions becoming unsuitable to mobile fishes when readily able to disperse (Schindler et al. 2015). The heterogeneity of habitats may also control the rates and patterns of recolonization after dam removal (Pess et al. 2014). The study streams varied significantly in flow, temperature regimes, and physical habitat characteristics, suggesting a plethora of habitat conditions available to pioneering adult and juvenile coho salmon.

Future Work

What is the food landscape in streams above IGD? How does invertebrate abundance and composition temporally and spatially vary in these streams? Food availability may dictate the ability of juvenile coho salmon to persist in streams with elevated summertime water temperatures such as Jenny and Spencer creeks. Future studies should identify summertime resident invertebrate abundance suitable for juvenile coho consumption in streams above IGD prior to dam removal. Fish biomass data collected as part of this work provide an initial assessment of relative productivity in streams above IGD. Will coho appropriate resources from resident fishes is another question for another study.

Can downstream coho populations support recolonization above IGD? Additional parameters that will govern the rates of recolonization by coho salmon in the upper Klamath River include the proximity to a source population, stray rate, and lifespan limitations (Pess et al. 2014). I suggest conducting a comprehensive study of “wild” origin coho salmon populations in nearby streams downstream of IGD and their associated viability as source populations. I also suggest conducting studies on the hatchery origin coho salmon at the Iron Gate Fish Hatchery as well as the selected stock for the future Fall Creek Fish Hatchery and associated viability as a source population (stray rates, genetic diversity, survival, etc.).

What is the occupancy probability for adult coho salmon in streams above IGD? A recent study by Anlauf-Dunn et al. (2014) found that adult coho salmon occupancy and abundance correlates with the capacity of the habitat to support parr in the winter, availability of complex pools, high percent bedrock, and lower site distances to the ocean. A future study could utilize this model and my instream habitat measurements, with additional winter habitat measurements, to predict adult coho salmon occupancy in streams above IGD.

What is the cause of dewatering in Scotch, Camp, and other small streams in the KHP? Are these naturally seasonal streams or is dewatering the result of land use and water diversions? Over-summering juvenile coho salmon survival in some small Californian streams positively correlates with streamflow, wetted volume, dissolved oxygen, and clay or bedrock channel morphologies and negatively correlates with days of stream disconnection and alluvial channel morphology (Obedzinski et al 2018). Rates and timing of summertime flow disconnection in Scotch and Camp creeks warrants future investigation.

I would also recommend a comprehensive study of potential human-built barriers in Spencer Creek and the available tributary habitat below present-day Iron Gate, Copco, and J.C. Boyle reservoirs. I did not assess Spencer Creek in its entirety (only 15%) nor did I assess habitat below the reservoirs.

CONCLUSIONS

The Klamath River poses unique obstacles to species intolerant of high temperatures such as coho salmon. In a time of changing climate, these challenges may become more prolific and widespread in the near future. Cold water habitats identified in tributaries within the KHP could play an important role in the recolonization and persistence of coho salmon in the Klamath River.

This study contributes to the growing body of knowledge of baseline upstream habitat conditions and resident fish community structure before dam decommissioning, and to what makes good summertime rearing habitat for the SONCC coho salmon ESU. In tributary streams to the Klamath River within the KHP, I found that habitat is widely variable. I documented prolific cold water temperatures throughout Scotch, Camp, Fall, Shovel, and portions of Spencer creeks. I also found that newly accessible habitat in the study tributaries will provide substantial rearing and spawning habitat for coho salmon after dam removal.

LITERATURE CITED

Ackerman NK, B. Pyper, I. Courter, S. Cramer. (2006) Estimation of returns of naturally produced coho to the Klamath River - review draft. Klamath coho integrated modeling framework technical memorandum #1 of 8. Prepared by Cramer Fish Sciences, Gresham, Oregon for US Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

Agrawal, A., R.S. Schick, E.P. Bjorkstedt, R.G. Szerlong, M.N. Goslin, B.C. Spence, T.H. Williams, K.M. Burnett. (2005) Predicting the Potential for Historical Coho, Chinook, and Steelhead Habitat in Northern California. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWFSC-379.

Albanese, B., K. A. Owers, D. A. Weiler, W. Pruitt. (2011) Estimating Occupancy of Rare Fishes using Visual Surveys, with a Comparison to Backpack Electrofishing. Southeastern Naturalist. 10(3): 423–442.

Allen, M. B., R. O. Engle, J. S. Zendt, F. C. Shrier, J. T. Wilson, P. J. Connolly. (2016) Salmon and Steelhead in the White Salmon River after the Removal of Condit Dam–Planning Efforts and Recolonization Results. Fisheries. 41(4): 190–203.

Anlauf-Dunn, K.J., E.J. Ward, M. Strickland, K. Jones. (2014) Habitat connectivity, complexity, and quality: predicting adult coho salmon occupancy and abundance. Canadian Journal of Fisheries and Aquatic Sciences. 71(12): 1864-1876.

Bejarano, M. D., Á. Sordo-Ward, C. Alonso, C. Nilsson. (2017) Characterizing effects of hydropower plants on sub-daily flow regimes. Journal of Hydrology. 550: 186–200.

Belchik, M.R. (2003) Use of thermal refugial areas on the Klamath River by juvenile salmonids; Summer 1998. Yurok Tribal Fisheries Program Technical Report. 1-36.

Beyer, J.M. (1984) Rainbow trout fishery and the spawning stock in the Upper Klamath River Wild Trout Area, Copco, CA. Thesis: Humboldt State University.

Bisson, P. A., J. L. Nielsen, J. W. Ward (1988) Summer production of coho salmon stocked in Mount St. Helens streams 3 - 6 years after the 1980 eruption. Transactions of the American Fisheries Society. 117: 322-335.

Brenner, R.E., S.D. Moffitt, W.S. Grant. (2012) Straying of hatchery salmon in Prince William Sound, Alaska. Environmental Biology of Fishes. 94:179–195

Brett, J.R. (1952) Temperature tolerance in young Pacific salmon, genus Oncorhynchus. Journal of the Fisheries Research Board of Canada. 9(6): 265-323.

Brewitt, K.S., E. M. Danner, J. W. Moore. (2017) Hot eats and cool creeks: juvenile Pacific salmonids use mainstem prey while in thermal refuges. Canadian Journal of Fisheries and Aquatic Sciences. 74(10): 1588–1602.

Burnett, K.M., G.H. Reeves, D. Miller, S. Clarke, K. Christiansen, K. Vance-Borland. (2003) A First Step Toward Broad-Scale Identification of Freshwater Protected Areas for Pacific Salmon and Trout in Oregon, USA. Proceedings of the World Congress on Aquatic Protected Areas, Cairns, Australia, August 2002.

Busch, D.S., M. Sheer, K. Burnett, P. McElhany, T. Cooney. (2013) Landscape-Level Model to Predict Spawning Habitat for Lower Columbia River Fall Chinook Salmon (Oncorhynchus tshawytscha): Intrinsic Potential Model for Spawning Fall Chinook. River Research and Applications. 29(3): 297–312.

Chiaramonte, L.V., R. A. Ray, R. A. Corum, T. Soto, S. L. Hallett. (2016) Klamath River Thermal Refuge Provides Juvenile Salmon Reduced Exposure to the Parasite Ceratonova shasta. Transactions of the American Fisheries Society. 145(4): 810-820.

Cole, H. H. (1946) B. Courtright and K. Simmons, Affidavits 1941–1946 regarding historical salmon fishery upstream from Copco 1 Dam, U.S. Department of the Interior, Office of Indian of Indian Affairs, Klamath Agency.

Coots, M. (1953) King Salmon Count — Klamath River, Klamathon Racks. October 25, 1953.

Coots, M. (1954) Efficiency of King Salmon Spawning in Fall Creek, Siskiyou County Progress Report for 1953-54. California Department of Fish and Wildlife.

Coots, M. (1957) The Spawning Efficiency of King Salmon (Oncorhynchus tshawytscha) in Fall Creek, Siskiyou County - 1954-55 Investigations. California Department of Fish and Wildlife.

Coots, M. (1962) Klamath River 1957 and 1958 King Salmon Counts, Klamathon Racks, Siskiyou County. California Department of Fish and Wildlife.

Coots, M. (1965) Letter to Jack Hanel, Pacific Power and Light Company, dated 1 July 1965, from California Department of Fish and Game, Redding, CA.

Davis, J.C., G.A. Davis. (2011) The influence of stream-crossing structures on the distribution of rearing juvenile Pacific salmon. Journal of the North American Benthological Society. 30 (4): 1117-1128.

Deas, M.L., S.K. Tanaka, J.C. Vaughn. (2006) Klamath River Thermal Refugia Study: Flow and Temperature Characterization. Final Project Report. Report of Watercourse Engineering, Inc. to the US Bureau of Reclamation, Klamath Area Office, Klamath Falls, OR.

Faraway, J.J. (2015) Linear Models with R 2nd Edition. Taylor and Francis Group, LLC.

Fausch, K. D., C. L. Hawkes, M. G. Parsons. (1988) Models that predict standing crop of stream fish from habitat variables: 1950-85. Gen. Tech. Rep. PNW-GTR-213. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Fausch, K.D. (1993) Experimental analysis of microhabitat selection by juvenile steelhead (Oncorhynchus mykiss) and coho salmon (Oncorhynchus kisutch) in a British Columbia stream. Canadian Journal of Fisheries and Aquatic Sciences. 50: 1198–1207.

Fortune, J.D., A.R. Gerlach, C.J. Hanel. (1966) A study to determine the feasibility of establishing salmon and steelhead in the upper Klamath basin. Pacific Power and Light Company.

Garwood, J., S. Ricker. (2013) Juvenile Coho Salmon Summer Spatial Structure Monitoring Survey Protocol. California Department of Fish and Wildlife. Coastal Salmonid Monitoring Program.

Garwood, J., S. Ricker. (2017) Salmonid Spatial Structure Monitoring Survey Protocol: Summer Snorkel Survey Methods. California Department of Fish and Wildlife. Coastal Salmonid Monitoring Program.

Hamilton, J., G. Curtis, S. Snedaker, D. White. (2005) Distribution of Anadromous Fishes in the Upper Klamath River Watershed Prior to Hydropower Dams—A Synthesis of the Historical Evidence. Fisheries. 30(4): 10-20.

Hankin, D. G., G. H. Reeves. (1988) Estimating Total Fish Abundance and Total Habitat Area in Small Streams Based on Visual Estimation Methods. Canadian Journal of Fisheries and Aquatic Sciences. 45: 834-844.

Hassler, T. J. (1987) Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest): coho salmon. U.S. Fish and Wildlife Service. Biological Report 82(11.70).

Hohler, D. (1981) A Dwarfed Population of Catostomus rimiculus (Catostomidae: pisces) in Jenny Creek, Jackson County, Oregon. Thesis: Oregon State University.

Huey, R. B. (1991). Physiological consequences of habitat selection. The American Naturalist. 137: S91 – S115.

Jobling, M. (1995) Fish bioenergetics. Oceanographic Literature Review. 42(9): 785.

Kern, J.D., G.W. Characklis, M.W. Doyle, S. Blumsack, R.B. Whisnant, (2012) Influence of Deregulated Electricity Markets on Hydropower Generation and Downstream Flow Regime. Journal of Water Resources Planning and Management. 138(4).

Kery, M., M. Schaub. (2011) Bayesian Population Analysis Using WinBUGS : A Hierarchical Perspective. Elsevier Science and Technology.

Klamath Basin Restoration Agreement. (2010) Klamath Basin Restoration Agreement for the Sustainability of Public and Trust Resources and Affected Communities.

Klamath Hydropower Settlement Agreement. (2010).

Klamath Hydropower Settlement Agreement. (2016) (Amended).

Knechtle, M., D. Chesney. (2010) Bogus Creek Salmon Studies Final Report. California Department of Fish and Wildlife. 1-17. California Department of Fish and Game Northern Region Klamath River Project.

Knechtle, M., D. Chesney. (2014) Bogus Creek Salmon Studies Final Report. California Department of Fish and Wildlife. 1-23. California Department of Fish and Game Northern Region Klamath River Project.

