DISTRIBUTION, MOVEMENTS, AND LIFE-HISTORY CHARACTERISTICS OF YELLOWSTONE CUTTHROAT TROUT *ONCORHYNCHUS CLARKII BOUVIERI* IN THE UPPER YELLOWSTONE RIVER DRAINAGE

by

Brian Daniel Ertel

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

May 2011

APPROVAL

of a thesis submitted by

Brian Daniel Ertel

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to The Graduate School.

Dr. Thomas E. McMahon

Approved for the Department of Ecology

Dr. David W. Roberts

Approved for The Graduate School

Dr. Carl A. Fox

STATEMENT OF PERMISSION TO USE

Brian Daniel Ertel

May, 2011

ACKNOWLEDGEMENTS

This work could not have been completed without the support of many organizations. I thank the National Park Service and the Wyoming Game and Fish Department for supplying funding and personnel throughout this endeavor. I would also like to thank the Jackson Hole One Fly Foundation, National Fish and Wildlife Foundation, and the Yellowstone Park Foundation for financial support. The Student Conservation Association for provided valuable personnel support.

I would like to express my sincere gratitude to my advisor, Dr. Tom McMahon. His support, input, and patience throughout this project have been invaluable to me. I would also like to thank the members of my graduate committee, Dr. Robert Gresswell, Dr. Todd Koel, and Dr. Carter Kruse for their guidance and assistance through this undertaking.

I would like to thank the many biologists, technicians, and volunteers who assisted me over the years. Julie Alexander, Jeff Behncke, Pat Bigelow, Hilary Billman, Jason Burckhardt, Amanda Dickson, Joe Facendola, Conor Gorgi, Bonnie Griffis, Hunter Hutchinson, Kristy Kollus, Dan Mahony, Sylvia Murcia, Brad Olzewski, Chris Romankiewicz, Anna Varian, and Steve Yekel provided countless hours of assistance with field operations and technical support.

Finally, I would like to thank my family for their support and positive attitudes. Thank you for not allowing me to give up when things seemed insurmountable. You have always been there with encouragement and care when I needed it the most. I wouldn’t be here without you.

TABLE OF CONTENTS

TABLE OF CONTENTS-CONTINUED

LIST OF TABLES

LIST OF TABLES-CONTINUED

LIST OF FIGURES

LIST OF FIGURES-CONTINUED

LIST OF FIGURES-CONTINUED

Figure Page

ABSTRACT

Distribution and abundance of Yellowstone cutthroat trout, *Oncorhynchus clarkii bouvieri*, has declined across the historic range because of anthropogenic influences. Habitat has been fragmented and non-native species have been introduced that compete with, feed upon, or interbreed with cutthroat trout. As a result, many cutthroat trout populations are now isolated in headwater streams and life-history forms are lost or reduced. The upper Yellowstone River basin, above Yellowstone Lake, offers a rare opportunity to study Yellowstone cutthroat trout in a large, intact, river system with few anthropogenic influences. Understanding of life-history forms present in the upper Yellowstone River basin assist in proper conservation and management of the watershed. To determine cutthroat trout life-history forms present, their abundance, and habitat preferences, a combination of radio-telemetry, electrofishing, underwater census, habitat assessment, and age and growth were used. Movements of 151 cutthroat trout were tracked by aircraft, 2003-2005. Most relocated fish (98%) followed a lacustrine-adfluvial life history migration pattern, spending an average 24 days in the river. Cutthroat began entering the river in April and most emigrated by August. Fish migrated as far as 67 km to spawn and spawning aggregations within the system were found in only 11 locations. Underwater census and electrofishing surveys were used to determine fish distribution and abundance in the Yellowstone River and its tributaries. Main stem cutthroat trout densities were low and not evenly distributed. A mean of 8 fish/500 m reach were sampled with the majority in 8 reaches. Juvenile (<150 mm, ≤ 2 years old) and large adult (>330 mm, ≥ 4 years old) cutthroat trout were found in the main stem, but fish from 151–330 mm (age 3) were absent. Within tributaries, fish densities ranged from 1.7–49.5 fish/100 m reach. Fish up to 305 mm were sampled and ranged 1 to 4 years in age. Data from this study suggest most cutthroat trout in the upper Yellowstone River express a lacustrine-adfluvial life history, however, some fluvial fish are present in tributaries. These findings will be important in driving conservation and management decisions in this drainage and provide critical information in future ESA listing considerations.

CHAPTER 1

INTRODUCTION

Life-history movements are fundamental determinants of population performance and central to fish ecology and management (Winemiller and Rose 1992). Salmonids in particular, exhibit a complex variety of life-history movements (Varley and Gresswell 1988; Gresswell et al. 1994; Northcote 1997). These movements typically arise from spatial, seasonal, and ontogenetic separation of prime habitats for growth, spawning, and survival (Northcote 1997). Telemetry studies have shown that salmonid species may make long migrations (Schmetterling 2001; Meka et al. 2003) or remain within a small area if habitat is optimal (Young 1996; Mulfeld et al. 2001). Four life-history forms have been described for potamodromous salmonids. Fluvial fish move within a single stream, fluvial-adfluvial fish move between a river and its tributaries, lacustrine-adfluvial fish move between a lake and its tributaries, and allacustrine fish move between a lake and its outlet streams (Varley and Gresswell 1988; Gresswell et al. 1994; Northcote 1997).

Intraspecific variations in life-history characteristics have been documented for anadromous and potamodromous fishes across extensive geographic scales (L'Abee-Lund et al. 1989; Gresswell et al. 1994) and in fishes within the same drainage basin (Riget et al. 1986; Varley and Gresswell 1988; Hogen and Scarnecchia 2006). A review of potamodromy in salmonids showed that 16 of the 19 species examined displayed fluvial or fluvial-adfluvial migration patterns, 17 of the 19 also displayed lacustrine-adfluvial movement, and 4 displayed allacustrine movement (Northcote 1997). The occurrence of multiple migration patterns within a watershed suggests a local adaptation to diverse habitats over time (Gresswell et al. 1994). One life-history type may be dominant for a species or a particular population, but a combination of strategies is an important component in fish distribution and population survival (Winemiller and Rose 1992; Northcote 1997).

Many factors have contributed to the decline of native salmonids across the western United States. Competition and predation from nonnative species, hybridization, and habitat disruption and degradation have all contributed to the decline of native species distribution and abundance (Rieman and McIntyre 1995; Kruse et al. 2000; Hogen and Scarnecchia 2006). These declines have been most severe in high-order, low-elevation streams where human impacts are greatest (Gresswell 1988; Kruse et al. 1997). Because the impacts are more severe in waters lower in drainages, it is the migratory life-history forms, most dominant in high order streams, that have been more heavily impacted and in some instances, lost (Nelson et al. 2002). Thus, fluvial, headwater populations have become the dominant life history in many species (Nelson et al. 2002). The continued loss of migratory populations could have deleterious effects on species survival, as fluvial headwater populations are typically isolated and comprised of fewer, smaller, and less fecund individuals compared to fish located in lower elevation, higher order, and more complex interconnected streams (Wilcox and Murphy 1985; Allendorf and Leary 1988; Kruse et al. 2000). In the lower 48 states, few areas remain with large interconnected watersheds that support fish populations with a complete array of life-history strategies in place. However, the upper Yellowstone River in Yellowstone National Park and the Bridger-Teton Wilderness is one such area.

Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* is an example of a subspecies that uses multiple spawning migration patterns across its range and within individual watersheds (Thurow et al. 1988; Varley and Gresswell 1988; Kaeding and Boltz 2001). Yellowstone cutthroat trout evolved as the only trout species within the Yellowstone and Snake river drainages above Shoshone Falls (Behnke 1992). They are believed to have been derived in the Columbia River basin and passed from Pacific Creek to Atlantic Creek (Columbia River to Missouri River drainage) on Two Ocean Plateau just south of Yellowstone National Park in the Bridger-Teton Wilderness (Jordan 1892). This is thought to have occurred when the meadow area between these two creeks (just 0.2 km apart) was flooded. From Atlantic Creek they descended into Yellowstone Lake and throughout much of the Yellowstone River basin (Jordan 1892).

Historically, Yellowstone cutthroat trout covered the second largest geographic region of any inland cutthroat trout subspecies (Behnke 2002). Only westslope cutthroat trout *O. c. lewisi*, occupied a larger area. More recently however, distribution and abundance of Yellowstone cutthroat trout has declined greatly throughout its historic range (Behnke 2002; May et al. 2007). Although cutthroat trout are sensitive to changes in environmental conditions, the main cause for their decline has been the introduction of nonnative species (Campton and Utter 1985; Kruse et al. 1997, 2000). Cutthroat trout are highly susceptible to hybridization with rainbow trout *O. mykiss* and replacement by brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, and lake trout *S. namaycush*

(Behnke 2002). Although a large portion of their current range is found within federally protected lands, Yellowstone cutthroat trout are still affected by nonnative introductions and habitat degradation. The subspecies was petitioned for listing as a threatened species under the Endangered Species Act in 1998 and 2004 (USFWS 2001, 2006). Decisions by the United States Fish and Wildlife Service in 2001 and 2006 found that listing under the Endangered Species Act was not warranted (USFWS 2001, 2006).

Yellowstone Lake was home to the largest, genetically-pure population of Yellowstone cutthroat trout within their native range, (Gresswell and Varley 1988). Cutthroat trout in Yellowstone National Park and the surrounding wilderness areas are not subject to most of the habitat alterations that affect many cutthroat populations and the Yellowstone River flows unimpeded for over 100 km from its headwaters to the Upper Falls at Canyon. The cutthroat trout in this system, however, are not immune to the effects of nonnative species introductions. From 1881 trough 1955 over 16 million nonnative fish were stocked in Yellowstone Park waters (Varley 1981). Despite stocking 6,800 rainbow trout, and 12,000 landlocked Atlantic salmon *Salmo salar* in Yellowstone Lake (Varley 1981), Yellowstone cutthroat trout remained the only salmonid species in Yellowstone Lake until brook trout were discovered in Arnica Creek, a tributary to Yellowstone Lake, in 1985 (Gresswell 1991). Brook trout were eliminated with piscicide treatments in 1985 and 1986 (Gresswell 1991). In 1994, lake trout were discovered in Yellowstone Lake (Kaeding et al. 1996). A study of otolith microchemistry indicates that initial introduction of lake trout most likely took place in mid- to late 1980s (Munro et al. 2005). Longnose suckers *Catostomus catostomus*, lake chub *Couesius plumbeus*, and redside shiners *Richardsonius balteatus* became established in the lake in the early 1900s. These fish do not appear to have had a negative impact on native cutthroat trout (Gresswell and Varley 1988). In 1998, several cutthroat trout from the lake were found to be infected with *Myxobolus cerebralis*, the parasite that causes whirling disease (Koel et al. 2006). The discovery was made in adult cutthroat trout in the lake, indicating that the disease had been present for several years before detection (Koel et al. 2006). The discovery of both lake trout and whirling disease was of great concern for Yellowstone National Park managers as introduction of nonnative species to lakes and streams have had devastating consequences to indigenous fish fauna (Marnell 1988; Ruzycki et al. 2003; Koel et al. 2005; Balirwa et al. 2007).

Cutthroat trout play a significant role in the Yellowstone Lake ecosystem by providing an important trophic link to the terrestrial community (Ruzycki et al. 2003). Cutthroat trout have a predominately shallow water distribution and spawn in tributary streams exposing them to predation from avian and mammalian predators. In the Yellowstone Lake system, up to 42 bird and mammal species use, or are believed to use, cutthroat trout as a food source (Varley and Schullery 1995).

Fishes in Yellowstone National Park have been studied extensively since the late 1800s. In 1889, David Starr Jordan was commissioned to visit the Park, “for the purpose of procuring exact data preliminary to the work of introducing trout and other fishes” (Jordan 1891). During the expedition he visited many of the waters in and around Yellowstone Park, including Yellowstone Lake and several lake tributary streams documenting trout in many waters. Although his expedition did not visit any tributaries of the upper Yellowstone River, Jordan reported that common accounts state that streams in the area are all well stocked with trout (Jordan 1891). Since then, cutthroat trout in Yellowstone Lake and some areas of the Yellowstone Lake basin have been studied extensively, but not the upper Yellowstone River. Spawning runs of cutthroat trout have been documented in 68 of the 124 known tributaries of Yellowstone Lake (Jones et al. 1986). Some of these streams, such as Clear, Pelican, and Arnica creeks, have been monitored since the mid-1940's. Cutthroat trout homing to natal streams, returning to the same stream in successive or later years, has been documented in Yellowstone Lake tributaries (Ball 1955; Cope 1957; McCleave 1967; Jones et al. 1986).

Yellowstone Lake cutthroat trout display all four spawning life-history migration patterns discussed earlier: lacustrine-adfluvial, fluvial, fluvial-adfluvial, and allacustrine. Within the Yellowstone Lake basin, the lacustrine-adfluvial migration pattern is most common (Gresswell et al. 1994), but it is relatively rare over the entire Yellowstone cutthroat trout distribution (YCT status review Feb. 2006). For the most part, cutthroat trout spawn between April and August in the tributaries of Yellowstone Lake (Ball 1955; Gresswell et al. 1997). Spawners typically spend 1-3 weeks in the stream before returning to Yellowstone Lake (Gresswell et al. 1997). Upon emergence the majority of fry begin to migrate downstream to Yellowstone Lake, but some may over-winter and migrate to the lake the following summer as fingerlings (Ball and Cope 1961). The exception to this appears to be Pelican Creek, the second largest tributary to Yellowstone Lake, where spawners have been reported to over-winter and many fry move downstream in their second and third years (Bulkley and Benson 1962; Gresswell et al. 1997).

Because migratory populations have declined across their historic range (May et al. 2007), effective conservation of this cutthroat trout metapopulation will require a comprehensive understanding of the life-history forms present throughout the Yellowstone Lake drainage upstream of the Upper Falls of the Yellowstone River.

Despite the plethora of data existing on Yellowstone cutthroat trout in Yellowstone Lake and smaller tributaries, the largest tributary to the lake, the upper Yellowstone River, has remained largely unstudied. On account of its remoteness, over 48 km to the nearest road in some areas, no comprehensive assessment of the cutthroat trout in this region had been undertaken. Because of the lack of knowledge of cutthroat trout in this region, the serious threats to cutthroat trout from recent introductions of lake trout and whirling disease, and the recent attempts to list the Yellowstone subspecies as a threatened or endangered species, a complete assessment of cutthroat trout in the upper Yellowstone basin was initiated.

Study objectives were to determine 1) what life-history forms of Yellowstone cutthroat trout are present in the upper Yellowstone River system and 2) the relative distribution, spawning locations, abundance, and habitat use of these life-history forms. Based on insight gained through previous studies of other tributaries of Yellowstone Lake and potamodromous salmonids in other large lake systems, I hypothesized that cutthroat trout in the upper Yellowstone River basin would (1) display multiple life-history forms (Chapters 2, 3, and 4) and exhibit extended rearing (Chapter 3) within the main stem river and its tributaries, (2) migrate long distances to spawn (Chapter 2), (3) spawn over a wide range of locations in the main-stem and tributaries (Chapter 2 and 3), and (4) be associated with specific habitat features (Chapter 3). This study used a combination radiotelemetry, electrofishing, underwater counts, age structure, and habitat use to examine the life history, distribution, and relative abundance of Yellowstone cutthroat trout in the upper Yellowstone River basin. Knowledge gained through this study will provide insight into the Yellowstone cutthroat trout population or populations in this previously unstudied region. This knowledge will help guide conservation and management decisions of Yellowstone cutthroat trout in this region and throughout their range. It will also provide critical baseline data to help determine if lake trout removal efforts are having a positive effect on the Yellowstone cutthroat trout population in the Yellowstone Lake basin.

Literature Cited

Balirwa, J.S. 2007. Ecological, environmental and socioeconomic aspects of the Lake Victoria's introduced Nile perch fishery in relation to the native fisheries and the species culture potential: lessons to learn. African Journal of Ecology 45:120-129.

Ball, O.P. 1955. Some aspects of homing in cutthroat trout. Utah Academy Proceedings 32:75-80.

Ball, O.P., and O.B. Cope. 1961. Mortality studies on cutthroat trout in Yellowstone Lake. U.S. fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife Research Report 55.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, Maryland.

Behnke, R.J. 2002. Trout and salmon of North America. New York: The Free Press.

Buckley, R.V., and N.G. Benson. 1962. Predicting year-class abundance of Yellowstone Lake cutthroat trout. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Research Report 59.

Campton, D.E., and F.M. Utter. 1985. Natural hybridization between steelhead trout (*Salmo gairdneri*) and coastal cutthroat trout (*Salmo clarkii clarkii*) in two Puget Sound streams. Canadian Journal of Fisheries and Aquatic Sciences 42:110-119.

Colyer, W.T., J.L. Kershner, and R.H. Hilderbrand. 2005. Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho-Wyoming. North American Journal of Fisheries Management 25:954-963.

Cope, O.B. 1957. Races of cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Special Science Report.

Gresswell, R.E. 1991. Use of Antimycin for removal of brook trout from a tributary of Yellowstone Lake. North American Journal of Fisheries Management 11:83-90.

Gresswell, R.E., and J.D. Varley. 1988. Effects of a century of human influence on the cutthroat trout of Yellowstone Lake. American Fisheries Society Symposium 4:45-52.

Gresswell, R.E., W.J. Liss, and G.L. Larson. 1994. Life-history organization of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 51(supplement 1):298-309.

Gresswell, R.E., W.J. Liss, G.L. Larson, and P.J. Bartlein. 1997. Influence of basin-scale physical variables on life history characteristics of cutthroat trout in Yellowstone Lake. North American Journal of Fisheries Management 17:1046-1064.

Hogen, D.M., and D.L. Scarnecchia. 2006. Distinct fluvial and adfluvial migration patterns of relict charr, *Salvelinus confluentus*, stock in a mountainous watershed, Idaho, USA. Ecology of Freshwater Fish 15:376-387.

Jones, R.D., D.G. Carty, R.E. Gresswell, C.J. Hudson, L.D. Lentsch, and D.L. Mahony. 1986. Fishery and aquatic management program in Yellowstone National Park. U.S. Fish and Wildlife Service, Technical Report for 1985, Yellowstone National Park, Wyoming.

Jordan, D.S. 1891. A reconnaissance of the streams and lakes of the Yellowstone National Park, Wyoming, In the interest of the United States Fish Commission. The Bulletin of the U.S. Fish Commission 9 for 1889:41-63.

Jordan, D.S. 1892. The story of a strange land. Popular Science Monthly 40:447-458.

Kaeding, L.R., G.D. Boltz, and D.G. Carty. 1996. Lake trout discovered in Yellowstone Lake threaten native cutthroat trout. Fisheries 21:16-20.

Kaeding, L.R., and G.D. Boltz. 2001. Spatial and temporal relations between fluvial and allacustrine Yellowstone cutthroat trout, *Oncorhynchus clarkii bouvieri*, spawning in the Yellowstone River, outlet stream of Yellowstone Lake. Environmental Biology of Fishes 61:395-406.

Koel, T.M., J.L. Arnold, P.E. Bigelow, P.D. Doepke, B.D. Ertel, and D.L. Mahony. 2005. Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers. Fisheries 30:10-19.

Koel, T.M., D.L. Mahony, K.L. Kinnan, C.Rasmussen, C.J. Hudson, S. Murcia, and B.L. Kerans. 2006. *Myxobolus cerebralis* in native cutthroat trout of the Yellowstone Lake ecosystem. Journal of Aquatic Animal Health 18:157-175.

