2015

Smallmouth bass abundance and diet composition in the upper Spokane River

Michael Taylor McCroskey
Eastern Washington University

Recommended Citation

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SMALLMOUTH BASS ABUNDANCE AND DIET COMPOSITION IN THE UPPER SPOKANE RIVER

A Thesis
Presented To
Eastern Washington University
Cheney, Washington

In Partial Fulfillment of the Requirements
For the Degree
Master of Science

By
Michael Taylor McCroskey
Fall 2015

THESIS OF TAYLOR McCROSKEY APPROVED BY

Dr. Paul Spruell, Graduate Study Professor Date

Dr. Camille McNeely, Graduate Study Committee Date

Dr. Stacy Warren, Graduate Study Committee Date

MASTERS THESIS

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ABSTRACT

I conducted a three month study, between June and August, in 2015 of Redband Trout (*Oncorhynchus mykiss* var. *gairdneri*) and Smallmouth Bass (*Micropterus dolomieu*) in the upper Spokane River in Washington, from the border between Washington and Idaho (rkm 154.5) to Harvard Road (rkm 149.2). The primary goals of the project were to: (1) determine the abundance and density of Redband Trout and Smallmouth Bass in the Starr Road area, as well as two reference sites, prior to possible habitat manipulation, (2) estimate the Smallmouth Bass population and density between the Washington/Idaho Stateline and Harvard Road, and (3) determine the rate of piscivory on Redband Trout by Smallmouth Bass.

Day and night snorkel surveys were conducted to determine abundance and density at the Starr Road experimental site, and two additional references sites. Only two adult and three juvenile Redband Trout were at any of the sites during the study, therefore no statistical testing was done. There were significantly more Smallmouth Bass were observed at Starr Road (n=2692) than either reference site 1 (n=864) and site 3 (n=901) ($p = < 0.001$, 95% C.I. = 36.002/38.828).

The Smallmouth Bass population between the Washington/Idaho Stateline and Harvard Road was estimated by mark/recapture techniques. Fish, collected by raft electrofishing and angling, ≥ 150mm were tagged with a Floy tag and fish ≤ 150mm were tagged with elastomer. Fish were also given right pelvic fin clip if captured by angling and a left pelvic fin clip if captured by electroshocking. I used an open population model POPAN in the mark program to conduct estimates for both Smallmouth Bass ≥ 150mm TL and Smallmouth Bass TL and ≥ 200mm TL. Populations estimates (± SE; 95% CI; AIC value) were 1,645 (SE=287; 95% C.I. =1,171-2,310, AIC=429) Smallmouth Bass ≥ 150mm and 1,307 (SE = 218; 95% C.I. = 945-1807, AIC=402) Smallmouth Bass ≥ 200mm TL. Density of Smallmouth Bass ≥ 150mm TL and ≥ 200mm TL were 284 fish/km and 225 fish/km, respectively. In a previous study conducted by the Washington Department of Fish and Wildlife in (2009), the Smallmouth Bass population ≥ 200mm TL (± 95% CI) between the Stateline, of Washington and Idaho, to McMillian

Road was estimated at 902 (524-1691) and had a density of 100 fish/km. The density of Smallmouth Bass ≥ 200mm TL increased 125 percent between 2009 and 2015.

A diet survey was conducted to determine the amount of predation occurring on Redband Trout by Smallmouth Bass. No predation of Redband Trout by Smallmouth Bass was observed during the study, though only 5 young-of-the-year Redband Trout were seen during the entirety of the study. Smallmouth Bass in the study area consumed substantial numbers of non-salmonid fish, which comprised 33 percent of their diet by weight.

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ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Paul Spruell of Eastern Washington University, for the opportunity to become one of his graduate students and all the help with my project, as well as thesis. I would especially like to thank him in helping me to better my abilities, knowledge, and skill in my education career in the Masters of Science program. For allowing me to conduct the project for the Washington Department of Fish and Wildlife (WDFW), as well as helping to plan, conduct, and give support as needed, I would like to thank Charles D. Lee of the WDFW. I would like to thank Dr. Peggy O'Connell, the Biology Department chair, for all her help and guidance in helping me to get through my graduate career. I would like to thank Dr. Camille McNeely, one of my committee members, for all the extra support and finesse in the way my graduate studies were handled. I would like to thank my other graduate committee member, Dr. Stacy Warren, for all the help in geographic information systems and the help with making maps for my thesis. I would also like to acknowledge Dr. Allan Scholz, for all his help and guidance in a variety of data analysis, edits to my thesis, and all the questions he answered during my graduate career. Another person's help that was absolutely essential during the statistical analysis portion of my working with, and analyzing, my data was Dr. Krizstian Magori. I would also like to thank Bill Abrahamse, the president of the Spokane Falls Chapter of Trout Unlimited, for his help and involvement in working with the university to ensure proper funding and handling of the project.

I would like to acknowledge all those in the Eastern Washington University's Fisheries Research Center that spent time working on my project: Derek Entz, Sam Gunselman, Tyler Janasz, Jessica Walston, Shawna Warehime, Bryan Witte.

I would like to thank the Spokane Falls Chapter of Trout Unlimited, Silverbow Fly Shop, and Clearwater Fly Casters for providing the research funding for my project. Without their gracious financial help, I would not been able to conduct the research for my project. I would also like to thank Jason O'Connor, of the Kalispell Tribe of Indians fisheries department, for allowing me to use the raft electrofisher. I would also like to thank those that came out to help angle on August, 26, 2015, which included: Spokane

RiverKeeper, members of the Spokane Falls Chapter of Trout Unlimited, Rich Landers of the Spokesman Review, Fay Mills, Michael McCroskey, and Ryan Bailey.

Introduction

Throughout the western United States, the decline and extinction of native fish populations have been attributed to the introduction of non-native species (Wydoski and Bennett 1981; Moyle et al. 1986; Miller et al. 1989; Zimmerman 1999). While some invasions of exotic species have had no discernable impact on native species, others have had disastrous effects that have caused extinctions and altered entire ecosystems (Spencer et al. 1991; Lodge 1993; Vitousek et al. 1996; Strayer et al. 1999; Vander Zanden et al. 2004). How introduced fishes interact with, reduce, or eliminate native species is often unknown, but some factors may include: competition, predation, habitat alteration, genetic effects, and disease transmission (Moyle et al. 1986; Allendorf 1991; Zimmerman 1999). The intentional or unintentional, introduction of most fish has had negative effects on the native fishes and the ecosystem through predation (Allendorf 1991). Introduced species can alter the habitat selection and prey availability of native species through competition for prey items, as well as prey on native species themselves (Crowder 1980, He and Kitchell 1990, Weidel et al. 2000). The effects of predation are wide spread, not only within the predator/prey relationship but also throughout the food web. Prey use a number of behavioral traits to escape predation (Endler 1986; Carter et al. 2010), whereas predators must determine where, when, and how to capture prey (Dill 1983, Carter et al 2010). It is unpredictable what consequences introductions of non-native species will have when they persist alongside native species (Zimmerman 1999).

In the Pacific Northwest (PNW), the most common introduced fishes are native to the shallow, warm waters of the eastern United States (Bonar et al. 2005). Throughout the late 19th and early 20th centuries in western United States, the U. S. Fish Commission and European settlers stocked lakes, ponds, and rivers with a variety of non-native species (Lampman 1946; Wydoski and Whitney 1979; Bonar et al. 2005), including: centrarchids, ictalurids, percids, and salmonids. Today, littoral predators continue to expand their ranges by unauthorized introductions and dispersal throughout drainage networks (Vander Zanden et al. 2004).

One introduced fish species that has had a major effect on the native salmonids in the PNW through predation is the Smallmouth Bass (*Micropterus dolomieu*). The native range of the Smallmouth Bass encompasses from the Great Lakes, St. Lawrence River, and Mississippi River drainage (Carey et al. 2011). The range of Smallmouth Bass has now expanded their range across North America, as well as the European, Asian, and African continents as a result of intentional stocking to provide angling opportunities (Scott and Crossman 1998; Sharma et al. 2009). Smallmouth Bass occupy both lentic and lotic environments in the PNW, inhabiting hundreds of lakes in Washington, Idaho, and Oregon, (Pflug and Pauley 1984; Fayram and Sibley 2000; Carey et al. 2011) as well as the Columbia River and Snake Rivers (Tabor et al. 1993; Zimmerman and Parker 1995; Naughton et al. 2004; Carey et al. 2011). In western North America, Smallmouth Bass have impacted salmonid populations, both anadromous and resident, through predation on fry and smolts (Harvey and Karevia 2005; Sharma et al. 2009).

In most ecosystems Smallmouth Bass are considered a top predator (Olson and Young 2003; Warren 2009; Carey et al. 2011). A shift in diet from invertebrates and zooplankton to crayfish and fish occurs as the Smallmouth Bass grow from juvenile to the adult stage. This shift to piscivory may have the greatest impact on native fishes. Piscivorous fishes influence the distribution, habitat selection, feeding space and time, as well as the immigration/emigration of other fish species (Power et al. 1985; Jackson et al. 2001; MacRae and Jackson 2001). Smallmouth Bass piscivory on juvenile salmonid populations could potentially have major impacts if Smallmouth Bass abundance increased over time or if their distribution shifted resulting in more juvenile salmonids to in their diet (Fayram and Thomas 2000). Predation by Smallmouth Bass on native salmonid populations has the potential to extremely impact the salmonid population, when there is spatial and temporal overlap with juvenile individuals in spawning or rearing areas (Tabor et al. 1993). Fritts and Pearsons (2006) showed that Smallmouth Bass (150-199 mm FL) consumed 49.2% of the total salmonids consumed in a study done on the Yakima River, Washington. In a comprehensive survey on Smallmouth Bass in the Columbia and Snake rivers, Carey et al. (2011) found that consumptions rates of juvenile salmon by Smallmouth Bass ranged from 0 to 3.89 fish consumed per individual per day. Stroud (2011) found that kokanee (*Oncorhynchus nerka*) and rainbow (*Oncorhynchus mykiss*) fry and yearlings made up 20.2 and 4.6 percent of the diet of

Smallmouth Bass in a study conducted on the Sanpoil River within the Lake Roosevelt system.

Smallmouth Bass likely invaded the upper Spokane River after the illegal introduction into Lake Coeur d' Alene in approximately 1990, after which they entrained over the Post Falls dam (OConnor and McLellan 2009). This introduction created the possibly of predation on and competition with the native Redband Trout. Smallmouth Bass were not documented in the upper Spokane River prior to 2000 (O'Connor and McLellan 2009). In 2008, O'Connor and McLellan (2009) estimated there were 1,270 Smallmouth Bass ≥ 200mm total length (TL) in the upper Spokane River in Washington between the Stateline (rkm 154.5) and Donkey Island (rkm 134.2), though most of the population, 908 Smallmouth Bass ≥ 200mm TL, were distributed between the Stateline and McMillian Road (rkm 145.3) The abundance of Smallmouth Bass in the upper most portion of the Spokane River is likely due to the fact that Smallmouth Bass prefer slower moving rivers, less than 11m in depth, with water temperatures between 21 and 27ºC, and substrate composed of large boulder and medium cobble (Wydoski and Whitney 2003; O'Connor and McLellan 2009), which is very representative of the upper Spokane River.

The high density of Smallmouth Bass in the upper most section of the Spokane River has potential conservation implications as this area has also been documented to be where the majority of the spawning for the Redband Trout occurs. The two primary spawning locations for the Redband Trout were, as reported by Parametrix (2003), in a directly riffle below Harvard Road (rkm 139.9) and Starr Road (rkm 152.3). The Avista Corporation counted 31 redds at the Starr Road site and 44 redds at the Harvard Road site on May 13, 2003 (Parametrix 2003). Parametrix (2003) counted approximately 40-50 spawning fish and 22 redds at the Starr Road and 40-50 spawning fish and 76 redds at the Harvard Road site on May 23, 2003.

Columbia Redband Trout are a subspecies of rainbow trout, *Oncorhynchus mykiss*, with a native range from the Columbia and Fraser River drainages to the northern rivers such as the Pend Oreille, Kootenai, and Spokane (Muhlfeld 2002). Both anadromous and resident life history forms exist in the Columbia River Redband Trout (Behnke 1992). Redband Trout inhabit a wide variety of environments, ranging from desert to montane streams with large differences in habitat, elevation, and stream gradient

(Meyer et al. 2010). Redband Trout can inhabit streams with large variations in temperature, flow, and dissolved oxygen (Behnke 1992; Vinson and Levesque 1994; Zoellick 1999; Rodnick et al. 2004). Redband Trout are able to withstand high stream temperatures, with a critical thermal maxima reported to be approximately 29°C (Bowers et al. 1979; Rodnick et al. 2004; Tate et al. 2006).

The population of Redband Trout in the upper Spokane River spawn in the main river, since no suitable spawning habitat exists in the tributaries. Spawning of the Redband Trout takes place throughout the section of the free-flowing river in the upper Spokane River (Bailey and Saltes 1982; Bennett and Underwood 1988; Johnson 1997; Avista 2000; Parametrix 2003; Parametrix 2004; O'Connor and McLellan 2009). Peak spawning time occurred between April 1st and the 15th, with peak hatching typically occurring between May 24-30 in 2003, as reported by Parametrix (2003).

Redband Trout is considered to be a species at risk, even though they adapt easily to harsh conditions and have a fairly wide distribution (Marshall et al. 1996; Rodnick et al. 2004). There are a variety of factors that have contributed to the decline of the Redband Trout abundance, distribution, and genetic diversity in the Columbia River basin, including: dams, mining, hybridization, loss of spawning and rearing habitat, competition with and predation by nonnative species (Williams et al. 1989; Benke 1992; Muhlfeld et al. 2001). Historically Redband Trout were one of the most widely distributed salmonids in the Columbia River basin, occupying roughly 73% of the watershed, however today they only occupy 43% of the watershed (Muhlfeld et al 2015) Dams construction blocked the anadromous form of the Redband Trout life history (Scholz et al. 1985; Nehlsen et al. 1991), which also likely blocked migration routes and created isolated populations of resident Redband Trout (O'Connor and McLellan 2009). There is less know about the current population of Redband Trout in the Columbia River basin, which only occupies 17% of their potential range, than of any other salmonid (Thurow et al. 1997; Zoellick et al. 2005). The management of Columbia River Redband Trout populations at the present date, is complicated because very little is known about the physical and biological factors that limit the distribution and physiological tolerances of these fish (Rodnick et al. 2004).