Kondolf, G.M. (1997) PROFILE Hungry Water: Effects of Dams and Gravel Mining on River Channels. Environmental Management. 21(4): 533-551.

Konecki, J.T., C.A. Woody, T.P. Quinn. 1995. Temperature preference in two populations of juvenile coho salmon, Oncorhynchus kisutch. Environmental Biology of Fishes. 44: 417-421.

Kramer, G. (2003) Klamath Hydroelectric Project Federal Energy Regulatory Commission Project Number 2082 Historic Context Statement. PacifiCorp. 1-66.

Lusardi, R.A., B.G. Hammock, C.A. Jeffres, R.A. Dahlgren, J.D. Kiernan. (2020) Oversummer growth and survival of juvenile coho salmon (Oncorhynchus kisutch) across a natural gradient of stream water temperature and prey availability: an in situ enclosure experiment. Canadian Journal of Fisheries and Aquatic Sciences. 77(2): 413-424.

Mackenzie, D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, C. A. Langtimm, (2002). Estimating Site Occupancy Rates when Detection Probabilities are Less than One. 83(8): 8.

McCullough, D. A., S. Spalding, D. Stuyrdevant, M. Hicks. (2001) Summary of technical literature examining the physiological effects of temperature on salmonids. Region 10 temperature water quality criteria guidance development project. U.S. Environmental Protection Agency. EPA-910-D-01-005: 1-20.

McMahon, T. E. (1983) Habitat Suitability Index Models: Coho Salmon. U.S. Fish and Wildlife Service. Biological Report 82(10.49).

McMillan, J., R. Peters, M. McHenry, S. Brenkman, S. Morley, G. Pess, J. Anderson, T. Quinn, M. Foley, K. Denton, M. Moser, R. Paradis, P. Crain, H. Hugunin, J. Geffre, A. Geffre. (2019) The Elwha River: What Have We Learned Since Dam Removal? The Osprey. 93: 14-17

Moyle, P.B., R.M. Yoshiyama, J.E. Williams, E.D Wikramanayake, (1995) Fish species of special concern in California. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

Mundie, J.H. (1969) Ecological implications of the diet of juvenile coho in streams. In Symposium on Salmon and Trout in Streams. Edited by T.G. Northcote. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver, B.C. pp. 135–152.

Nagel, D., J., M. Buffington, D. Isaak (2010). Estimating Stream Gradient Using NHD Stream Lines and DEM Data. 54.

Nickelson, T.E., M.F. Solazzi, S.L. Johnson, J.D. Rodgers. (1992) An approach to determining stream carrying capacity and limiting habitat for coho salmon (Oncorhynchus kisutch). In Proceedings of the coho workshop. Edited by L. Berg and P.W. Delaney. Nanaimo, B.C., May 26-28, 1992. pp. 251-260.

Nickelson, T.E. (1998) A Habitat-Based Assessment of Coho Salmon Production Potential and Spawner Escapement Needs for Oregon Coastal Streams. ODFW. Information Reports Number 98-4.

NMFS (National Marine Fisheries Service). (2013) Klamath Dam Removal Overview Report for the Secretary of the Interior. U.S. Department of the Interior, U.S. Department of Commerce, National Marine Fisheries Service.

NMFS (National Marine Fisheries Service). (2014) Final Recovery Plan for the Southern Oregon/ Northern California Coast Evolutionarily Significant Unit of Coho Salmon (Oncorhynchus kisutch). U.S. Department of the Interior, U.S. Department of Commerce, National Marine Fisheries Service.

Obedzinski, M., S. Nossaman Pierce, G. E. Horton, M. J. Deitch. (2018) Effects of Flow-Related Variables on Oversummer Survival of Juvenile Coho Salmon in Intermittent Streams. Transactions of the American Fisheries Society. 147(3): 588-605.

Overton, C. K., S.P. Wollrab, B.C. Roberts, M.A. Radko. (1997) R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. USDA. United States Forest Service General Technical Report INT-GTR-346.

OWRD (Oregon Water Resources Department) (2019). Station ID 11510000 Near Real Time Hydrographics Data. https://apps.wrd.state.or.us/apps/sw/hydro_near_real_time/

PacifiCorp. (2004) Final Technical Report Klamath Hydroelectrical Project (FERC No. 2082). PacifiCorp.

PacifiCorp. (2007) Iron Gate, Copco and J.C. Boyle Reservoir Tributary Surveys Klamath Hydroelectric Project. PacifiCorp Energy. FERC Project No. 2082-027.

PacifiCorp. (2012) Klamath Facilities Removal Final EIS/EIR. 1 (3.1). December 2012.

PacifiCorp, State of California, State of Oregon, Karuk Tribe, Yurok Tribe, Klamath River Renewal Corporation (2020). Memorandum of Agreement.

Perry, R.W., J.C. Risley, S.J. Brewer, E.C. Jones, D.W. Rondorf. (2011) Simulating Water Temperature of the Klamath River under Dam Removal and Climate Change Scenarios. USGS. Open-File Report 2011-1243.

Pess, G. R., T. P. Quinn, S. R. Gephard, R. Saunders. (2014). Re-colonization of Atlantic and Pacific rivers by anadromous fishes: linkages between life history and the benefits of barrier removal. Reviews in Fish Biology and Fisheries. 24(2014): 881-900.

Peterson, W.T., J.L. Fisher, J.O. Peterson, C.A. Morgan, B.J. Burke, K.L. Fresh. (2014) Applied fisheries oceanography: Ecosystem indicators of ocean conditions inform fisheries management in the California Current. Oceanography, 27, 80-89. doi:10.5670/oceanog.2014.88.

Petts G.E., A.M Gurnell. (2005) Dams and geomorphology: Research progress and future directions. Geomorphology. 71: 27–47.

Quinn, T.P., N.P. Peterson. (1996) The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (Oncorhynchus kisutch) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences. 53(7): 1555-1564.

Quinn, T.P. (2005). The Behavior and Ecology of Pacific Salmon and Trout. 1st edition. University of Washington Press.

Rebenack, J.J., S. Ricker, C. Anderson, M. Wallace, D.M. Ward. (2015) Early Emigration of Juvenile Coho Salmon: Implications for Population Monitoring. Transactions of the American Fisheries Society. 144: 163-172.

Reeves, G. H., F. H. Everest, T. E. Nickelson. (1989) Identification of physical habitats limiting the production of coho salmon in western Oregon and Washington. General Technical Report PNW-GTR-245. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Reiser, D. W., S. Beck. (2006) Defining Flow Windows for Upstream Passage of Adult Anadromous Salmonids at Cascades and Falls. Transactions of the American Fisheries Society. 135: 668–679.

Ries, K.G., J.K. Newson, M.J. Smith, J.D. Guthrie, P.A. Steeves, T.L. Haluska, K.R. Kolb, R.F. Thompson, R.D. Santoro, H.W. Vraga. (2017) StreamStats, version 4: U.S. Geological Survey Fact 2017–3046, 4 p.

Rosenberg, D. M., F. Berkes, R. A. Bodaly, R. E. Hecky, C. A. Kelly, J. W. M. Rudd. (1997) Large-scale impacts of hydroelectric development. Environmental Reviews. 5: 28.

Rosenfeld, J. 2003. Assessing the habitat requirements of stream fishes: an overview and evaluation of different approaches. Transactions of the American Fisheries Society. 132: 953-968.

Samarasin, P., B.J. Shuter, F.H. Rodd. (2017) After 100 years: hydroelectric dam-induced life-history divergence and population genetic changes in sockeye salmon (Oncorhynchus nerka). Conservation Genetics. 18: 1449-1462.

San Francisco Call. (1909) Where Shovel Creek Reaches Klamath: The Famous Fishing and Hunting Ground of Northern California. June 27, 1909.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers, M.S Webster. (2010) Population diversity and the portfolio effect in an exploited species. Nature. 465(7298): 609-612.

Schindler, D. E., J. B. Armstrong, T. E. Reed. (2015) The portfolio concept in ecology and evolution. Frontiers in Ecology and the Environment. 13(5): 257-263.

Schroeder, K., B. Cannon, L. Whitman, M. Walker. (2012) Sandy River Basin Spring Chinook Salmon Spawning Surveys – 2012. Oregon Department of Fish and Wildlife 4034 Fairview Industrial Drive SE Salem, Oregon 97302. 73.

Sharma, R., R. Hilborn. (2001) Empirical relationships between watershed characteristics and coho salmon (Oncorhynchus kisutch) smolt abundance in 14 western Washington streams. Canadian Journal of Fisheries and Aquatic Sciences. 58: 1453-1463.

Sheer, M.B., D.S. Busch, E. Gilbert, J.M. Bayer, S. Lanigan, J.L. Schei, K. Burnett, D. Miller. (2009) Development and Management of Fish Intrinsic Potential Data and Methodologies: State of the IP 2008 Summary Report. Pacific Northwest Aquatic Monitoring Partnership Series. 2009-004: 56.

Shirvell, C.S. (1990) Role of Instream Rootwads as Juvenile Coho Salmon (Oncorhynchus kisutch) and Steelhead Trout (O. mykiss) Cover Habitat Under Varying Streamflows. Canadian Journal of Fisheries and Aquatic Sciences. 47(5): 852-861.

Soto, T. (2011) Juvenile Coho Life History Tactics Utilizing the Mid-Klamath River Corridor with Linkages Between Inland and Coastal Riverine Habitats. American Fisheries Society 140th Annual Meeting.

Spence, B. C., G. A. Lomnicky, R. M. Hughes, R. P. Novitzki. (1996) An ecosystem approach to salmonid conservation. TR 4501-96-6057. ManTech Environmental Research Services Corporation, Corvallis, Oregon, USA.

Starcevich, S. J., S. E. Jacobs, W. Tinniswood. (2006). Effects of Dams on Redband Trout Life History in the Upper Klamath River: A Summary and Synthesis of Past and Recent Studies. ODFW Information Report. Corvallis, Oregon.

Sutton R.J., M.L. Deas, S.K. Tanaka, T. Soto, R.A. Corum, (2007) Salmonid observations at a Klamath River thermal refuge under various hydrological and meteorological conditions. River Research and Applications. 23: 775-785.

Ugedal, O., T. F. Næsje, E. B. Thorstad, T. Forseth, L. M. Saksgård, T. G. Heggberget. (2008) Twenty years of hydropower regulation in the River Alta: Long-term changes in abundance of juvenile and adult Atlantic salmon. Hydrobiologia. 609(1): 9–23.

USDA (United States Department of Agriculture). (1992). Smith River National Recreation Area Management Plan. Six Rivers National Forest.

USEPA (U. S. Environmental Protection Agency). (1999) Van Duzen River and Yager Creek Total Maximum Daily Load for Sediment.

USGS (United States Geological Survey). (2020) USGS 11512000 FALL C A COPCO CA. USGS Current Conditions for the Nation. https://nwis.waterdata.usgs.gov/nwis/uv?

Vora, R. S. (1988) "A Comparison of the Spherical Densiometer and Ocular Methods of Estimating Canopy Cover." : 5.

Welsh, H. H., G. R. Hodgson, B. C. Harvey. (2001) Distribution of Juvenile Coho Salmon in Relation to Water Temperaturs in Tributaries of the Mattole River, CA. North American Journal of Fisheries Management. 21: 464-470.

Wigington Jr., P. J., J. L. Ebersole, M. E. Colvin, S. G. Leibowitz, B. Miller, B. Hansen, H. R. Lavigne, D. White, J. P. Baker, M. R. Church, J. R. Brooks, M. A. Cairns, J. E. Compton. (2006) Coho Salmon Dependence on Intermittent Streams. Frontiers in Ecology and the Environment. 4(10): 513-518.

Witmore, S. K. (2014) Seasonal growth, retention, and movement of juvenile coho salmon in natural and constructed habitats of the mid-Klamath River. MS Thesis, Humboldt State University.