Koel, T.M., J.L. Arnold, P.E. Bigelow, P.D. Doepke, B.D. Ertel, and M.E. Ruhl. 2007. Yellowstone Fisheries & Aquatic Sciences: Annual Report, 2006. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, YCR-2007-04.

Kruse, C.G., W.A. Hubert, and F.J. Rahel. 1997. Geomorphic influences on the distribution of Yellowstone cutthroat trout in the Absaroka Mountains, Wyoming. Transactions of the American Fisheries Society 126:418-427.

Kruse, C.G., W.A. Hubert, and F.J. Rahel. 2000. Status of Yellowstone cutthroat trout in Wyoming waters. North American Journal of Fisheries Management 20:693-705.

L'Abbe-Lund, J.H., B. Jonsson, A.J. Jensen, L.M. Saettem, T.G. Heggberget, B.O. Johnsen, and T.F. Naesje. 1989. Latitudinal variation in life history characteristics of sea-run migrant brown trout *Salmo trutta*. Journal of Animal Ecology 58:525-542.

May, B.E., S.E. Albeke, and T. Horton. 2007. Range-wide status of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*): 2006. Montana Department of Fish, Wildlife, and Parks, Helena, MT.

McCleave, J.K. 1967. Homing and orientation of cutthroat trout (*Salmo clarkii*) in Yellowstone Lake, with special reference to olfaction and vision. Journal of the Fisheries Research Board of Canada 24:2011-2044.

Meka, J.M., E.E. Knudsen, D.C. Douglas, and R.B. Benter. 2003. Variable migratory patterns of different adult rainbow trout life history types in a southwest Alaska watershed. Transactions of the American Fisheries Society 132:717-732.

Mulfeld, C.C., D.H. Bennett, and B. Marotz. 2001. Fall and winter habitat use and movement by Columbia River redband trout in a small stream in Montana. North American Journal of Fisheries Management 21:170-177.

Munro, A.R., T.E. McMahon, and J.R. Ruzycki. 2005. Natural chemical markers identify source and date of introduction of an exotic species: lake trout (*Salvelinus namaycush*) in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 62:79-87.

Nelson, M.L., T.E. McMahon, and R.F. Thurow. 2002. Decline of the migratory form of bull char, *Salvelinus confluentus*, and implications for conservation. Environmental Biology of Fishes 64:321-332.

Northcote, T.G. 1997. Potamodromy in salmonidae-Living and moving in the fast lane. North American Journal of Fisheries Management 17:1029-1045.

Novinger, D.C., and F.J. Rahel. 2003. Isolation management with artificial barriers as a conservation strategy for cutthroat trout in headwater steams. Conservation Biology 17:772-781.

Riget, F.F., K.H. Nygaard, and B. Christensen. 1986. Population structure, ecological segregation, and reproduction in a population of Arctic Char (*Salvelinus alpinus*) from Lake Taseruaq, Greenland. Canadian Journal of Fisheries and Aquatic Sciences 43:985-992.

Ruzycki, J.R., D.A. Beauchamp, and D.L. Yule. 2003. Effects of introduced lake trout on native cutthroat trout in Yellowstone Lake. Ecological Applications 10:23-37.

Schmetterling, D.A. 2001. Seasonal movements of fluvial westslope cutthroat trout in the Blackfoot River drainage, Montana. North American Journal of Fisheries Management 21:507-520.

Thurow, R.F., C.E. Corsi, and V.K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in the upper Snake River drainage, Idaho. American Fisheries Society Symposium 4:25-36.

USFWS (U.S. Fish and Wildlife Service). 2001. Endangered and threatened wildlife and plants: 90-day finding for a petition to list the Yellowstone cutthroat trout as threatened. Federal Register Volume 66:1244-11249.

USFWS (U.S. Fish and Wildlife Service). 2006. Endangered and threatened wildlife and plants: 12-month finding for a petition to list the Yellowstone cutthroat trout as threatened. Federal Register Volume 71:8818-8813.

Varley, J.D. 1981. A history of fish stocking activities in Yellowstone National Park between 1881 and 1980. Informational Paper 35. U.S. National Park Service, Yellowstone National Park, Wyoming.

Varley, J.D., and R.E. Gresswell. 1988. Ecology, status, and management of Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Varley, J.D., and P. Schullery. 1995. The Yellowstone Lake crisis: confronting the lake trout invasion. Yellowstone Center for Resources, U.S. National Park Service, Yellowstone National Park, Wyoming.

Winemiller, K.O., and K.A. Rose. 1992. Patterns of life-history diversification in North American fishes: Implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196-2217.

Young, M.K. 1996. Summer movements and habitat use by Colorado River cutthroat trout (*Oncorhynchus clarkii pleuriticus*) in small, montane streams. Canadian Journal of Fisheries and Aquatic Sciences 53:1403-1408.

CHAPTER 2

SEASONAL MOVEMENT PATTERNS OF ADULT YELLOWSTONE CUTTHROAT TROUT IN THE UPPER YELLOWSTONE RIVER BASIN

Introduction

Migration is an important component in the life history of many taxonomic groups. From the monarch butterfly *Danaus plexippus* 3,600 km migration across North America to central Mexico (Oren et al. 2003) to the sockeye salmon *Oncorhynchus nerka* migrating from its hatching location to the ocean and returning to breed (Quinn et al. 2007), long distance movements are adaptations that have evolved over many generations. Migratory movements often result in increased fitness of the individual by enhancing growth, fecundity, and survival (Northcote 1978, 1997). Within fish taxa, migration patterns for diadromous species are well documented (Ricker 1981; Chapman 1986; Bernatchez and Dodson 1987; Quinn et al. 2007); however, the movements of potadromous fish have received less attention.

Potamodromy, cyclic migrations that take place wholly within freshwater, has been documented in many salmonid species (Riget et al. 1986; Gresswell et al. 1994; Northcote 1997; Meka et al. 2003; Hogen and Scarnecchia 2006). These movements are thought to occur because of spatial, seasonal, and ontogenetic separation of optimal habitats for growth, survival, and reproduction (Northcote 1997). Understanding seasonal movement patterns of fish species is important for proper understanding and management of aquatic ecosystems. Fish that undertake migrations to more optimal habitat often achieve larger body size, have greater fecundity and reproductive success, and live longer (Northcote 1997; Behnke 2002). For example, Yellowstone cutthroat trout that reside in headwater streams typically reach a maximum total length of 229–254 mm and live 3–5 years, whereas fish that migrate into lentic systems following hatching typically reach sizes of 500–610 mm and live 6–9 years (Varley and Gresswell 1988; Thurow et al. 1988; Behnke 2002; Meyer et al. 2003).

Throughout their range, salmonids display a variety of potamodromous life history migration patterns that can vary among or within populations (Ball 1955; Schaffer and Elson 1975; Hogen and Scarnecchia 2006). These include: fluvial (movements within a single stream), fluvial-adfluvial (movements between a river and its tributaries), lacustrine-adfluvial (movements between a lake and its inlet tributaries), and allacustrine (movements between a lake and its outlet streams) (Varley and Gresswell 1988; Northcote 1997). A review of potamodromy in salmonids showed that 16 of the 19 species examined displayed fluvial or fluvial-adfluvial migration patterns, 17 of the 19 also displayed lacustrine-adfluvial movement, and 4 displayed allacustrine movement (Northcote 1997). Evidence suggests that migration patterns can be highly variable even within a single drainage system. For example rainbow trout *Oncorhynchus mykiss* in the Alagnak River, Alaska, display three distinct migratory patterns (Meka et al. 2003) and bull trout *Salvelinus confluentus* in the East Fork South Fork Salmon River, Idaho displayed both fluvial and fluvial-adfluvial life history migrations (Hogen and Scarnecchia 2006).

Cutthroat trout subspecies, which inhabit a broad range of habitats across western North America, display a wide range of migration patterns (Fleener 1952; Varley and Gresswell 1988; Schmetterling 2001; Colyer et al. 2005; Saiget et al. 2007). In Yellowstone National Park, which contains the largest genetically pure Yellowstone cutthroat trout population (Gresswell and Varley 1988), several long term surveys of cutthroat trout spawning migrations in Yellowstone Lake tributaries have been conducted (Ball 1955; Jones et al. 1986; Gresswell et al. 1997; Kaeding and Boltz 2001). Indeed, much of the initial discovery of the range of life history variation among potamodromous salmonids originated from studies of Yellowstone cutthroat trout in Yellowstone National Park. Beginning with the Jordan expedition in 1889 (Jordan 1891) spawning runs have been documented in 68 of the 124 known tributaries of Yellowstone Lake (Jones et al. 1986). All potamodromous life history migration patterns discussed above have been documented in cutthroat trout in Yellowstone Lake and its tributaries (Cope 1957; Bulkley 1963; Varley and Gresswell 1988; Kaeding and Boltz 2001). The lacustrine-adfluvial migration pattern is by far the most common pattern in Yellowstone Lake (Gresswell et al. 1994), but it is relatively uncommon in other parts of their range (Varley and Gresswell 1988; USFWS 2006; May et al. 2007; Sanderson and Hubert 2009). Throughout their historic distribution, lake dwelling Yellowstone cutthroat trout occupied just 50,470 ha in 61 lakes (May et al. 2007). Yellowstone Lake accounted for just over 34,500 ha of occupied lake habitat.

Yellowstone cutthroat trout typically spawn between April and August in the tributaries and outlet of Yellowstone Lake (Ball 1955; Gresswell et al. 1997) with spawners spending from 6–25 days in a stream before returning to the Lake (Gresswell et al. 1997). The known exception to this is Pelican Creek, the second largest tributary to Yellowstone Lake, where spawners have been reported to over-winter (Bulkley and Benson 1962; Gresswell et al. 1997). In most tributaries, the majority of fry begin to migrate downstream to Yellowstone Lake immediately after hatching, but some may over-winter and migrate to the lake the following summer as fingerlings (Ball and Cope 1961). Despite the plethora of data existing on Yellowstone cutthroat trout in the Yellowstone Lake basin, the largest tributary to the lake, the upper Yellowstone River, has been essentially unexplored because of its remoteness, and the life history patterns of Yellowstone cutthroat trout in this major tributary system are unstudied. The Jordan expedition of 1889 did not visit the tributaries of the upper Yellowstone River, but noted that reports state that waters in the region are well stocked with trout (Jordan 1891). The large size and diversity of habitat types of the upper river drainage suggests the potential for the presence of both long distance upstream spawning migrations and the occurrence of multiple life-history strategies.

Yellowstone cutthroat trout in Yellowstone Lake have undergone a sharp decline in abundance in recent years (Koel et al. 2005). The likely causes of this decline are predation by introduced lake trout *Salvelinus namaycush*, presence of whirling disease, and prolonged drought (Ruzycki et al. 2003, Koel et al. 2006, 2007). These continued threats and recent petitions to list Yellowstone cutthroat trout as a threatened or endangered species under the Endangered Species Act underscore the need to understand the extent to which the upper Yellowstone River cutthroat trout metapopulation supports the overall Yellowstone Lake population and the life-history forms present. The knowledge of resident or large migratory metapopulations within the upper Yellowstone River drainage will be critical in aiding status determination in future assessments and protecting existing populations.

To gather baseline information and to evaluate Yellowstone cutthroat trout status for possible listing under the Endangered Species Act, accurate data on life history distribution and abundance of the full range of genetic and life-history diversity of the subspecies is required. This information will also help park managers assess the impacts of lake trout and lake trout removal in Yellowstone Lake. This study seeks to address this need by determining spawning distribution, movement, and life-history patterns of Yellowstone cutthroat trout within the extensive upper Yellowstone River drainage. Because whirling disease has yet to be detected in this tributary system and lake trout density is thought to be concentrated in the northern and western portions of Yellowstone Lake (Koel et al. 2005), the relatively undisturbed upper river entering the southeastern end of the lake may be increasingly important for support of the overall Yellowstone Lake population of Yellowstone cutthroat trout. Developing knowledge and understanding of the status of resident or migratory populations of Yellowstone cutthroat trout in the upper Yellowstone River is, therefore, critical to the conservation of the subspecies. Based on previous studies of potamodromous salmonids and cutthroat trout in other tributaries of Yellowstone Lake, I hypothesized that cutthroat trout in the upper Yellowstone River basin will (1) exhibit multiple life-history characteristics, (2) migrate long distances upstream to spawn, and (3) spawn over a wide range of locations in both the main stem and tributaries.

Study Area

This study was conducted in the upper Yellowstone River, its tributaries, and Yellowstone Lake in northwestern Wyoming (Figure 2.1). From the confluence of the North and South forks (9.2 km and 11.4 km respectively) the Yellowstone River flows 73 km through the Bridger-Teton Wilderness and Yellowstone National Park to its mouth at Yellowstone Lake. This region of the Yellowstone River basin contains over 200 km of tributary streams and covers an area of 1,244 km^2 (42% of the Yellowstone Lake basin). The upper Yellowstone River is one of 68 tributaries to Yellowstone Lake where spawning Yellowstone cutthroat trout have been observed (Jones et al. 1986). Yellowstone Lake (34,500 ha) and the Yellowstone River from the lake outlet to the Upper Falls (25 km) were also included in the study.

The headwater reaches of the main-stem upper Yellowstone River consists of riffle-pool complexes that flow through steep forested slopes of lodgepole pine *Pinus contorta*, whitebark pine *Pinus ablicaulis*, limber pine *Pinus flexilis*, blue spruce *Picea pungens*, and douglas fir *Psuedotsuga menziesii* trees. From the headwaters to Castle Creek, the river gradient is 11.6 m/km and substrate is dominated by boulders and cobble. From Castle Creek to Yellowstone Lake, gradient flattens to 0.96 m/km and the river consists of long runs, glides, and a few large pools. Substrate is dominated by gravel, cobble, and sand. The over-story is similar in structure to the upper reaches, but is more heavily dominated by lodgepole pine. The understory includes fields of willow *Salix spp.* and grasses *Bromus spp.* and *Phleum spp.* Wildfires have occurred in recent decades and large burned areas are common in the watershed.

Native fish species in the Yellowstone River include Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae*. Nonnative species include redside shiner *Richardsonius balteatus*, and longnose sucker *Catostomus catostomus*. Although not documented in the Yellowstone River, lake chub *Couesius plumbeus*, and lake trout have been documented in Yellowstone Lake.

Methods

Radiotelemetry was used to monitor the movements of 152 adult Yellowstone cutthroat trout in the upper Yellowstone River basin from June 2003 to August 2006. Sixty-three, 71, and 18 adult cutthroat trout, were surgically implanted with radio transmitters in 2003, 2004, and 2005, respectively (Figure 2.2). Radio-tagged fish were captured primarily by angling with hook and line (n = 144), but gill-nets (n = 6) and fyke-nets (n = 2) were also used in the Yellowstone River mouth and in Yellowstone Lake. Prior studies have shown that cutthroat trout enter Yellowstone Lake tributaries to spawn from late spring through early summer and spend two to three weeks in the stream (Ball and Cope 1961; Varley and Gresswell 1988; Gresswell et al. 1997). Therefore, capture and implantation efforts were concentrated during this period and again later in the summer in order to capture both lacustrine-adfluvial trout migrating from Yellowstone Lake and possibly the fluvial and fluvial-adfluvial trout in the basin. Sampling was conducted from the mouth of the main stem river to upper tributary reaches when possible. In order to maximize the likelihood of implanting radio transmitters in cutthroat trout with different life-history strategies, specific quotas were developed for the main stem and tributaries during the spawning and post-spawning periods (Table 2.1). The number of fish captured and implanted with transmitters during the spawning season (May – July, n = 146) was greater than the post spawning season (August – October, n = 6). Almost half of the fish (n = 70), were tagged in the main-stem Yellowstone River (Figure 2.2). The remaining fish were tagged in tributaries (n = 74), or in Yellowstone Lake, (n = 8) (Table 2.2).

Transmitter were implanted in fish >650 g to ensure that transmitter weight did not exceed 2% of total body weight (Winter 1996). Prior to implantation, fish were anaesthetized with clove oil (1:10 clove oil:ethanol) mixed with stream water (Anderson et al. 1997; Prince and Powell 2000), measured (total length mm), weighed (g), and sexed. Scale samples were obtained from the left side of the fish just posterior of the dorsal fin above the lateral line for age and growth analysis (Chapter 4).

During transmitter implantation, fish were placed on their dorsum in a V-shaped operating table. Gills were irrigated with fresh water throughout surgery. A surgical incision about 2 cm long was made in the abdominal cavity just anterior to the pelvic girdle about 1 cm from the midventral line. A small hole was punctured approximately 3 cm to the posterior of the incision using a horse catheter to guide the trailing whip antenna through the body wall. Incisions were closed with two or three sutures (Ethilon black monofilament nylon). Following surgery, fish were held in live cars until equilibrium was regained and allowed to swim out of their own volition. All fish were released within 0.5 km of their capture location.

Fish were implanted with Advanced Telemetry Systems, Inc., Model F1835 transmitters weighing 13 g (air weight). Tags emitted a unique code in the 166.267 - 166.967 MHZ frequency range and were programmed with one of three duty cycles to allow monitoring of different aspects of cutthroat trout movement patterns. Duty cycle 1 (12 hours on, 12 hours off, 6 months on, 6 months off, battery life of 308-770 days) was used to assess frequency of repeat spawning, spawning site fidelity (McCleave 1967; Kaeding and Boltz 2001), and interannual spawning movements. Duty cycle 2 (12 hours on, 12 hours off, battery life of 216-432 days) was used to assess spawning and post-spawning movements and identify overwintering areas. Duty cycle 3 (8 hours on, 16 hours off, 90 days on, 275 days off battery life of 763-1,908 days) was used to determine potential for spawning events in successive years and spawning site fidelity. Together, the three duty cycles allowed assessment of all possible life-history strategies used by cutthroat trout in the upper Yellowstone River basin.

Tracking of radio-tagged fish was conducted primarily from a fixed wing aircraft to more easily relocate fish over the large study area (Figure 2.3). To determine fish movements and locations, tracking flights were conducted weekly during the peak spawning migration period (May to August), biweekly during April and September each year and monthly from November 2004 - March 2005 when the majority of duty cycle 2 transmitters were operational. Forty-five tracking flights were conducted from July 2003 through July 2006. Additional tracking events were conducted on foot and boat 2003-

2005. Six trips were conducted on foot, three in August - September of 2003, and three in September - October of 2004 to more precisely locate tagged fish and to recover transmitters from dead fish. Four tracking sessions were conducted from a boat on Yellowstone Lake: two in late September 2004 and two in September 2005, to more precisely locate fish in Yellowstone Lake and to locate additional fish.

Tagged fish were relocated with an Advanced Telemetry Systems R4500 radio transmitter receiver and data logger, which recorded tag frequency, code number, date, time, signal strength, and GPS location (North American Datum 83). Multiple point locations for each fish were recorded during a single tracking event to increase the likelihood of accurately determining fish position. Final point location for an individual fish was determined from the point with the highest corresponding signal strength during each flight. If two point locations had equal signal strengths, the mid-point between the two was selected. Each final point location was then overlaid on maps of the study area using GIS (ArcGIS 9, ArcMap version 9.3). Individual fish locations were grouped by river km to measure migration distances and identify areas of concentrated use.