Over the last 15 to 20 years, the population of Redband Trout in the upper Spokane River has declined. Bailey and Saltes (1982) estimated between 7,200 and 13,200 rainbow trout (length range not reported) in the upper Spokane River. Davis and Horner (1991) conducted a mark-recapture study in which they estimated 4,000 rainbow trout (≥ 200 mm TL) in the upper Spokane River. O'Connor and McLellan (2008) estimated a population of 1,149 Redband Trout in the Washington reach of the upper Spokane River, which indicated a substantial decline from previous studies. In the reach from the Washington/Idaho Stateline (rkm 154.5) to McMillian Road (rkm 145.3) the Redband Trout population was estimated to be 342 in 2008 and 96 in 2009, which was 83% and 96% lower than the 1990 (Davis and Horner) estimate between the Washington/Idaho Stateline to Harvard Road (rkm 148.9) (McLellan and King 2011). Increased competition with and predation by Smallmouth Bass on Redband Trout is one of the major factors that is thought to have contributed to the decline in abundance of Redband Trout in the upper Spokane River (O'Connor and McLellan 2009).

Improving and protecting critical habitat is one way that fisheries managers can develop and enhance native fish populations. In-stream habitat is believed to play a critical role in the population dynamics and density of salmonids, especially for stream rearing species (National Research Council 1996; Roni and Quinn 2001). Complex habitats provide more refuge for fish, which allows prey a physical location to live or temporarily hide from predators (McNair 1986). The improvement of habitat for salmonids typically includes the installation of logs, structures, and small dams that imitate the effect that naturally occurring large woody debris (LWD) would have in the ecosystem (Angermeier and Karr 1984). Woody debris performs numerous different functions in stream habitats. The importance of LWD in the stream channel has been documented by a variety of studies, which show that LWD can slow bedload movement, deposit and sort gravels, and increase nutrients (Swanson et al. 1976; Cederholm and Peterson 1985; Ralph et al. 1994). LWD can create habitat for spawning and rearing, increase organic matter and nutrient retention, allow for escape from predators, and provide cover during high spring flows (Bustars and Narver 1975; Lestelle 1978; Lestelle and Cederholm 1982; McMahon and Hartman 1989; Hicks et al. 1991; Cederholm et al. 1997). In-stream LWD placement is one of the most widely used stream restoration techniques to improve fish habitat, which compensates for the reduction in LWD by stream cleaning and different land use practices (Kauffman et al. 1977; Roni and Quinn 2001).

Purpose

This primary goal of this project is to complete a baseline survey for a proposed habitat modification site in the upper Spokane River. The proposed project would include the instillation of five habitat structures that would be placed in the river by Washington Department of Fish and Wildlife (WDFW) to provide habitat and refuge for juvenile Redband Trout. Three of these structures would be placed along the shoreline and two structures would be placed further out in the river to provide optimal refuge from high spring flows during emergence, as well as provide structure to escape predation. During high spring flows all 5 structures would be completely inundated, however during low flow months, July through October, only two of the five structures would be partially inundated. This survey will provide valuable baseline data about the fish composition of Starr Road, prior to habitat modification. A follow up survey would likely be conducted to evaluate the impact of the structures.

Objectives

To achieve our ultimate goal, we will address three specific objectives. The main objective of this project is to determine the abundance and density of Redband Trout, specifically juvenile fish, and Smallmouth Bass within the Starr Road site compared to the two reference sites, 1 and 3. A second objective is to calculate a population and density estimate of Smallmouth Bass within the study area, between the Washington/Idaho Stateline and Harvard Road. The third objective is to evaluate the amount of predation occurring on Redband Trout by Smallmouth Bass in the study area.

Hypotheses

For this study there are five main hypotheses:

(1) I expect to see a higher abundance and density of Redband Trout at the Starr Road site, compared to the two other sites. Starr Road is a known spawning area for Redband Trout and therefore should have higher density and abundance of Redband Trout at this site.

(2) I expect to see no difference in Smallmouth Bass abundance or density at any of the three sites. All three sites were selected based on similar habitat and flow characteristics, therefore there should be no difference in abundance and densities of Smallmouth Bass between sites.

(3) I expect to see a higher abundance and density at the Starr Road site in the month of June for Redband Trout, compared to July and August. Since Redband Trout emergence typically occurs between May 28th and June 4th, there should be a higher number of subyearling Redband Trout at the Starr Road site.

(4) I expect to see greater Smallmouth Bass abundance and density in the study area when compared to the previous estimate done in 2008. The population of Smallmouth Bass in the upper Spokane River had likely just established when the estimate was conducted in 2008, so population expansion was likely.

(5) I expect to see Redband Trout as a primary diet item, measured as percent by weight, of Smallmouth Bass in the study area. Starr Road, a documented spawning area for Redband Trout (Parametrix 2003), is located in the portion of river where the highest population of Smallmouth Bass reside, piscivory of Redband Trout should be should substantial.

Study Location

The Spokane River (Figure 1) is a Columbia River tributary located in North-Eastern Washington State and has a drainage area of approximately 6904 km^2. The Spokane River originates at the southern tip of Lake Coeur d'Alene and flows 180.25 km to its' confluence with the Columbia River in eastern Washington. The lower 29 miles of the Spokane River, below Little Falls Dam, is known as the Spokane Arm of Lake Roosevelt. The Spokane River has three major tributaries: the Little Spokane River, Hangman Creek, and Chamokane Creek. The minimum annual discharge for the Spokane River was recorded in 1944, 2,974 cfs, and the maximum annual discharge was recorded in 1974, 12,310 cfs (USGS 2013). The Spokane River is characterized by riffle, run, and pool sequences typical of lotic systems, with substrate that consists of small gravel to medium and large boulders (Kleist 1987). The climate ranges from semiarid to subhumid; summers are warm and dry; winters are cool and moist. The annual mean precipitation (1971-2000) for the Spokane River area ranges from about 42.4 cm/yr at the Spokane Airport to about 67.5 cm/yr in Coeur d'Alene (Western Regional Climate Center).

The Spokane River has a total of 7 dams that generate hydroelectricity. Six dams on the Spokane River are owned by the Avista Corporation, (Post Falls Dam, Upper Falls Dam, Monroe Street Dam, Nine Mile Dam, Long Lake Dam, and Little Falls Dam) and operated under a single license from the Federal Energy Regulatory Commission (FERC 2545). The seventh dam on the river is owned and operated by City of Spokane Water Department. Historically there were anadromous runs of fish in the Spokane River drainage. In 1911, Little Falls Dam was completed and blocked all anadromous species fish passage. In 1933 Grand Coulee Dam started its construction, and when completed in 1942 it blocked anadromous fish passage above of Grand Coulee Dam to the upper Columbia River.

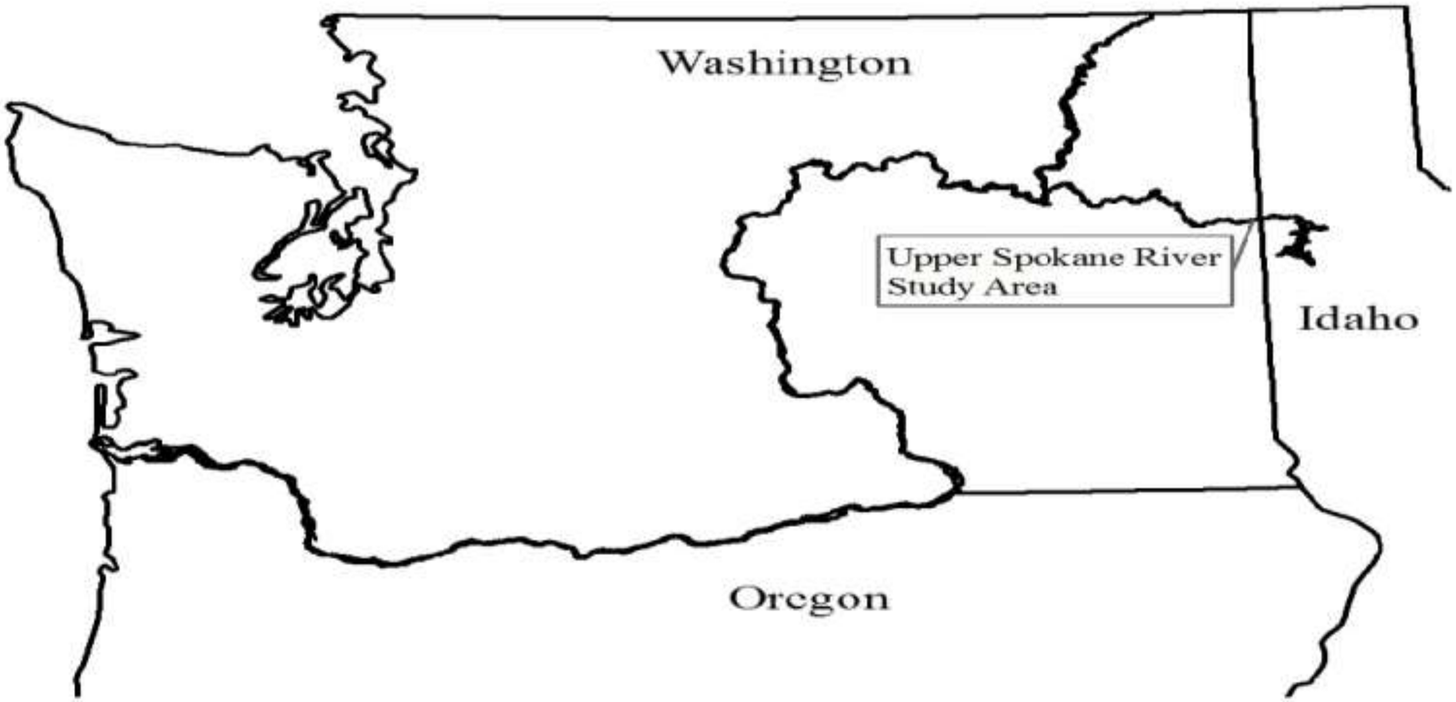


Figure 1. (Washington Department of Fish and Wildlife) Map of Washington, Idaho, and Oregon with relation to the entirety of the Spokane River. The Spokane River starts at the southern tip of Lake Coeur d'Alene and empties into the Columbia River. The upper Spokane River in Washington, indicated on right side of the map, is considered the area Stateline between Washington and Idaho (rkm 154.5) to Donkey Island (rkm 134.8).

In addition to surface tributaries, the Spokane Valley-Rathdrum Prairie aquifer (SVRP) is a major source of water to the Spokane River. The SRVP is approximately 596 km^2, which extends from the Idaho-Washington state line northeast of the City of Spokane (Bartolino 2007). The SVRP aquifer was created from a series of floods resulting from the repeated collapse of the ancient Glacial Lake Missoula that left thick layers of coarse-grained sediments (Brentz 1930; Kahle and Bartolino 2007). The SVRP aquifer is one of the most productive aquifers in the United States, in terms of the total withdrawals and gallons produced relative to the size of the aquifer (Hortness and Covert, 2005). Most wells located in the SVRP aquifer typically produce several thousand gallons per minute (Bolke and Vaccaro, 1979). The primary uses for ground water in the Spokane area are: public supply, domestic, irrigation, and industrial (Hutson et al., 2004).

Within the Spokane River, the SVRP aquifer provides ground water flow, both below and above ground, throughout the year. The SVRP aquifer has areas where it flows into the river, called gaining reaches, and other areas where the river flows back into the aquifer to recharge it, called losing reaches, which have been identified by United States Geological Service (Cusimano 2004). Typically the river loses water upstream of Barker Road in Washington, and gains water from the SVRP aquifer downstream near the Sullivan Road (Parametrix, 2004). Water temperatures can regularly exceed 20 ˚C, with maximum temperatures as high as 26 ˚C, upstream of Sullivan Road and cold water (9-11 ˚ C) from the SVRP aquifer cools the river downstream of Sullivan Road (Cusimano 2004; HDR 2005; Gregory and Covert 2006; McLellan and King 2011). In my study area (Figure 2), the river receives little, if any, input from the SVRP to cool the water temperatures.

Habitat Structures

WDFW has proposed the placement of five habitat structures in the Spokane River. If installed, the structures would be placed in the river with heavy machinery by WDFW engineers. Three of the structures would be on the shoreline and the other two would be farther out in the water column. During high to mid flows all five structures would be in inundated, however during low flows only two of the five structures would be inundated. The three structures that would be placed in shallower water, directly on the shoreline, would be a V- Shaped design. The V would be constructed out of two large logs, Douglas fir or Cedar. The trees would be anchored together by a rebar pin and have two large boulders as anchoring points on the ends of the logs. These anchoring boulders would be buried in the ground, with a wire rope tether on top. There would be a rootwad in the middle of the two large logs measuring forty feet in total length. The two deeper water structures, placed approximately 8 to 9 meters out from the riparian zone, would be a triangle shape and also be pinned with rebar in each connecting point. The triangle would be constructed out of three large logs, Douglas fir or Cedar. Two of the connecting points on the logs would be anchored by buried boulders with wire tethers oriented on top of the boulders.