Williams, T. H., B. C. Spence, W. Duffy, D. Hillemeier, G. Kautsky, T. E. Lisle, M. McCain, T. E. Nickelson, E. Mora, T. Pearson. (2008) Framework for Assessing Viability of Threatened Coho Salmon in the Southern Oregon/Northern California Coast Evolutionarily Significant Unit. NOAA-TM-NMFS-SWFSC-432. U.S. Department of Commerce, National Marine Fisheries Service, Southwest Fisheries Science Center.

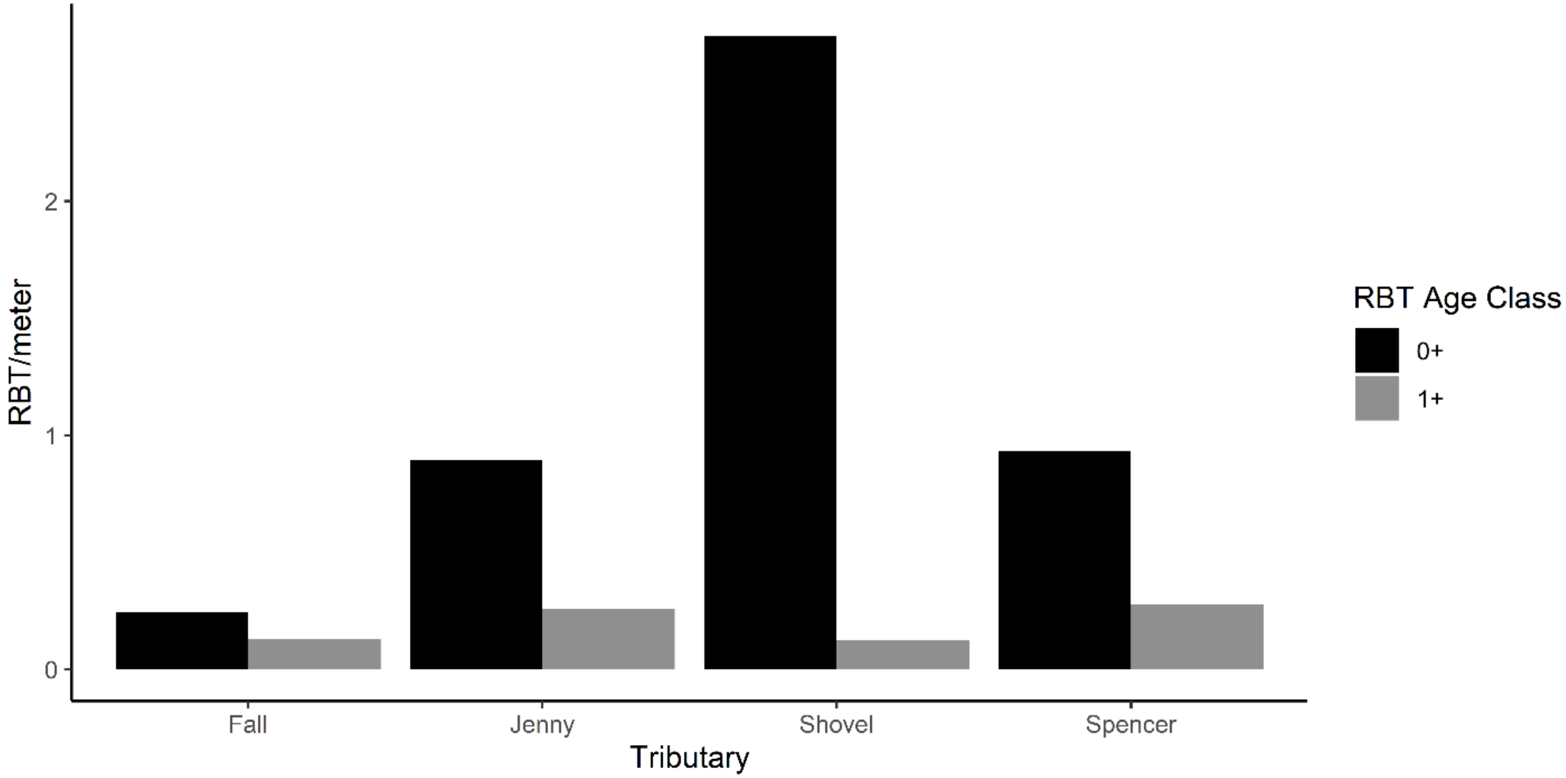
Williams, T. H., B. C. Spence, D. A. Boughton, R. C. Johnson, L. G. Crozier, N. J. Mantua, M. R. O'Farrell, S. T. Lindley. (2016) Viability Assessment for Pacific Salmon and Steelhead Listed Under the Endangered Species Act: Southwest. NOAA-TM-NMFS-SWFSC-564.

Zimmerman, M.P. (1999) Food Habits of Smallmouth Bass, Walleyes, and Northern Pikeminnow in the Lower Columbia River Basin during Outmigration of Juvenile

Anadromous Salmonids. Transactions of the American Fisheries Society. 128(6): 1036-1054.

APPENDIX A

Appendix A: Rainbow trout presence in tributaries upstream of the IGD from snorkel surveys conducted in the summers of 2018 and 2019. Black and gray bars differentiate age class 0+ and 1+ rainbow trout abundances per linear upstream m respectively.



APPENDIX B

Appendix B: Raw resident fish data for snorkel surveys conducted in tributaries above IGD during the summers of 2018 and 2019.

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/20/2018	Shovel Creek	--	14.1	1	SHVL035	29	2	--	--
7/20/2018	Shovel Creek	--	14.1	2	SHVL035	17	5	--	--
7/20/2018	Shovel Creek	--	14.1	1	SHVL037	76	1	--	--
7/20/2018	Shovel Creek	--	14.1	2	SHVL037	77	0	--	--
7/20/2018	Shovel Creek	--	14.1	1	SHVL040	27	1	--	--
7/20/2018	Shovel Creek	--	14.1	2	SHVL040	31	0	--	--
7/20/2018	Shovel Creek	--	14.1	1	SHVL041L	22	2	--	--
7/20/2018	Shovel Creek	--	14.1	2	SHVL041L	33	2	--	--
7/20/2018	Shovel Creek	--	14.1	1	SHVL041R	19	0	--	--
7/20/2018	Shovel Creek	--	14.1	2	SHVL041R	17	1	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL029	21	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL033	48	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL039	40	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/27/2018	Shovel Creek	--	12.8	1	SHVL045R	89	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL047	37	3	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL051	70	2	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL053	28	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL055	67	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL057	20	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL059	52	0	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL066	123	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL067	27	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL070	30	0	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL074	36	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL075	60	1	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL079	39	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL080	72	1	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL089	37	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL090	14	1	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/27/2018	Shovel Creek	--	13.3	1	SHVL093	22	1	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL095	32	0	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL103	39	2	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL104	31	2	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL107L	9	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL109	21	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL114	41	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL115	2	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL027	8	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL029	20	0	--	--
7/27/2018	Shovel Creek	--	12.8	3	SHVL033	52	1	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL039	33	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL045L	2	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL045R	83	1	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL049	130	1	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL052	16	1	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/27/2018	Shovel Creek	--	12.8	2	SHVL053	38	0	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL056	20	2	--	--
7/27/2018	Shovel Creek	--	12.8	2	SHVL057	28	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL060	60	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL066	62	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL068	191	1	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL070	35	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL074	35	0	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL077	38	1	--	--
7/27/2018	Shovel Creek	--	13.2	2	SHVL079	52	1	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL090	19	2	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL092	20	2	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL095	53	0	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL097	13	1	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL104	19	1	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL105	25	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/27/2018	Shovel Creek	--	13.3	1	SHVL109	21	1	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL112	36	3	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL115	35	0	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL117	9	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL027	14	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL033	34	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL036L	4	1	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL045L	12	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL047	32	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL049	205	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL051	60	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL052	22	0	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL055	42	1	--	--
7/27/2018	Shovel Creek	--	12.8	1	SHVL056	15	1	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL059	26	0	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL060	53	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/27/2018	Shovel Creek	--	13.2	1	SHVL067	55	0	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL068	231	0	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL075	34	3	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL077	73	5	--	--
7/27/2018	Shovel Creek	--	13.2	1	SHVL080	49	0	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL089	51	2	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL092	15	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL093	11	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL097	8	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL103	26	2	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL105	39	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL107L	7	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL112	17	0	--	--
7/27/2018	Shovel Creek	--	13.3	1	SHVL114	6	0	--	--
7/27/2018	Shovel Creek	--	13.3	2	SHVL117	36	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL002	0	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL002	0	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL003	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL003	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL001SC001	6	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL001SC001	1	2	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL002SC001	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL002SC001	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL003SC001	4	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL003SC001	1	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL005SC001	2	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL005SC001	3	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL006SC001	1	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL006SC001	0	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL008SC001	4	3	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL008SC001	5	3	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL006	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL006	2	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL001SC002	9	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL001SC002	10	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL013	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL013	0	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL014	1	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL014	7	1	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL016	1	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL016	1	0	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	1	FAL018	7	3	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	11.2	2	FAL018	2	2	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	12.7	1	FAL023	7	3	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	12.7	2	FAL023	11	2	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	12.7	1	FAL024	0	2	--	--
9/15/2018	Fall Creek	Mild, smokey, sunny	12.7	2	FAL024	4	0	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	1	FAL026	6	0	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	2	FAL026	2	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	1	FAL028	4	1	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	2	FAL028	2	0	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	1	FAL030	2	1	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	2	FAL030	10	2	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	1	FAL031	0	0	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	2	FAL031	1	0	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	1	FAL034	3	1	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	2	FAL034	3	0	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	1	FAL035	2	1	--	--
9/16/2018	Fall Creek	Mild, smokey, sunny	11.4	2	FAL035	4	2	--	--
9/16/2018	Fall Creek	Mild, sunny,	12.1	1	FAL041	6	1	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		clear, no smoke							
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	2	FAL041	3	3	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	1	FAL043	1	1	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	2	FAL043	10	0	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	1	FAL047	7	2	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	2	FAL047	4	1	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	1	FAL002SC003	5	0	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	2	FAL002SC003	4	0	--	--
9/16/2018	Fall Creek	Mild, sunny,	12.1	1	FAL050	5	0	--	--