A review of telemetry studies has shown that aerial telemetry locations had a mean error of 178 m and range of 22 to 426 m (Roberts and Rahel 2005). To determine the detectability of radio tags in this study, five “dummy” tags were deployed in Yellowstone Lake at depths ranging from 0 to 4 m. Signal strength and location were recorded during aerial surveys for comparison to their known location. A signal strength of 80 (scale 1–136) was set as the cutoff for reliable detection. Pilot and data recording personnel were unaware of dummy tag location during tracking flights. Transmitters in shallower water could be detected at greater distances. Detection distance for a transmitter placed at the lake surface was approximately 1 km. At a depth of one meter detection distance dropped to roughly 500 m and at three meters was about 200 m. The test transmitter could not be detected at four meters during aircraft surveys, but could be detected from a boat if the vessel was within 25 m of the transmitter location.

Movement patterns and spawning timing were classified for 95 (62.5%) of the 152 fish implanted with radio transmitters. To facilitate analysis, radio-tagged fish were separated into three groups based on movement patterns. Cutthroat trout that were relocated in Yellowstone Lake or showed a distinct downstream migration pattern towards the lake until their signal was lost were classified as lacustrine-adfluvial. Fish that remained in the Yellowstone River or a combination of the river and its tributaries throughout the year were classified as fluvial or fluvial-adfluvial. The remaining 57 fish were either not relocated after initial tagging or were relocated so infrequently that it was not possible to identify distinct movement patterns.

Movements and locations were classified using several parameters. Beginning migration date was determined by the date an individual was first located in the Yellowstone River following tagging the previous year. Spawning date and location was determined by the time and location of maximum upstream migration distance for each fish (Henderson et al. 2000). Spawning period was defined as the date a fish was first located in the river system to the date a fish exited the system. River exit date was determined as the mid-date between our last relocation date in the Yellowstone River and our next tracking event. Migration distance was considered the distance migrated upstream from the mouth of the Yellowstone River. Home ranges for fluvial or fluvial-adfluvial fish were considered the area between their maximum upstream and downstream locations. Spawning locations were identified by high concentrations of radio-tagged fish at the upstream extent of their migration or observed spawning behavior (digging redds, fish pairing) during implantation trips. These parameters combined with movements observed during the non-spawning period were used to determine life-history categorization for each radio-tagged fish. When possible, lake movements were used to determine if fish tended to remain within distinct sub-basins in Yellowstone Lake.

Annual and seasonal environmental conditions, including stream temperature, are known to affect the timing of cutthroat trout migration into a tributary system as well as timing of spawning (Thurow 1988; Varley and Gresswell 1988; Schmetterling 2001). To help assess the relationship between fish movements and temperature, water temperatures were recorded hourly August 2003 - September 2005 using Optic Stowaway temperature thermographs deployed at two main stem locations and in five tributary streams (Figure 2.4). Because no fish were seen in Cabin Creek, its thermograph was relocated to Phlox Creek in September 2004. Thermographs were downloaded annually so data could be analyzed and thermographs could be checked and replaced if necessary. Because no significant difference was detected in the mean daily temperatures from the different locations, temperatures recorded by the lower main stem thermograph were used for analysis (ANOVA $p = 0.43$, $F = 14.20$, $df = 6$). Mean daily stream temperatures were compared with the number of fish found in the river on a given date.

Fish total length was compared between the main stem river, Yellowstone Lake, and Yellowstone River tributary streams using one-way ANOVA ($\alpha = 0.05$) (Kutner et al. 2005). Spawning date and river exit dates were compared using a Kruskal-Wallis rank test ($\alpha = 0.05$). River entry dates for 2004 and 2005 were compared using a Welch's two sample t-test ($\alpha = 0.05$) (Kutner et al. 2005).

Results

Yellowstone cutthroat trout implanted with transmitters averaged 460 mm in total length (range 400–544 mm, SE 1.96) (Figure 2.5). No significant differences in the total length of fish captured in the main-stem Yellowstone River (456 mm), tributaries of the River (463 mm), or Yellowstone Lake (462 mm) were found (ANOVA, $F = 1.4$, $P = 0.25$, $df = 2$). The 95 fish used for analysis were relocated an average of 4.7 times (range, 1-29) over the four years of tracking flights. Of the remaining 57 fish not used for analysis, 39 (26% of all tagged fish) were not relocated after initial tagging, 17 (11% of all tagged fish) were mortalities (mortality signal received from transmitter or recovered transmitter) with undetermined movement patterns, and one fish tagged in Yellowstone Lake at the mouth of the Yellowstone River never entered the river system.

Based on the movement patterns of radio-tagged cutthroat trout, lacustrine-adfluvial, fluvial, and fluvial-adfluvial life-history strategies were identified. The majority of these fish (n = 91) were classified as lacustrine-adfluvial. Within this group, 60 fish were relocated in Yellowstone Lake and 31 showed a distinct downstream migration pattern before signal loss. Three fish displayed movement characteristics of a fluvial life-history strategy and one displayed a fluvial-adfluvial migration pattern.

Radio-tagged cutthroat trout were concentrated in the river system from late May through mid-July (Figure 2.6). In 2004 and 2005, upstream migrating fish entered the Yellowstone River from May 24 to July 20 with a median date of June 11. Date of entry into the river system differed significantly for 2004 and 2005 (t = 3.2, P = 0.002, df = 7.5). In 2004, median river entry date was June 1 (mean June 3) (n = 10) and in 2005, median entry date was June 13 (mean June 15) (n = 21) (Table 2.3). From 2003 through 2005 fish reached their maximum upstream migration point between June 3 and August 17 with a median date June 28. There was no significant difference in median spawning dates from 2003 through 2005 (Kruskal Wallis F = 4.5, P = 0.10, df = 2) (Table 2.3). Lacustrine-adfluvial fish spent an average of 24 days in the river system before returning to Yellowstone Lake. From 2003 through 2005, fish returned to Yellowstone Lake from June 1 to September 23 with a median date of July 10. There was no significant difference between years for river emigration (Kruskal Wallis F = 0.6, P = 0.74, df = 2) (Table 2.3). Extended stay (after August 1) in the river system was rare (Figure 2.7). Eleven fish that migrated into Yellowstone Lake were found in the river system after August 1 and only two were in the river after September 1. Of these 11 fish, only one fish repeated this behavior in multiple years.

Spawning dates could not be determined for three of the four fish that showed fluvial or fluvial-adfluvial life-history characteristics. The three individuals implanted near Castle Creek were in spawning condition by a known spawning ground; this was most likely their spawning location, but because of their extended stay in this area, spawning date could not be determined. The one fish classified as fluvial-adfluvial migrated into Thorofare Creek in late May or early June over two seasons before returning to the main stem river (Figure 2.8). Based on the timing of movements and final migration point, this is most likely when this fish spawned.

Yellowstone cutthroat trout migrated over long distances to spawn in main stem and tributary locations. Trout traveled a mean distance of 42.7 km (median = 46.5 km, range, 3.2 km to 65.9 km, SE = 1.54) upstream during spawning migrations (Figure 2.9, Table 2.4). Eleven distinct spawning areas were identified in the main-stem Yellowstone River and its tributaries (Figure 2.10). All spawning locations contained gravel sized spawning substrate and were typically located a short distance downstream from a tributary stream. Eight of 11 spawning locations were located upstream of the Cliff Creek confluence with the Yellowstone River, approximately 35 km upstream of Yellowstone Lake (Figure 2.10). Spawning trout were identified in seven reaches in the main-stem Yellowstone River and an additional four reaches in tributary streams. The highest concentrations of radio-tagged fish during the spawning period were found in two locations at rkm 52 and 60 (Figure 2.9). These two areas contained over 30% of the radio-tagged fish spawning in the basin.

Home ranges for fluvial and fluvial-adfluvial cutthroat trout averaged 13.9 km (range, 5–33 km). All fish were implanted in the Yellowstone River, between the Yellowstone River/Thorofare Creek confluence and Castle Creek. Three of the four fish remained in the main-stem Yellowstone River throughout the year and no distinct migration patterns were identified for these fish. The fish classified as fluvial-adfluvial migrated into Thorofare Creek, a tributary of the Yellowstone River, to a known spawning area during the spawning season in both 2004 and 2005 (Figure 2.8).

Iteroparity was displayed by 29 (31% of fish used for analysis) radio-tagged cutthroat trout. Of these 29 fish, 26 were considered for analysis. Two were killed or dropped their transmitter shortly after beginning their upstream migration during their second year and a third was likely tagged on its post-spawning downstream migration. On average, return spawners were found within 3.7 km (range 0 – 52 km) of their previous spawning location (Table 2.4). Only two of 26 fish showed an alternate year spawning pattern. Seven tagged fish returned to spawn in all three seasons, all of which were males. Of these seven fish, four were found in the same location each season and six of seven were found within 3 km of their original spawning location. One male fish was found in a different spawning location each year.

Cutthroat trout spawning migrations into the upper Yellowstone River began when mean daily water temperature rose above freezing. The number of fish present in the Yellowstone River and its tributaries peaked when water temperature rose above 8^{o}C (Figure 2.11). As temperature increased into August, fish returned to Yellowstone Lake. Trout numbers in the river system continued to decline through August and September as temperatures cooled. Few lacustrine- adfluvial spawners remained in the river after early September.

Following emigration from the Yellowstone River cutthroat trout moved throughout Yellowstone Lake. During the spawning season (May – July) few radio-tagged fish were found in Yellowstone Lake. However, in August immediately following the spawning period, fish quickly spread throughout the lake (Figure 2.7). Most fish traveled a minimum of 12 km leaving the Southeast Arm of the lake. Just two of 12 fish located in the lake in August were located in the Southeast Arm and just three of eight fish located over the rest of the year were in the arm. Several fish traveled over 28 km once entering the Lake (Figure 2.12). Fish 668-16 was initially tagged in Thorofare Creek, relocated in the southern portion of the West Thumb basin in Yellowstone Lake, before returning to the Yellowstone River to spawn again. Following spawning, fish 519-19 gradually moved north through the Southeast Arm of the Lake and entered the Yellowstone River outlet for a short time (Figure 2.12). Movement of this distance was not uncommon for fish relocated in the lake. Assessment of overwinter movement and winter habitat use was not possible because of the low number of relocations during winter surveys.

Discussion

Knowledge of life-history types of Yellowstone cutthroat trout present in the upper Yellowstone River basin is crucial for determining conservation strategies and developing a management plan for preservation of the subspecies in the Yellowstone Lake basin. It will also prove helpful to determine future listing status of the subspecies if it is again petitioned to be listed as threatened or endangered under the Endangered Species Act. This study provides insight into the life history movement patterns of cutthroat trout in the previously unstudied upper Yellowstone River basin. Lacustrine-adfluvial, fluvial-adfluvial, and fluvial life-history types were observed within the basin. The dominance of lacustrine-adfluvial life-history strategy, (96% of relocated fish), in the drainage corresponds with previous observations of spawning life history in other tributaries to Yellowstone Lake (Ball and Cope 1961; Varley and Gresswell 1988; Gresswell et al. 1994). The presence of possible fluvial (3%) or fluvial-adfluvial (1%) cutthroat trout in the upper Yellowstone River have not been reported in other tributary streams of Yellowstone Lake that do not contain barriers to migration. Fluvial fish have been reported in the Yellowstone River outlet of Yellowstone Lake (Schill et al. 1986; Kaeding and Boltz 2001). A movement study of cutthroat trout in the Yellowstone River outlet showed that 11% (4 of 38) of the radio-tagged fish classified showed a fluvial life-history strategy (Kaeding and Boltz 2001). No fluvial-adfluvial fish were reported.

The inability to determine movement patterns for 38% (n = 57) of tagged fish was troubling, but not uncommon in radio-telemetry studies (De Rito 2004; Sanderson and Hubert 2009). De Rito (2004) reported the 55% of tagged trout in the Yellowstone River north of Yellowstone National Park either perished or expelled transmitters as a result of spawning. Tags expelled or lost because of fish mortality in the upper Yellowstone River would have likely been washed downstream into deep water pools where detection was difficult. Since Yellowstone cutthroat trout in the upper Yellowstone River spend little time in tributary streams after spawning it is possible that a portion of tagged fish moved into Yellowstone Lake and resided at depths greater than tags could be detected. Twelve fish were preyed upon or scavenged by avian or terrestrial animals. This estimate is based on the recovery locations of transmitters outside of the river banks. Eight of 12 transmitters were recovered close to or on the Molly Islands in Yellowstone Lake, location of white pelican *Pelecanus erythrorhynchos* and double-crested cormorant *Phalacrocorax auritus* rookery. Three transmitters were found below trees frequented as perch sites by bald eagles *Haliaeetus leucocephalus*, and one was found in bear scat on the shore of the Yellowstone River by Mountain Creek.

Spawning timing for cutthroat trout in the upper Yellowstone River basin corresponds with peak spawning dates reported for other tributary streams of Yellowstone Lake (Gresswell 1995; Gresswell et al. 1997). Peak spawning for cutthroat trout has been reported to occur from late May through early July in Clear, Pelican, Arnica, Chipmunk, and Bridge creeks, and the Yellowstone River outlet (Varley and Gresswell 1988; Gresswell et al. 1994 and 1997) and from late April through early August dependent on altitude, water temperature, and runoff throughout their range (Thurow et al. 1988; Gresswell 1995). The duration of stream occupancy of 24 days lies within the reported 6–25 day range reported for other Yellowstone Lake tributaries (Varley and Gresswell 1988; Gresswell et al. 1997).

The presence of spawners inhabiting the river for an extended period, while rare, did occur. Eleven fish did not leave the river system until after August 1 and several were found in the river as late as mid-September. This has previously been reported for just one other tributary to Yellowstone Lake and the Yellowstone River outlet. Cutthroat trout spawners in Pelican Creek are reported to have migrated to the lake in late summer and in some instances spring of the following year (Bulkley and Benson 1962; Gresswell 1995; Gresswell et al. 1997). In the Yellowstone River outlet, spawning cutthroat trout have been reported to spend several months in the river (Schill and Griffith 1984; Kaeding and Boltz 2001).

Long distance migrations to spawning grounds by Yellowstone cutthroat trout observed during this study are not uncommon for potamodromous salmonid species (Fraley and Shepard 1989; Dupont et al. 2007) or subspecies of cutthroat trout (Northcote 1997; Derito 2004; Schrank and Rahel 2004; Colyer et al. 2005). Migrations of this extent, however, have not been previously documented in the Yellowstone Lake watershed. Nearly 60% of the fish relocated migrated over 40 km to spawning grounds. The longest documented migration in the river system was 65.9 km for a fish that spawned in upper Thorofare Creek. Within the main-stem Yellowstone River, the longest migration was 63.2 km. Only one fish migrated less than 6 km upstream to a spawning area near Cabin Creek.

Estimates of movement distance within the river system based on the radiotelemetry may be inflated for this study as tag weight limited the individuals we tagged to those that weighed 650 g or more. Previous reports of Yellowstone Lake cutthroat trout stated that larger, older fish migrate farther upstream than smaller, younger individuals (Cope 1957b; Varley and Gresswell 1988). This, however, does not appear to be the case in the upper Yellowstone River system as the majority of return spawners showed site fidelity. Although few fish captured during radio transmitter implantation surveys were < 650 g threshold, later electrofishing surveys of this region indicated that while not abundant, fish of this size were present (Chapters 3). Length at age determination of cutthroat trout sampled during electrofishing surveys indicated the size of possible resident cutthroat trout in tributaries of the Yellowstone River was below the minimum size limit necessary for transmitter implantation; therefore, it is possible that fluvial fish were more abundant then the tracking study indicated. The lack of fish captured in headwater reaches may have further compounded the problem of overestimating migration distance as these were likely locations of fluvial fish. Electrofishing surveys of headwater reaches within the Mountain Creek drainage (Chapter 3) and Coyote Creek (Wyoming Game and Fish Department unpublished data) also produced possible fluvial populations of cutthroat trout. Although these fish appear to comprise a small percentage of fish in the drainage, they most likely reside in a relatively small area throughout their lifetime, as has been reported for other headwater cutthroat trout populations (Heggenes et al. 1991; Gresswell and Hendricks 2007).

Spawning was concentrated in just 11 locations in the upper Yellowstone River drainage. The majority of these reaches (8 of 11) were located at a distance > 35 km upstream from the mouth of the river at Yellowstone Lake. All identified spawning locations were located a short distance downstream from tributary confluences. However, eleven spawning locations in the drainage is a minimum estimate. Given the large size (1,244 sq km) of the watershed and the presence of cutthroat trout fry in most tributary streams sampled during autumn electrofishing surveys (Chapter 3), cutthroat trout are likely spawning in locations that were not identified during radio-telemetry surveys. Although all spawning areas may not have been identified during the study, the fact that approximately 78% of return spawners showed spawning site fidelity and concentrations of spawning fish were identified in just 11 locations throughout the drainage may be an indication that spawning activities are occurring in limited locations in the main stem river.

Iteroparity has been reported in varying prevalence in spawning tributaries of Yellowstone Lake (Ball and Cope 1961; Jones et al. 1985; Varley and Gresswell 1988; Gresswell et al. 1994). This trait was displayed by approximately 31% (n = 29) of telemetered cutthroat trout relocated in this study. This number is higher than that reported for other populations of cutthroat trout in tributaries of Yellowstone Lake and other systems. Previous reports state that 23% of spawning fish in Clear Creek were return spawners and just 15% for fluvial populations in Idaho (Thurow et al. 1988, Gresswell 1995). The majority of return spawners were consecutive year spawners. This has been reported to be more common in tributaries to Yellowstone Lake (Bulkley 1961), and less so in other populations present at higher elevations (Varley and Gresswell 1988). Prevalence of iteroparity has been linked to growth, parasitic infection, and other physiological factors (Ball and Cope 1961; Gresswell 1995). The high percentage of repeat spawners in the system, in comparison to fluvial or fluvial-adfluvial populations outside of the Yellowstone Lake drainage could be a result of the fitness advantages gained by migrating to Yellowstone Lake following spawning each season.

Spawning migrations began and peaked within a specific water temperature range. Cutthroat trout began to enter the river when mean daily temperatures climbed above freezing and peaked when the Yellowstone River reached a mean daily temperature of 8^{o}C. This temperature range is similar to that reported for spawning cutthroat trout in other tributaries to Yellowstone Lake and throughout their range (Varley and Gresswell 1988; Gresswell 1995; Meyer et al. 2003).

Post-spawning movements in Yellowstone Lake were greater than expected. Although the study was not designed to track fish after entrance Yellowstone Lake, cutthroat trout residing near the lake surface were found during most tracking flights. Transmittered cutthroat trout in the upper Yellowstone River drainage were found throughout the lake once leaving the river system (Figures 2.7, 2.12). Fish traveled over 35 km in many instances once entering the lake. Previous studies of cutthroat trout in Yellowstone Lake indicated that once in the lake fish tend to reside within subbasins within the lake (Liebelt 1968, Gresswell et al. 1997). This was not the case in this study as fish were located at different locations within the lake throughout the tracking season. Fish locations were typically associated with near shore areas around the lakeshore and islands. This was likely a result of the flight pattern and the fact that radio transmitters were difficult to detect at depths greater than four meters. More extensive movements in the lake probably occurred, but the use of radio telemetry is not effective in large, deep lakes (Winter 1996) such as Yellowstone Lake, and therefore, was likely to miss some fish movements once fish returned to the lake.