Methods

The current study was conducted over a three-month period, from June through August of 2015. The study area included the Spokane River from the Washington/Idaho Stateline (rkm 155.1) to N Harvard Road (rkm 149.2) (Figure 2). Three sites were selected to conduct snorkel and minnow trap surveys for juvenile Redband Trout and Smallmouth Bass. All three sites were selected due to similarities in habitat, flow regimes, as well as the possibly for spawning/rearing. Site 1, (rkm 154.6) located at/near N Haye Street, is the uppermost site and is 94.6 meters long by 18.7 meters wide. Site 1 has some riparian vegetation along the bank, although most of the site is devoid. Site 1 has mostly small to medium cobble for substrate, with a mixture of sand and gravel. The depth of site 1 is less than 1 meter to 2 meters. Site 2, Starr Road Complex, is 138.3 long meters by 25.6 meters wide. Site 2 is devoid of vegetation in the riparian zone and has primarily small cobble for substrate, with a partial spit that is created in the river channel at the top of the site during low flows. The depth of the site 2 varies from less than 1 meter to approximately 2.5 meters. Site 3, located near N Malvern Road, is 131.2 meters long by 21.4 meters wide. Site 3 is devoid of riparian vegetation during low flows and has medium to small cobble for substrate. Site 3 has the largest spit of the three sites, creating a large back pool during low flows. Site 3 is less than 1 meter to approximately 3 meters in depth.

Objective 1:

The main objective of this project is to determine the abundance and density of Redband Trout, specifically juvenile fish, and Smallmouth Bass within the Starr Road site compared to the two reference sites, 1 and 3.

Hypothesis 1: I expect to see a higher abundance and density of Redband Trout at the Starr Road site, compared to the two other sites. Starr Road is a known spawning area for Redband Trout and therefore should have higher density and abundance of Redband Trout at this site.

Hypothesis 2: I expect to see no difference in Smallmouth Bass abundance or density at any of the three sites. All three sites were selected based on similar habitat and flow characteristics, therefore there should be no difference in abundance and densities of Smallmouth Bass between sites.

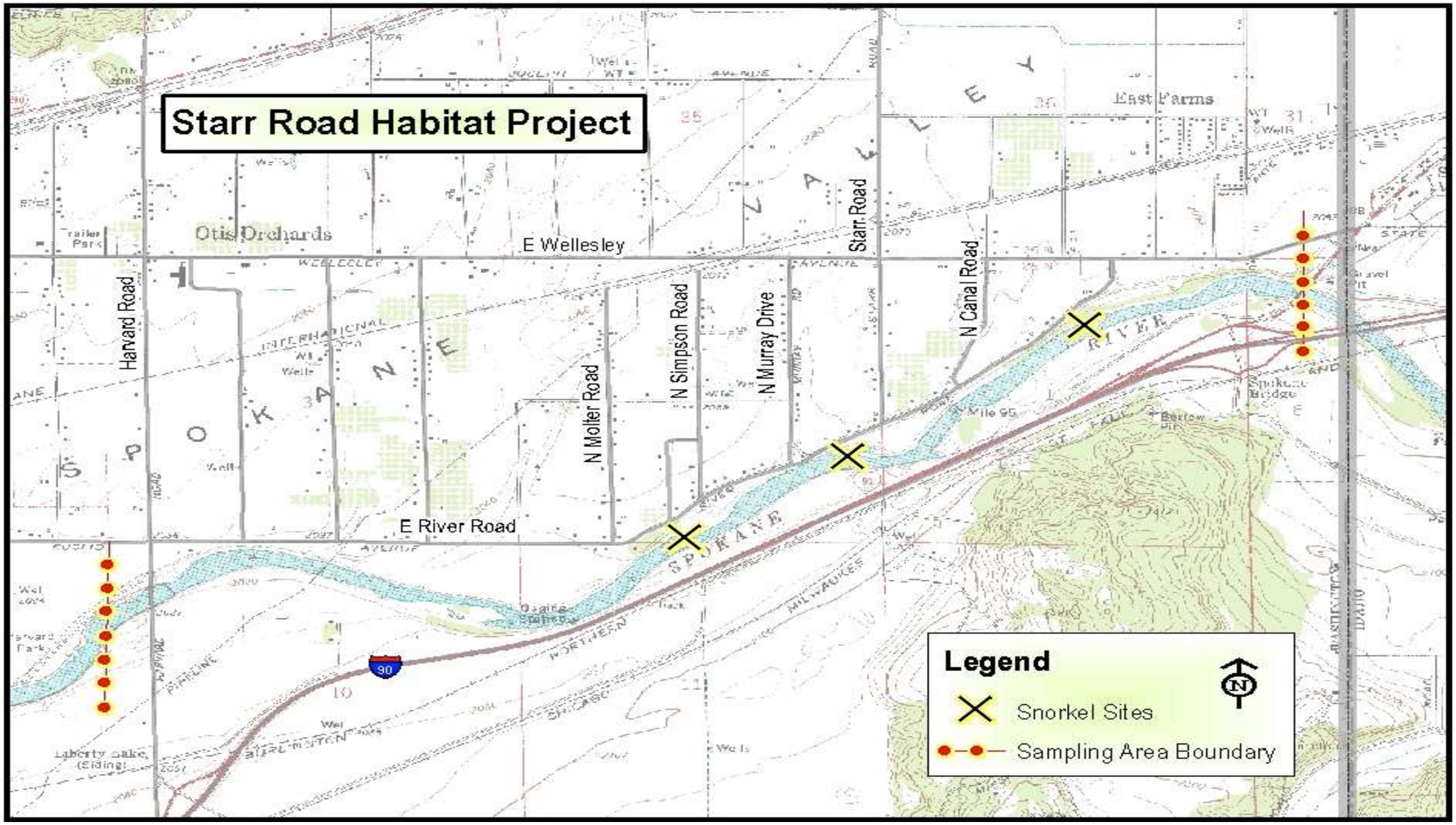
Hypothesis 3: I expect to see a higher abundance and density at the Starr Road site in the month of June for Redband Trout, compared to July and August. Since Redband Trout emergence typically occurs between May 28th and June 4th, there should be a higher number of subyearling Redband Trout at the Starr Road site

Field Sampling

For objective one, hypothesis 1-3, abundance was determined with a combination of snorkel surveys and minnow trapping conducted at sites 1 through 3. Prior to conducting the snorkel surveys, snorkelers practiced estimating fish lengths and visual distances by observing Plexiglas models of a Redband Trout and Smallmouth Bass. Snorkelers observed these models underwater in the Eastern Washington University aquatic facility. All snorkelers viewed models while swimming away from them.

The visual distance at which observers were able to detect species correctly and estimation of distance away from the model was then measured with a measuring tape.

Figure 2. Study area on the Spokane River located between the Stateline of Washington and Idaho. Circles with dashes indicate total study area boundary and X's are snorkel and minnow trap survey locations.



Since Redband Trout are the main salmonid species in the survey reach, identification should be relatively easy compared to other species.

Day and night, snorkel surveys were conducted monthly, with a day and night survey completed at each site from June through August (Figure 3). Snorkel surveys were conducted in a three-person crew and followed the guidelines described in Thurow (1994). The daytime surveys were conducted between the hours of 1000 and 1700, when the sun is highest overhead. Nighttime surveys were conducted between half an hour after sunset and 0400 hours. Day and night surveys were conducted within the same 24 hour period at each site. Identical techniques were used during the day and night, except that halogen lights were used to aid visual identification fish in the night surveys.

During each survey, a snorkeler equipped with a mask, snorkel, dry suit, and a recording sleeve, proceeded slowly downstream searching for fish. Fish lengths were estimated visually to the nearest 10mm using a ruler attached to the snorkeler’s glove. Fish observed were identified to species and recorded on the recording sleeve of the snorkeler. Snorkelers recorded all fish observed within the study site. Snorkeling counts began in the upstream end of each individual reach, with snorkelers floating downstream. Three snorkelers each maintained an assigned lane within the sample site. Each snorkeler was assigned a lane of approximately 5 meters wide and counted fish directly in front of the snorkeler and towards the bank. Surveys were conducted at site 1 first, with surveys being conducted in succession at sites 2 and 3. After the completion of snorkel survey, each site was undisturbed for approximately an hour before it was sampled again. Three replicate counts were made per individual site in both the day and night surveys. Temperature was recorded, with a handheld temperature gage, at beginning of each site before the survey took place. Discharge for each day sampled was obtained from the USGS daily discharge site from the Post Falls gage, as well as the Spokane gage.

Minnow traps were placed at each site once per month to help better estimate the juvenile population of salmonids and Smallmouth Bass at those sites. Minnow traps have been used in a variety of studies in Alaska to estimate abundance of juvenile salmonids (Bramblett et al. 2002). Two different trap types were used to conduct the survey. One was a circular trap, with .635 cm wire mesh and a 2.54 cm circular opening on each side. The other type was a square trap, with a .3175 cm cloth mesh and a 6.35 cm square opening on each side. A total of 20 traps, 10 of each kind, per site were set at each site 1-3, and alternating trap types, throughout each location. Traps were baited with two different types of bait, either salmon egg roe or wet cat food, in perforated plastic bags. Traps were then placed systematically, with each bait type being alternated throughout the reach. Traps were set and left for approximately 10-12 hours overnight in each site, within the same day. The traps were then pulled in the same order that they were initially set. All fish captured in the traps were measured, then be released back into the site where captured.

Data Analysis

For objective 1, hypothesis 1-3, abundance was determined for both Redband Trout and Smallmouth Bass in each snorkel unit (site 1-3). A systematic sample of n units was taken from paired independent diver counts of fish. To estimate abundance in each snorkel site, 1-3, the average number of number of fish observed per habitat unit, pooled from both day and night surveys (fish/unit). (Pess et al. 2008). The density of site 1-3, for Redband Trout and Smallmouth Bass was estimated by dividing the estimated total abundance (N) by the length (m^2) of total habitat unit.

For hypothesis 1-3, to compare the differences in abundance of Redband Trout and Smallmouth Bass between sites, I used variety of different statistical test since abundance was calculated from a variety of different equations. I used a Possion regression with 95% confidence intervals, to determine the difference in abundance between sites with regards to the number of fish in each site. Abundance estimates, (fish/unit), were made at each site, according to Pess et al. (2008). Minnow traps were also used in sites to help determine the abundance of juvenile Redband Trout and Smallmouth Bass. An ANOVA and Tukey tests were used to determine if there were any differences in the interactions between: date, sample site, size class, and day/night surveys for sites.

Figure 3. Snorkel survey sites in the upper Spokane River. Stars indicate the proposed LWD structures located at the Starr Road site.

Results

Abundance at sites 1-3 — A total of 4478 fish were counted during the snorkel surveys conducted. Fish species observed during all snorkel surveys included (n): Smallmouth Bass (4455) Pumpkinseed (*Lepomis gibbosus*) (20) Redband Trout (2), Brown trout (*Salmo trutta*) (1) (Figure 4). Site 2 had the greatest number of Smallmouth Bass in both June (2106) and July (272), while site 3 had the greatest number in August (430) (Table 1). Site 2 had the highest abundance of Smallmouth Bass in June 702 (fish/unit) and July 112 (fish/unit), while site 3 had the highest abundance 104 (fish/unit). Site 2 also had the highest density of Smallmouth Bass in June (.595 fish/m^2) and July (.076 fish/m^2), while in August site 3 had the highest (.243 fish/m^2).

Over the entire study period only two adult Redband Trout were seen during snorkel surveys and five young of the year Redband Trout were captured in minnow traps. All Redband Trout during the study were observed at site 3 during the month of June. There were not enough Redband Trout seen in the snorkel surveys or captured in minnow traps to warrant any statistical analysis on the abundance at any of the three sites.

Comparisons between sites 1,2 and 3 — There was a significant difference in the total abundance of Smallmouth Bass at site 2 ($p < 0.001$, 95% C.I. = 36.002-38.828) when compared to site 1 and site 3 over the entirety of the sampling period, with both night and day surveys pooled (Figure 5). Site 2 had significantly more Smallmouth Bass observed during the night ($p < 0.001$, 95% C.I. = 63.652-58.401) when compared to site 1 and site 3 (Figure 6). The abundance of 0-100mm Smallmouth Bass was greatest at site 2 ($p < 0.001$, 95% C.I. = 61.111-73.794) when compared to site 1 and 3 (Figure 7). The 0-100mm Smallmouth Bass had a higher abundance during the night, compared to day, at site 2 ($p < 0.001$, 217.149-236.832) (Figure 8), when compared to site 1 and 3. The 100-450mm Smallmouth Bass had a greater abundance site 2 ($p < 0.01$, 95% C.I. = 61.611-73.794) during the day, compared to night, than site 1 and 3 (Figure 8). Smallmouth Bass were piscivorous at 155-370mm TL. There were significantly more Smallmouth Bass in the piscivorous size class range seen at site 2 ($p < 0.001$, 95% C.I. = 7.603-10.654), when compared to site 1 and site 3 (Figure 9).

Figure 4. Total number of fish observed at sites 1-3, combined for day and night surveys.