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		clear, no smoke							
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.1	2	FAL050	8	0	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.4	1	FAL054	1	0	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.4	2	FAL054	0	0	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.4	1	FAL055	4	2	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.4	2	FAL055	3	1	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.4	1	FAL060	8	0	--	--
9/16/2018	Fall Creek	Mild, sunny, clear, no smoke	12.4	2	FAL060	6	0	--	--
6/24/2019	Jenny Creek	Partly Cloudy; Windy;	19.1	1	JEN001	11	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		Warm ~80F							
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	19.1	2	JEN001	24	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	19.1	1	JEN002	5	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	19.1	2	JEN002	9	2	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN003	4	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN003	6	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN004	25	2	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN004	32	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN005	16	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN005	21	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN006	9	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN006	12	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN007	12	2	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy;	18.9	2	JEN007	7	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		Warm ~80F							
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN008	8	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN008	8	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN013	14	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN013	16	5	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN001SC002	6	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN001SC002	14	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN018	7	3	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN018	8	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN021	3	2	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN021	14	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN024	13	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN024	18	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy;	18.9	1	JEN025	11	7	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		Warm ~80F							
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN025	20	2	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN028	3	5	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN028	8	2	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	1	JEN030	13	6	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.9	2	JEN030	17	2	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.3	1	JEN046	11	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.3	2	JEN046	3	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.3	1	JEN047	12	4	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.3	2	JEN047	4	0	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.3	1	JEN051	9	1	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.3	2	JEN051	5	4	0	0
6/24/2019	Jenny Creek	Partly Cloudy; Windy; Warm ~80F	18.1	1	JEN055	6	0	0	0
6/24/2019	Jenny Creek	--	18.1	2	JEN055	22	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
6/25/2019	Jenny Creek	--	16.8	1	JEN056	13	1	0	0
6/25/2019	Jenny Creek	--	16.8	2	JEN056	18	1	0	0
6/25/2019	Jenny Creek	--	16.8	1	JEN058	21	4	0	0
6/25/2019	Jenny Creek	--	16.8	2	JEN058	17	0	0	0
6/25/2019	Jenny Creek	--	17	1	JEN061	32	5	0	0
6/25/2019	Jenny Creek	--	17	2	JEN061	21	0	0	0
6/25/2019	Jenny Creek	--	17	1	JEN065	14	0	0	0
6/25/2019	Jenny Creek	--	17	2	JEN065	12	0	0	0
6/25/2019	Jenny Creek	--	17.4	1	JEN067B	18	1	0	0
6/25/2019	Jenny Creek	--	17.4	2	JEN067B	20	0	0	0
6/25/2019	Jenny Creek	--	17.4	1	JEN069	18	1	0	0
6/25/2019	Jenny Creek	--	17.4	2	JEN069	15	3	0	0
6/25/2019	Jenny Creek	--	17.4	1	JEN070	0	0	0	0
6/25/2019	Jenny Creek	--	17.4	2	JEN070	1	0	0	0
6/25/2019	Jenny Creek	--	17.4	1	JEN072	11	1	0	0
6/25/2019	Jenny Creek	--	17.4	2	JEN072	16	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
6/25/2019	Jenny Creek	--	17.9	1	JEN075	23	2	0	0
6/25/2019	Jenny Creek	--	17.9	2	JEN075	16	0	0	0
7/1/2019	Jenny Creek	--	19	1	JEN078	4	0	0	0
7/1/2019	Jenny Creek	--	19	2	JEN078	16	0	0	0
7/1/2019	Jenny Creek	--	19	1	JEN084L	4	0	0	0
7/1/2019	Jenny Creek	--	19	2	JEN084L	0	0	0	0
7/1/2019	Jenny Creek	--	19	1	JEN085	4	0	0	0
7/1/2019	Jenny Creek	--	19	2	JEN085	16	1	0	0
7/1/2019	Jenny Creek	--	19	1	JEN090	21	1	0	0
7/1/2019	Jenny Creek	--	19	2	JEN090	18	0	0	0
7/1/2019	Jenny Creek	--	19	1	JEN094	16	0	0	0
7/1/2019	Jenny Creek	--	19	2	JEN094	29	4	0	0
7/1/2019	Jenny Creek	--	19	1	JEN095	29	1	0	0
7/1/2019	Jenny Creek	--	19	2	JEN095	13	1	0	0
7/1/2019	Jenny Creek	--	19	1	JEN096	3	1	0	0
7/1/2019	Jenny Creek	--	19	2	JEN096	9	3	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/1/2019	Jenny Creek	--	19	1	JEN101	13	1	0	0
7/1/2019	Jenny Creek	--	19	2	JEN101	9	0	0	0
7/1/2019	Jenny Creek	--	19	1	JEN103	13	1	0	0
7/1/2019	Jenny Creek	--	19	2	JEN103	10	2	0	0
7/1/2019	Jenny Creek	--	18.9	1	JEN104	6	0	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN104	12	3	0	0
7/1/2019	Jenny Creek	--	18.9	1	JEN105	11	0	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN105	23	1	0	0
7/1/2019	Jenny Creek	--	18.9	1	JEN107	11	0	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN107	7	0	0	0
7/1/2019	Jenny Creek	--	18.9	1	JEN108	5	1	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN108	7	1	0	0
7/1/2019	Jenny Creek	--	18.9	1	JEN110	0	0	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN110	1	0	0	0
7/1/2019	Jenny Creek	--	18.9	1	JEN112	15	2	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN112	1	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/1/2019	Jenny Creek	--	18.9	1	JEN113	11	0	0	0
7/1/2019	Jenny Creek	--	18.9	2	JEN113	6	0	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN116	5	2	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN116	15	1	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN118	4	1	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN118	8	1	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN121R	6	1	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN121R	3	1	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN122R	3	2	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN122R	7	1	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN123L	2	0	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN123L	6	0	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN124L	0	0	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN124L	0	0	0	0
7/1/2019	Jenny Creek	--	18.8	1	JEN124R	11	0	0	0
7/1/2019	Jenny Creek	--	18.8	2	JEN124R	17	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL002	7	4	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL002	7	8	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL003	0	0	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL003	2	4	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL001SC001	18	5	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL001SC001	13	1	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy;	13.7	1	FAL002SC001	2	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		Warm ~80F							
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL002SC001	3	0	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL003SC001	12	1	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL003SC001	7	1	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL005SC001	8	0	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL005SC001	12	3	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL006SC001	2	2	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL006SC001	4	4	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL008SC001	7	2	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL008SC001	5	9	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL006	5	10	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL006	11	6	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL001SC002	13	4	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy;	13.7	2	FAL001SC002	21	3	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
		Warm ~80F							
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	1	FAL013	1	5	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	13.7	2	FAL013	2	2	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	15.1	1	FAL014	1	4	0	0
7/14/2019	Fall Creek	Partly Cloudy; Windy; Warm ~80F	15.1	2	FAL014	1	3	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	1	SHVL022	124	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	2	SHVL022	124	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	1	SHVL023	8	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	2	SHVL023	31	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	1	SHVL027	6	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	2	SHVL027	12	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	1	SHVL029	26	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	2	SHVL029	37	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	1	SHVL031	21	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	10.9	2	SHVL031	29	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	1	SHVL032	24	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	2	SHVL032	14	3	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	1	SHVL033	10	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	2	SHVL033	72	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	1	SHVL035	57	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	2	SHVL035	97	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	1	SHVL036	7	0	0	0
~~7/2/2019~~	~~Shovel Creek~~	~~Sunny; Cool; ~75F~~	~~11.7~~	~~2~~	~~SHVL036~~			~~0~~	~~0~~
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	1	SHVL037	118	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	2	SHVL037	246	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	11.7	1	SHVL038	27	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL038	14	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL039	38	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL039	21		0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL040	48	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL040	40	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL041R	4	2	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL041R	14	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL041L	49	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL041L	52	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL044	29	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL044	36	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL045L	160	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL045L	219	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL045R	133	1	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL045R	108	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	1	SHVL047	28	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.2	2	SHVL047			0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	1	SHVL049	145	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	2	SHVL049	199	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	1	SHVL050	15	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	2	SHVL050	9	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	1	SHVL051	65	1	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	2	SHVL051	31	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	1	SHVL052	29	0	0	0
7/2/2019	Shovel Creek	Sunny; Cool; ~75F	13.6	2	SHVL052	28	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL053	51	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL053	114	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL055	75	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL055	85	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL056	21	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL056	24	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL057	17	4	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL057	14	2	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL059	32	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL059	42	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL060	76	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL060	56	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL066	147	5	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL066	194	3	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL067	48	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL067	64	2	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL068	172	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	2	SHVL068	159	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	14	1	SHVL070	61	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	13.4	2	SHVL070	54	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	13.4	1	SHVL071	38	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	13.4	2	SHVL071	14	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	13.4	1	SHVL072	23	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/8/2019	Shovel Creek	Sunny; Warm; 83F	13.4	2	SHVL072	27	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	13.4	1	SHVL074	18	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	12.8	2	SHVL074	30	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	12.8	1	SHVL075	30	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	12.8	2	SHVL075	34	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	12.8	1	SHVL077	58	5	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	2	SHVL077	20	2	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	1	SHVL079	34	0	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	2	SHVL079	12	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	1	SHVL080	24	2	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	2	SHVL080	17	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	1	SHVL083	36	3	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	2	SHVL083	30	1	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	1	SHVL087	59	4	0	0
7/8/2019	Shovel Creek	Sunny; Warm; 83F	--	2	SHVL087	56	0	0	0
9/9/2019	Spencer Creek	--	--	1	SPN001SC01	20	0	0	0
9/9/2019	Spencer Creek	--	--	1	SPN003SC01	21	0	0	0
9/9/2019	Spencer Creek	--	--	1	SPN004SC01	28	2	0	0
9/9/2019	Spencer Creek	--	--	1	SPN005SC01	46	4	0	0
9/9/2019	Spencer Creek	--	--	2	SPN001	19	1	0	0
9/9/2019	Spencer Creek	--	--	2	SPN003	18	2	0	0
9/9/2019	Spencer Creek	--	--	2	SPN004	12	1	0	0
9/9/2019	Spencer Creek	--	--	2	SPN005	23	4	0	0
9/9/2019	Spencer Creek	--	--	2	SPN002SC02	10	0	0	0
9/9/2019	Spencer Creek	--	13.8	2	SPN003SC02	4	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/9/2019	Spencer Creek	--	13.8	2	SPN004SC02	27	0	0	0
9/9/2019	Spencer Creek	--	13.8	2	SPN005SC02	18	9	0	0
9/9/2019	Spencer Creek	--	13.8	1	SPN007	6	1	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN008	14	1	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN009	20	7	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN001SC03	12	0	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN011	37	14	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN012	7	2	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN014	9	8	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN015	6	5	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN016	29	8	0	0
9/9/2019	Spencer Creek	--	15.7	1	SPN017	8	2	0	0
9/9/2019	Spencer Creek	--	16.3	1	SPN019	10	4	0	0
9/9/2019	Spencer Creek	--	16.3	2	SPN023	2	1	0	0
9/9/2019	Spencer Creek	--	16.3	2	SPN024	26	0	0	0
9/10/2019	Spencer Creek	--	10.9	1	SPN001SC06	12	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/10/2019	Spencer Creek	--	10.9	1	SPN001SC07	6	1	0	0
9/10/2019	Spencer Creek	--	10.9	1	SPN001SC002SC08	5	1	0	0
9/10/2019	Spencer Creek	--	10.9	1	SPN003SC08	3	1	0	0
9/10/2019	Spencer Creek	--	10.9	1	SPN004SC08	2	0	0	0
9/10/2019	Spencer Creek	--	10.9	1	SPN025	4	0	0	0
9/10/2019	Spencer Creek	--	10.9	1	SPN030	28	8	0	0
9/10/2019	Spencer Creek	--	12.5	2	SPN033	6	1	0	0
9/10/2019	Spencer Creek	--	12.5	2	SPN036	33	7	0	0
9/10/2019	Spencer Creek	--	12.5	NA	SPN001SC09	Not Surveyable			
9/10/2019	Spencer Creek	--	12.5	2	SPN037	38	2	0	0
9/10/2019	Spencer Creek	--	12.5	2	SPN038	11	4	0	0
9/10/2019	Spencer Creek	--	12.5	2	SPN001SC10	4	0	0	0
9/10/2019	Spencer Creek	--	12.5	1	SPN042	14	2	0	0
9/10/2019	Spencer Creek	--	13.9	1	SPN044	7	3	0	0
9/10/2019	Spencer Creek	--	13.9	1	SPN045	19	3	0	0
9/10/2019	Spencer Creek	--	13.9	1	SPN047	12	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/10/2019	Spencer Creek	--	13.9	1	SPN051	12	1	0	0
9/10/2019	Spencer Creek	--	12	2	SPN052	7	0	0	0
9/10/2019	Spencer Creek	--	12	2	SPN053	7	0	0	0
9/10/2019	Spencer Creek	--	12	2	SPN001SC11	Not Surveyable			
9/10/2019	Spencer Creek	--	12	2	SPN054	12	1	0	0
9/10/2019	Spencer Creek	--	12	2	SPN001SC12	5	0	0	0
9/11/2019	Spencer Creek	--	12	2	SPN057	11	0	0	0
9/11/2019	Spencer Creek	--	8.9	1	SPN059	9	0	0	0
9/11/2019	Spencer Creek	--	8.9	1	SPN060	3	0	0	0
9/11/2019	Spencer Creek	--	10	1	SPN062	18	0	0	0
9/11/2019	Spencer Creek	--	10	1	SPN002SC15	1	2	0	0
9/11/2019	Spencer Creek	--	11.9	1	SPN070	15	1	0	0
9/11/2019	Spencer Creek	--	11.9	2	SPN075	6	0	0	0
9/11/2019	Spencer Creek	--	11.9	2	SPN076	6	2	0	0
9/11/2019	Spencer Creek	--	11.9	1	SPN077	6	5	0	0
9/11/2019	Spencer Creek	--	11.9	2	SPN002SC16	12	1	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/11/2019	Spencer Creek	--	12.8	2	SPN081	13	6	0	0
9/11/2019	Spencer Creek	--	12.8	2	SPN082	1	2	0	0
9/11/2019	Spencer Creek	--	13.5	2	SPN086	16	3	0	0
9/11/2019	Spencer Creek	--	13.5	1	SPN087	2	0	0	0
9/11/2019	Spencer Creek	--	13.5	2	SPN089	4	1	0	0
9/11/2019	Spencer Creek	--	13.5	1	SPN090	18	12	0	0
9/11/2019	Spencer Creek	--	13.5	2	SPN091	21	14	1	0
9/11/2019	Spencer Creek	--	13.5	1	SPN092	7	4	0	0
9/11/2019	Spencer Creek	--	13.8	2	SPN094	12	9	0	0
9/11/2019	Spencer Creek	--	13.8	1	SPN098	4	2	0	0
9/11/2019	Spencer Creek	--	13.8	1	SPN099	5	1	0	0
9/11/2019	Spencer Creek	--	13.8	1	SPN100	3	1	0	0
9/11/2019	Spencer Creek	--	13.8	1	SPN101	16	15	0	0
9/11/2019	Spencer Creek	--	13.8	1	SPN104	4	0	0	0
9/11/2019	Spencer Creek	--	13.2	1	SPN001SC17	1	0	0	0
9/11/2019	Spencer Creek	--	13.2	1	SPN002SC17	20	2	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/11/2019	Spencer Creek	--	13.2	1	SPN003SC17	7	2	0	0
9/11/2019	Spencer Creek	--	13.2	1	SPN108	20	4	0	0
9/11/2019	Spencer Creek	--	13.2	1	SPN114	16	2	0	0
9/12/2019	Spencer Creek	--	10	1	SPN115	6	0	0	0
9/12/2019	Spencer Creek	--	10	2	SPN117	12	7	0	0
9/12/2019	Spencer Creek	--	10	2	SPN123L	12	2	0	0
9/12/2019	Spencer Creek	--	10	2	SPN124	6	1	0	0
9/12/2019	Spencer Creek	--	10	1	SPN126	19	5	0	0
9/12/2019	Spencer Creek	--	11.7	1	SPN128	8	1	0	0
9/12/2019	Spencer Creek	--	11.7	1	SPN131	29	9	0	0
9/12/2019	Spencer Creek	--	11.7	1	SPN135	5	3	0	0
9/12/2019	Spencer Creek	--	11.7	1	SPN136	3	5	0	0
9/12/2019	Spencer Creek	--	11.7	1	SPN138	4	6	0	0
9/12/2019	Spencer Creek	--	12.1	2	SPN140	6	1	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN142	8	2	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN144	23	3	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/12/2019	Spencer Creek	--	12.5	2	SPN145	7	3	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN147	7	5	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN152	14	2	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN156	15	6	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN157	13	2	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN162	3	0	0	0
9/12/2019	Spencer Creek	--	14.9	1	SPN163	3	3	0	0
9/9/2019	Spencer Creek	--	--	2	SPN001SC01	6	0	0	0
9/9/2019	Spencer Creek	--	--	2	SPN003SC01	27	0	0	0
9/9/2019	Spencer Creek	--	--	2	SPN004SC01	24	0	0	0
9/9/2019	Spencer Creek	--	--	2	SPN005SC01	25	1	0	0
9/9/2019	Spencer Creek	--	--	1	SPN001	16	0	0	0
9/9/2019	Spencer Creek	--	--	1	SPN003	17	0	0	0
9/9/2019	Spencer Creek	--	--	1	SPN004	3	1	0	0
9/9/2019	Spencer Creek	--	--	1	SPN005	27	0	0	0
9/9/2019	Spencer Creek	--	--	1	SPN002SC02	6	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/9/2019	Spencer Creek	--	13.8	1	SPN003SC02	15	1	0	0
9/9/2019	Spencer Creek	--	13.8	1	SPN004SC02	22	1	0	0
9/9/2019	Spencer Creek	--	13.8	1	SPN005SC02	25	8	0	0
9/9/2019	Spencer Creek	--	13.8	2	SPN007	12	1	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN008	16	1	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN009	12	6	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN001SC03	11	0	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN011	24	4	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN012	8	0	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN014	18	3	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN015	6	4	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN016	12	3	0	0
9/9/2019	Spencer Creek	--	15.7	2	SPN017	12	10	0	0
9/9/2019	Spencer Creek	--	16.3	2	SPN019	17	9	0	0
9/9/2019	Spencer Creek	--	16.3	1	SPN023	4	1	0	0
9/9/2019	Spencer Creek	--	16.3	1	SPN024	16	3	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/10/2019	Spencer Creek	--	10.9	2	SPN001SC06	14	2	0	0
9/10/2019	Spencer Creek	--	10.9	2	SPN001SC07	12	1	0	0
9/10/2019	Spencer Creek	--	10.9	2	SPN002SC08	7	2	0	0
9/10/2019	Spencer Creek	--	10.9	2	SPN003SC08	2	2	0	0
9/10/2019	Spencer Creek	--	10.9	2	SPN004SC08	7	0	0	0
9/10/2019	Spencer Creek	--	10.9	2	SPN025	13	0	0	0
9/10/2019	Spencer Creek	--	10.9	2	SPN030	48	7	0	0
9/10/2019	Spencer Creek	--	12.5	1	SPN033	11	0	0	0
9/10/2019	Spencer Creek	--	12.5	1	SPN036	21	9	0	0
9/10/2019	Spencer Creek	--	12.5	1	SPN001SC09	Not Surveyable			
9/10/2019	Spencer Creek	--	12.5	1	SPN037	21	8	0	0
9/10/2019	Spencer Creek	--	12.5	1	SPN038	10	7	0	0
9/10/2019	Spencer Creek	--	12.5	1	SPN001SC10	12	0	0	0
9/10/2019	Spencer Creek	--	12.5	2	SPN042	10	0	0	0
9/10/2019	Spencer Creek	--	13.9	2	SPN044	6	2	0	0
9/10/2019	Spencer Creek	--	13.9	2	SPN045	12	10	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/10/2019	Spencer Creek	--	13.9	2	SPN047	6	2	0	0
9/10/2019	Spencer Creek	--	13.9	2	SPN051	16	5	0	0
9/10/2019	Spencer Creek	--	12	1	SPN052	7	5	0	0
9/10/2019	Spencer Creek	--	12	1	SPN053	6	5	0	0
9/10/2019	Spencer Creek	--	12	1	SPN001SC11	9	2	0	0
9/10/2019	Spencer Creek	--	12	1	SPN054	6	1	0	0
9/10/2019	Spencer Creek	--	12	2	SPN001SC12	6	0	0	0
9/11/2019	Spencer Creek	--	12	1	SPN057	6	1	0	0
9/11/2019	Spencer Creek	--	8.9	2	SPN059	4	0	0	0
9/11/2019	Spencer Creek	--	8.9	2	SPN060	6	1	0	0
9/11/2019	Spencer Creek	--	10	2	SPN062	4	2	0	0
9/11/2019	Spencer Creek	--	10	2	SPN002SC15	2	0	0	0
9/11/2019	Spencer Creek	--	11.9	2	SPN070	4	5	0	0
9/11/2019	Spencer Creek	--	11.9	1	SPN075	13	1	0	0
9/11/2019	Spencer Creek	--	11.9	1	SPN076	2	1	0	0
9/11/2019	Spencer Creek	--	11.9	2	SPN077	8	13	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/11/2019	Spencer Creek	--	11.9	1	SPN002SC16	12	0	0	0
9/11/2019	Spencer Creek	--	12.8	1	SPN081	14	5	0	0
9/11/2019	Spencer Creek	--	12.8	1	SPN082	5	2	0	0
9/11/2019	Spencer Creek	--	13.5	1	SPN086	11	4	0	0
9/11/2019	Spencer Creek	--	13.5	2	SPN087	3	0	0	0
9/11/2019	Spencer Creek	--	13.5	1	SPN089	8	6	0	0
9/11/2019	Spencer Creek	--	13.5	2	SPN090	10	8	0	0
9/11/2019	Spencer Creek	--	13.5	1	SPN091	17	15	0	0
9/11/2019	Spencer Creek	--	13.5	2	SPN092	6	5	0	0
9/11/2019	Spencer Creek	--	13.8	1	SPN094	6	8	0	0
9/11/2019	Spencer Creek	--	13.8	2	SPN098	3	2	0	0
9/11/2019	Spencer Creek	--	13.8	2	SPN099	8	3	0	0
9/11/2019	Spencer Creek	--	13.8	2	SPN100	6	3	0	0
9/11/2019	Spencer Creek	--	13.8	2	SPN101	15	11	0	0
9/11/2019	Spencer Creek	--	13.8	2	SPN104	3	1	0	0
9/11/2019	Spencer Creek	--	13.2	2	SPN001SC17	3	0	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/11/2019	Spencer Creek	--	13.2	2	SPN002SC17	13	2	0	0
9/11/2019	Spencer Creek	--	13.2	2	SPN003SC17	14	2	0	0
9/11/2019	Spencer Creek	--	13.2	2	SPN108	16	10	0	0
9/11/2019	Spencer Creek	--	13.2	2	SPN114	18	2	0	0
9/12/2019	Spencer Creek	--	10	2	SPN115	21	5	0	0
9/12/2019	Spencer Creek	--	10	1	SPN117	6	7	0	0
9/12/2019	Spencer Creek	--	10	1	SPN123L	5	2	0	0
9/12/2019	Spencer Creek	--	10	1	SPN124	8	2	0	0
9/12/2019	Spencer Creek	--	10	2	SPN126	21	4	0	0
9/12/2019	Spencer Creek	--	11.7	2	SPN128	11	4	0	0
9/12/2019	Spencer Creek	--	11.7	2	SPN131	24	12	0	0
9/12/2019	Spencer Creek	--	11.7	2	SPN135	7	0	0	0
9/12/2019	Spencer Creek	--	11.7	2	SPN136	3	4	0	0
9/12/2019	Spencer Creek	--	11.7	2	SPN138	8	3	0	0
9/12/2019	Spencer Creek	--	12.1	1	SPN140	4	2	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN142	12	4	0	0