The Yellowstone cutthroat trout of the upper Yellowstone River basin are unique when compared to other populations of cutthroat trout in the Yellowstone Lake drainage. While the dominant lacustrine-adfluvial life-history type is abundant in tributaries of the lake, the presence fluvial and fluvial-adfluvial fish, while in low numbers, has not been documented in other tributaries to the lake without barriers to migration. Fluvial fish have also been reported in the Yellowstone River outlet to Yellowstone Lake in low numbers (Kaeding and Boltz 2001). It is unknown why some of the cutthroat trout in this system do not migrate to Yellowstone Lake following the spawning period. The low number of possible stream resident fish coupled with the fact that fish with different life-history forms appear to spawn in conjunction with one another further complicates this issue. The long distance migrated by fish in the upper Yellowstone River has not been documented elsewhere in the basin. However, this may be a result of the limited size of other tributary streams to Yellowstone Lake. Studies of Yellowstone cutthroat trout spawning migrations in the Yellowstone River downstream of Yellowstone National Park reported that fish migrated up to 51.7 km through the year (DeRito 2004).

Within the Yellowstone National Park boundary, all waters in the upper Yellowstone River are closed to fishing until July 15th and catch-and-release thereafter. This opening date is later than the median date (July 7th) that tagged lacustrine-adfluvial cutthroat trout had returned to Yellowstone Lake. However, fishing regulation outside of the park boundary allow for angling and creel of two cutthroat trout throughout the year. With the recent introductions of predatory lake trout and the *Myxobolus cerebralis* into Yellowstone Lake and continued drought in the region, the need for protection of Yellowstone cutthroat trout, particularly during the spawning season, should be a top priority for management agencies.

Table 2.1. Radio transmitter implantation design for cutthroat trout in the upper Yellowstone River basin, Wyoming. Numbers indicate the total number of radio transmitters scheduled to be implanted in each stream during the spawning and post-spawning periods 2003-2005.

Stream	Spawning	Post-spawning
Yellowstone River	20	20
Trappers Creek	6	6
Mountain Creek	6	6
Cliff Creek	3	3
Escarpment Creek	3	3
Thorofare Creek	10	10
Open Creek	6	6
Atlantic Creek	6	6
Castle Creek	5	5
Yellowstone Lake	10	0

Table 2.2. Year, location, and number of radio transmitters implanted in adult cutthroat trout in the upper Yellowstone River basin, Wyoming.

Year	Location	Number
2003	Yellowstone River	41
	Thorofare Creek	13
	Mountain Creek	6
	Tributary of Thorofare	3
2004	Yellowstone River	29
	Thorofare Creek	33
	Trappers Creek	1
	Yellowstone Lake	8
2005	Thorofare Creek	1
	Trappers Creek	5
	Mountain Creek	6
	Atlantic Creek	6

Table 2.3. Median date and (range) of river entry, exit, spawning, and maximum upstream river location (mean, range) for radio-tagged cutthroat trout, classified lacustrine-adfluvial, in the upper Yellowstone River basin, Wyoming, 2003 – 2005.

Year	Entry	Spawn	Exit	Maximum upstream location (rkm)
2003	N/A	June 28 (June 24 – August 12)	July 10 (July 3 – August 17)	35.5 (7.8 –57.9)
2004	June 1 (May 24 – July 5)	July 6 (June 3 – August 16)	July 10 (June 8 – August 17)	48.3 (3.2 –65.9)
2005	June 13 (May 27 – July 8)	June 13 (June 3 – July 22)	June 29 (June 17 – August 27)	44.9 (13.6 –63.8)

Table 2.4. Spawning year and locations (distance from Yellowstone Lake (km)) of cutthroat trout repeat spawners in the upper Yellowstone River basin, Wyoming, 2003 – 2006. (MC = Mountain Creek, THC = Thorofare Creek, TRP = Trappers Creek, YSR = Yellowstone River)

Fish code	Stream	Year 1	Year 2	Year 3
267-20	MC	22.2	N/A	22.6
317-22	YSR	35.2	37.1	35.2
368-20	YSR	35.0	35.0	N/A
418-20	YSR	35.8	35.8	N/A
418-21	THC	60.7	60.7	N/A
466-21	YSR	32.3	32.3	N/A
516-21	YSR	N/A	60.1	60.1
566-17	YSR	61.1	60.6	58.3
566-24	MC	21.4	N/A	22.6
617-16	THC	63.8	63.8	N/A
617-17B	THC	16.5	16.5	N/A
617-18	YSR	61.6	61.6	N/A
617-19	YSR	65.1	13.1	19.8
668-16	THC	52.8	61.1	N/A
668-17	THC	61.7	52.8	N/A
668-19	THC	52.8	48.1	N/A
668-21	YSR	39.9	22.2	N/A
716-16	THC	52.8	52.8	52.8
742-19	THC	43.4	46.5	N/A
742-21	THC	43.1	54.1	N/A
766-18	YSR	60.7	60.7	N/A
766-21	THC	40.3	43.1	N/A
792-19	THC	53.4	54.2	N/A
817-16	THC	52.8	55.6	N/A
817-23	THC	41.1	41.1	41.1
923-15	YSR	17.9	17.9	17.9
967-15	THC	53.0	53.8	N/A

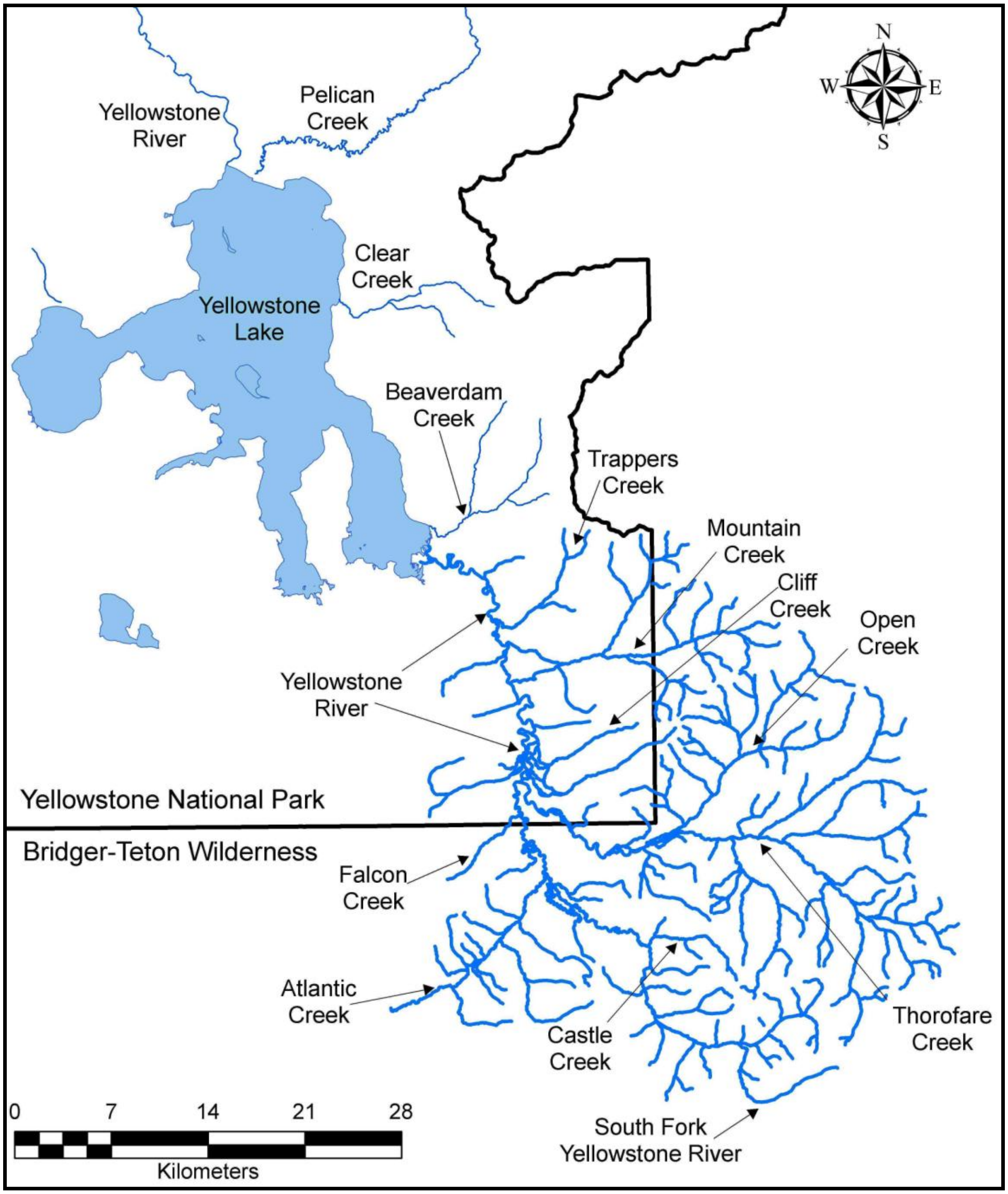

Figure 2.1. Upper Yellowstone River basin study area, Yellowstone National Park, Bridger-Teton Wilderness, Wyoming.

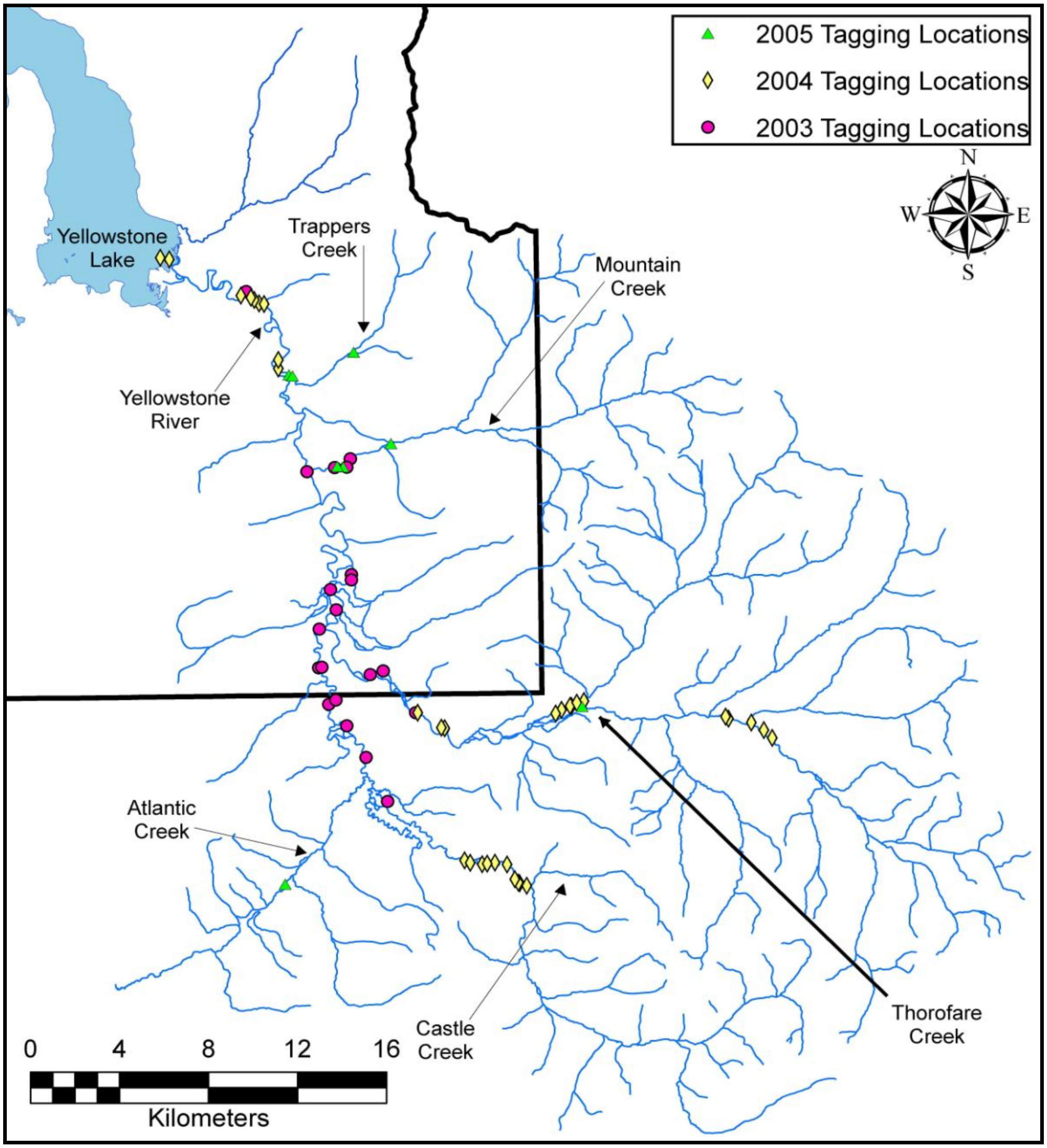

Figure 2.2. Release locations for cutthroat trout implanted with radio transmitters in the upper Yellowstone River basin, 2003–2005.

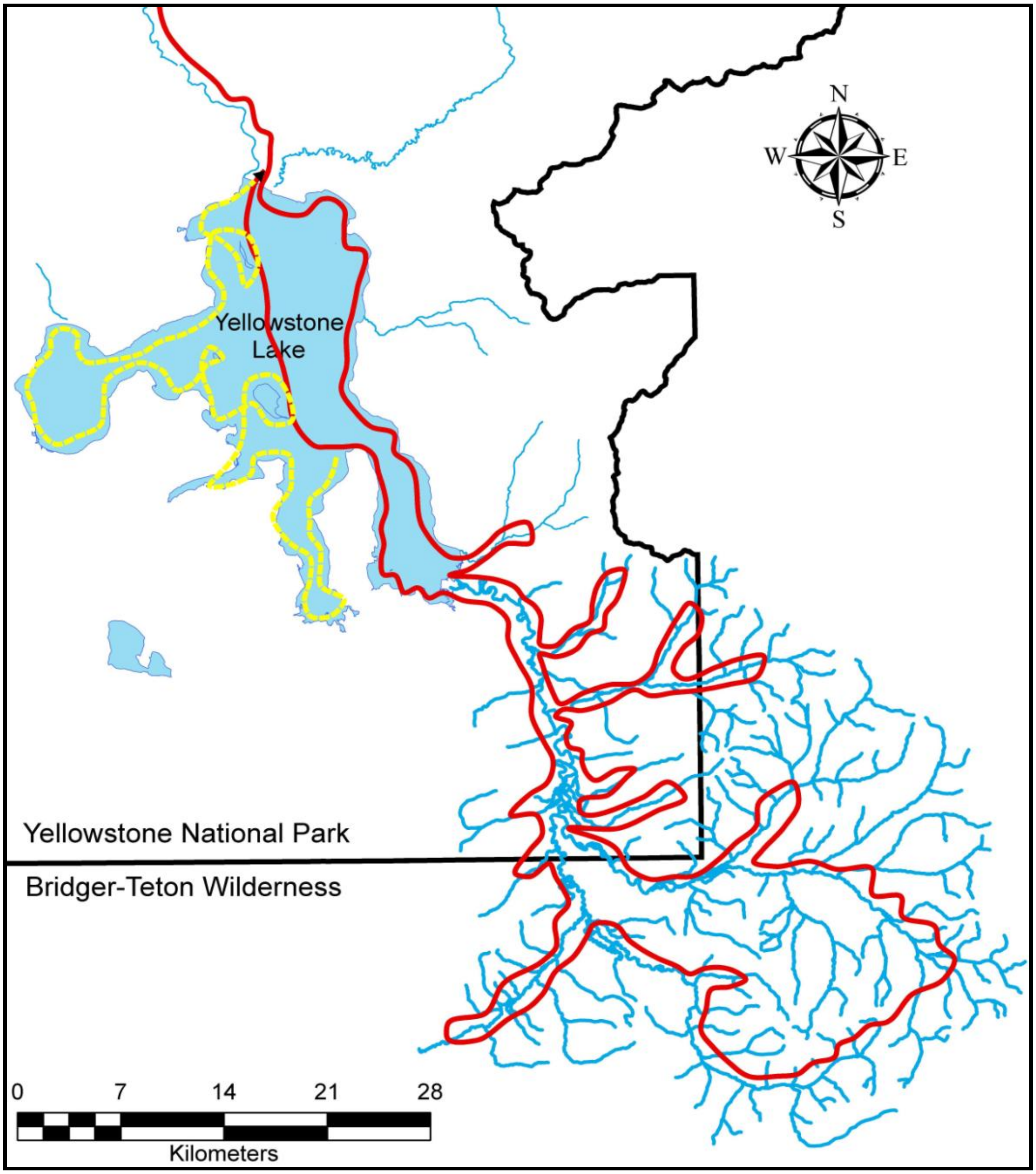

Figure 2.3. Tracking flights were conducted by fixed wing aircraft, 2003-2006 (solid line). Dashed line area added to flight path for 2005 and 2006.

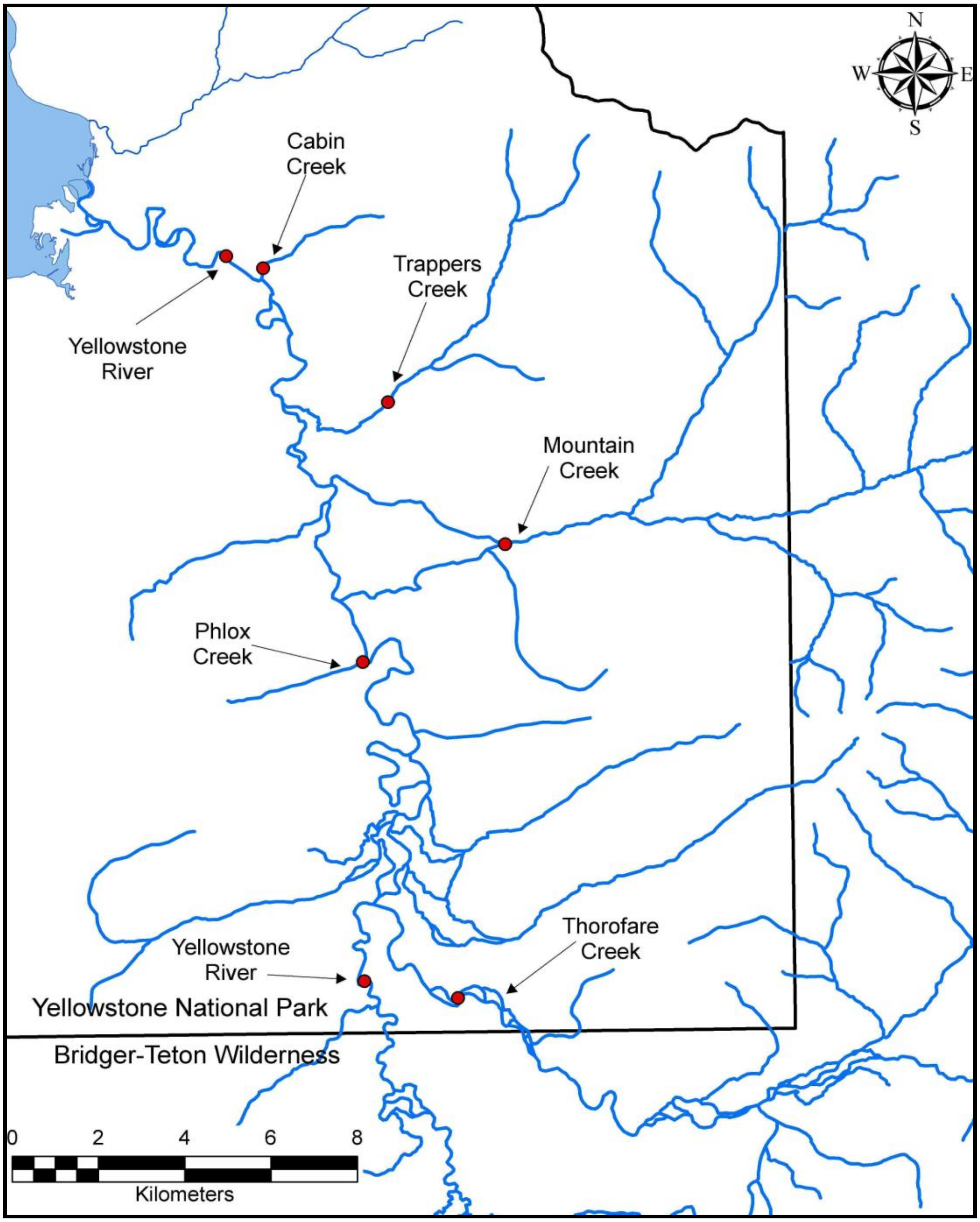

Figure 2.4. Upper Yellowstone River basin temperature thermograph locations. Thermographs were deployed from 2003–2005. Cabin Creek was monitored 2003-2004 and Phlox Creek 2004-2005.