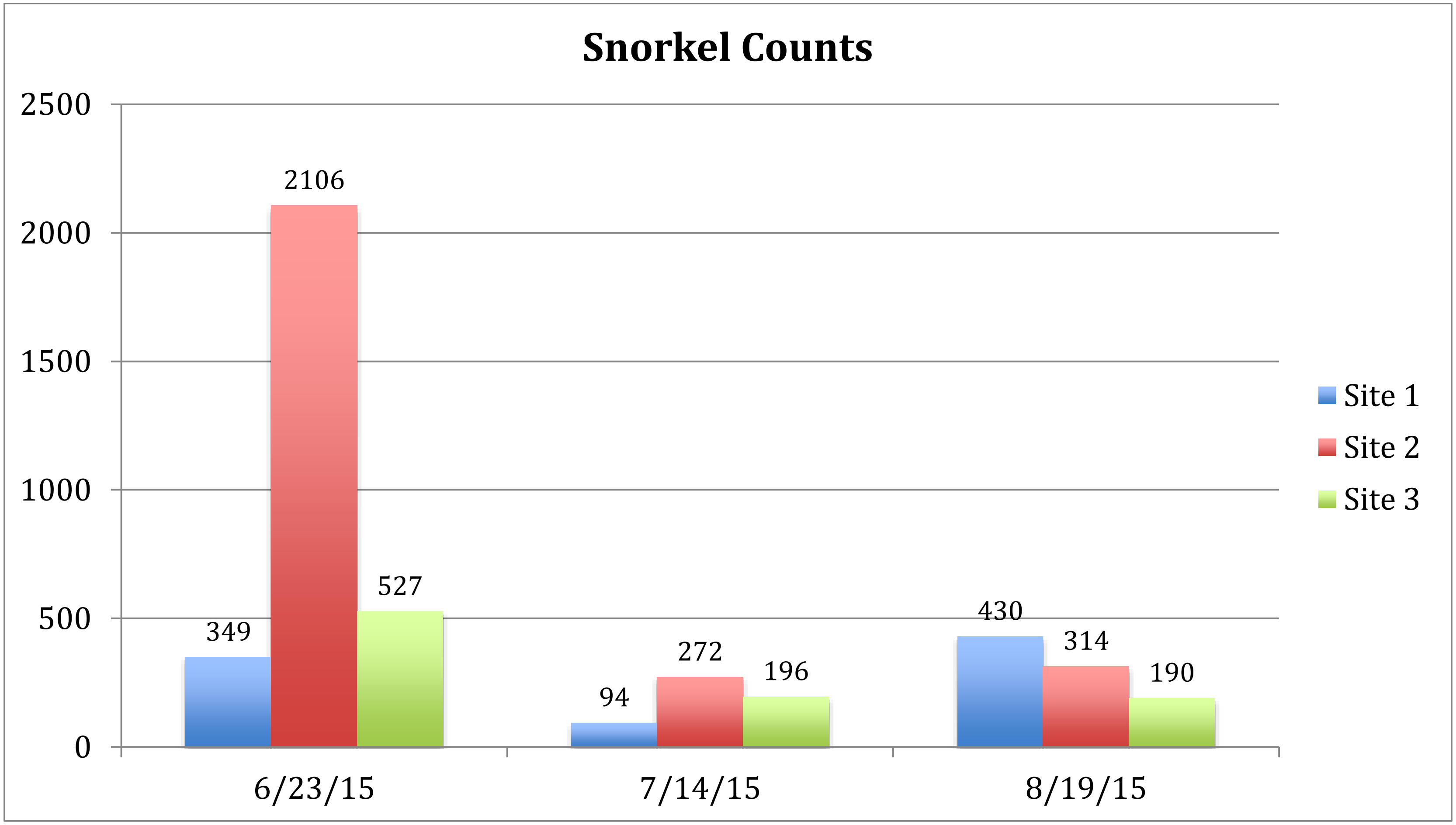


Table 1. Smallmouth Bass total number (N), abundance (fish/unit), and density (fish/m2) for snorkel surveys conducted at sites 1-3.

Date	Site	Total (N)	Abundance (fish/unit)	Density (fish/m^2)
6/23/15	1	349	116	0.197
6/23/15	2	2106	702	0.595
6/23/15	3	525	75	0.188
7/14/15	1	90	30	0.053
7/14/15	2	270	112	0.076
7/14/15	3	191	64	0.07
8/19/15	1	427	142	0.243
8/19/15	2	311	104	0.089
8/19/15	3	186	62	0.068

Figure 5. Mean count of Smallmouth Bass at sites over the entire study, pooled for both day and night snorkel surveys. Error bars represent 95 percent confidence intervals around each mean count.

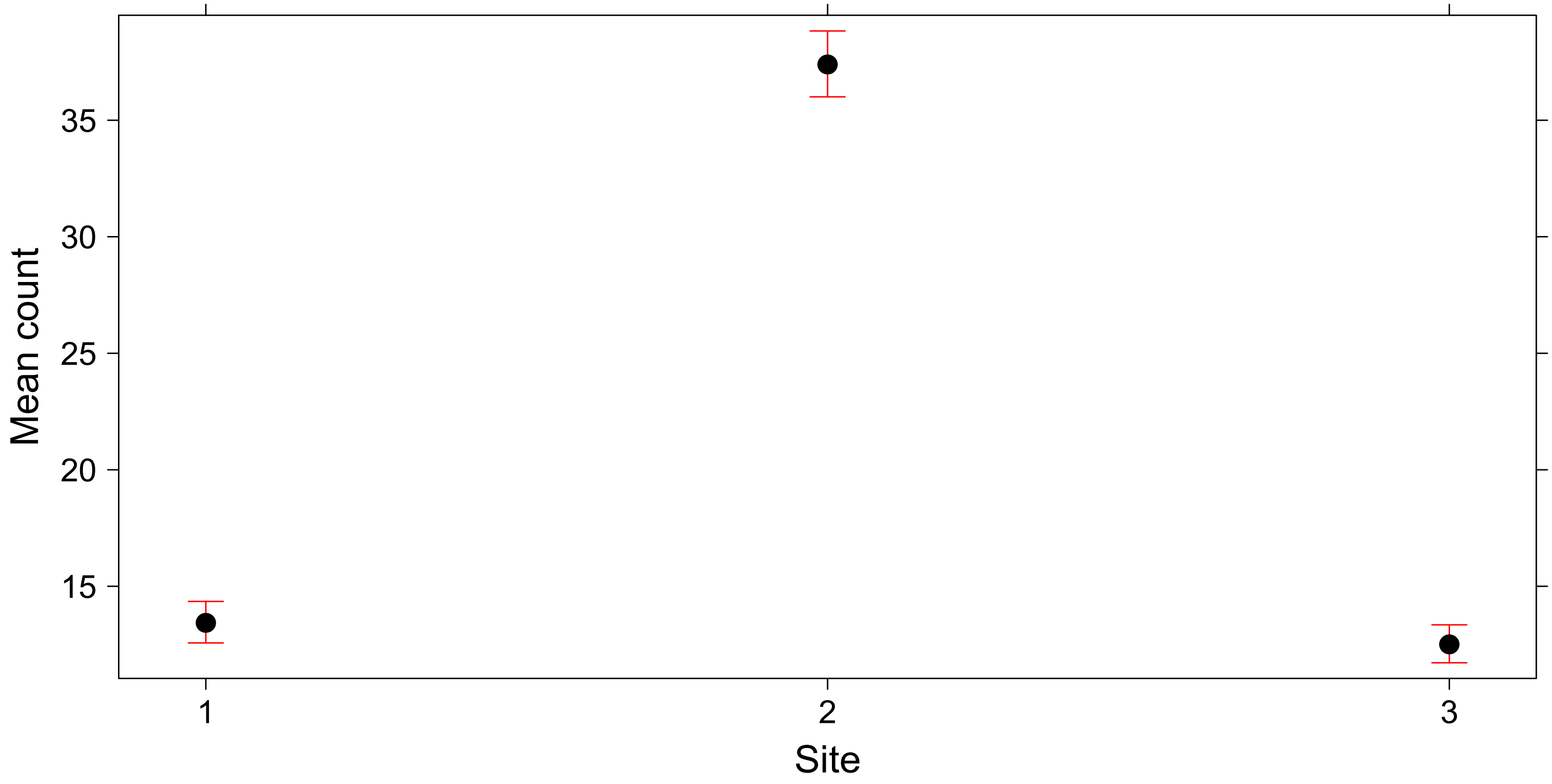


Figure 6. Mean count of Smallmouth Bass for each site, pooled over the entire study, in day and night snorkel surveys. Error bars represent 95 percent confidence intervals around each mean count.

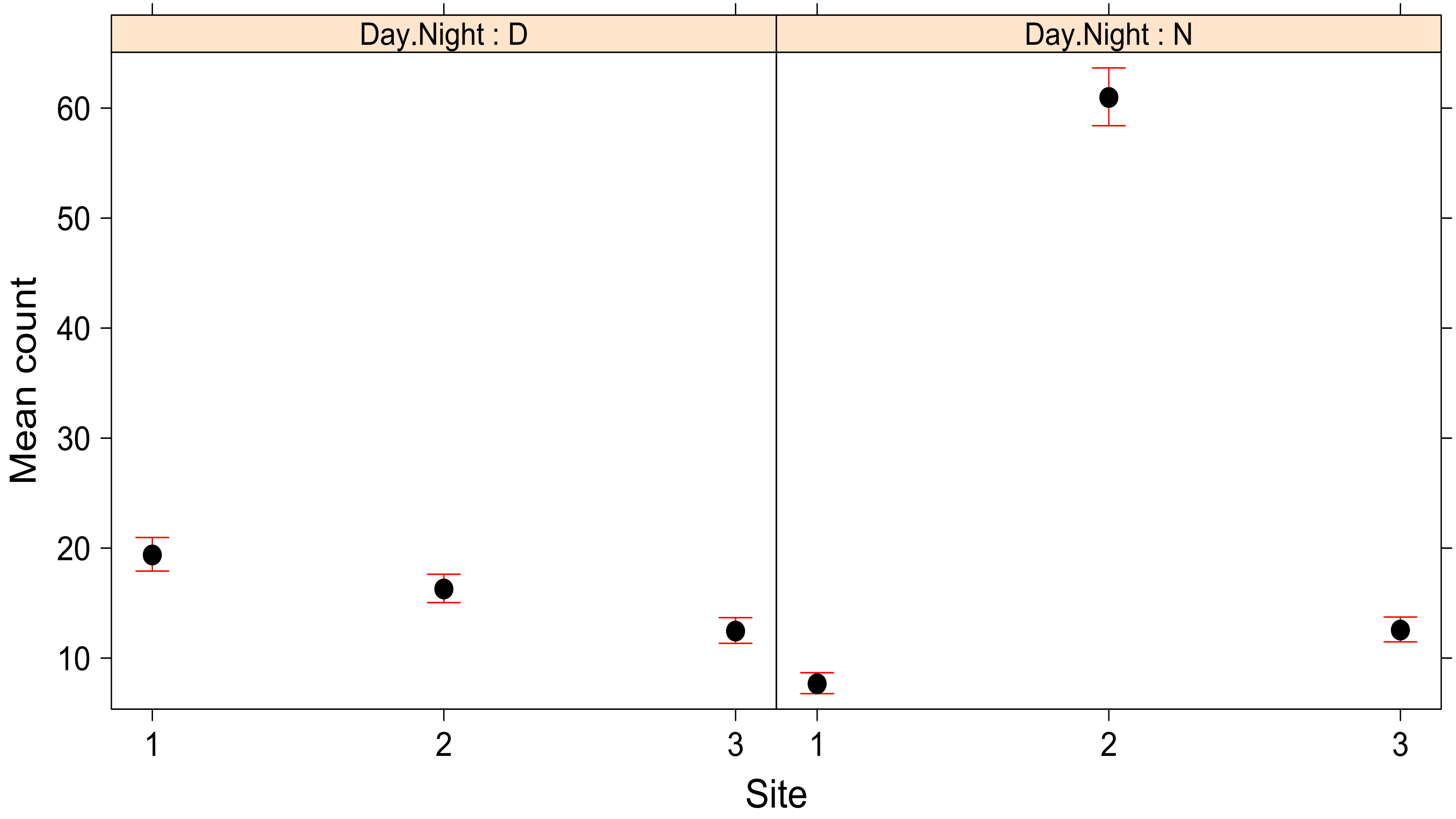


Figure 7. Mean count of 0-100mm TL Smallmouth Bass for each site, pooled over the entire study, in day and night snorkel surveys. Error bars represent 95 percent confidence intervals around each mean count.

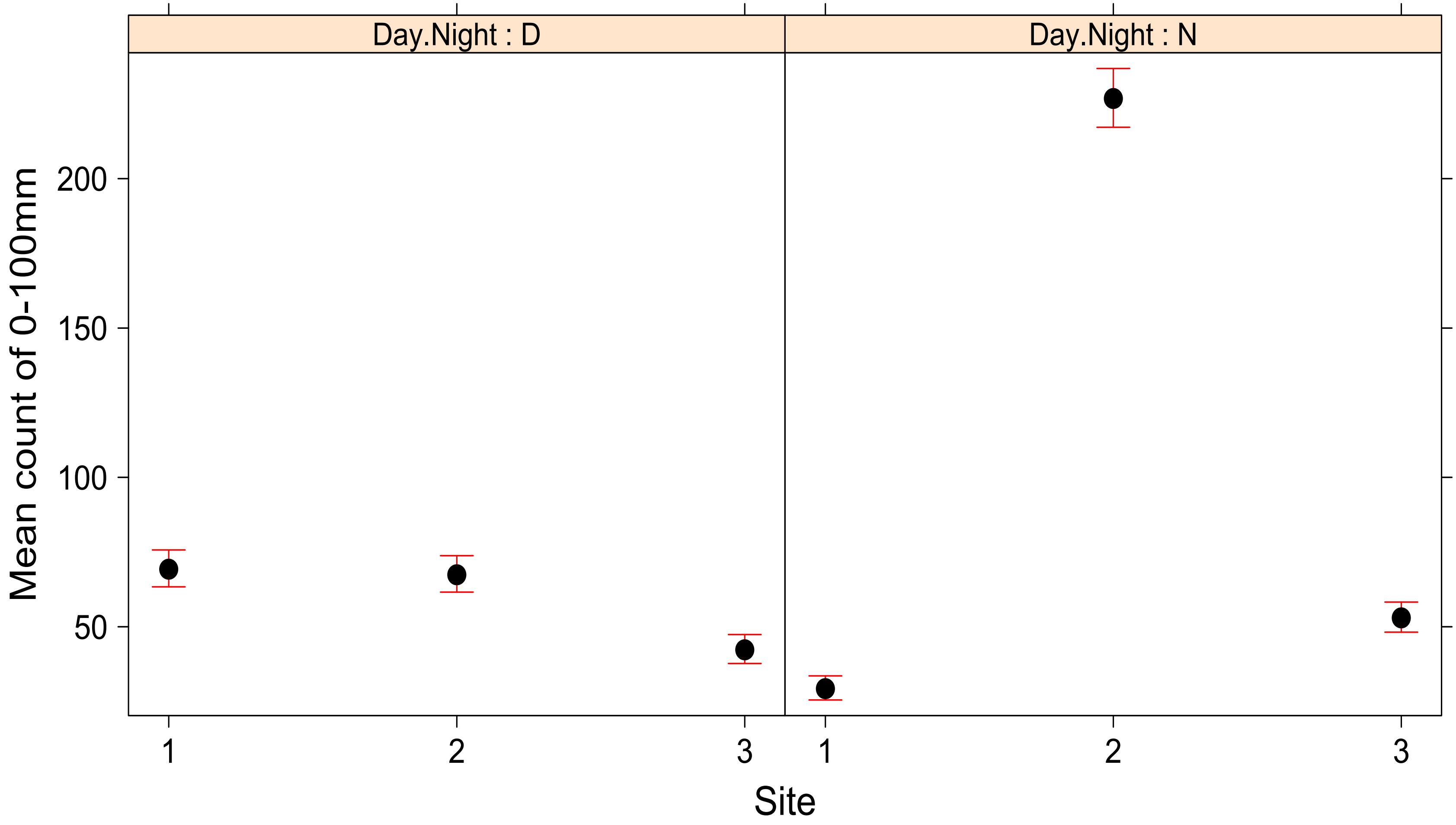


Figure 8. Mean count of Smallmouth Bass, 0-100mm TL and 100-450mm TL, pooled over the entire study, in day and night snorkel surveys. Error bars represent 95 percent confidence intervals around each mean count.