Date	Tributary	Weather	Water Temperature (°C)	Pass #	Habitat Unit	Age 0+ Trout	Age 1+ Trout	Lamprey	Unidentified Juvenile Salmonid
9/12/2019	Spencer Creek	--	12.5	1	SPN144	14	2	0	0
9/12/2019	Spencer Creek	--	12.5	1	SPN145	9	9	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN147	18	4	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN152	16	1	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN156	25	2	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN157	17	2	0	0
9/12/2019	Spencer Creek	--	12.5	2	SPN162	4	0	0	0
9/12/2019	Spencer Creek	--	14.9	2	SPN163	12	3	0	0

APPENDIX C

Appendix C: Depletion estimates of resident fishes from electrofishing surveys conducted in 2019 in Jenny, Fall, and Shovel creeks using the “Zippin” method.

Within each stream reach, I selected a subset of snorkeled habitat units near the stream mouths for surveys in the late summer of 2019. Electrofishing techniques followed the Moran-Zippen equal effort sampling methods for electrofishing as described by Hankin and Reeves (1988). Electrofishing sampling consisted of a team of a minimum of three individuals. I used block nets at the upstream and downstream extents of the selected habitat unit to prevent fish movements. I used one electrofishing unit to make successive passes of a selected habitat unit until the number of rainbow trout reached zero or less than twenty percent of the number removed in the previous pass. A small laundry hamper located instream and outside of the sampled unit stored fish from each pass in-stream. I kept the storage hamper in a section of stream with high water exchange and shade to keep water temperatures below 18 degrees Celsius for the duration of the sampling effort. I identified, counted and recorded the fish from each pass, binning age 0+ and age 1+ rainbow trout into two separate counts. I measured lengths and weights of rainbow trout using Alka-Seltzer tablets as a mild anesthetic.

Table C1. Depletion estimates for age class 0+ RBT in Fall Creek.