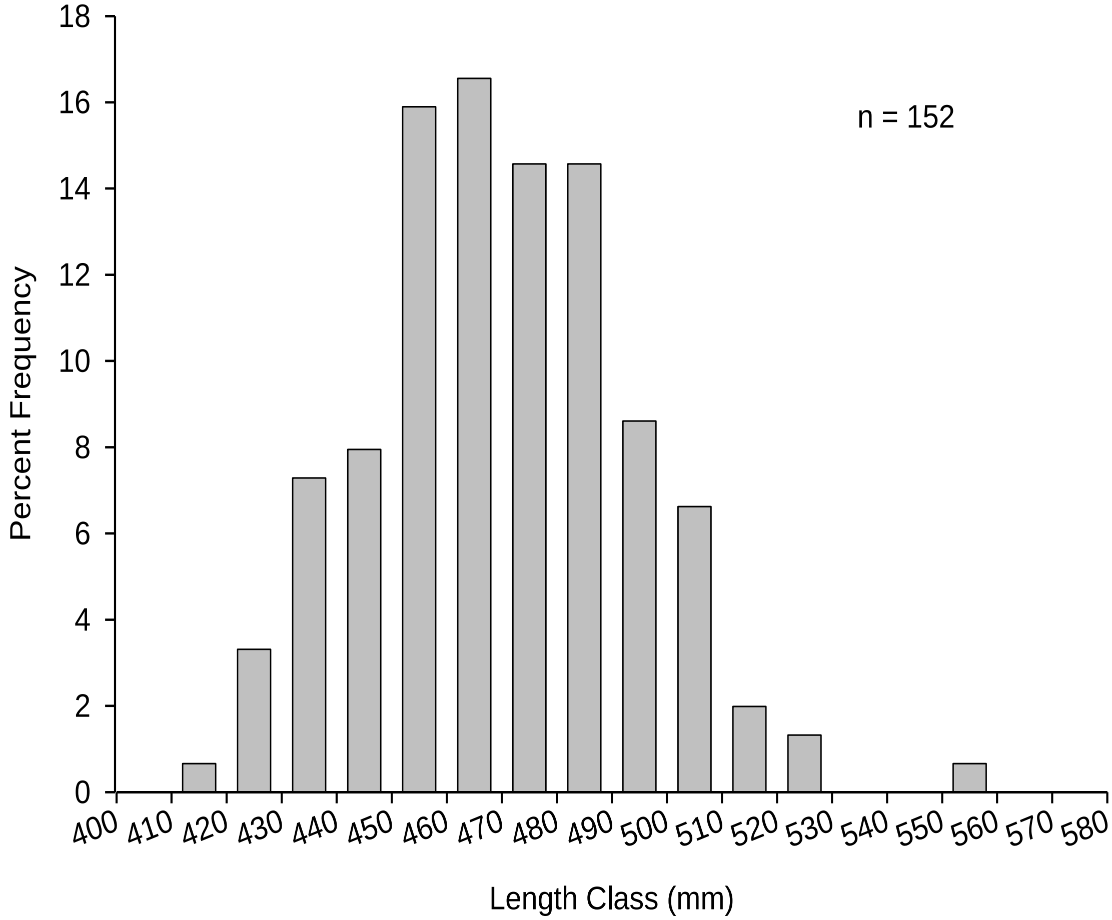

Figure 2.5. Length frequency of adult cutthroat trout implanted with radio transmitters in the upper Yellowstone River basin, Wyoming, 2003–2005.

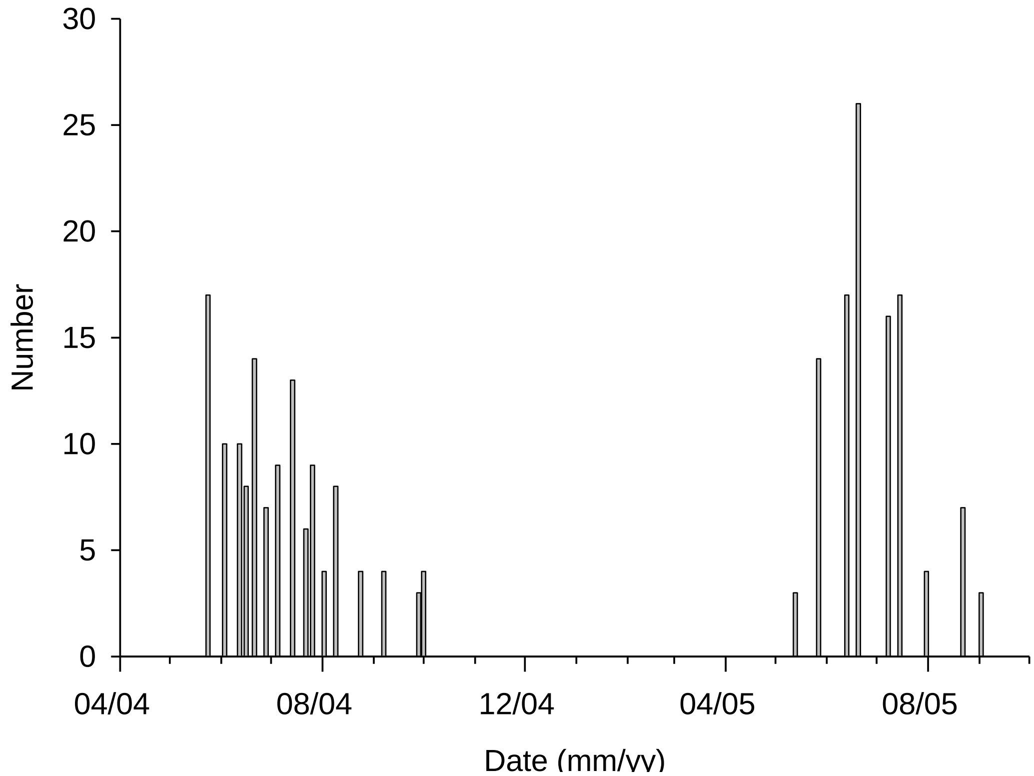

Figure 2.6. Number of radio-tagged cutthroat trout located in the upper Yellowstone River basin during 2004 and 2005. The majority of transmitters were active from May to November each year.

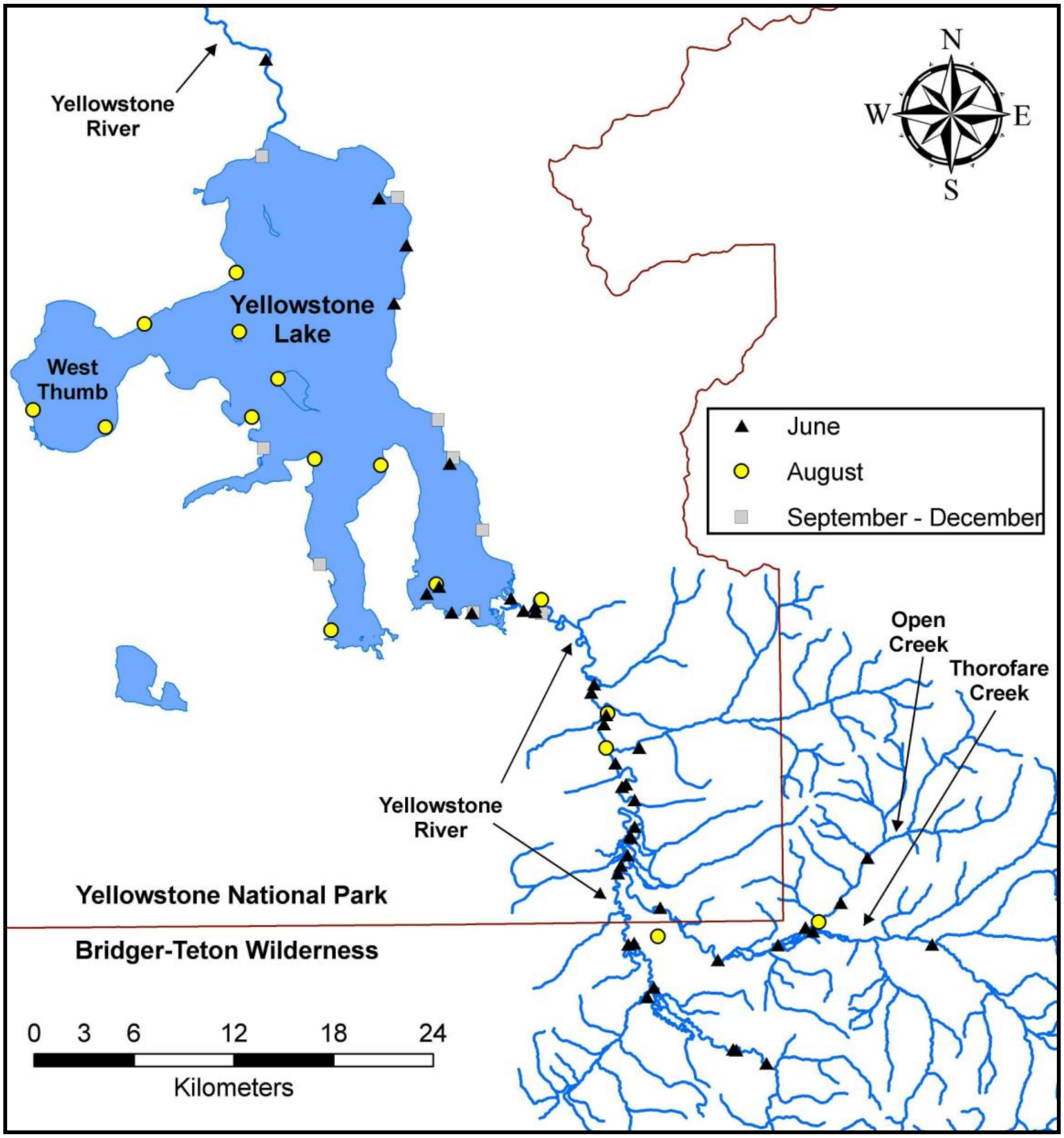

Figure 2.7. Location of radio-tagged cutthroat trout during the peak spawning period (June), immediately post-spawning period (August), and remainder of the year (September - December), in the upper Yellowstone River basin and Yellowstone Lake, 2005.

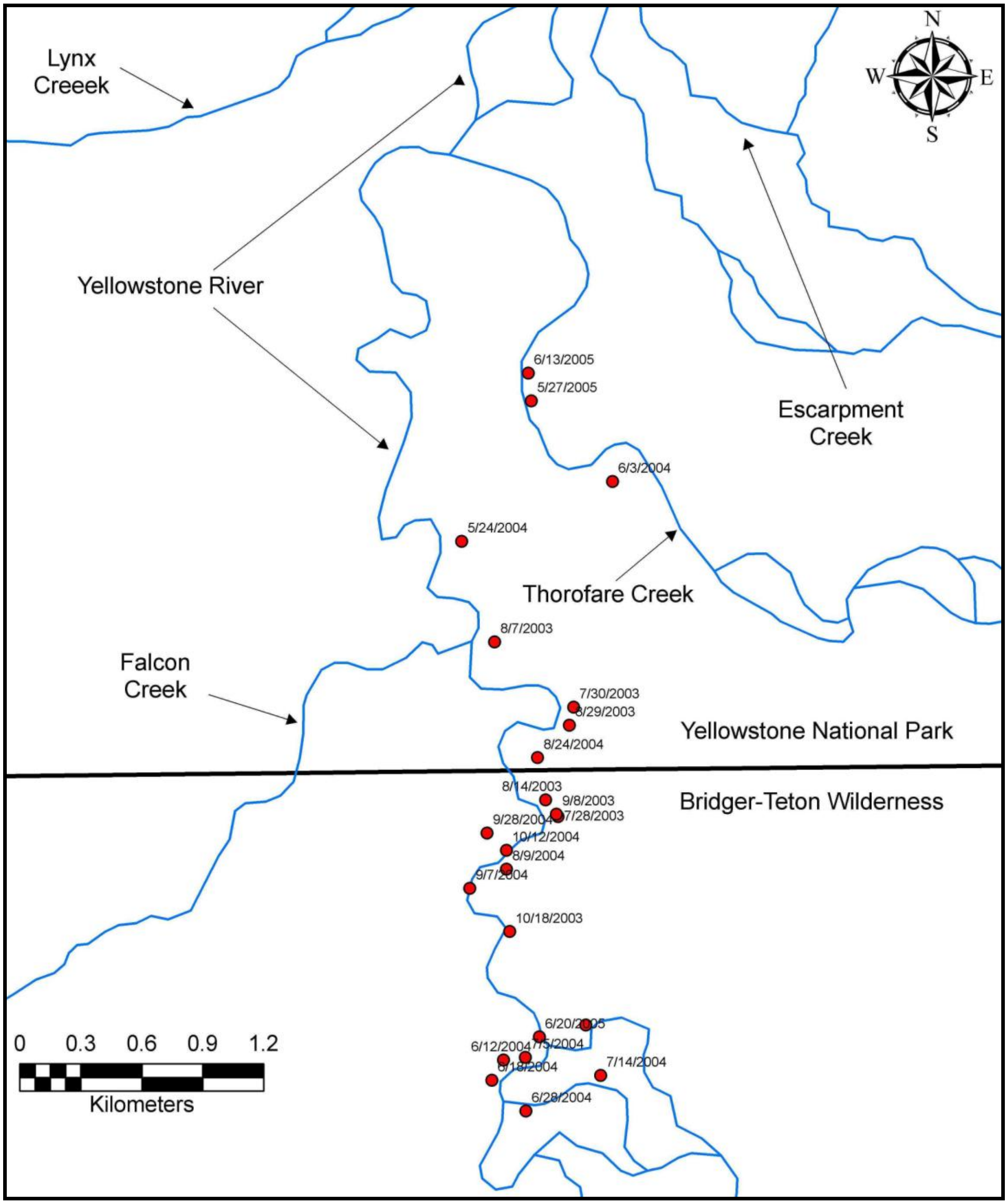

Figure 2.8. Example of a movement pattern classified as fluvial-adfluvial. Shown as location by date of cutthroat trout 466-20. This fish migrated from the Yellowstone River into Thorofare Creek each spring during the spawning period and returned to the Yellowstone River for the remainder of the year.

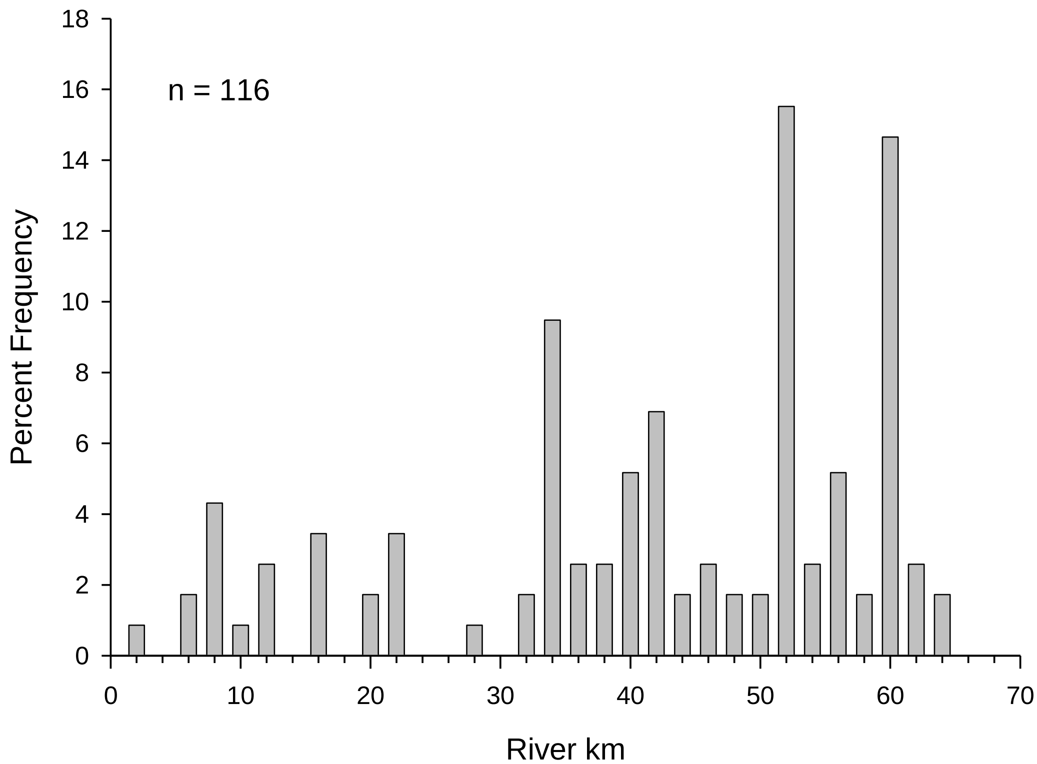

Figure 2.9. Farthest upstream distance migrated from Yellowstone Lake by cutthroat trout implanted with radio transmitters in the upper Yellowstone River basin, Wyoming, 2003–2006. A higher percentage of fish found in certain locations is an indication that these areas are likely cutthroat trout spawning grounds.