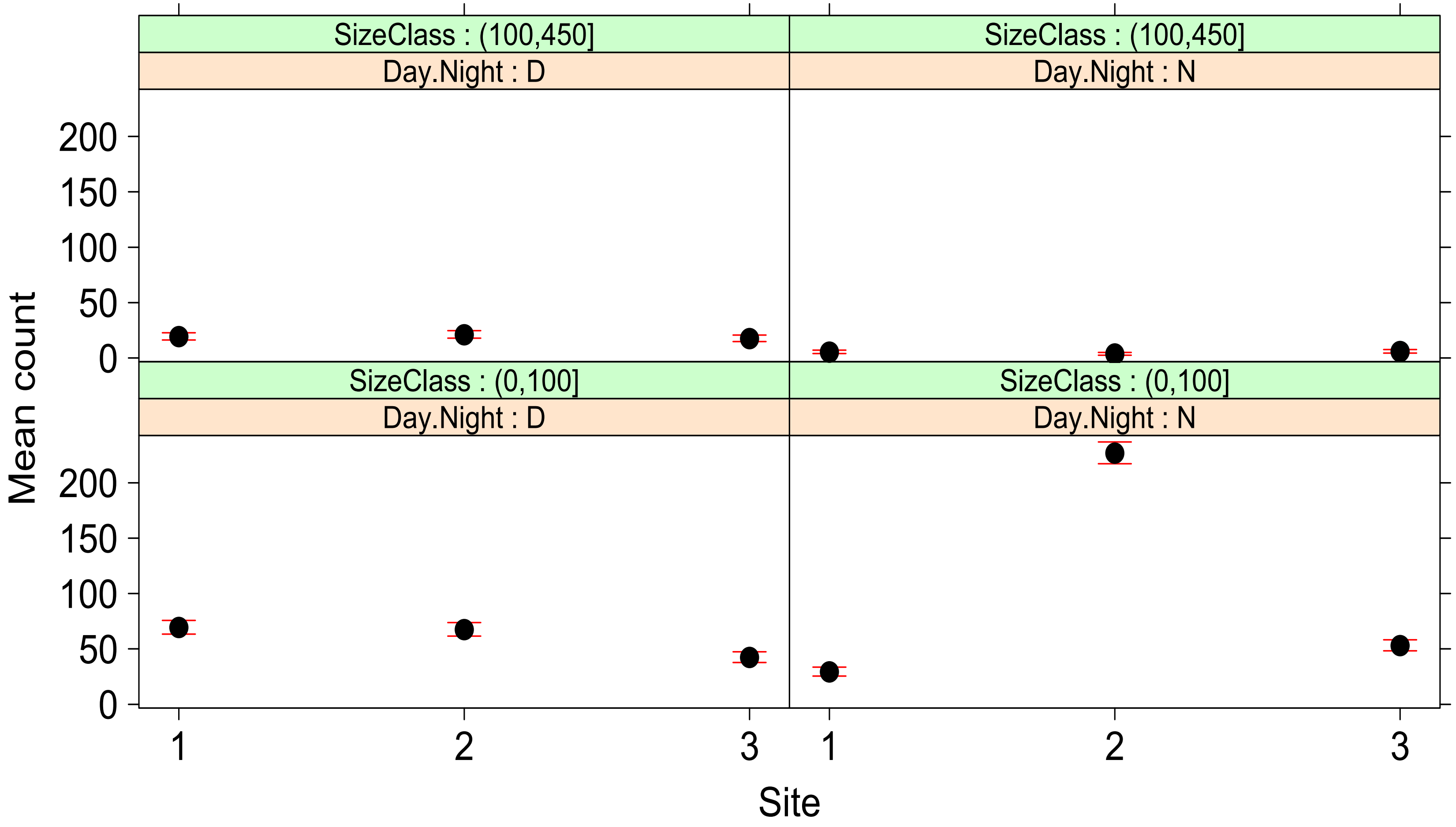
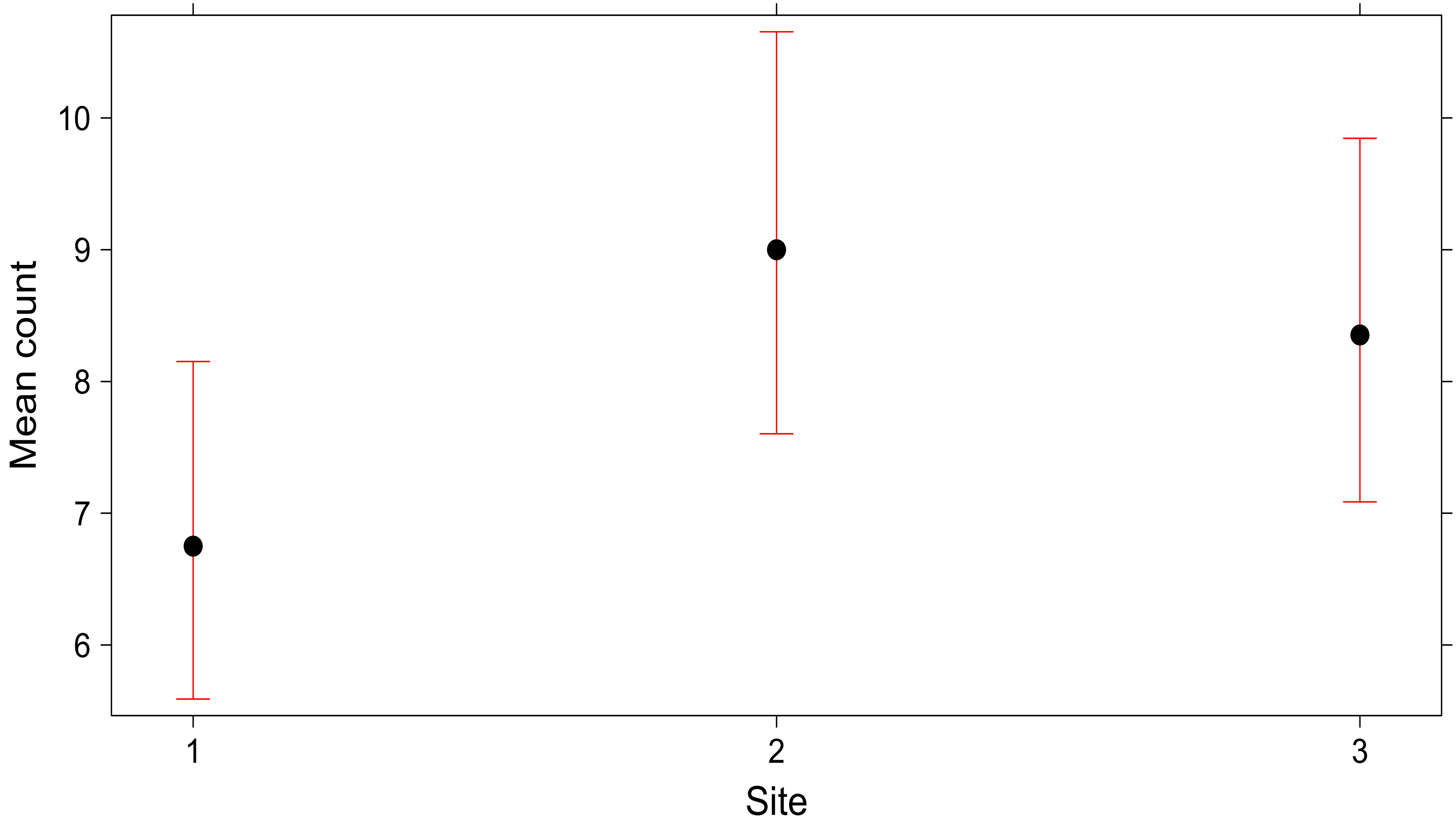


Figure 9. Mean count of piscivorous Smallmouth Bass, 155-370mm, pooled for day and night snorkel surveys, over the entire study. Error bars represent 95 percent confidence intervals around each mean count.



Discussion

Comparisons between sites 1, 2, and 3—WDFW and the Avista Corporation previously identified site 2 as one of the major spawning areas for Redband Trout in the upper Spokane River. One of the main goal of this project was to provide a baseline survey to determine the species composition, size classes, and abundance at site 2 compared to the reference. Only two adult Redband Trout were observed during the snorkel surveys, during the month of June, which were observed at site 3 during the night. No juvenile Redband Trout were observed at any of the three sites during snorkel surveys.

There was a complete absence of juvenile Redband Trout at site 2, Starr Road, during all sampling events. The only juvenile Redband Trout seen during both the snorkel surveys and minnow trapping events were at site 3, which were captured during the first minnow trapping event in the second week of June. During normal water flows and temperatures, peak spawning would typically occur between April 1st and 15th (Johnson 1997; Avista 2000; Parametrix; O'Connor and McLellan 2009), with the peak hatching event occurring between May 24th and 30th and fry emergence occurring 4 to 10 days after the hatching event (Bailey and Saltes 1982; Bennett and Underwood 1988; Davis and Horner 1991; Underwood and Bennett 1992; O'Connor and McLellan 2009). Since flows were atypical in 2015, flows and temperature could have affected spawn timing, location, and incubation time. However, if fish spawned at a time consistent with previous years, subyearling Redband Trout would be expected to be observed at site 2. Adult Redband Trout that spawned in site 2 would have likely moved out of the spawning area after spawning was completed, to seek out cold water refuge in area between Sullivan Road and Plants Ferry, which could account for the absence of adults in the snorkel surveys in June.

The majority of fish seen during snorkel survey were Smallmouth Bass. One of the main considerations of the Starr Road habitat project is to install the habitat structures into the site to provide subyearling Redband Trout a refuge to escape high spring flows and predation, while not providing Smallmouth Bass habitat. Site 2 had a significantly higher abundance of Smallmouth Bass ($p < 0.001$, 95% C.I. = 36.002-38.828) during snorkel surveys compared to site 1 and 3, with all day and night surveys pooled, over the entire sampling period. Since site 2 is where the proposed habitat structures would be implemented, this poses a major issue since Smallmouth Bass have been shown to consume salmonids where spatial and temporal overlaps occur (Tabor et al. 1993). Since Redband Trout in the upper Spokane River have limited spawning areas, installing structures into site 2, where the Smallmouth Bass had a significantly higher abundance, may only create and predator sink and therefore possibly increase the amount of predation on Redband Trout.

There are a variety of reason that could account for the higher number of Smallmouth Bass in the Starr Road area, compared to sites, 1 and 3. One possible reason is that Redband Trout spawned earlier than normal, due to warmer water temperature and lower spring flows, and Smallmouth Bass congregated at the Starr Road site to feed on the emerging fry. Though, if this were to be the case, Redband Trout fry should have been observed in the diet of Smallmouth Bass during the June sampling event.

The subyearling and yearling size class of Smallmouth Bass, 0-100mm, had a significantly higher abundance ($p < 0.001$, 95% C.I. = 61.111/73.794) at site 2. This size class was the major driver in creating the significant difference between the three sites when looking at the pooled day and night data. A large number of 0-50mm Smallmouth Bass were observed during night snorkel surveys, congregated near or around a large boulders, in the nearest snorkeling lane to the shore. The high density of 0-50mm Smallmouth Bass observed in condensed areas made counting a specific number of fish too difficult. To account for this, a subset of the number of fish was counted by the snorkeler and then multiplied by the number of subsets seen in the specific area. This strategy was used throughout the study to minimize bias. The greatest number of the subyearling and yearling size class was seen in the month of June, which would relate to emergence of Smallmouth Bass typically occurring in June. Another possible reason that there were a higher number of Smallmouth Bass at the Starr Road site, is that Smallmouth Bass are using the Starr Road are as a spawning area. Since the 0-100 mm TL size class was the key component of causing the main difference between Starr Road and the two reference sites, 1 and 3, it is possible that smallmouth could be using the Starr Road area as a spawning ground as well. However, no spawning fish were captured throughout the entirety of the study though, or in the Starr Road area. Since there were significantly more Smallmouth Bass seen in the subyearling and yearling size class, installing structures into the Starr Road area would not only provide escapement from high spring flows and predation for Redband Trout, but also for Smallmouth Bass as well.

Site 2 had significantly higher numbers of 100-450mm Smallmouth Bass ($p < 0.001$, 95% C.I. =61.611-73.794) compared to site 1 and 3. Unlike the 0-100mm Smallmouth Bass, there was a significant difference in the 100-450mm Smallmouth Bass observed during the day at site 2, compared to night, than at site 1 or 3.

The size classes at which Smallmouth Bass were piscivorous ranged from 155-370mm. There were significantly more piscivorous Smallmouth Bass at site 2 ($p < 0.001$, 95% C.I. = 7.603-10.654) compared to site 1 and 3. Although no direct predation occurred on any salmonids throughout the study, the high abundance of Smallmouth Bass in the piscivorous size class at site 2 could have a major impact on the subyearling Redband Trout population when normal water and spawning conditions occur.