Habitat Unit	FALL002	FALL001SC001	FALL002SC001
N_0	11	23	4
Standard Error N_0	0.58	10.47	0.21
95% Confidence Interval N_0 (%)	9.87 – 12.13	2.49 – 43.51	3.60 – 4.40
p	0.73	0.25	0.80
Standard Error p	0.14	0.18	0.21
95% Confidence Interval p (%)	0.45 – 1.00	0.00 – 0.59	0.40 – 1.00

Table C2. Depletion estimates for age class 1+ RBT in Fall Creek.

Habitat Unit	FALL002	FALL001SC001	FALL002SC001
N_0	8	4	1
Standard Error N_0	0.51	0.26	0
95% Confidence Interval N_0 (%)	7.00 – 9.00	3.49 – 4.51	1.00 – 1.00
p	0.73	0.67	1.00
Standard Error p	0.17	0.23	--
95% Confidence Interval p (%)	0.39 – 1.00	0.22 – 1.00	--

Table C3. Depletion estimates for Marbled Sculpin in Fall Creek.

Habitat Unit	FALL002	FALL001SC001	FALL002SC001
N_0	1	1	--
Standard Error N_0	0.73	0	--
95% Confidence Interval N_0 (%)	0.00 – 2.44	1.00 – 1.00	--
p	0.50	1.00	--
Standard Error p	0.73	--	--
95% Confidence Interval p (%)	0.00 – 1.00	--	--

Table C4. Depletion estimates for age class 0+ RBT in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	22	16
Standard Error N_0	2.72	1.88
95% Confidence Interval N_0 (%)	16.67 – 27.33	12.32 – 19.68
p	0.54	0.58
Standard Error p	0.15	0.16
95% Confidence Interval p (%)	0.26 – 0.83	0.26 – 0.89

Table C5. Depletion estimates for age class 1+ RBT in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	25	12
Standard Error N_0	2.78	0.94
95% Confidence Interval N_0 (%)	19.54 – 30.46	10.16 – 13.85
p	0.55	0.67
Standard Error p	0.14	0.16
95% Confidence Interval p (%)	0.28 – 0.81	0.36 – 0.97

Table C6. Depletion estimates for Klamath River Lamprey in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	5	6
Standard Error N_0	3.72	15.68
95% Confidence Interval N_0 (%)	4.00 – 12.29	2.00 – 36.73
p	0.36	0.19
Standard Error p	0.43	0.60
95% Confidence Interval p (%)	0.00 – 1.00	0.00 – 1.00

Table C7. Depletion estimates for Marbled Sculpin in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	15	28
Standard Error N_0	1.75	3.66
95% Confidence Interval N_0 (%)	11.57 – 18.43	20.83 – 35.17
p	0.58	0.51
Standard Error *p*	0.16	0.14
95% Confidence Interval *p* (%)	0.26 – 0.90	0.24 – 0.78

Table C8. Depletion estimates for Speckled Dace in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	16	4
Standard Error N_0	0.27	0969
95% Confidence Interval N_0 (%)	15.46 – 16.54	2.10 – 5.90
p	0.84	0.57
Standard Error *p*	0.09	0.32
95% Confidence Interval *p* (%)	0.66 – 1.00	0.00 – 1.00

Table C9. Depletion estimates for Brown Bullhead in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	3	--
Standard Error N_0	6.41	--
95% Confidence Interval N_0 (%)	0.00 – 15.56	--
p	0.25	--
Standard Error *p*	0.71	--
95% Confidence Interval *p* (%)	0.00 – 1.00	--

Table C10. Depletion estimates for Green Sunfish in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	1	--
Standard Error N_0	0.00	--
95% Confidence Interval N_0 (%)	1.00 – 1.00	--
p	1.00	--
Standard Error *p*	--	--
95% Confidence Interval *p* (%)	--	--

Table C11. Depletion estimates for Klamath River Sucker in Jenny Creek.

Habitat Unit	JEN001	JEN002
N_0	1	2
Standard Error N_0	2.03	0.38
95% Confidence Interval N_0 (%)	1.00 – 4.97	1.25 – 2.75
p	0.33	0.67
Standard Error p	1.01	0.38
95% Confidence Interval p (%)	0.00 – 1.00	0.00 – 1.00

Table C12. Depletion estimates for age class 0+ RBT in Shovel Creek.

Habitat Unit	SHVL022	SHVL023	SHVL027	SHVL029	SHVL031	SHVL032	SHVL033
N_0	101	107	26	53	49	40	62
Standard Error N_0	21.29	3.34	2.88	4.17	5.13	2.19	3.27
95% Confidence Interval N_0 (%)	59.27 – 142.72	100.45 – 113.55	20.37 – 31.63	44.83 – 61.17	38.94 – 59.06	35.72 – 44.28	55.60 – 68.40
p	0.25	0.53	0.55	0.44	0.40	0.52	0.49
Standard Error p	0.08	0.05	0.13	0.08	0.09	0.09	0.07
95% Confidence Interval p (%)	0.09 – 0.42	0.43 – 0.63	0.29 – 0.81	0.28 – 0.60	0.22 – 0.58	0.35 – 0.69	0.35 – 0.63

Table C13. Depletion estimates for age class 1+ RBT in Shovel Creek.

Habitat Unit	SHVL022	SHVL023	SHVL027	SHVL029	SHVL031	SHVL032	SHVL033
N_0	4	7	1	3	4	5	1
Standard Error N_0	0.26	2.69	0.734	0.68	4.36	0.62	0.00
95% Confidence Interval N_0 (%)	3.49 – 4.51	1.73 – 12.27	1.00 – 2.44	1.67 – 4.34	2.00 – 12.55	3.79 – 6.21	1.00 – 1.00
p	0.67	0.35	0.50	0.50	0.25	0.56	1.00
Standard Error p	0.23	0.26	0.734	0.32	0.42	0.23	--
95% Confidence Interval p (%)	0.22 – 1.00	0.00 – 0.86	0.00 – 1.00	0.00 – 1.00	0.00 – 1.00	0.10 – 1.00	--

Table C14. Depletion estimates for Marbled Sculpin in Shovel Creek.

Habitat Unit	SHVL022	SHVL023	SHVL027	SHVL029	SHVL031	SHVL032	SHVL033
N_0	--	--	--	1	--	--	3
Standard Error N_0	--	--	--	0.00	--	--	0.36
95% Confidence Interval N_0 (%)	--	--	--	1.00 – 1.00	--	--	2.30 – 3.70
p	--	--	--	1.00	--	--	0.60
Standard Error p	--	--	--	--	--	--	0.28
95% Confidence Interval p (%)	--	--	--	--	--	--	0.04 – 1.00

Table C15. Depletion estimates for Klamath River Lamprey in Shovel Creek.

Habitat Unit	SHVL022	SHVL023	SHVL027	SHVL029	SHVL031	SHVL032	SHVL033
N_0	2	--	--	--	--	--	--
Standard Error N_0	0.56	--	--	--	--	--	--
95% Confidence Interval N_0 (%)	0.91 – 3.09	--	--	--	--	--	--
p	0.50	--	--	--	--	--	--
Standard Error p	0.39	--	--	--	--	--	--
95% Confidence Interval p (%)	0.00 – 1.00	--	--	--	--	--	--

APPENDIX D

Appendix D: Habitat type composition of tributaries to the Klamath River above IGD.

Table D1. Habitat types Scotch Creek based on surveys conducted in the summer of 2019.

Habitat Type	Low gradient riffles	High gradient riffles	Glides	Runs	Dam-pools	Scour-pools	Total
Count	16	1	6	1	5	13	42
Mean Depth (m)	0.09	--	0.15	0.15	0.29	0.88	

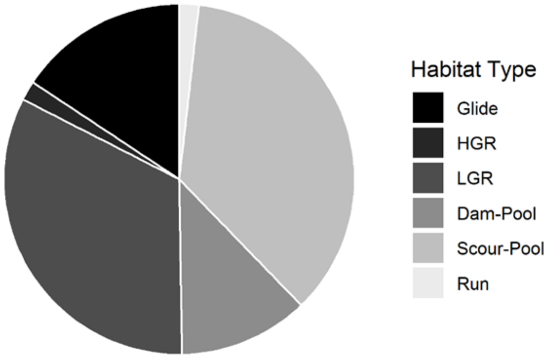


Figure D1. Habitat type composition by surface area for Scotch Creek based on surveys conducted in the summer of 2019.

Table D2. Habitat types of Jenny Creek based on surveys conducted in the summer of 2018.

Habitat Type	Low gradient riffles	High gradient riffles	Glides	Runs	Dam-pools	Scour-pools	Total
Count	17	31	0	40	4	41	133
Mean Depth (m)	0.20	0.19	--	0.27	0.45	0.39	

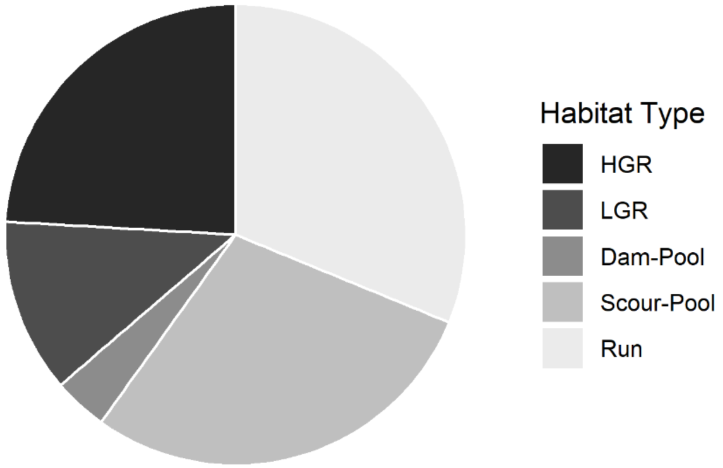


Figure D2. Habitat type composition by surface area for Jenny Creek based on surveys conducted in the summer of 2018.

Table D3. Habitat types of Fall Creek based on surveys conducted in the summer of 2018.

Habitat Type	Low gradient riffles	High gradient riffles	Glides	Runs	Dam-pools	Scour-pools	Total
Count	20	24	0	36	0	7	87
Mean Depth (m)	0.19	0.20	--	0.29	--	0.7	

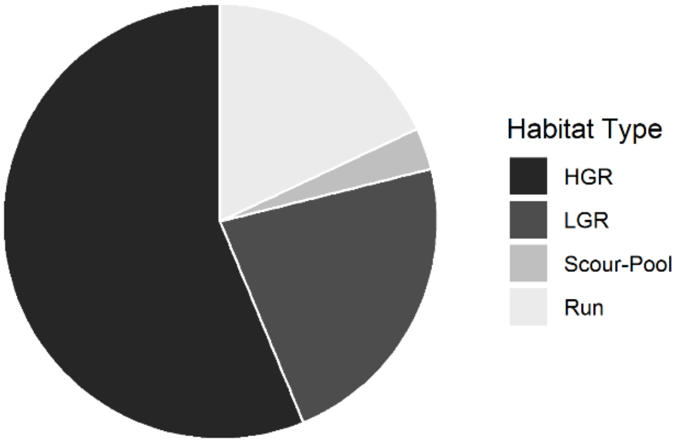


Figure D3. Habitat type composition by surface area for Fall Creek based on surveys conducted in the summer of 2018.

Table D4. Habitat types of Shovel Creek based on surveys conducted in the summer of 2018.

Habitat Type	Low gradient riffles	High gradient riffles	Glides	Runs	Dam-pools	Scour-pools	Total
Count	36	24	2	24	4	37	127
Mean Depth (m)	0.12	--	0.14	0.19	0.19	0.22	

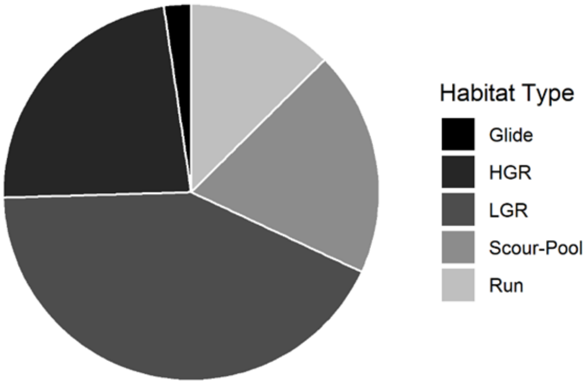


Figure D4. Habitat type composition by surface area for Shovel Creek based on surveys conducted in the summer of 2018.