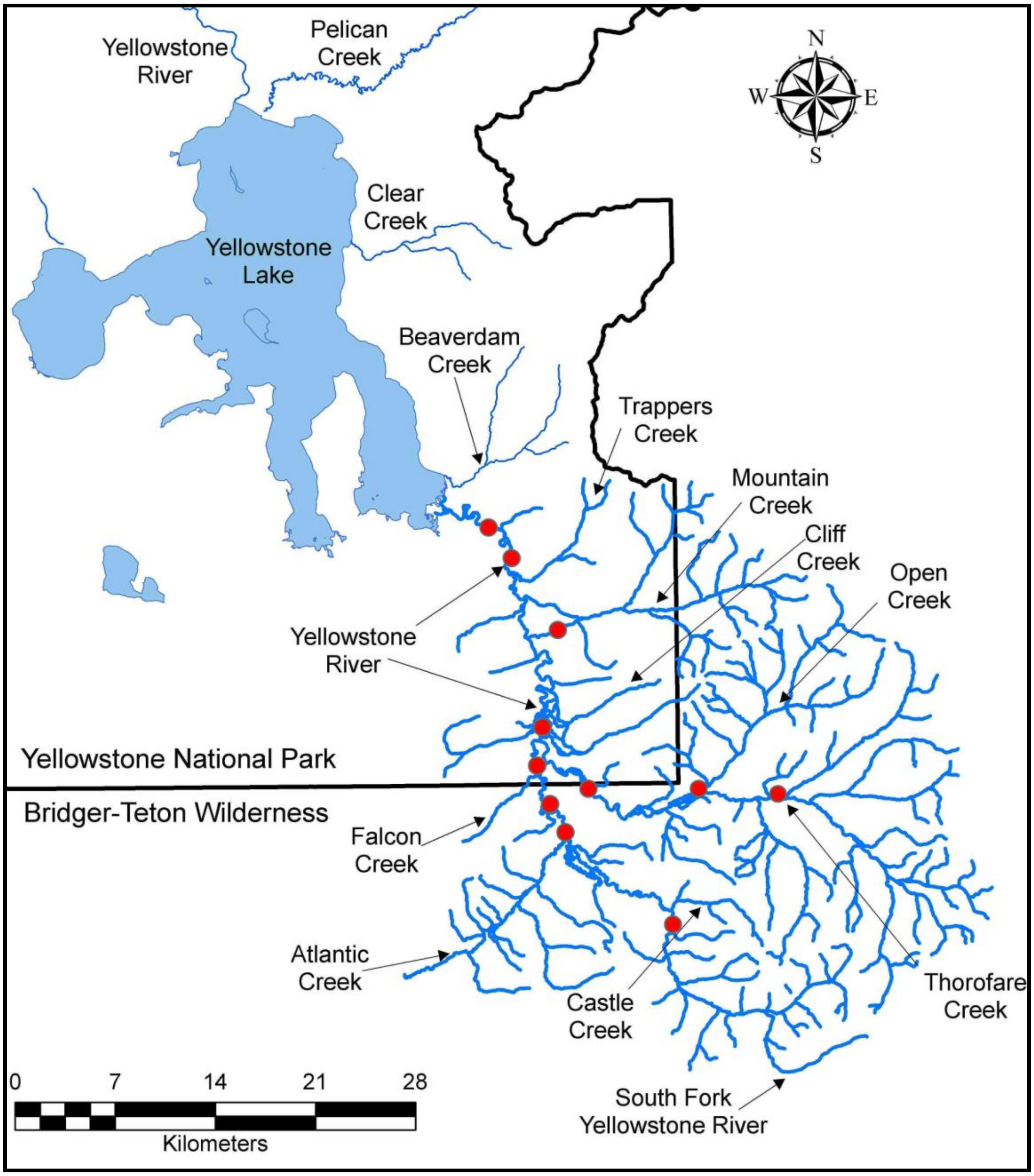

Figure 2.10. Spawning locations of radio-tagged cutthroat trout identified through radio-tracking surveys of the upper Yellowstone River basin, Wyoming, 2004–2006.

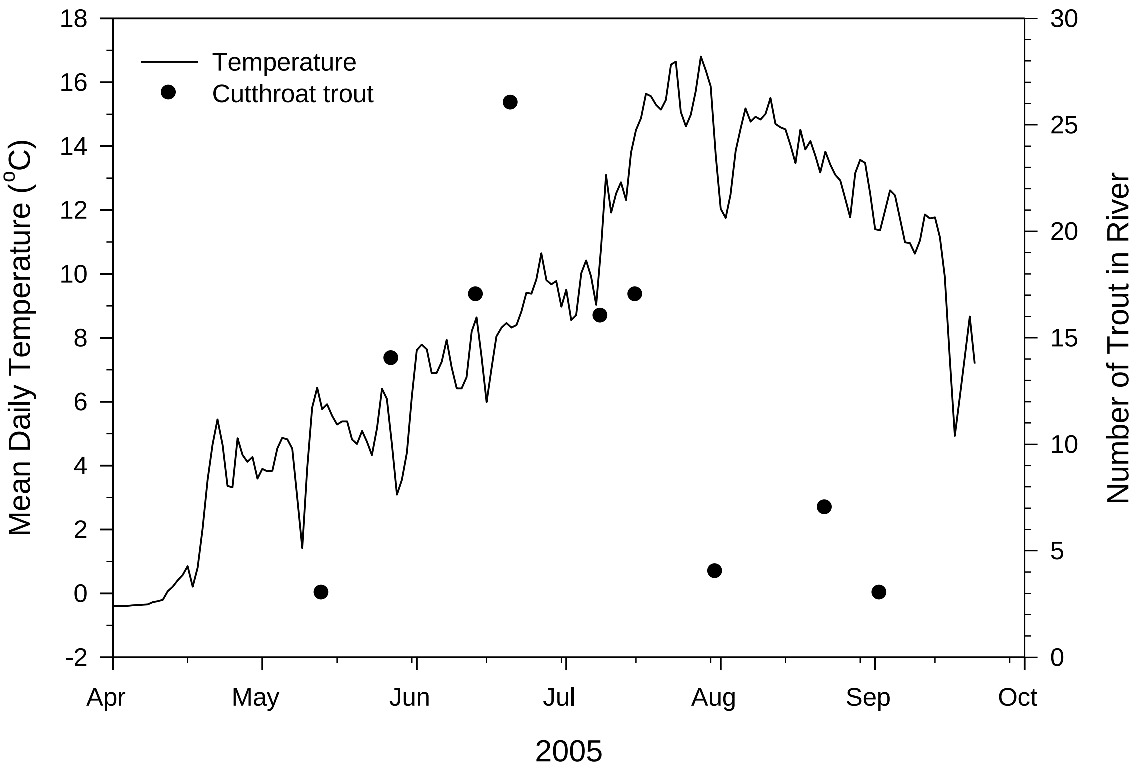

Figure 2.11. Number of radio-tagged cutthroat trout located in the upper Yellowstone River basin, Wyoming, compared to mean daily water temperature of the Yellowstone River 2005.

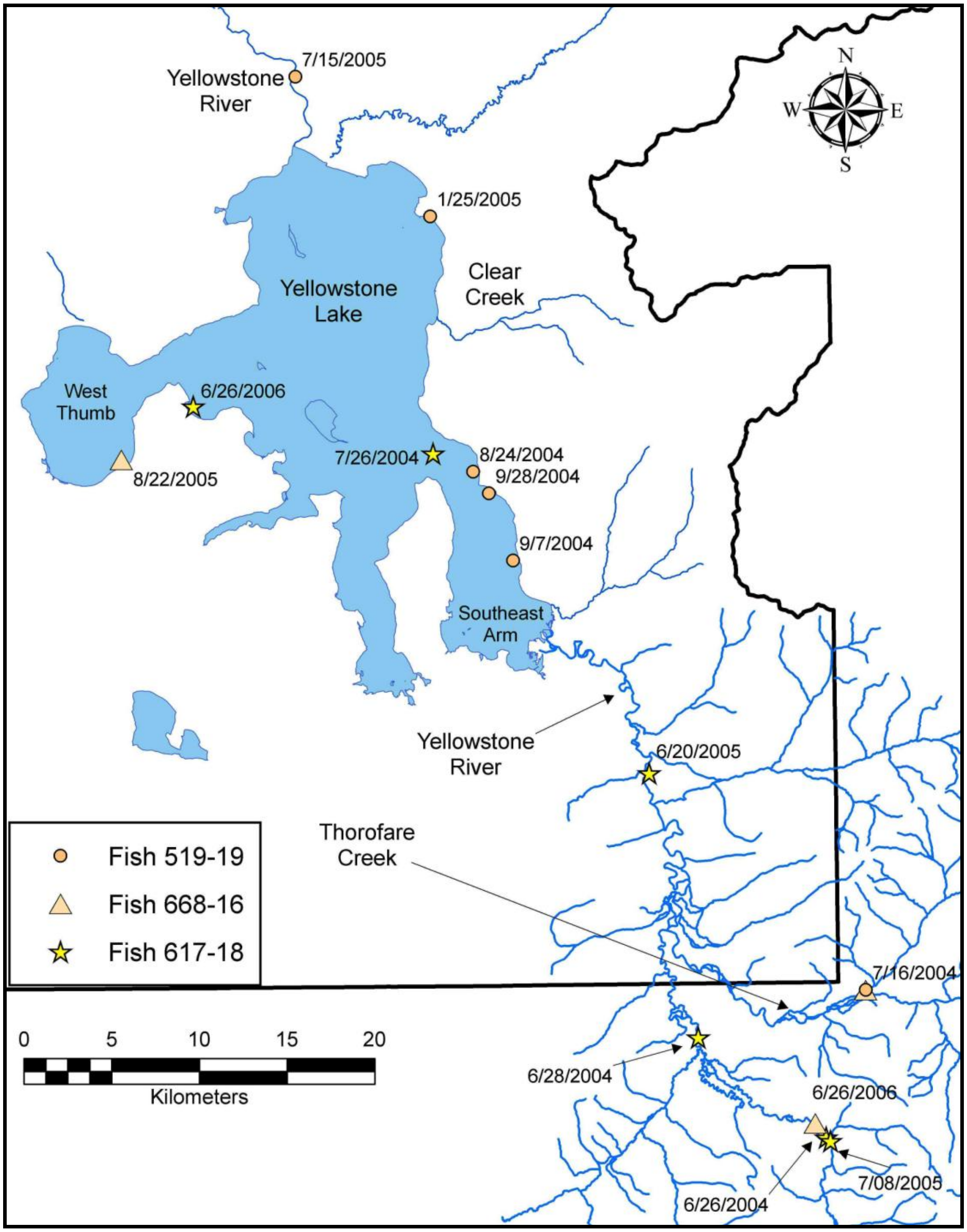

Figure 2.12. Locations by date of three cutthroat trout implanted with radio transmitters in the upper Yellowstone River basin. Fish migrated a minimum of 28 km once entering Yellowstone Lake following the spawning period.

Literature Cited

Anderson, W.G., R.S. McKinley, and M. Colavecchia. 1997. The use of clove oil as an anesthetic for rainbow trout and its effects on swimming performance. North American Journal of Fisheries Management 17:301-307.

Ball, O.P. 1955. Some aspects of homing in cutthroat trout. Utah Academy Proceedings 32:75-80.

Ball, O.P., and O.B. Cope. 1961. Mortality studies on cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Research Report 55.

Bulkley, R.V. 1961. Fluctuations in age composition in growth rate of cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Research Report 54.

Bulkley, R.V., and N.G. Benson. 1962. Predicting year-class abundance of Yellowstone Lake cutthroat trout. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife Research Report 59.

Bulkley, R.V. 1963. Natural variation in spotting, hyoid teeth counts, and coloration of Yellowstone cutthroat trout. U.S. Fish and Wildlife Service Special Science Report Fish 460.

Colyer, W.T., J.L. Kershner, and R.H. Hilderbrand. 2005. Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho-Wyoming. North American Journal of Fisheries Management 25:954-963.

Cope, O. B. 1957a. Races of cutthroat trout in Yellowstone Lake, U.S. Fish and Wildlife Service Special Science Report. Fish 208:74-84.

Cope, O.B. 1957b. The choice of spawning reaches by cutthroat trout. Proceedings of the Utah Academy of Sciences, Arts, and Letters 34:73-79.

De Rito, J.N. 2004. Assessment of reproductive isolation between Yellowstone cutthroat trout and rainbow trout in the Yellowstone River, Montana. M.S. Thesis, Montana State University, Bozeman, Montana.

Downing, D.C., T.E. McMahon, B.L. Kerans, and E.R. Vincent. 2002. Relation of spawning and rearing life history of rainbow trout and susceptibility to *Myxobolus cerebralis* infection in the Madison River, Montana. Journal of Aquatic Animal Health 14:191-203.

DuPont, J.M., R.S. Brown, and D.R. Geist. 2007. Unique allacustrine migration patterns of a bull trout population in the Pend Oreille River drainage, Idaho. North American Journal of Fisheries Management 27:1268-1275.

Fleener, G.G. 1952. Life history of the cutthroat trout, *Salmo clarki Richardson*, in Logan River, Utah. Transactions of the American Fisheries Society 81:235-248.

Fraley, J.J., and B.B. Shepard. 1989. Life history, ecology and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and River System, Montana. Northwest Science 63:133-142.

Gresswell, R.E., W.J. Liss, and G.L. Larson. 1994. Life-history organization of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 51(supplement 1):298-309.

Gresswell, R.E. 1995. Yellowstone cutthroat trout. Pages 36-54 *in* M.K. Young, editor. Conservation assessment for inland cutthroat trout. U.S. Forest Service General Technical Report RM-GTR-256.

Gresswell, R.E., W.J. Liss, G.L. Larson, and P.J. Bartlein. 1997. Influence of basin-scale physical variables on life history characteristics of cutthroat trout in Yellowstone Lake. North American Journal of fisheries Management 17:1046-1064.

Gresswell, R.E., and S.R. Hendricks. 2007. Population-scale movement of coastal cutthroat trout in a naturally isolated stream network. Transactions of the American Fisheries Society 136:238-253.

Heggenes, J., T.G. Northcote, and A. Peter. 1991. Spatial stability of cutthroat trout (*Oncorhynchus clarki*) in a small, coastal stream. Canadian Journal of Fisheries and Aquatic Sciences 48:757-762.

Henderson, R., J.L. Kershner, and C.A. Toline. 2000. Timing and location of spawning by nonnative wild rainbow trout and native cutthroat trout in the South Fork Snake River, Idaho, with implications for hybridization. North American Journal of Fisheries Management 20:584-596.

Hogen, D.M., and D.L. Scarnecchia. 2006. Distinct fluvial and adfluvial migration patterns of relict charr, *Salvelinus confluentus*, stock in a mountainous watershed, Idaho, USA. Ecology of Freshwater Fish 15:376-387.

Jones, R.D., D.G. Carty, R.E. Gresswell, K.A. Gunther, L.D. Lentsch, and J. Mohrman. 1985. Fishery and aquatic management program in Yellowstone National Park. U.S. fish and wildlife Service, Technical Report for 1984, Yellowstone National Park, Wyoming.

Jones, R.D., D.G. Carty, R.E. Gresswell, C.J. Hudson, L.D. Lentsch, and D.L. Mahony. 1986. Fishery and aquatic management program in Yellowstone National Park. U.S. fish and wildlife Service, Technical Report for 1985, Yellowstone National Park, Wyoming.

Jordan, D.S. 1891. A reconnaissance of the streams and lakes of the Yellowstone National Park, Wyoming. The bulletin of the U.S. Fish Commission 9 for 1889:41-63.

Kaeding, L.R., and G.D. Boltz. 2001. Spatial and temporal relations between fluvial and allacustrine Yellowstone cutthroat trout, *Oncorhynchus clarki bouvieri*, spawning in the Yellowstone River, outlet stream of Yellowstone Lake. Environmental Biology of Fishes 61:395-406.

Kaplinski, M.A. 1991. Geomorphology and geology of Yellowstone Lake, Yellowstone National Park, Wyoming. M.S. thesis, Northern Arizona University, Flagstaff, AZ.

Koel, T.M., P.E. Bigelow, P.D. Doepke, B.D. Ertel, and D.L. Mahony. 2005. Yellowstone Fisheries & Aquatic Sciences: Annual Report, 2004. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, YCR-2005-04.

Koel, T.M., D.L. Mahony, K.L. Kinnan, C. Rasmussen, C.J. Hudson, S. Murcia, and B.L. Kerans. 2006. *Myxobolus cerebralis* in native cutthroat trout of the Yellowstone Lake Ecosystem. Journal of Aquatic Animal Health 18:157-175.

Koel, T.M., J.L. Arnold, P.E. Bigelow, P.D. Doepke, B.D. Ertel, and M.E. Ruhl. 2007. Yellowstone Fisheries & Aquatic Sciences: Annual Report, 2006. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, YCR-2007-04.

Kutner, M.H., C.J. Nachtsheim, J. Neter, and W. Li. 2005. Applied linear statistical models. Fifth edition. McGraw-Hill. United States.

Liebelt, J.E. 1968. A serological study of cutthroat trout (*Salmo Clarkii*) from tributaries and the outlet of Yellowstone Lake. M.S. Thesis, Montana State University, Bozeman, Montana.

McCleave, J.D. 1967. Homing and orientation of cutthroat trout (*Salmo clarki*) in Yellowstone Lake, with special reference to olfaction and vision. Journal of the Fisheries Research Board of Canada 24:2011-2044.

Meka, J.M., E.E. Knudsen, D.C. Douglas, and R.B. Benter. 2003. Variable migratory patterns of different adult rainbow trout life history types in a southwest Alaska watershed. Transactions of the American Fisheries Society 132:717-732.

Meyer, K.A., D.J. Schill, F.S. Elle, and J.A. Lamansky Jr. 2003. Reproductive demographics and factors that influence length at sexual maturity of Yellowstone cutthroat trout in Idaho. Transactions of the American Fisheries Society 132:183-195.

Morgan, L.A., W.C. Shanks, D.A. Lavalvo, S.Y. Johnson, W.J. Stephenson, K.L. Pierce, S.S. Harlan, C.A. Finn, G. Lee, M. Webring, B. Schulze, J. Duhn, R. Sweeney, and L. Balistrieri. 2003. Exploration and discovery in Yellowstone Lake: results from high-resolution sonar imaging, seismic reflection profiling, and submersible studies. Journal of Volcanology and Geothermal Research 122:221-242.

Northcote, T.G. 1997. Potamodromy in salmonide-Living and moving in the fast lane. North American Journal of Fisheries Management 17:1029-1045.

Prince, A., and C. Powell. 2000. Clove oil as an anesthetic for invasive field procedures on adult rainbow trout. North American Journal of Fisheries Management 20:1029-1032.

Riget, F.F., K.H. Nygaard, and B. Christensen. 1986. Population structure, ecological segregation, and reproduction in a population of Arctic Char (*Salvelinus alpinus*) from Lake Taseruaq, Greenland. Canadian Journal of Fisheries and Aquatic Sciences 43:985-992.

Roberts, J.J., and F.J. Rahel. 2005. Accuracy of aerial telemetry in fisheries studies. North American Journal of Fisheries Management 25:660-666.

Ruzycki, J.R., D.A. Beauchamp, and D.L. Yule. 2003. Effects of introduced lake trout on native cutthroat trout in Yellowstone Lake. Ecological Applications 10:23-37.

Saiget, D.A., M.R. Sloat, and G.H. Reeves. 2007. Spawning and movement behavior of migratory coastal cutthroat trout on the western Copper River Delta, Alaska. North American Journal of Fisheries Management 27:1029-1040.

Sanderson, T.B., and W.A. Hubert. 2009. Movements by adult cutthroat trout in a lotic system: implications for watershed-scale management. Fisheries Management and Ecology 16:329-336.

Schaffer, W.M., and P.F. Elson. 1975. The adaptive significance of variations in life history among local populations of Atlantic salmon in North America. Ecology 56:577-590.

Schill, D.J., and J.S. Griffith. 1984. Use of underwater observation to estimate cutthroat trout abundance in the Yellowstone River. North American Journal of Fisheries Management 4:479-487.

Schill, D.J., J.S. Griffith, and R.E. Gresswell. 1986. Hooking mortality of cutthroat trout in a catch-and-release segment of the Yellowstone River, Yellowstone National Park. North American Journal of Fisheries Management 6:226-232.

Schmetterling, D.A. 2001. Seasonal movements of fluvial westslope cutthroat trout in the Blackfoot River drainage, Montana. North American Journal of Fisheries Management 21:507-520.

Schrank, A.J., and R.J. Rahel. 2004. Movement patterns in inland cutthroat trout (*Oncorhynchus clarki utah*): management and conservation implications. Canadian Journal of fisheries and Aquatic Sciences 61(8):1528-1537.

Thurow, R.F., C.E. Corsi, and R.K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in the upper Snake River drainage, Idaho. American Fisheries Society Symposium 4:25-36.

U.S. Fish and Wildlife Service. 2006. Endangered and threatened wildlife and plants: 12-month finding for a petition to list the Yellowstone cutthroat trout as threatened. Federal Register 71:8818-8831.

Varley, J.D., and R.E. Gresswell. 1988. Ecology, status, and management of Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Winter, J. 1996. Advances in underwater biotelemetry. pp.555-590. In: B.R. Murphy & D.W. Willis (ed.) fisheries Techniques, 2nd ed., American Fisheries Society, Bethesda, Maryland.