Objective 2: The second objective was to estimate the population and density of Smallmouth Bass between Washington/Idaho Stateline to Harvard Road.

Hypothesis 4: I expect to see greater Smallmouth Bass abundance and density in the study area when compared to the previous estimate done in 2008. The population of Smallmouth Bass in the upper Spokane River had likely just established when the estimate was conducted in 2008, so population expansion was likely.

Field Sampling

Abundance— For objective 2, hypothesis 4, a mark-recapture survey was conducted from the Stateline, between Washington and Idaho, to Harvard Road. Individual sites were marked using a recreational grade GPS unit to ensure consistency throughout the survey. Sites were marked during the day, prior to any survey work conducted as allow for better representation of marked sites. Two float trips were required to sample the entire river. The initial float started on either the north or south shoreline and then alternated shorelines after approximately 600 seconds, or the end of the transect depending on capture method, to avoid capture of recently released Smallmouth Bass. The amount of effort, depending on capture method, varied during subsequent floats due to environmental conditions as well as amount of captured method used.

The mark-recapture survey was conducted twice a month, June through August, with one raft electrofishing and one angling event per month. For the raft electrofishing portion, a cataraft outfitted with a Smith-Root 2.5 GPP electrofishing unit was used. The raft was maneuvered by an oarsmen, while two netter in the front to the raft captured fish with nets. Catch-per-unit-effort (CPUE) was recorded for the electroshocking, with amount of effort taken per individual transect as well as total time sampled. The initial electrofishing sampling event started on either the north or south shoreline and alternated to the opposite shoreline, with electrofishing being conducted for 600-second intervals. The electrofishing method followed the standards established by WDFW and American Fisheries Society (AFS) and the United States Fish and Wildlife (USFWS). Electrofishing was conducted with extreme care to protect the spawning area from disturbance.

Each electrofishing mark-recapture event was conducted over a two-day period, from half an hour after sunset to completion of the pass. Each float began along one shoreline on one date each month and then along the opposite shoreline on the second date each month to ensure sampling of the entire reach. All Smallmouth Bass captured during electroshocking events were kept in a live well until the completion of each transect. All Smallmouth Bass collected during the raft electrofishing mark-recapture survey were measured total length (TL); mm, weighed (g), and marked. Smallmouth Bass captured ≥ 150mm TL were tagged with a Floy ® tag at the left base of the dorsal fin, and were given left pelvic fin clip. Each Floy tag was imprinted with a unique identification number and telephone to the Eastern Washington University's Fisheries Research Center. Smallmouth Bass captured ≤ 150 mm TL, were injected with Elastomer ® in the base of the anal fin, and were given a left pelvic fin clip. Scale samples were taken from all Smallmouth Bass captured for age determination. A different color of elastomer was injected during each marking session so that we could keep track of the number of times an individual elastomer fish was recaptured. For example a fish that bore two colors of elastomer was captured twice, on the dates those particular colors of elastomer were used. The left or right pelvic fin clips were used in conjunction with Floy tags or Elastomer injections to determine Floy tag and Elastomer tag loss throughout the study.

Angling events used the same transect GPS points marked previously for raft electrofishing. Anglers floated both shorelines simultaneously in rafts, angling from mid-river towards the shoreline they were floating along. Anglers used a combination of both lures and flies to capture Smallmouth Bass. All Smallmouth Bass that were successfully angled to the boat were then transferred into a live well until the end of each individual transect. All Smallmouth Bass collected during the angling mark-recapture survey were measured total length (TL); mm, weighed (g), and mark recorded. Smallmouth Bass captured ≥ 150mm TL were tagged with a Floy ® tag at the left base of the dorsal fin, plus were given right pelvic fin clip. Each Floy tag was imprinted with a unique identification number and telephone to the Eastern Washington Universities Fisheries Research Center. Smallmouth Bass captured ≤ 150 mm TL, were injected with Elastomer ® in the base of the anal fin, plus were given a right pelvic fin clip. Scale samples were taken from all Smallmouth Bass captured for age determination.

Age Class— Scale samples were collected from each Smallmouth Bass to determine length at age class. Scale samples were put into scale envelopes and marked with individual fish number, weight, length, and specific transect the fish was captured in. This allowed for determination of which age class is the most predaceous and at what age the Smallmouth Bass become predaceous (Fritts and Pearsons 2006). At least three scales from each individual fish were taken to allow for better results when determining age and backcalculating lengths at age in the lab. Scale samples were measured to the nearest millimeter from the focus of the anterior edge of the longest axis using a micro-fiche reader and aged by counting annuli (Jearld 1983).

Data Analysis

Abundance— An open population parameter model, POPAN, provided in the MARK program, was used to calculate abundance estimates for Smallmouth Bass ≥ 150mm and ≥ 200mm. The estimate obtained gave the estimated population and the associated standard error, 95% confidence intervals, and AIC values for both abundance estimates. Since the study was conducted over an extended time period, the population could not be assumed to be closed and therefore the open POPAN model was chosen. This allowed for an abundance estimates, as well as capture probabilities, birth and death probabilities, which were assumed to be the same for all fish captured. Current regulations allow for the harvest of Smallmouth Bass within the study area, so this made an open model more applicable. No Floy identification tags were called in to the Eastern Washington Fisheries research center that any individual fish were taken out of the population. Also, no fish that were captured during the study had lost their tag but had a pelvic fin clipped. Therefore, I assumed that short-term tag loss did not occur during the study. Sampling both shorelines, during both angling and electroshocking, also assumed the equal catchability of all fish within the total area sampled. The POPAN model is an "open" model that makes certain assumptions, which are:

1) All animals retained tags throughout the entirety of the study.
2) The probability for survival is the same for both marked and unmarked animals, as well for each sampling event.
3) The catchability for all animals within the population is the same for each sampling event.
4) The study area during the experiment remains constant.

However, the POPAN model also assumes that the population is open during the period of study. In an open model: 1) there is a possibility that individuals are lost due to predation or angling; 2) individuals may be lost or gained either by emigration into or immigration out of the population; and 3) certain individuals within the population that were not large enough to be marked at the beginning of the estimate could grow to a size by the end of the estimate that they are included in the estimate.

Density— Smallmouth Bass density was estimated by dividing the estimated abundance (*N*) by the length (km) of the river within the total study area.

Catch per unit of effort (CPUE). — CPUE was calculated for Smallmouth Bass caught in the mark-recapture survey using both electrofishing and angling techniques. This was obtained by dividing the number of fish caught in each event by the total effort (hr) in each event.

Age Class—The Fraser-Lee model method was used to back-calculate length at age, using a standard intercept of 35mm, as supported by Klumb et al. (1999). All scales that were obtained from fish captured were aged. An age-length key was created from Smallmouth Bass scales obtained, which allowed ages to be assigned to fish from which scales that were not analyzed or age classes that were not captured. The mean total length (TL) and age class structure of Smallmouth Bass in the study was then compared to previous studies of Smallmouth Bass in the Spokane River (O'Connor and McLellan 2009) and other northwest rivers (Zimmerman 1999; Fritts and Pearsons 2004, 2006).

Results

Abundance. — The estimated abundance of Smallmouth Bass ≥ 150mm was 1,645 (SE=287; 95% C.I. =1,171-2,310, AIC=429) in the upper Spokane River between the Washington/Idaho Stateline to Harvard Road (Table 2). The estimated abundance for Smallmouth Bass ≥ 200mm was 1,307 (SE = 218; 95% C.I. = 945-1807, AIC=402). According to the assumptions of the POPAN model, estimates obtained were unbiased. No fish were reported to be harvested by anglers during the entirety of the study. No long-term tag-loss was observed, since no fish were captured without tags but with a pelvic fin clip.

Density. —The estimated density for Smallmouth Bass ≥ 150mm was 284 fish/km and 225 fish/km for fish ≥ 200mm.

CPUE. —There were 409 Smallmouth Bass captured between all angling and electroshocking events (Table 3). The mean fish caught for angling per event was 65 (SD=34) with a CPUE of 13.7 (SD= 6.2). The mean fish caught for electroshocking was 25 (SD=3.5) and a CPUE of 13.8 (SD=0.23). The month that had the CPUE was in July

(15.2) compared to other months sampled, using both techniques. When compared to the previous Smallmouth Bass study done in 2009, the CPUE was higher in 2015 (Table 4)

Size Class— Mean TL of Smallmouth Bass was 232 mm (SD=56) and ranged from 63 – 395 mm. Mean weight was 181 g (SD=111) and ranged from 4 – 607g. The mean of both the TL and weight was smaller in 2015 compared to 2008 (Table 5), though there were no fish < 200mm collected in 2008 and there was substantially more fish captured in 2015 (n=411) compared to 2008 (n=190). The peak size classes, according to the length-frequency distribution (Figure 4), were at 220-229mm and 240-249mm. Compared to WDFW results in 2008 (Figure 5), the peak size classes in the length-frequency distribution were smaller.

Age Class—Three hundred and fourteen Smallmouth Bass were aged, though not all scales provided adequate regeneration marks for the aging process. Ages of Smallmouth Bass ranged from 1 to 9 years, which when compared to backcalculated lengths of Smallmouth Bass in Washington State the ages were consistent to previously published studies. Only scales from age 1+, and above, fishes were aged. Using the Fraser-Lee method, ages were back calculated to determine age at length, as well as standard deviation. The Fraser-Lee formula for back-calculating lengths at previous annuli was calculated as:

$$L_i = \frac{Lc-a}{Sc} S_i + a;$$

a = intercept parameter,

$\frac{Lc-a}{Sc}$ = Slope of a two-point regression line to equation L_i

Table 6 shows the age class structure with the associated mean size (TL), weight (g), and standard deviation of length and weight of each age class. Table 7 shows back-calculated lengths at age using the Fraser-Lee method for Smallmouth Bass in the upper Spokane River for 2015.

Table 2. Estimated abundance (95% CI) and density for Smallmouth Bass ≥ 200mm in 2009 and Smallmouth Bass ≥ 200mm, as well as ≥ 150mm in 2015.

Year	Size Class (TL)	Estimate (N; 95% C.I.)	SE	Density (fish/km)
2009	≥ 200mm	908 (524-1691)	284	100
2015	≥ 150 mm	1645 (1,171-2,310)	287	284
	≥ 200mm	1307 (945-1,807)	218	225

Table 3. Catch per unit effort (CPUE), by date, of Smallmouth Bass captured from Washington/Idaho to Harvard Road.

Date	Gear	n	Effort (hr)	CPUE (fish/hr)
9/21/15	Angling	15	3.13	4.79
8/26/15	Angling	111	6.13	18.1
8/6/15	Angling	70	4.95	14.14
7/21/15	Angling	66	3.7	17.83
7/8/15	Electro Pass 2	29	2.06	14.07
7/7/15	Electro Pass 1	22	2.5	13.8
6/30/15	Angling	64	3.5	18.28
6/9/15	Electro Pass 2	26	1.91	13.61
6/8/15	Electro Pass 1	19	1.93	9.84

Table 4. Catch per unit effort (CPUE) of Smallmouth Bass in 2009 compared to 2015.

		Total Length		Weight	
Date	n	Mean	Range	Mean	Range
2009	190	269 (41)	206-422	255 (134)	108-855
2015	410	232 (55)	63-395	181 (111)	4-607

Table 5. Mean length (±SD), mean weight (±SD), and range of Smallmouth Bass captured in 2009 and 2015.

Date	n	Mean Effort (hr)	Mean CPUE (fish/hr)
2009	168	5.4	10.6
2015	422	3.31	13.8

Table 6. Age class structure of Smallmouth Bass captured in 2015, with mean total length TL (± SD) and mean weight Wt (± SD).

Age	n	TL ± SD	Wt ± SD
0+	0	0	0
1+	3	90 ± 19	11 ± 7
2+	9	120 ± 17	37 ± 40
3+	29	172 ± 24	71 ± 26
4+	76	196 ± 27	109 ± 45
5+	91	230 ± 37	168 ± 66
6+	56	257 ± 35	221 ± 67
7+	33	291 ± 41	314 ± 112
8+	16	326 ± 24	428 ± 117
9+	1	345 ± 0	550 ± 0
Total	314	228 ± 58	179 ± 118

Table 7. Back-calculated lengths at age of Smallmouth Bass in the upper Spokane River 2015.

Age	n	1	2	3	4	5	6	7	8	9
1+	3	65 ± 18								
2+	9	45 ± 12	90 ± 13							
3+	30	62 ± 25	108 ± 32	144 ± 32						
4+	75	64 ± 21	111 ± 26	152 ± 31	186 ± 26					
5+	91	70 ± 25	112 ± 36	148 ± 39	184 ± 41	217 ± 43				
6+	56	69 ± 26	107 ± 31	145 ± 33	181 ± 34	216 ± 34	246 ± 35			
7+	33	75 ± 29	112 ± 37	145 ± 40	180 ± 43	216 ± 43	249 ± 45	279 ± 45		
8+	16	83 ± 14	121 ± 21	156 ± 22	194 ± 19	227 ± 16	265 ± 20	298 ± 21	327 ± 23	
9+	1	57	79	117	162	195	227	258	290	319
Grand Mean		68 ± 25	110 ± 32	148 ± 35	184 ± 35	217 ± 39	249 ± 37	284 ± 39	325 ± 24	319

Discussion

Abundance— The abundance estimate for Smallmouth Bass in the upper Spokane River in 2015, for fishes ≥ 200mm was 1,307 (SE = 218; 95% C.I. = 945-1807) was higher than the previous estimate done by O'Connor and McLellan (2009) (908 Smallmouth Bass ≥ 200mm, SE = 284; 95% C.I. = 524-1691). The estimate calculated by O'Connor and McLellan (2009) for Smallmouth Bass included 3.6 more river miles than the estimate done in 2015, Harvard Road (rkm 148.9) to McMillian Road (rkm 145.3). The abundance estimate for Smallmouth Bass ≥ 150mm was 1,645 individuals (SE=287; 95% C.I. =1,171-2,310). Both the ≥ 150mm and ≥ 200mm population estimates in the current study had narrower confidence intervals compared to 2008 estimate as a result of the greater number of fish captured. The abundance estimate of Smallmouth Bass ≥ 150mm, provides a better overall estimate of the total population since it incorporates another size class and more fish captured. No fish ≤ 150mm were recaptured during the study, so statistically they could not be included in the estimate.