Table D5. Habitat types of Spencer Creek based on surveys conducted in the summer of 2019.

Habitat Type	Low gradient riffles	High gradient riffles	Glides	Runs	Dam-pools	Scour-pools	Total
Count	70	16	74	6	17	23	203
Mean Depth (m)	0.22	0.31	0.29	0.35	0.49	0.50	

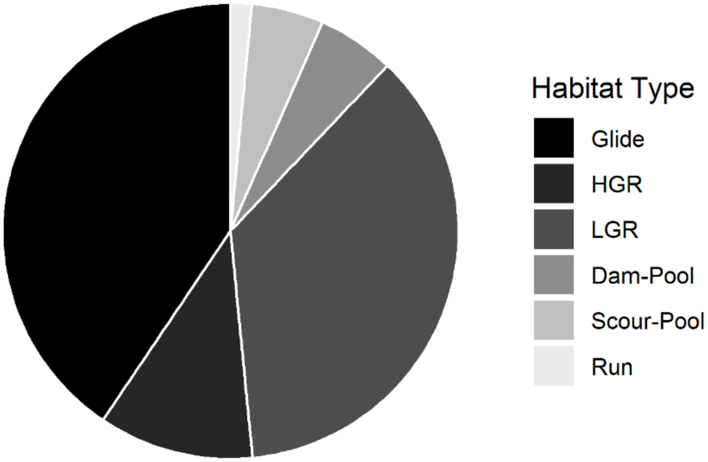


Figure D5. Habitat type composition by surface area for Spencer Creek based on surveys conducted in the summer of 2019.

APPENDIX E

Appendix E: General habitat structure of streams above IGD and variation with upstream distance from surveys conducted in 2018 and 2019.

Table E1. Habitat structure of study streams based on surveys conducted in the summers of 2018 and 2019.

Stream	Scotch Creek	Jenny Creek	Fall Creek	Shovel Creek	Spencer Creek
Length surveyed (m)	581	1496	1155	1821	3238
Available habitat surveyed (%)	58.1	51.6	64.2	38.7	15.8
Mean gradient of available habitat (%)	2.7	3.4	3.3	3.3	1.6
Mean August water temperature (°C)	17.6	18.8	13.0	12.1	15.9
Mean wetted width (m)	3.0	7.7	4.5	5.6	4.9
Beaver dam structures	0	0	0	0	3

Table E2. Large woody debris features in study streams based on habitat surveys done in the summers of 2018 and 2019.

Stream	Scotch Creek	Jenny Creek	Fall Creek	Shovel Creek	Spencer Creek
LWD count	30	41	78	48	427
LWD area (m^2)	11.8	45	55.7	26	594
LWD (pieces / linear stream km)	51.6	27.4	67.5	26.3	131.9

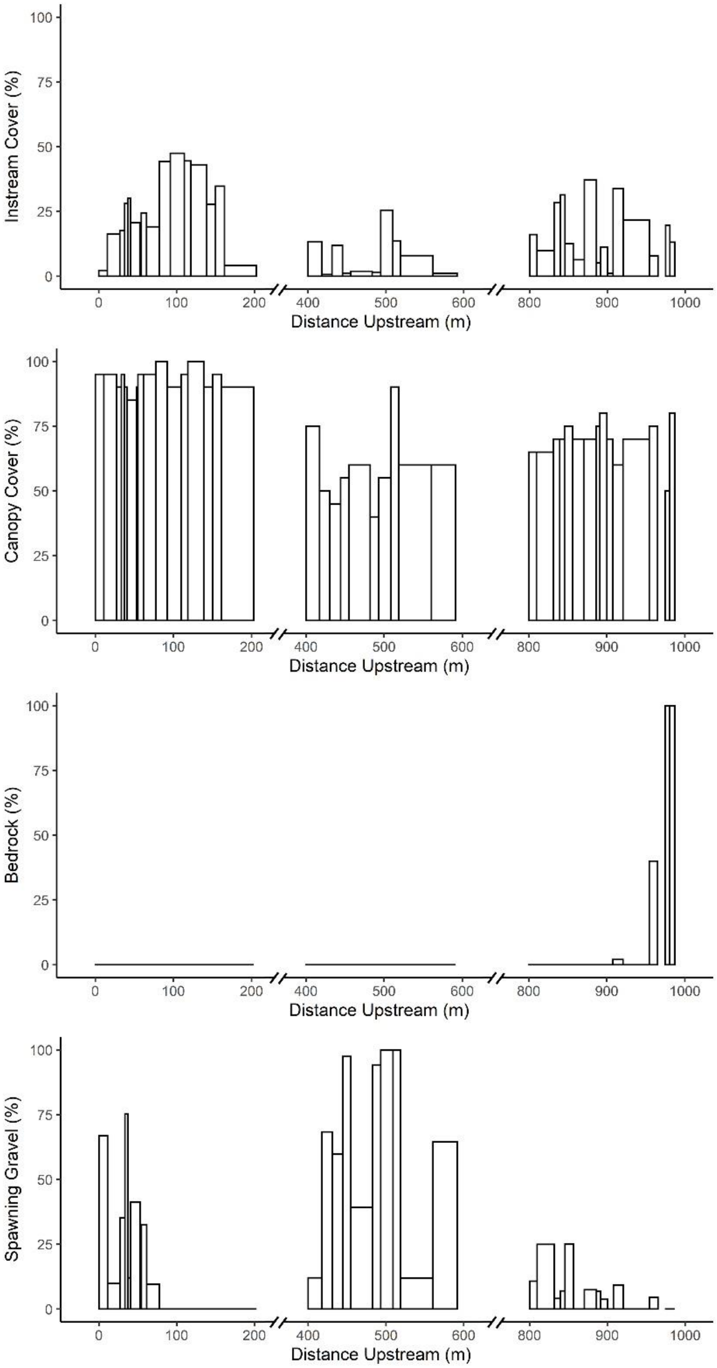


Figure E1. Physical habitat characteristics (percent instream cover, percent canopy cover, percent bedrock, and percent spawning gravel from top to bottom) of Scotch Creek in relation to distance upstream from 2018 surveys. Box width specifies the habitat unit length and overlapping boxes indicate side-channel(s). I did not survey habitat units with missing boxes. I did not survey omitted lengths delineated by "-/ /-".

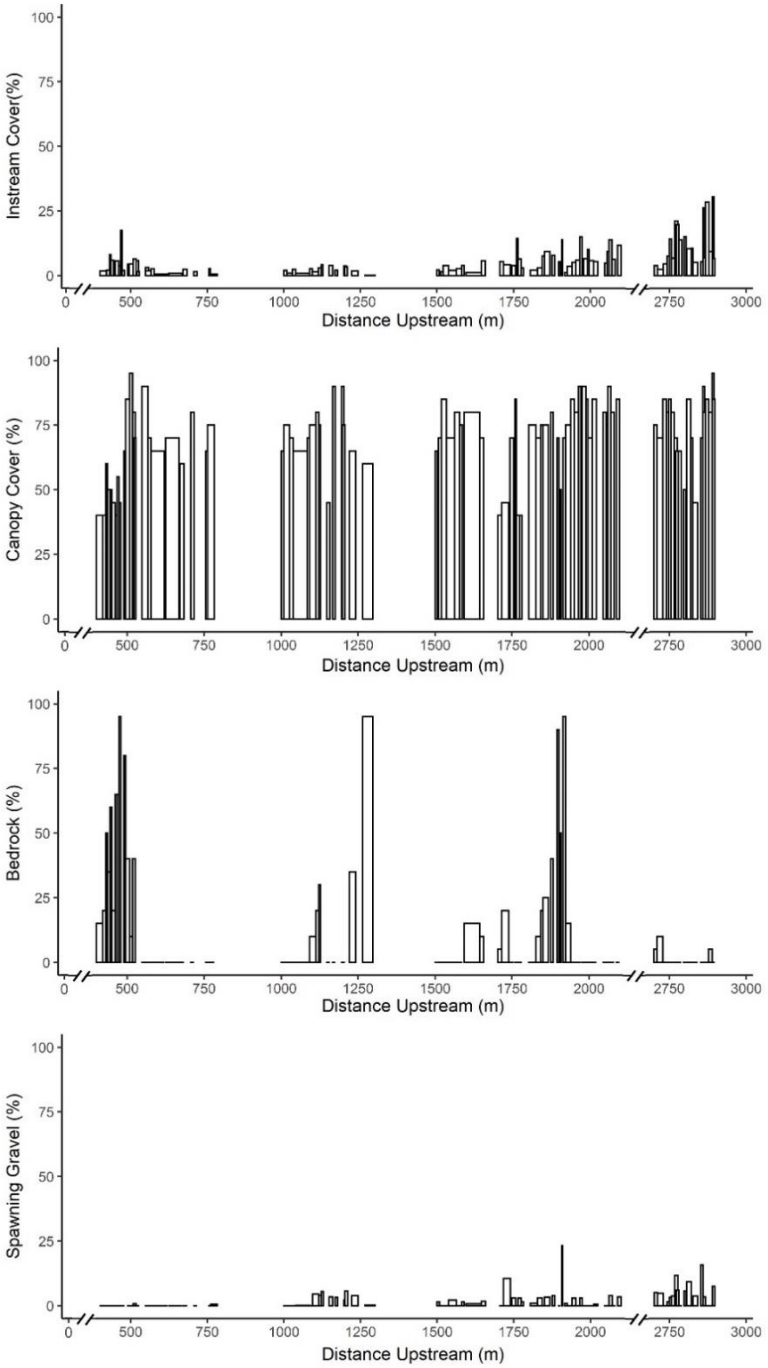


Figure E2. Physical habitat characteristics (percent instream cover, percent canopy cover, percent bedrock, and percent spawning gravel from top to bottom) of Jenny Creek in relation to distance upstream from 2018 surveys. Box width specifies the habitat unit length and overlapping boxes indicate side-channel(s). I did not survey habitat units with missing boxes. I did not survey omitted lengths delineated by "-/ /-".

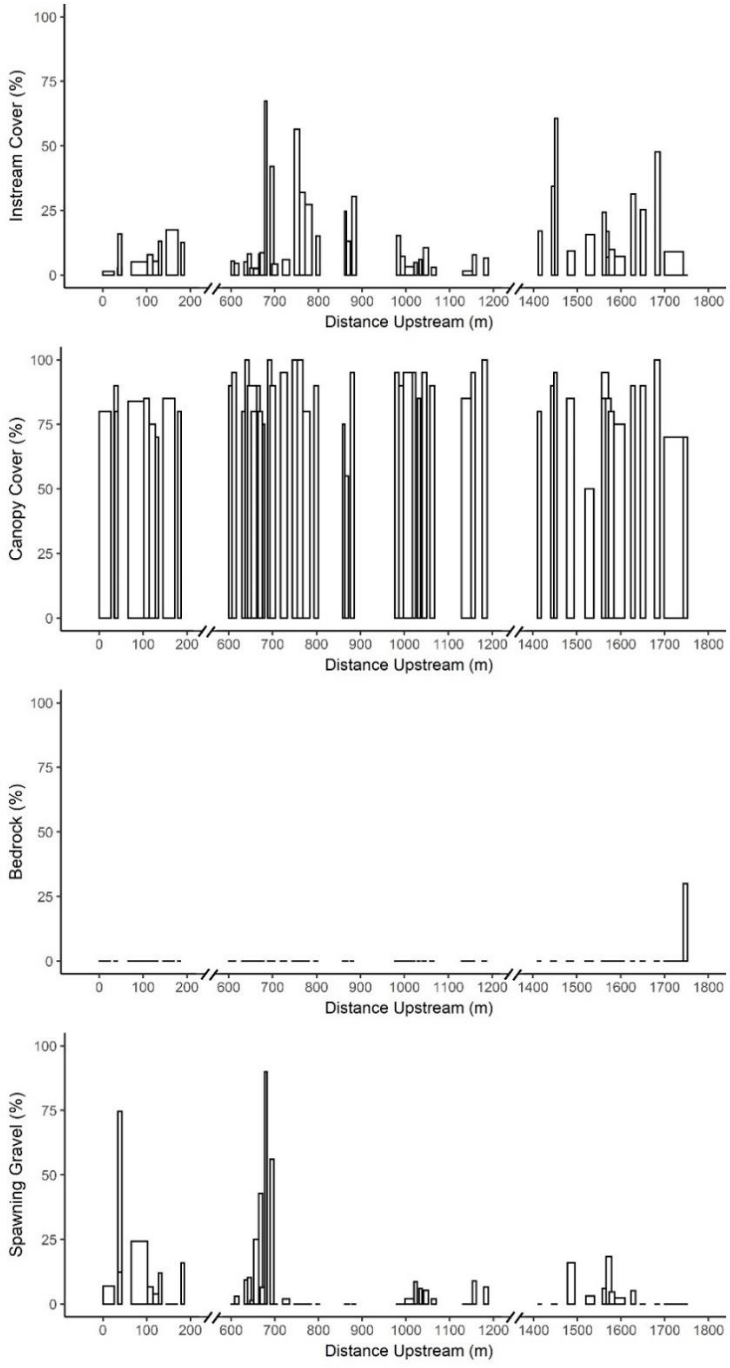


Figure E3. Physical habitat characteristics (percent instream cover, percent canopy cover, percent bedrock, and percent spawning gravel from top to bottom) of Fall Creek in relation to distance upstream from 2018 surveys. Box width specifies the habitat unit length and overlapping boxes indicate side-channel(s). I did not survey habitat units with missing boxes. I did not survey omitted lengths delineated by "-/ /-".