Young, M.K. 1996. Summer movements and habitat use by Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in small, montane streams. Canadian Journal of Fisheries and Aquatic Sciences 53:1403-1408.

CHAPTER 3

DISTRIBUTION, ABUNDANCE, AND HABITAT USE OF YELLOWSTONE CUTTHROAT TROUT LIFE-HISTORY FORMS IN THE UPPER YELLOWSTONE RIVER BASIN, YELLOWSTONE NATIONAL PARK

Introduction

The natural factors influencing fish distribution and abundance occur on several scales. On a continental scale, fish distribution throughout the major basins of the United States is a result of recolonization that occurred following the Wisconsin Glaciation Period about 10,000 years ago (Paul and Post 2001; Behnke 2002). At smaller scales, however, fish distribution and density within individual river basins is largely dependent on their ability to utilize limited habitat to feed, reproduce, find cover, and compete with other species (Frissell et al. 1986; Bozek and Hubert 1992; Kruse et al. 1997; Paul and Post 2001; Bryant et al. 2004). Physical habitat components (e.g., stream depth, width, and gradient) can be limiting for salmonid species and both poor quality habitat and low habitat diversity are often associated with low fish densities, small fish sizes, and low life history and species diversity when compared to stream systems with better habitat quality and diversity (Scarnecchia and Bergersen 1987; Schlosser 1982; Rosenfeld et al. 2000; Rosenfeld et al. 2002; Bryant et al. 2004).

Abiotic factors are generally most important in determining distribution of larval and early juvenile life stages, whereas biotic factors become more important once fish begin to compete for prey items (Houde 2002; Coleman and Fausch 2007). However, abiotic factors continue to play a role in river drainages characterized by harsh physical conditions (e.g., extreme cold, erratic discharge) at all life stages (Coleman and Fausch 2007). Habitat factors such as gradient (Kozel and Hubert 1989; Bozek and Hubert 1992; Rosenfeld et al. 2000), stream size (Murphy et al. 1986; Rosenfeld et al. 2000), percent pool habitat (Bowlby and Roff 1986), temperature (Shuter and Post 1990), and ice formation (Jakober et al. 1998; Lindstrum and Hubert 2004) have all been reported as primary factors influencing salmonid distribution and relative abundance in western North America. In some drainages, harsh physical conditions can inhibit recruitment and limit growth and survival of all life stages, thereby affecting fish distribution, density, and life-history forms displayed in an area (Stonecypher et al. 1994; Coleman and Fausch 2007).

For the last two centuries, fish distribution has been impacted by human influences (Nelson et al. 1992; Dunham et al. 1997; Sanderson and Hubert 2009). Habitat fragmentation and degradation and introduction of nonnative species are the two leading causes for the decline in abundance and distribution of native fish species (Dunham et al. 1997; Kershner et al. 1997; Simberloff 2001; Sanderson and Hubert 2009). Almost all of the large rivers in the world have been impacted by dams fragmenting habitat (Jaeger et al. 2001). Dams are detrimental to fish communities by creating physical barriers, changing flow regimes, and disrupting sediment transport (Winston et al. 1991; Catalano et al. 2007). Agricultural practices and urbanization have caused degradation and destruction of fish habitat by altering stream flows, stream channels, and nutrient inputs (Burcher and Benfield 2006; Slawski et al 2008; Verro et al. 2009). The introduction of nonnative fish species has negatively impacted native fish assemblages through competition, predation, and hybridization (Young 1995; Kruse et al. 2000). Despite these widespread impacts, the upper Yellowstone River is an example of a system affected by harsh environmental conditions, but has relatively few impacts from anthropogenic influences.

Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* is the only salmonid species native to the upper Yellowstone River system. Historically, the Yellowstone cutthroat trout was one of the most widely distributed subspecies of cutthroat trout in North America (Varley and Gresswell 1988; Gresswell et al. 1994; Behnke 2002). However, the current range has been greatly reduced over the past century by habitat fragmentation and degradation and introduction of nonnative fish species (Varley and Gresswell 1988; Gresswell 1995, Kruse et al. 2000). In many areas, local Yellowstone cutthroat trout populations have been extirpated or restricted to headwater environments (Kruse et al. 2000; Kruse et al. 2001). The Yellowstone Lake drainage however, is a large intact ecosystem with little anthropogenic influences, and contains one of the largest genetically pure populations of Yellowstone cutthroat trout that still exists (Gresswell and Varley 1988). Although historic habitat connectivity has not been fragmented in most locations, cutthroat trout in Yellowstone Lake are currently impacted by recent introductions of nonnative lake trout *Salvelinus namaycush* (discovered 1994) and whirling disease (discovered 1998) (Kaeding et al. 1996; Koel et al. 2005).

Although efforts are underway to reduce the effects of lake trout on the cutthroat trout population in Yellowstone Lake, obtaining information on various aspects of the life histories of cutthroat trout throughout the lake drainage will be important to broadening understanding of factors that influence the distribution and abundance of cutthroat trout in the system and how those relationships change through time. Specifically, information on the presence and relative abundance of cutthroat trout displaying fluvial and fluvial-adfluvial life-history forms in the upper Yellowstone River basin will be important components of future conservation and management decisions. This information will be particularly important because these life-history forms are rare in other Yellowstone Lake tributaries and fish displaying them will be less susceptible to predation from lake trout in Yellowstone Lake. Additionally, information confirming whether juvenile cutthroat trout use the extensive tributary networks for extended rearing is needed because this behavior could lessen their exposure to predatory lake trout in Yellowstone Lake. If extended rearing is found to be prevalent in the system, further protection of the area may be warranted.

The distribution and density of cutthroat trout has been studied in Yellowstone Lake and many of its tributaries (Bulkley and Benson 1962; Jones et al. 1986; Gresswell and Varley 1988; Gresswell et al. 1997). Cutthroat trout in the system predominately display the lacustrine-adfluvial life history, wherein mature adults migrate to tributary streams to spawn and fry migrate to the lake soon after emergence (Bulkley and Benson 1962; Varley and Gresswell 1988; Gresswell et al. 1994). In contrast, fluvial fish have only been documented in three locations around Yellowstone Lake, the Yellowstone

River outlet, Sedge Creek, and South Fork Yellowstone River. The Yellowstone River outlet supports a small number of fluvial fish (Kaeding and Boltz 2001). The Sedge Creek and South Fork Yellowstone River cutthroat trout populations are isolated above barriers. The Sedge Creek population has been isolated for over 8,000 years by thermal and chemical barriers to upstream and downstream fish movement (Varley and Gresswell 1988; Gresswell et al. 1994) and the South Fork Yellowstone River cutthroat trout population is isolated from upstream migrants above a barrier waterfall (Wyoming Game and Fish Department, unpublished data). Allacustrine fish have been documented in the Yellowstone River outlet, the only outlet stream to Yellowstone Lake (Kaeding and Boltz 2001).

The upper Yellowstone River system offers a unique opportunity to study a native salmonid species in a large, intact riverine-lacustrine ecosystem, with no anthropogenic barriers to movement and few nonnative species. Because of its size (1,244 square km), complexity, and intact nature, fluvial, fluvial-adfluvial, and lacustrine-adfluvial forms of Yellowstone cutthroat trout are likely present in the drainage. However, despite extensive surveys of tributary streams of Yellowstone Lake, a comprehensive fisheries assessment of the upper Yellowstone River drainage has never been conducted. To properly understand and manage cutthroat trout in this large interconnected riverscape, an understanding of distribution, abundance, and key habitat components utilized by the various life-history forms of cutthroat trout present in the system is crucial for their conservation. The objectives of this study were to determine: (1) the distribution and abundance of different life-history types of Yellowstone cutthroat trout in the upper

Yellowstone River and its tributary streams within Yellowstone National Park; and (2) identify habitat factors influencing the distribution of juvenile and adult cutthroat trout within the main stem river and headwater tributaries. I hypothesized that: (1) multiple life history forms of cutthroat trout would be present in the main-stem Yellowstone River and its tributaries; and (2) fish would be associated with specific habitat features. The information gained through this study will assist fisheries managers in properly managing and protecting Yellowstone cutthroat trout populations in the upper Yellowstone River drainage and throughout the Yellowstone Lake system from the recent nonnative threats in the system. It will provide baseline data to help assess the progress of Yellowstone cutthroat trout recovery in Yellowstone Lake and will also be important in helping to determine listing status of the subspecies under the Endangered Species Act if a new petition is filed.

Study Area

Research was conducted in the upper Yellowstone River and its tributaries from the inlet at Yellowstone Lake to the southern boundary of Yellowstone National Park (Figure 3.1). The upper Yellowstone River drainage is approximately 1,233 square kilometers and comprises 42% of the total Yellowstone Lake drainage. The drainage is located at high elevation, ranging from 2,356 m at the inlet to over 3,200 m at the headwaters of Mountain Creek.

The main stem river flows 41 km within the park boundary and has 10 named tributary streams: Cabin, Trappers, Mountain, Cliff, Escarpment, Thorofare, Falcon, Lynx, Phlox, and Badger creeks, and one unnamed tributary. The main stem is characterized by a wide floodplain formed by extensive deltaic deposits throughout the lower portion of the drainage (Gresswell et al. 1994; Gresswell et al. 1997). The main stem river gradient is low and habitat consists of long runs and glides with few pools or riffles. Tributaries are characterized by steep headwater sections that drop to Yellowstone River floodplain. Barriers to upstream fish movement are located on Cliff, Escarpment, and Falcon creeks, and Trappers Spring (Figure 3.2). Vegetation in the drainage is dominated by lodgepole pine *Pinus contorta*, willow *Salix spp.*, and grasses *Bromus spp.* and *Phleum spp.* Burned patches (1988, 2003, and 2005 fires) are located throughout the drainage.

Native fish species present in the upper river include Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae*. Nonnative species include redside shiner *Richardsonius balteatus* and longnose sucker *Catostomus catostomus*. Lake chub *Couesius plumbeus*, and lake trout occur in Yellowstone Lake and may be found in the main stem river in low numbers near the inlet.

Methods

Trout Distribution and Abundance

Main Stem – Two sampling methods, underwater counts and electrofishing, were used to sample Yellowstone cutthroat trout in the main-stem Yellowstone River. The main-stem Yellowstone Rivers large size, slow, clear water, few large log jams, and few deep pools made it a good candidate for use of both sampling methods in order to minimize bias and maximize detecting multiple size classes of cutthroat trout. The methods have been shown to provide accurate assessments of trout populations in large rivers (Schill and Griffith 1984; Slaney and Martin 1987; Zubik and Fraley 1988; Lonzarich et al. 2004). Underwater counts are often more effective than electrofishing in areas of low conductivity, deep pools, or undercut banks and can provide important data on population size structure, distribution, and abundance (Slaney and Martin 1987; Dolloff et al. 1996). Electrofishing is more effective than underwater counts in shallow areas, turbid waters, and areas with abundant cover and allows for more accurate measurements of fish length and weight and for the collection of scale and tissue samples (Lonzarich et al. 2004).

Sampling reaches in the main stem river were determined by first dividing the river into forty-one 1-km sections. Each 1-km section was then subdivided into two 500-m reaches and one of the reaches was randomly chosen for sampling (Figure 3.1). Fish abundance and habitat sampling surveys were conducted during low flow periods in September to increase the effectiveness of both underwater counts and electrofishing. Also, to coincide with the time period when lacustrine-adfluvial cutthroat trout had returned to Yellowstone Lake (Chapter 2), and to maximize the probability of detection of potential fluvial and fluvial-adfluvial life-history forms. Both sampling methods were conducted in a downstream direction.

Underwater counts were conducted by three snorkelers spaced evenly across the stream channel. Prior to counts, all divers were trained in estimating fish length using models of various known sizes. Observation lanes were randomly assigned to divers each day. To avoid multiple counts of the same fish, each swimmer had a designated lane in which to observe fish and divers would discuss fish movement and locations after each count. Underwater visibility was determined before each census by measuring the horizontal distance each diver could observe a 150-mm model fish. For all surveys visibility was good, averaging 5.4 m (range, 4.1–6.1 m). All cutthroat trout observed were counted and placed in one of four size categories based on total length (<70 mm, 70–150 mm, 151–330 mm, and >330 mm). These size-classes approximate lacustrine-adfluvial cutthroat trout age classes determined from scale samples analyzed from other Yellowstone Lake tributary streams (National Park Service unpublished data). Because previous studies have shown that 330 mm is approximately the minimum size in which lacustrine-adfluvial cutthroat trout from Yellowstone Lake mature (Varley and Gresswell 1988; Gresswell et al. 1994 and 1997) and cutthroat trout in headwater streams rarely exceed 250 mm, fish >330 mm were considered mature fish.

Electrofishing surveys were performed from a 4.5-m raft outfitted with a Coffelt Mark XXII electrofishing unit in the same reaches as underwater fish counts. Although fish exhibited a low fright response to divers, electrofishing was not initiated until a minimum of 30 minutes had elapsed since underwater counts were performed to allow fish to redistribute if displaced. Two electrofishing surveys were conducted in September 2006, approximately 10 days apart. All reaches were electrofished on at least one occasion. Thirty-seven and 39 reaches, respectively, were sampled during the two surveys. Some reaches were omitted because of lightning and unsafe boating conditions.

All fish captured were identified to species, measured (total length, mm), weighed (g), and fin-clipped for identification purposes by removing a small portion of the adipose (run 1) or anal fin (run 2). Scales were removed for age determination from a subsample of captured fish (up to 10 samples in 10 mm size-class increments) (Chapter 4). Fish sampled during electrofishing surveys were also categorized based on total length as listed for underwater counts. After sampling, fish were transported a short distance upstream to minimize the chance of recapture during the same run and released.

Because underwater counts and electrofishing surveys appeared to sample different size classes and no fish were recaptured during the second electrofishing pass, counts from the three samples were combined for analysis. Following sampling, the main stem river was divided into five segments based on similarities in stream gradient (Figure 3.4). Cutthroat trout relative abundance (fish/500 m) was determined for each reach by combining counts from underwater and electrofishing surveys. Abundance for each segment was determined by summing fish numbers and dividing by the number of reaches in each segment. Relative abundance estimates were determined for each size class and for total fish sampled.

Cutthroat trout relative abundance for the five stream segments were compared using a Kruskal-Wallis rank test (Kutner et al. 2005). Comparisons were made for all fish captured and for individual size classes. All tests were conducted at a significance level of $\alpha = 0.05$. All statistical analysis was conducted using R statistical software or SYSTAT 11 (SYSTAT Software Inc. 2004).

Tributary Streams – Fish distribution, abundance, and habitat surveys were conducted in the Mountain Creek drainage (Mountain Creek, Howell Creek, and an unnamed tributary that will be referred to as Mountain Creek Tributary). Fish distribution and abundance surveys were conducted on Trappers, Cliff, Escarpment, Badger, Phlox, Lynx, and Falcon creeks (Figure 3.1). Because only a small section of Thorofare Creek was located within the park boundary it was omitted from sampling. Fish in tributary streams were sampled by electrofishing during low flow periods (August to October) from 2005 through 2007. Sample locations were selected by dividing each stream into 1-km sections then subdividing each kilometer into ten 100-m reaches and randomly selecting one of the 10 reaches for sampling. The upstream limit of sampling was determined if: 1) no fish were sampled in two consecutive reaches; 2) no fish were sampled for one reach above a probable fish migration barrier (barriers were defined as waterfalls or cascades >2 m); or 3) the stream source was reached.

A total of 82 reaches were sampled in eight tributary streams (Figure 3.1). A Smith-Root model LR-24 battery powered backpack electrofisher was used to conduct a single electrofishing pass. Single-pass electrofishing has been shown to be an effective method for sampling fish to obtain abundance estimates in mountain streams with sparse habitat (Kruse et al. 1998; Bateman et al. 2005). Each reach was electrofished in an upstream direction using two netters to increase capture efficiency. Block nets were not used to isolate sample reaches. All fish captured were identified to species, measured (total length, mm), weighed (g), and clipped for identification purposes in case of recapture. Scale samples were collected from up to 10 cutthroat trout in 10-mm size-class increments from each stream sampled for age determination (Chapter 4). Additional scale samples were collected from cutthroat trout in headwater or isolated reaches. All cutthroat trout sampled were classified in one of the four length categories as described above.

Mean fish length and fish relative abundance were determined in each stream and compared among streams using one-way ANOVA ($\alpha = 0.05$) and Tukey's post-hoc multiple comparison procedure (Devore and Peck 2005). One-way ANOVA was used to test for significant differences in the mean length of fish in the individual streams and Tukey's post-hoc multiple comparison procedure was used to test for pairwise differences between mean fish length for each stream (Kutner et al. 2005). Because fish relative abundance data was not normally distributed, a Kruskal-Wallis rank test ($\alpha = 0.05$) was used to test for significant differences in the densities of all fish and fish from the individual size classes within sampled streams (Kutner et al. 2005).

Habitat

Main Stem - Habitat assessments were conducted in the same reaches as underwater counts and electrofishing surveys. Reaches were placed into one of the five stream segments described in the fish distribution and abundance section. Channel units were classified as fast water (riffle or run) or slow water (glide or pool) and the percent occurrence of each type was calculated for each sample reach and stream segment. Thalweg depth and wetted width were measured to the nearest 0.1 m at transects positioned every 10 m throughout each sample reach. Dominant substrate was identified as, bedrock, boulder (>256 mm), cobble (64 – 256 mm), gravel (2 – 64 mm), and sand (<2-mm) at each transect and reported for each reach based on percent occurrence. Large woody debris (LWD) jams were counted and area (m^2) was determined to calculate the percentage of a sample reach and stream segment in which LWD jams were present. Length of undercut and unstable banks were measured for total length. Undercut banks were defined as banks overhanging the channel for a minimum of 0.1 m for a minimum distance of 1 m. Unstable banks were defined as areas a minimum of 1 m in length in contact with the bankfull stream bank that were actively eroding. Stream gradient and tributary entry locations were determined in ArcGis (ArcMap version 9.3).

Regression analysis was used to evaluate if variability in cutthroat trout relative abundance could be explained by the habitat features listed above (Kutner et al. 2005). Comparisons were made between stream segments based on fish relative abundance in each size class. These analyses were conducted for all fish and each of the four size classes. Additionally, because of the large number of null values for slow water habitat and LWD jams, a Welch's two-sample t-test was used to determine if significant differences in fish relative abundance existed in reaches that contained slow water habitat or LWD jams and those reaches that did not.

Tributary Streams - Habitat measurements were limited to the Mountain Creek drainage. A total of 37 reaches were sampled in the drainage. Within each reach, habitat units were identified to the pool/riffle level (Frissell et al. 1986). Units were classified as fast water (cascade, high gradient riffle, low gradient riffle, step run, or run) or slow water (pool or glide) (Overton et al. 1997). A variety of features were measured, including wetted width (0.1 m), mean depth (0.01 m), maximum pool depth (0.01 m), and length of undercut or unstable bank. Dominant in-stream substrate was visually categorized as bedrock, boulder, cobble, gravel, or fines in each habitat unit using the same size classifications described for main-stem sampling. Large woody debris was counted, measured (m), and reported as m/reach. Stream gradient was determined for each stream km using ArcMap (ArcGis version 9.3).

Regression analysis was used to evaluate if variability in cutthroat trout relative abundance could be explained by measured habitat features in the Mountain Creek drainage. As with the main stem river, a Welch's two-sample t-test was used to determine if significant differences in fish relative abundance existed in reaches where slow water habitat or LWD was present and reaches where they were not. Comparisons were made for all cutthroat trout sampled and again for fish in the individual size classes. All tests were conducted at $\alpha = 0.05$.