Comparing the abundance estimate conducted by WDFW in 2009 to the 2015 estimate should be done with caution. Many differences between the two studies. The two studies were conducted at different times of year, October (2008) and June through September (2015), when water temperatures, flows, and fish behavior were different. The 2008 study also used a closed statistic model and sampling took place over a one month period, whereas the current study used an open statistic models and sampling took place over a four month period. Additionally, the 2008 was conducted using a drift boat electrofisher, whereas the study in 2015 used both an electrofisher raft and angling were used in the current study.

Although comparing the 2008 estimate to the 2015 does not allow for direct comparison, it is clear that the Smallmouth Bass population in the upper Spokane River has grown substantially since the previous abundance estimate in 2008. The expansion of the Smallmouth Bass population could be related to the warmer water temperatures, habitat, and availability of food sources. The previous abundance estimate also showed that there were low numbers of Smallmouth Bass in the lower portion of the upper Spokane River, considered MacMillan Road to Plants Ferry (OConnor and McLellan

2009). Since no sampling occurred in this section, no inference could be made on whether Smallmouth Bass have increased in abundance the lower portion.

Density— Densities of Smallmouth Bass per mile/km between the 2008 and the 2015 studies, is a way to more directly compare results between both studies since different methodologies and sampling techniques were used. When comparing densities, the fish mile/km of Smallmouth Bass ≥ 200mm was considerably higher during 2015 (225 fish/km) compared to 2008 (100 fish/km). The density estimate for Smallmouth Bass ≥ 150mm was 284 fish/km which gave a better representation of the overall population since it incorporated another age class of fishes. The density estimate for Smallmouth Bass ≥ 200mm, was 125 percent higher than the previous density estimate in 2009. This is a very startling number since the population has almost doubled in the number of fish/km in less than 10 years.

CPUE— There was no difference in the CPUE between angling and raft electrofishing in the current study. Angling had a higher mean of fish caught (65.5) to when compared to raft electrofishing (25.6) Angling events had more effort since fish had to be landed and the boat maneuvered to help retain fish. Also a major angling event occurred, on August 21st, which had a greater effort than usual angling events, therefore skewing the amount of effort in the CPUE calculation for angling. One electroshocking and angling event occurred in the months of June and July. However, the electrofishing raft was not able navigate the river due to low water conditions in August, so another angling event was conducted in August. Another contributing factor to the CPUE with electroshocking when compared to angling, is that the Spokane River has extremely low conductivity and the water temperatures were very warm compared to other years prior, which exacerbated catch related to the electrofishing effort. Electrofishing collected smaller size classes (208mm) on average, than angling (239mm). The CPUE for electrofishing in 2015 was higher (13.9) than in 2008 (10.6) for Smallmouth Bass.

Size Class— The mean TL in 2008 was higher, though only by 37mm, than in 2015. The range of fish captured in 2008 was 206-422mm, compared to 63-395mm in 2015. The size class structure in 2015 better represents the population as a whole. The number of Smallmouth Bass caught in 2008 (190) was less than half of the number captured in 2015 (411). Only Smallmouth Band ≥ 200mm were sampled during 2008, whereas all fish captured in 2015 were sampled. The length-frequency distribution was a normal distributed in 2015, with the majority of Smallmouth Bass being between 170mm to 280mm. The length-frequency distribution in 2008 was not normally distributed since only fish ≥ 200mm were sampled. When comparing the peak size classes between 2008 and 2015, results were similar with peaks at 240mm and 250mm in 2008 while 2015 had peaks at 220mm and 240mm.

Age Class— The age class structure of the Smallmouth Bass in the upper Spokane River was consistent with previously published studies in eastern Washington. The 4+, 5+, and 6+ age classes had the highest number of fish seen during the current study. Since no previous on the age class structure was done in 2009, no comparisons could be made between 2009 and 2015. The mean TL at age of Smallmouth Bass in 2009 was consistently larger in all age classes, when compared to 2015. There were only 80 fish were aged in 2009, with 314 fish being aged in 2015, which would possibly account for the smaller mean TL at age. Also, only fish ≥ 200mm were captured during the 2009 survey so therefore no fish below 2+ were accounted for in the age analysis.

Objective 3: The third objective is to determine the amount of predation occurring on Redband Trout by Smallmouth Bass from the Stateline to Harvard Road.

Hypothesis 5: I expect to see Redband Trout as a primary diet item, percent by weight, of Smallmouth Bass in the study area. Starr Road, a documented spawning area for Redband Trout (Parametrix 2003), site is located in the portion of river where the highest population of Smallmouth Bass reside, piscivory of Redband Trout should be should substantial.

Field Sampling

For objective three, Smallmouth Bass were collected by electrofishing and angling surveys during the mark-recapture estimate. For each Smallmouth Bass 150mm and above, diet samples were collected using pulsed gastric lavage. Gastric lavage is very effective, which results in a high recovery of prey (98%) and high survival rate (approximately 90%) in bass species (Foster 1977). Diet samples were placed in Whirl-Pak bags with 70% ethanol and marked with: date of collection, weight, length, and transect number in which it was captured. Samples were stored in a lab freezer prior to examination.

Lab Analysis

Stomach contents were thawed in the laboratory, blotted dry, and then sorted into five prey types: salmonids, non-salmonid fish, crayfish, invertebrates (aquatic and terrestrial invertebrates) and other. The number of organisms in each prey category were counted and wet weighed recorded to the nearest 0.1g for each individual sample. The samples were then drained of ethanol, and let dry of any excess ethanol on samples. Once samples were completed they were returned to the original whirlpack and filled with 70% ethanol.

Diagnostic bones (dentaries, cleithera, pharygenal arches) were examined under a dissecting microscope to identify fish down to the lowest possible taxon, diagnostic bones (Hansel et al. 1988). Consumed fishes that were not able to be identified to species, were identified as either salmonid or non-salmonid using vertebrate of the ingested fish for determination.

Data Analysis

I examined the stomach contents of Smallmouth Bass larger than 150 mm TL. The size class, 150 mm TL, is the smallest size at which Smallmouth Bass are expected to consume substantial numbers of salmonids (Poe et al. 1991; Tabor et al. 1993). Smallmouth Bass were grouped into four size classes for diet analysis (150-199mm, 200-249mm, 250-299mm, 300-349mm, 350-399mm TL) for diet comparisons, as well as comparing each month sampled. Each prey item group of Smallmouth Bass diet (salmonids, Smallmouth Bass, Pumpkin Seed , Longnose Dace (*Rhinichthys cataractae*), unidentified non-salmonids, crayfish, macroinvertebrates, and other) was expressed as the total number of times seen in the diet, total weight, average weight, percent by weight, percent by number, frequency of occurrence, and index of relative importance. The index of relative importance was calculated as:

IRI = (% by number + % by weight) X (% frequency of occurrence).

This allowed for a comparison of Smallmouth Bass' total diet within each size class range, as well as the amount of predation occurring on juvenile Redband Trout by Smallmouth Bass during each month.

Results

A total of 251 stomach samples were collected from Smallmouth Bass ≥ 150mm between June and September (2015). Samples were split into individual months sampled to determine the diet change of Smallmouth Bass between months (Table 8). During June, macroinvertebrates (55.6%) and non-salmonids (20.4%) were the primary and secondary diet items (percent by weight) of Smallmouth Bass (n=66). In July (89), a diet shift occurred where crayfish were the primary diet item (46.1%) and unidentified non-salmonid fishes were the highest secondary diet item (31.2%). The highest primary diet item in August (n=91) was crayfish (34.9%), while Pumpkinseed was the highest secondary diet item (25.9%). The prey item category with the highest frequency of occurrence for each month were: June (Macroinvertebrates = 95.5% and Other =25.7%); July (Crayfish = 59.5% and Macroinvertebrates = 56.1%); August (Macroinvertebrates = 76.6% and Crayfish = 25.5%). The prey item category with the highest index of relative importance for each month were: June (Macroinvertebrates = 55.7%); July (Crayfish=40.6%); and August (Macroinvertebrates = 47.7%).

A diet comparison for Smallmouth Bass, broken into 50mm size classes, was done to determine the differences in diet between individual size classes (Table 9). The primary diet item (percent by weight) for the 150-199mm (69.2%), 200-249mm (52.6%), and 250-299mm (42.6%) size classes was macroinvertebrates. A diet shift occurred in the 300-349mm size class, where crayfish was the primary diet item (38.8%). Another diet shift occurred in the 350-399mm size class, where unidentified non-salmonid fishes were the primary diet item (61.8%). The highest frequency of occurrence of prey item categories for individual size classes were: 150-199mm (Macroinvertebrates = 88.5%); 200-249mm (Macroinvertebrates = 70.0%); 250-299mm (Macroinvertebrates = 65.7%); 300-349mm (Macroinvertebrates = 69.2%); and 350-399mm (Crayfish = 100.0%). The prey item categories with the highest index of relative importance for individual size classes were: 150-199mm (Macroinvertebrates = 68.8%); 200-249mm (Macroinvertebrates = 52.5%); 250-299mm (Macroinvertebrates = 39.6%); 300-349mm (Crayfish = 30.7%); and 350-399mm (Crayfish = 33.9%).

The size range in which piscivory occurred was between 155 and 372mm TL. July was the month with the greatest amount of piscivory, with a frequency of occurrence of 34.7% and an index of relative importance of 26.5%). The 350-399mm size class had the highest frequency of occurrence (66.6 %) and highest index of relative importance (32.9%) of piscivory (66.6 % and 32.9%), however there were only 6 individuals captured in this size range.

Discussion

Though no predation on salmonids was documented during this study, however there have been a variety of studies that have shown the effects of Smallmouth Bass predation on salmonids, primarily anadromous salmonids. Fritts and Pearsons (2006) found that Smallmouth Bass between 150-199mm consumed majority of the anadromous salmonids during the study, 49%, in the lower Yakima River, while bass >300mm targeted larger prey items such as non-salmonids, crayfish, and both aquatic and terrestrial macroinvertebrates. Naughton et al. (2004) and Poe et al. (1991) found that only 11% and 4% of smallmouth diets contained anadromous juvenile salmonids on the Snake River, in the Lower Granite Reservoir system, and John Day Reservoir, respectively. Whereas, Angela (1997) and Tabor et al. (1993) found that 72% and 59% of Smallmouth Bass diets contained anadromous juvenile salmonids on the Snake River, in the lower Granite Reservoir and McNary Reservoir, respectively. These six studies show the vast differences in the rate at which Smallmouth Bass predation occurs on salmonids. Piscivory did occur in Smallmouth Bass, making up 33% of the total diet (by weight) throughout the current study. The population of Smallmouth Bass in the upper Spokane

River could likely impact the Redband Trout population through predation (Fritts and Pearsons 2006; O'Connor and McLellan 2009). One possible reason for the lack of subyearling Redband Trout at any of the sites could be that either emergence occurred earlier than documented (Parametrix 2003), due to low spring flows and higher than normal water temperatures, or there was a possible decline in the recruitment of the young of the year population during the current study. During normal emergence events, it would be likely that salmonids would occur in the diet of the Smallmouth Bass, primarily in the month of June.

Conclusion

The lack of Redband Trout in the upper Spokane River during the study period is a major concern for the health of the Redband Trout fishery. The absence of Redband Trout in this area may be possibly associated with a variety of environmental and biological factors. According to the USGS Spokane River gage at Post Falls, the Spokane River discharge dropped from approximately 4,000 cfs to 700 cfs between June 6th and June 8th. If peak emergence occurred, during normal water flows, between May 28th and June 10th (Parametrix 2003) this would have would occurred during the major decline in flow. The major decrease in flow could have dewatered preferred habitat during emergence, and possibly dewatered redds, causing mortality of the Redband Trout young of the year. No young of the year Redband Trout were seen at Starr Road, site 2, during the second week in June when snorkel surveys and minnow trapping were conducted. Starr Road was the sites where I predicated young of the year Redband Trout were most likely to have been observed. Five young of the year Redband Trout were captured with minnow traps at site 3, Malvern Road, during the first minnow trapping event. This shows that there were some individuals that emerged successfully.

Table 8. Diet of Smallmouth Bass by each month sampled, June through August 2015, in the upper Spokane River from Washington/Idaho Stateline to Harvard Road. Page 1 of 2.

Date (n)	**Prey Item**	**N times in Diet**	**Total Wt.(g)**	**Avg. Wt.(g)**	**% by Wt.(g)**	**% by number**	**FO**	**IRI**
6/2015 (66)	Salmonid				0%			
	Smallmouth Bass	1	0.984	0.984	0.1%	1.1%	1.5%	0.7%
	Pumpkinseed				0.0%			
	Longnose dace	5	11.45	2.287	6.4%	4.1%	7.6%	4.9%
	Crayfish	11	17.653	1.605	9.9%	9.7%	16.7%	9.9%
	Un I.D. Non-salmonid	16	36.581	2.286	20.4%	14.2%	24.2%	15.8%
	Macroinvertebrates	63	99.797	1.584	55.6%	55.8%	95.4%	55.7%
	Other	17	13.601	0.8	7.6%	15.1%	25.7%	13.0%
	Total	**113**	**180.066**	**9.546**	**100.00%**	**100.0%**		**100.0%**
7/2015 (89)	Salmonid	0	0	0	0%	0%	0%	0%
	Smallmouth Bass	0	0	0	0%	0%	0%	0%
	Pumpkinseed	0	0	0	0%	0%	0%	0%
	Longnose dace	3	6.749	2.249	7.2%	2.2%	3.4%	3.6%
	Crayfish	53	43.101	0.828	46.1%	38.4%	59.5%	40.6%
	Un I.D. Non-salmonid	27	29.235	1.083	31.2%	19.6%	30.3%	22.9%
	Macroinvertebrates	50	14.117	0.282	15.1%	36.2%	56.1%	30.3%
	Other	5	0.21	0.035	0.1%	3.6%	5.6%	2.6%
	Total	**138**	**93.412**	**4.477**	**100%**	**100.0%**		**100.0%**
8/2015 (91)	Salmonid	0	0	0	0%	0.0%	0	

Table 8. Diet of Smallmouth Bass by each month sampled, June through August 2015, in the upper Spokane River from Washington/Idaho Stateline to Harvard Road. Page 2 of 2.