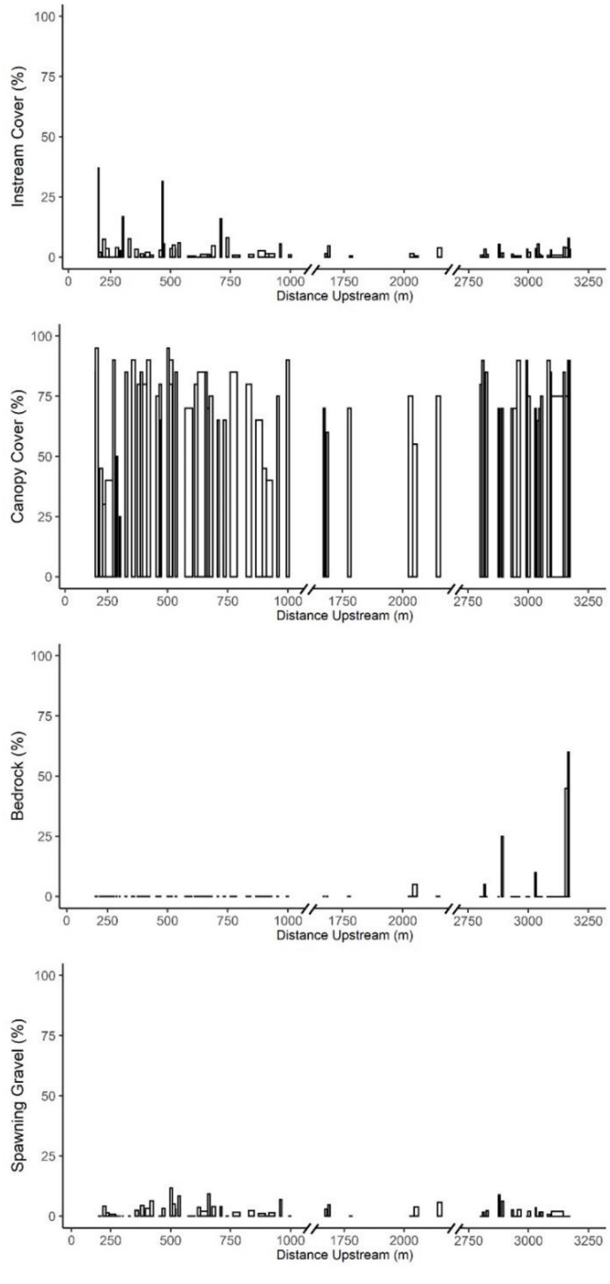


Figure E4. Physical habitat characteristics (percent instream cover, percent canopy cover, percent bedrock, and percent spawning gravel from top to bottom) of Shovel Creek in relation to distance upstream from 2018 surveys. Box width specifies the habitat unit length and overlapping boxes indicate side-channel(s). I did not survey habitat units with missing boxes. I did not survey omitted lengths delineated by "-/ /-".

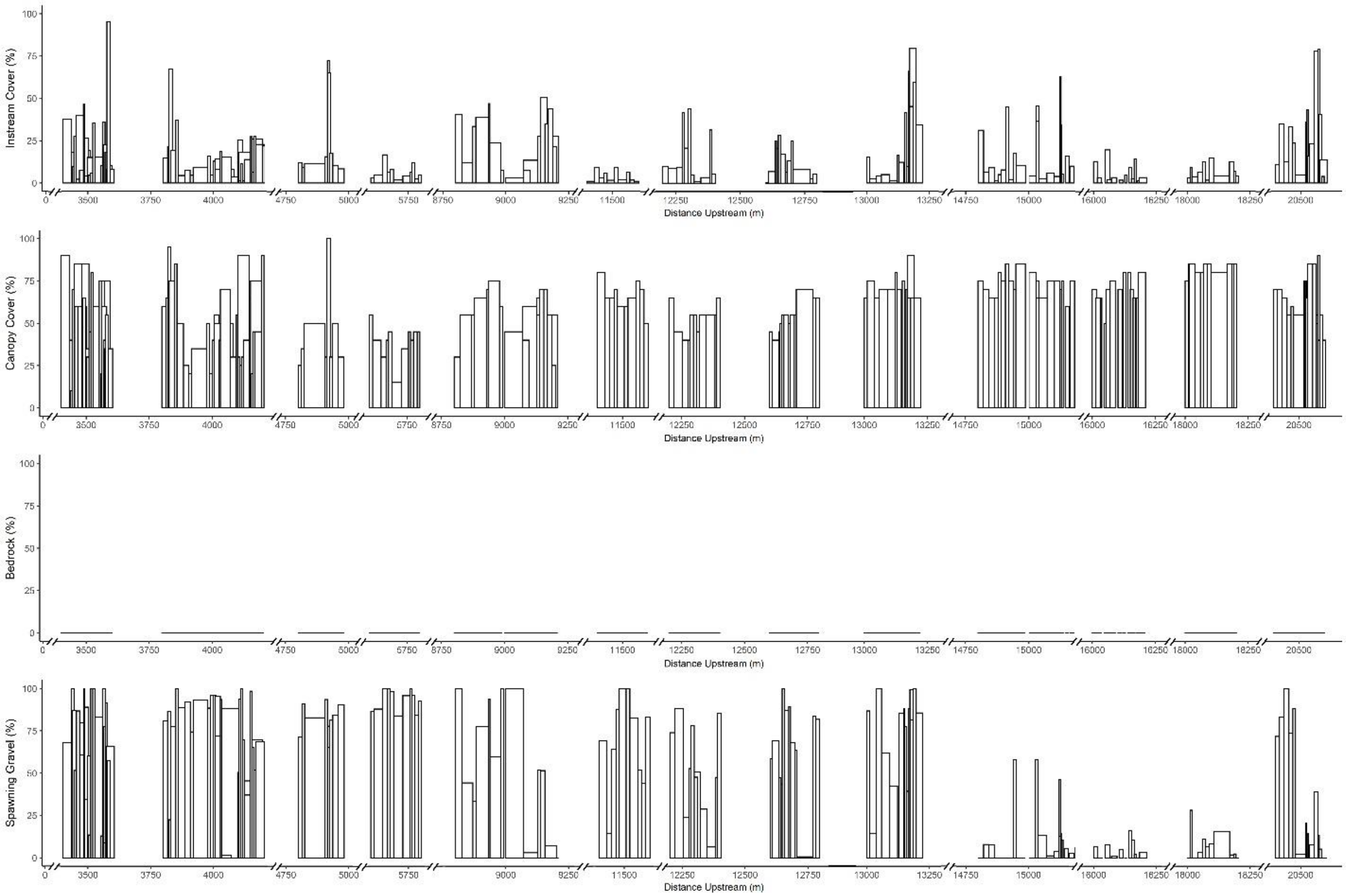


Figure E5. Physical habitat characteristics (percent instream cover, percent canopy cover, percent bedrock, and percent spawning gravel from top to bottom) of Spencer Creek in relation to distance upstream from 2019 surveys. Box width specifies the habitat unit length and overlapping boxes indicate side-channel(s). I did not survey habitat units with missing boxes. I did not survey omitted lengths delineated by "-/ /-".

APPENDIX F

Appendix F: Photographs of available habitat in tributaries above IGD in the summers of 2018 and 2019.

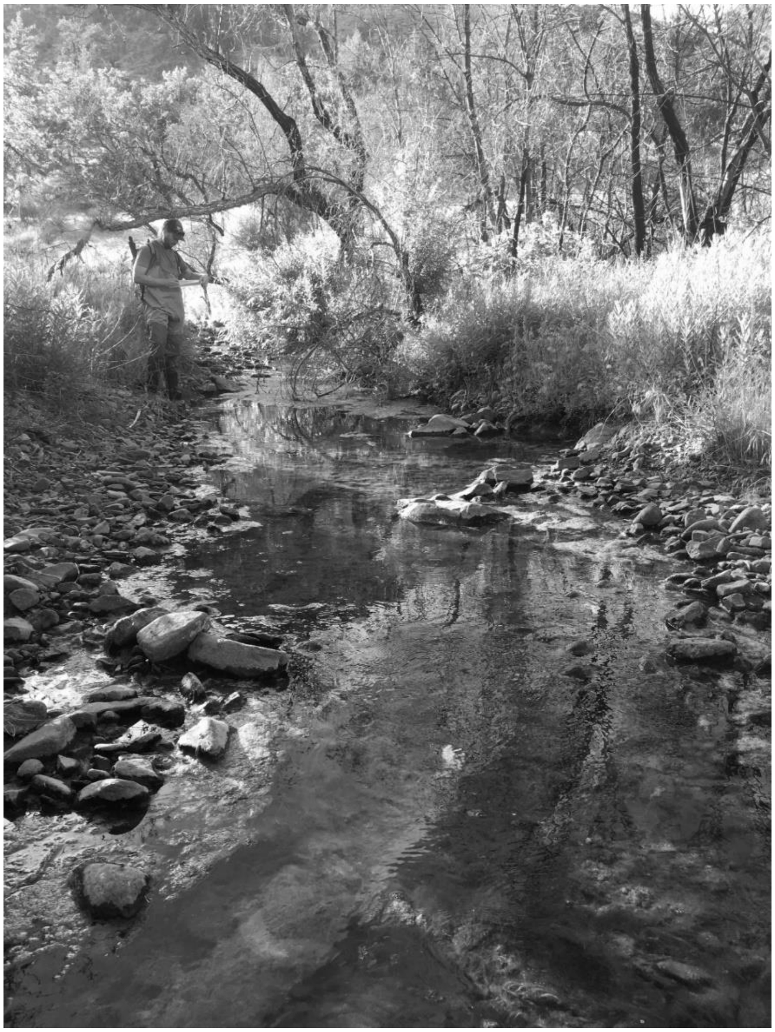


Figure F1. An example of spawning gravels pervasive throughout Scotch Creek.

Figure F2. Habitat in Shovel Creek.

Figure F3. Glide habitat feature with medium to small cobbles as seen throughout Spencer Creek.

Figure F4. A beaver dam structure in the “dismal swamp” region of Spencer Creek.

Figure F5. Large quantities of LWD in the middle reaches of Spencer Creek.

Figure F6. Open meadows suffering from cattle de-vegetation in the lower reaches of Spencer Creek.

Figure F7. The “dismal swamp” region of Spencer Creek contained a large amount of canopy coverage.