Date (n)	**Prey Item**	**N times in Diet**	**Total Wt.(g)**	**Avg. Wt.(g)**	**% by Wt.(g)**	**% by number**	**FO**	**IRI**
	Smallmouth Bass	3	3.478	1.159	4.4%	2.5%	3.3%	3.1%
	Pumpkinseed	1	20.314	20.314	25.9%	1.0%	1.0%	8.6%
	Longnose dace	1	1.205	1.205	1.5%	1.0%	1.0%	1.1%
	Crayfish	23	27.319	1.189	34.9%	20.0%	25.2%	24.6%
	Un I.D. Non-salmonid	12	10.115	0.843	12.9%	10.3%	13.2%	11.2%
	Macroinvertebrates	70	13.549	0.194	17.3%	60.9%	76.9%	47.6%
	Other	5	2.207	0.082	2.6%	4.3%	5.5%	3.8%
	Total	**115**	**78.187**	**24.986**	**100.0%**	**100.0%**		**100.0%**

Table 9. Diet of Smallmouth Bass by 50mm TL size class in the upper Spokane River from Washington/Idaho Stateline to Harvard Road. Page 1 of 3.

Size Class (n)	**Prey Item**	**N times in Diet**	**Total Wt.(g)**	**Avg. Wt.(g)**	**% by Wt.(g)**	**% by number**	**FO**	**IRI (%)**
150-199 (61)	Salmonid	0	0	0	0.0%	0.0%	0%	0.0%
	Smallmouth Bass	1	1.379	1.379	7.2%	1.3%	1.6%	3.1%
	Pumpkinseed	0	0	0	0.0%	0.0%	0.0%	0.0%
	Longnose dace	1	1.205	1.279	6.1%	1.2%	1.6%	2.7%
	Crayfish	7	1.529	0.22	7.8%	8.9%	11.4%	8.5%
	Un I.D. Non-salmonid	5	1.385	0.277	7.1%	6.3%	8.1%	6.5%
	Macroinvertebrates	54	13.564	0.25	69.7%	68.3%	88.5%	68.8%
	Other	11	0.396	0.036	2.1%	14.0%	18.0%	10.4%
	Total	**79**	**19.458**	**3.441**	**100.0%**	**100.0%**		**100.00%**
200-249 (90)	Salmonid	0	0	0	0%	0%	0.0%	0.0%
	Smallmouth Bass	1	0.984	0.984	0.1%	1.0%	1.0%	0.6%
	Pumpkinseed	0	0	0	0.0%	0%	0.0%	0.0%
	Longnose dace	5	12.817	2.543	14.1%	3.9%	5.5%	7.1%
	Crayfish	30	12.469	0.415	13.6%	24.6%	33.3%	21.3%
	Un I.D. Non-salmonid	21	17.487	0.832	19.2%	17.2%	23.3%	17.9%
	Macroinvertebrates	63	47.961	0.761	52.6%	52.3%	70.0%	52.5%
	Other	1	0.001	0.001	0.1%	1.0%	1.0%	0.6%
	Total	**121**	**91.719**	**5.536**	**100%**	**100.0%**		**100.0%**

Table 9. Diet of Smallmouth Bass by 50mm TL size class in the upper Spokane River from Washington/Idaho Stateline to Harvard Road. Page 2 of 3.

Size Class (n)	**Prey Item**	**N times in Diet**	**Total Wt.(g)**	**Avg. Wt.(g)**	**% by Wt.(g)**	**% by number**	**FO**	**IRI (%)**
250-299 (67)	Salmonid	0	0	0	0.0%	0.0%	0.0%	0.0%
	Smallmouth Bass	2	2.099	1.049	1.5%	1.7%	3.0%	1.7%
	Pumpkinseed	0	0	0	0.0%	0.0%	0.0%	0.0%
	Longnose dace	3	5.367	1.789	3.8%	2.6%	3.0%	2.5%
	Crayfish	32	39.926	1.247	28.5%	27.8%	47.8%	28.1%
	Un I.D. Non-salmonid	18	31.005	1.722	22.1%	15.7%	26.9%	17.5%
	Macroinvertebrates	44	59.819	1.359	42.6%	38.3%	65.7%	39.6%
	Other	16	2.056	1.285	1.5%	13.9%	23.9%	10.6%
	Total	**115**	**140.272**	**8.451**	**100.0%**	**100.0%**		**100.0%**
300-349 (26)	Salmonid	0	0	0	0.0%	0.0%	0.0%	0.0%
	Smallmouth Bass	0	0	0	0.0%	0.0%	0.0%	0.0%
	Pumpkinseed	1	20.314	20.314	19.5%	2.0%	3.8%	6.5%
	Longnose dace	0	0	0	0.0%	0.0%	0.0%	0.0%
	Crayfish	14	40.439	2.888	38.8%	28.0%	53.8%	30.7%
	Un I.D. Non-salmonid	9	28.136	3.126	27.0%	18.0%	34.6%	20.3%
	Macroinvertebrates	18	3.917	0.206	3.8%	36.0%	69.2%	27.8%
	Other	8	11.342	1.417	10.9%	16.0%	30.8%	14.7%
	Total	**50**	**104.148**	**27.951**	**100.0%**	**100.0%**		**100.0%**

Table 9. Diet of Smallmouth Bass by 50mm TL size class in the upper Spokane River from Washington/Idaho Stateline to Harvard Road. Page 2 of 3.

Size Class (n)	**Prey Item**	**N times in Diet**	**Total Wt.(g)**	**Avg. Wt.(g)**	**% by Wt.(g)**	**% by number**	**FO**	**IRI (%)**
350-399 (6)	Salmonid	0	0	0	0%	0.0%	0%	0%
	Smallmouth Bass	0	0	0	0%	0.0%	0%	0%
	Pumpkinseed	0	0	0	0%	0.0%	0%	0%
	Longnose dace	0	0	0	0%	0.0%	0%	0%
	Crayfish	6	2.981	0.496	20.7%	37.5%	100.0%	33.9%
	Un I.D. Non-salmonid	4	8.911	2.227	61.8%	25.0%	66.6%	32.9%
	Macroinvertebrates	4	2.271	0.567	15.8%	25.0%	66.6%	23.0%
	Other	2	0.252	0.126	1.7%	12.5%	33.3%	10.2%
	Total	**16**	**14.415**	**3.416**	**100.0%**	**100.0%**		**100.00%**

Another possible explanation for the absence of Redband Trout is the increased temperature that occurred once the flow dropped in the first week of June. During the second week of June temperatures ranged from 18°C to 21°C, however during the last week in June temperatures exceeded 26°C. At these temperatures, most salmonids would not be able to survive for long periods of time. In successive months, July and August, temperatures were in excess of 29°C. These temperatures are lethal to exceeded upper lethal temperatures for salmonids. In the summer months, trout seek thermal refuge in the lower portion of the upper Spokane River, Barker Road downstream to Plantes Ferry, where the inflow of water from the Spokane Valley Rathdrum Prairie Aquifer lowers temperatures (Parametrix 2004). Bailey and Saltes (1982) found that the aquifer provides an influx of 8-10°C influx water into the river, which cools the overall river temperature considerably, temperatures range between 19-23°C, where the aquifer inflow is present. Approximately 75 percent of the salmonid population in the upper Spokane River between the months of July and September were located between Barker Road and Plants Ferry. In a study done by Parametrix (2004), in which 14 Redband Trout were radio-tagged in the upper Spokane River, researchers found that 43 percent of the fish tagged moved downstream to the reach between Sullivan Road and Plants Ferry during the summer months. Parametrix (2004) also observed large concentrations of fish in the pools in the area between Sullivan Road and Plants Ferry.

Smallmouth Bass can withstand higher water temperature than salmonids and flourish in higher water temperatures. Their optimal water temperatures range from 12-31°C (Ferguson 1958; Barans and Tubb 1973; Naughton et al. 2004). The temperatures in the upper Spokane River, between the months of June and September in 2015, ranged from 18-29°C. At these temperatures, Smallmouth Bass experience their optimal growth and metabolic rates. The slow moving water, higher water temperatures, and habitat in the upper Spokane River, between the Washington/Idaho Stateline and Barker Road, favors Smallmouth Bass. Orth and Newcomb (2002) found that adult Smallmouth Bass favor deeper pools, with large coble for cover, while juvenile and subyearling primarily inhabited transition zones between pools and runs. A majority of habitat in the upper Spokane River is ideal for Smallmouth Bass.

Predation by Smallmouth Bass on the young of the year and juvenile Redband Trout may be another factor contributing to the decline of the Redband Trout population in the upper Spokane River. Smallmouth Bass have the potential to negatively affect salmonids in areas where spawning and rearing occurs (Tabor et al. 1993; O'Connor and McLellan 2009). The majority of spawning areas for Redband Trout have been shown to be in the upper portion of the Spokane River, where there is an overlap in Redband Trout spawning habitat and an abundant Smallmouth Bass population (O'Connor and McLellan 2009). It is possible that juvenile Redband Trout must migrate downstream to locate cooler water once they emerge, since summer water temperatures can become lethal in the area between the Washington/Idaho Stateline and Barker Road. Though no predation on juvenile Redband Trout was documented in this study, likely due to the fact that such a small number of juvenile Redband Trout were present, there was a significant amount of piscivory that occurred by Smallmouth Bass on other non-salmonids during the study. Since piscivory occurred on non-salmonids, it is to be expected that during normal water and spawning conditions that predation on juvenile Redband Trout would occur.

Management Implications

It has been well established that there has been a recent decline in the population of Redband Trout in the upper Spokane River. There are a variety of factors that could play a part in decline of the Redband Trout population. Some hypotheses that have been proposed for the decline include: reduction in discharge during juvenile emergence, reduction in stream habitat, reduction in productivity, and an increase in non-native predators. The rapid growing population of Smallmouth Bass and the complete lack of Redband Trout at the Starr Road area, site 2, are both a sign that the Redband Trout population in the upper Spokane River is in dire need of rehabilitation. Incorporating LWD into the stream channel to provide juvenile fish habitat and refuge from predation has been shown to increase juvenile fish populations in a variety of studies (Cederholm 1997). Though the conditions of the study period during 2015 did not provide data for a typical water year, another study during normal water years should be completed. This would help to better determine: habitat and spawning usage of the Starr Road area, site 2, by Redband Trout and Smallmouth Bass, the number of subyearling fish at site 2, the amount of predation occurring on Redband Trout by Smallmouth Bass, the abundance of Smallmouth Bass in all size class at site 2, and a population estimate of Smallmouth Bass from the Washington/Idaho Stateline to MacMillan Road. Having data from both a low water year and normal water year would allow fisheries managers to make a more informed decision about whether installing LWD structures at the Starr Road area would be a valid effort to help boost the Redband population in the upper Spokane River.

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Michael Taylor McCroskey

Graduate Student, Fisheries Research Center, Biology Department, Eastern Washington University, Cheney, Washington

VITA

AUTHOR: Michael Taylor McCroskey

PLACE OF BIRTH: Lewiston, Idaho

UNDERGRADUATE SCHOOLS ATTENDED:

Walla Walla Community College
Spokane Falls Community College
Eastern Washington University

GRADUATE SCHOOLS ATTENDED:

Eastern Washington University

DEGREES AWARDED:

2015 M.S.	Eastern Washington University, Fisheries Research Center, Department of Biology *Thesis:* Smallmouth Bass Abundance and Diet Composition in the upper Spokane River (Advisor: Dr. Paul Spruell)
2011 B.S.	Eastern Washington University, general biology

PROFESSIONAL EXPERIENCE

2015 & 2014	Fisheries Technician, BioAnalysts, Bosie, ID
2015 & 2014	Fly Fishing Guide, SilverBow Fly Shop

TEACHING EXPERIENCE

2015	Teaching Assistant: *Ichthyology* (Biol 462/562) (with Dr. Paul Spruell) Eastern Washington University, Cheney, WA

RESEARCH EXPERIENCE

2015	Smallmouth Bass abundance and diet consumption in the upper Spokane River, Fisheries Research Center, Eastern Washington University
2014	Acoustic tracking of Redband Trout in Lake Roosevelt, Volunteer Technician, Jessica Walston Thesis Project
2012	Impacts of spawning sockeye salmon on benthic macroinvertebrates, Volunteer Technican, Conor Giorgi Thesis Project
2011	Salmonid consumption in the Sanpoil River arm of Lake Roosevelt by Smallmouth Bass and Walleye using bioenergetics modeling, Volunteer Fisheries Technician for Eastern Washington University's Fisheries Research Center

FUNDING & GRANTS

2013	Clearwater Fly Caster Scholarship, Lewiston, ID (granted $1,000)
2013	Spokane Falls Chapter of Trout Unlimited in conjunction with SilverBow Fly Shop, Spokane, WA (granted $5,500)

PRESENTATIONS

McCroskey, M. T. 2016. *Smallmouth Bass abundance and diet composition of in the upper Spokane River,* Spokane Falls Chapter of Trout Unlimted Chapter Meeting, Spokane, WA

McCroskey, M. T. 2015. (Poster) *Smallmouth Bass abundance and diet composition of in the upper Spokane River,* SilverBow Fly Shop Film Tour, Bing Crosby Theater, Spokane, WA

McCroskey, M. T. 2014. (Poster) *Smallmouth Bass abundance and diet composition of in the upper Spokane River,* Graduate Research and Creative Works Symposium, Eastern Washington University, Cheney, WA

McCroskey, M. T. 2014. The use of underwater video as a sampling technique to determine fish abundance, Departmental Seminar Series, Biology Department, Eastern Washington University, Cheney, WA