Results

Trout Distribution and Abundance

Main Stem – Yellowstone cutthroat trout was the only fish observed in the upper Yellowstone River. Fish relative abundance was low, with a median of 7 fish/500 m, with only 329 total fish sampled over the 41-km main stem river. No marked fish were recaptured during the second electrofishing survey. Cutthroat trout were present in 37 of the 41 reaches sampled (Figure 3.5), but relative abundance was significantly different among the five river segments (Kruskal Wallis F = 9.54, p = 0.04, df = 4). Fish relative abundance were highest in Segments V and II with a median of 12 fish/500 m (range, 11-15) and 10 fish/500 m (range, 0-21) respectively (Figure 3.6). The lowest relative abundance occurred in Segment I with a median of 0 fish/500 m (range, 0-8).

Cutthroat trout size class distribution also differed longitudinally (Figure 3.7). Fish <70 mm in length were the most abundant, occurring in all river segments and accounting for 46.5% (n = 153) of the total fish sampled. Median relative abundance for this size class ranged from 0.0 fish/500 m (range, 0-7) in Segment I to 9.5 fish/500 m (range, 3-12) in Segment V. Trout in the 70–150 mm and >330 mm size classes comprised 24.6% (n = 81) and 28.5% (n = 94) of the total fish sampled, respectively. Fish 70-150 mm were relatively evenly distributed in Segments II through V (Figure 3.7) whereas fish >330 mm were most abundant in Segment IV median 3.7 fish/500 m (range, 0-15). There was only one fish in the 151–330 mm size range sampled. This fish was captured in Segment III.

<u>Tributary Streams</u> – As in the main-stem Yellowstone River, cutthroat trout was the only fish captured in the eight tributary systems sampled. Fish were located in all tributary systems sampled below migration barriers. Overall, mean fish abundance for tributary streams was 17.5 fish/100 m (SE = 5.16) and ranged from 49.5 fish/100 m in Cliff Creek to 1.7 fish/100 m in Escarpment Creek (Figure 3.8). Cutthroat trout relative abundance differed significantly among tributary streams (Kruskal Wallis p = 0.02, F =

17.36, df = 7). Relative abundance was highest in the four of the five tributaries flowing into the Yellowstone River from the west. Cliff Creek had the highest median value at 49.5 fish/100 m (range, 40-59) and Escarpment creek had the lowest 2 fish/100 m (range, 0-3).

As in the main stem river, cutthroat trout <70 mm were most abundant, accounting for 50.7% (n = 391) of the overall catch. Fish from this size class were sampled in all tributary streams surveyed. Fish from 70–150 mm were nearly as abundant, comprising 42.5% (n = 328) of the total catch. Fish from 151–330 mm accounted for the remaining 6.7% (n = 52) of the total catch. No fish from >330 mm were captured in any of the tributary streams sampled.

Cutthroat trout mean total length differed significantly between sampled tributary streams (ANOVA $p < 0.01$, $F = 13.43$, df = 7). Tukey post hoc multiple comparison testing showed differences existed between many of the tributary streams (Table 3.1). Fish up to 150 mm were captured in many locations, and fish from 150-330 mm were found in is several tributaries, but were most abundant in Mountain Creek. No fish >330 mm were captured in any tributary sample reach. Cutthroat trout in Trappers Creek had the largest length, mean = 106.3 mm (n = 56) and Badger Creek had the smallest mean = 54.8 mm (n = 75) (Table 3.2). In tributaries, excluding Trappers Spring, 771 cutthroat trout were sampled and had mean total length of 82.4 mm (range 28 – 305 mm, SE = 1.59). Within the Mountain Creek drainage (Mountain Creek, Howell Creek, and Mountain Creek Tributary) cutthroat trout in Mountain Creek Tributary were significantly larger than fish in Mountain and Howell creeks (ANOVA $p < 0.01$, $F = 54.58$, $df = 2$) (Table 3.1 and 3.2).

Only one population of cutthroat trout was found above a likely barrier to upstream migration. A total of 18 trout were captured in a 1 km meadow reach where three small springs ran together. No fish were collected in the individual forks or in the 1.5 km of spring creek below the meadow. Fish ranged from 104 – 198 mm (mean = 166.8 mm) (Table 3.2). Tukey post hoc multiple comparison testing revealed mean total length of fish in Trappers Spring was significantly different from all waters, with the exception of Mountain Creek Tributary (ANOVA $p < 0.01$, $F = 33.34$, $df = 10$) (Table 3.1).

Habitat

Main stem – Main stem habitat units were relatively homogenous with fast water habitat comprising 80% of the total riverine habitat (Table 3.3). Pool habitat was rare throughout the drainage, accounting for just 1% of the total river habitat. Wetted width during base flow averaged 40.7 m (range 21.3 m – 67.0 m; SE 0.32) and mean depth was 0.4 m (range 0.1 m – 7.0 m). Substrate was relatively evenly distributed among sand (38%), gravel (37%), and cobble (25%) (Table 3.3).

Comparison of key habitat components was made for the five river segments. Wetted width, percent of slow water habitat, percent LWD coverage, and stream gradient were compared for each stream segment. Only wetted width differed significantly (Kruskal-Wallis $p = 0.01$, $F = 13.19$, $df = 4$) in main stem river segments (Table 3.4).

Regression analysis revealed variability in fish relative abundance could not be explained by measured habitat parameters. High r^2 values were associated with several analyses, but none proved to be statistically significant (Table 3.5). This was also the case for individual fish size classes (Table 3.5). Statistical significance testing revealed no significant difference in total fish relative abundance in reaches with and without LWD or with and without slow water habitat (Table 3.6). Also, no significant differences were found for individual size classes (Table 3.6).

Tributary Streams - In the Mountain Creek drainage, habitat measurements were taken in 37 stream reaches in September 2006. As with main stem sampling, slow water habitat was sparse, comprising just 4.7% of sampled reaches. Gradient was fairly high in comparison to the main stem river at 17 m/km (1.7 m/reach) (Table 3.4). Wetted width averaged 7.2 m and there was approximately 26 m of woody debris/100 m. Regression analysis showed that variation in fish relative abundance could not be explained by measured habitat components in the Mountain Creek drainage (Table 3.7). Also, no significant differences were found when comparing fish relative abundance in reaches with and without LWD or in reaches with and without slow water habitat.

Discussion

Extensive sampling of the main-stem upper Yellowstone River and its tributary streams revealed that Yellowstone cutthroat trout was the only fish in this drainage despite five other fish species residing in the adjoining Yellowstone Lake. Cutthroat trout generally occurred in low abundance, especially in the main stem, where a median of only 7 fish/500 m were sampled. Sampled fish were mainly comprised of small fish <70 mm in length with few individuals >150 mm observed. The small size and low abundance of cutthroat trout sampled during autumn surveys suggests that the lacustrine-adfluvial life history is the dominant life-history form in the upper Yellowstone River. This life-history form has been reported to be the dominant life history in all other tributary streams of Yellowstone Lake that have been studied (Jones et al. 1986; Gresswell et al. 1994; Gresswell et al. 1997).

This research documents that extended rearing beyond the first few weeks following emergence is present in the upper Yellowstone River. In fact, based on the size classes of fish sampled, some fish stay in the system for up to 2 years before migrating to Yellowstone Lake. Extended rearing is rare in other tributary streams of Yellowstone Lake where newly hatched trout migrate out of natal streams during their first summer and larger fish are rare (Ball 1955; Benson 1960; Varley and Gresswell 1988). Migration out of natal streams during the first year has also been reported in tributaries to the Strawberry Reservoir, Utah (Knight et al. 1999) and in the Snake River, Idaho (Thurow et al 1988). In the upper Yellowstone River, however, the presence of larger juvenile fish (25%, 71 – 150 mm in length) suggests that a portion of the juvenile cutthroat trout do not migrate downstream to the lake soon after emergence, but rather rear in the river system beyond the first summer. Based on age at length of Yellowstone cutthroat trout from this study (Chapter 4) and other tributary streams of Yellowstone Lake, fish in the 71–150 mm range are likely one to two years old. However, the low densities of fish

<150 mm is evidence that while extended rearing is present in the system, it is not a prominent life-history characteristic. Fish displaying this behavior may become more prominent as the population of predatory lake trout continues to grow and spread throughout Yellowstone Lake. Fish displaying extended rearing habits would gain advantages over those fish that migrate earlier by spending less time in the presence of predatory lake trout and entering the lake at a larger size.

Because of its large size, it was anticipated that the main-stem upper Yellowstone River may harbor cutthroat trout displaying the fluvial or fluvial-adfluvial life history. Unlike other tributaries to Yellowstone Lake, 29% of cutthroat trout sampled in late September were >330 mm in length, suggesting a small number of year round fluvial fish may be present in the system. However, the lack of fish between 151-330 mm (n = 1), the typical length for mature fluvial salmonids (Gresswell 1995; Behnke 2002) suggests that few fish remain in the main stem river throughout their entire life cycle.

Several possible scenarios exist which could lead to the presence of large cutthroat trout remaining in the main stem river. The most likely explanation is these fish migrated into the river to spawn and returned to Yellowstone Lake later in the fall or remained in the main stem to overwinter. These behaviors were found in a small percentage of cutthroat trout implanted with radio transmitters in the upper Yellowstone River basin where most adult fish returned to the lake shortly after spawning, but several remained into October and a few overwintered (Chapter 1). Overwintering adults have also been reported in Pelican Creek, the second largest tributary to Yellowstone Lake (Varley and Gresswell 1988; Gresswell et al. 1994). Extended stays in spawning streams have also been reported for adfluvial bull trout *Salvelinus confluentus* in several systems in western North America (Fraley and Shepard 1989; Brenkman et al. 2001).

Another possibility is these fish may be fluvial downstream migrants from the South Fork Yellowstone River population. In the late 1970's, cutthroat trout from Sedge Creek were transplanted into a previously fishless portion of the South Fork Yellowstone River. This section is located above a waterfall that is a barrier to upstream fish movement. There is now a naturally reproducing population of fluvial cutthroat trout in the previously fishless section (Wyoming Game and Fish Department, unpublished data). It is possible that the few adult fish found overwintering in the main-stem Yellowstone River drifted downstream from the South Fork population and set up residency in the lower stream reaches. However, the large size of the fish sampled during this study (>330 mm) suggests that this is unlikely as true fluvial fish rarely reach this size. In any case, the abundance of fish >150 mm is likely too low to support a viable fluvial population.

The low relative abundance of Yellowstone cutthroat trout in the upper Yellowstone River basin is likely attributable to a combination of several factors. In Clear and Bridge creeks, tributaries on the east and north shore of Yellowstone Lake respectively, the spawning runs of cutthroat trout have declined over 90% since the introduction of lake trout into Yellowstone Lake in the mid-to late 1980's (Koel et al. 2005). This same trend could be occurring in the upper Yellowstone River, although it is difficult to determine because of the lack of historical data. The dominance of the lacustrine-adfluvial life history is another possibility. The majority of fish displaying this life history would have migrated to Yellowstone Lake prior to the September sampling period. The lacustrine-adfluvial life history is dominant in other tributaries of Yellowstone Lake (Varley and Gresswell 1988; Gresswell et al. 1997). The upper Yellowstone River also lacked high quality rearing and overwintering habitat. Trout species typically prefer pool habitat and areas that contain physical structure such as large woody debris for rearing and overwintering (Flebbe and Dolloff 1995; Gowan and Fausch 1996, 2002; Harig and Fausch 2002). These features comprised only a small percentage of available habitat in the main-stem Yellowstone River. The main stem river was mainly composed of long runs and glides with little bank or instream cover.

Cutthroat trout were not evenly distributed throughout the main stem river. Just 10 reaches accounted for over 50% of all fish sampled. The variability in cutthroat trout abundance could not be explained by measured habitat components. This may be a result of the low relative abundance of fish present in the system, and the fact that most large fish sampled were likely migrating downstream to Yellowstone Lake. Relative abundance of salmonid species has been shown to be related to available habitat. In systems other than Yellowstone Lake and River, cutthroat trout density was found to decrease significantly with increasing stream size (Murphy et al. 1986; Latterell et al. 2003). Rosenfeld et al. (2000) also found increasing cutthroat trout densities in smaller streams. Relative abundance of brook trout *Salvelinus fontanalis*, brown trout *Salmo trutta*, and rainbow trout *Oncorhynchus mykiss* were found to increase in areas that contained larger amounts of large woody debris when compared to areas that contained little or no large woody debris (Flebbe and Dolloff 1995). During restoration projects where large woody debris was placed into stream channels, researchers found increases in coho salmon *Oncorhynchus kisutch*, cutthroat trout, and steelhead trout *Oncorhynchus mykiss* with increased amounts of large woody debris (Roni and Quinn 2001).

As in the main-stem Yellowstone River, cutthroat trout displaying the lacustrine-adfluvial life-history strategy are dominant in the tributary streams of the upper Yellowstone River. Cutthroat trout up to 150 mm in length were present in all tributary streams sampled below migration barriers and in one location above a barrier to upstream migration. However, with the exception of the upper reaches of the Mountain Creek drainage and Trappers Spring, fish >150 mm in length were rarely found in tributary systems. The presence of juvenile fish and lack of adult fish in the majority of tributary streams is strong indication that lacustrine-adfluvial fish move into the system to spawn and quickly return to Yellowstone Lake.

Within the tributary streams of the upper Yellowstone River, the presence of cutthroat trout up to 150 mm in length in late September suggests extended rearing is occurring. Both immediate migration downstream and extended rearing behaviors have been documented in many tributary streams of Yellowstone Lake (Ball 1955; Bensen 1960; Gresswell et al. 1994). In the Yellowstone River north of Yellowstone National Park, Yellowstone cutthroat trout fry have been reported to migrate downstream shortly after emergence or remain in tributary streams for several years (Byorth 1990), and in Idaho streams, cutthroat trout have been reported to migrate out of tributaries soon after emergence or spend as long as three years in some systems (Thurow 1988). Similar to the main-stem upper Yellowstone River, the low relative abundance of fish indicates that extended rearing is not the dominant strategy of fish in these tributaries.

Although rare, fluvial or fluvial-adfluvial populations of cutthroat trout were found in two locations in the upper Yellowstone River drainage. In the Mountain Creek drainage fish up to 305 mm were found in the upper reaches of Mountain and Howell creeks and Mountain Creek tributary. Although densities of fish >150 mm were low in all locations, their presence in the system late in autumn, small size at maturity, and small length at age (Chapter 4) are indicators that these are true fluvial or fluvial-adfluvial fish. Similarly, migratory bull trout *Salvelinus confluentus* in the Flathead River drainage average 628 mm in length, but resident fish rarely exceed 300 mm in length (Fraley and Shepard 1989; Rieman and McIntyre 1995). Throughout their range, the typical maximum size of a Yellowstone cutthroat trout in small headwater streams is 229 – 254 mm with a life span of 3–5 years, but migratory fish in larger lakes and streams reach sizes of 533–610 mm and live 6–9 years (Benson and Bulkley 1963; Thurow et al. 1988; Gresswell et al. 1997). In isolated Trappers Spring, fish from both SC II and III were sampled. The isolated nature of the spring and presence of both mature and immature fish indicate that this is a self-sustaining resident population.

In the Mountain Creek drainage, variation in relative abundance of cutthroat trout in separate size classes could not be explained by measured habitat features. This is most likely because of the low abundance of fish in this drainage. While not statistically significant, within the Mountain Creek drainage for fish up to 150 mm, as gradient increased fish relative abundance decreased, but relative abundance of fish from 151-330 mm increased. In other systems, trout abundance has been shown to be strongly related to gradient (Chisholm and Hubert 1986; Kozel and Hubert 1989; Bozek and Hubert 1992). Kozel et al. (1989) found that standing stocks of brook and brown trout decreased significantly when moving from low (<1.4%) to moderate (1.5%-4.0%) gradient habitats. Possible factors for the decline of fish <150 mm and increase in 151-330 mm fish in higher gradient reaches could be because of stream velocity, location fish were hatched, or lack of food resources to support small fish at higher gradients.

Data from this study reveal that fluvial populations of cutthroat trout are present in some tributaries of the upper Yellowstone River drainage. As lake trout numbers continue to climb (Koel et al. 2010) and other nonnative invaders (whirling disease) continue to affect migratory populations of cutthroat trout around the lake, these headwater fluvial populations will likely become more important to the survival of Yellowstone cutthroat trout in the Yellowstone Lake basin. Because of their extremely low numbers, small area of persistence, and rarity in the Yellowstone Lake basin, special regulations could be put in place to protect these headwater populations of cutthroat trout from human impacts. In the future, headwater fluvial populations may become an even more important component for conservation of Yellowstone cutthroat trout especially if the abundance of the dominant lacustrine-adfluvial life-history form continues to decline in Yellowstone Lake.

Table 3.1. Comparison of cutthroat trout mean total length in the different tributary streams of the upper Yellowstone River basin. "+" indicates that streams were not significantly different and "-" indicates that streams were significantly different. (Escarp. = Escarpment Creek)

Stream	Trappers	Phlox	Lynx	Badger	Cliff	Escarp.	Mountain	Falcon
Trappers		-	+	-	-	+	+	+
Phlox	-		+	+	+	+	-	+
Lynx	+	+		-	+	+	+	+
Badger	-	+	-		+	+	-	+
Cliff	-	+	+	+		+	-	+
Escarp.	+	+	+	+	+		+	+
Mountain	+	-	+	-	-	+		+
Falcon	+	+	+	+	+	+	+	

Table 3.2. Number sampled, length range, median length, mean length, and standard error, of cutthroat trout sampled in streams in the upper Yellowstone River drainage, Yellowstone National Park, Wyoming.

Stream	N	Range (mm)	Median Length (mm)	Mean Length (mm)	Standard Error
Badger Creek	75	29 – 195	42.0	54.8	4.00
Cliff Creek	99	31 – 152	44.0	63.5	3.24
Escarpment Creek	5	31 – 178	44.0	77.8	27.31
Falcon Creek	27	34 – 123	95.0	81.4	6.02
Lynx Creek	42	44 – 171	78.0	85.9	5.01
Mountain Creek Drainage	429	31 – 305	81.0	90.0	2.32
Mountain Creek[a]	210	33 – 216	64.0	86.3	2.83
Howell Creek[a]	193	31 – 280	71.0	82.6	2.92
Mountain Creek Tributary[a]	26	81 – 305	162.5	175.2	12.87
Phlox Creek	38	28 – 110	68.5	62.5	4.06
Trappers Creek[b]	56	58 – 182	131.0	106.3	3.98
Trappers Spring[b]	18	104-198	173.0	166.8	6.52

[a] Mountain Creek Drainage
[b] Trappers Creek Drainage

Table 3.3. Habitat characteristics of the main-stem upper Yellowstone River. Surveys were conducted in 41, 500-meter-reaches over 41 km located within Yellowstone National Park, Wyoming, August 2007.

Reach variable	Mean (Range)
Elevation (m) boundary	2391
Elevation (m) mouth	2356
Gradient (m/km)	0.85
Wetted width (m)	40.7 (20.0 – 70.0)
Thalweg depth (m)	0.40 (0.12 – 7.00)
Fast water (%)	80
Slow water (%)	20
Bedrock (%)	0
Boulder (%)	0
Cobble (%)	25
Gravel (%)	37
Sand/Silt (%)	38

Table 3.4. Habitat components for the five river segments of the main-stem upper Yellowstone River and the Mountain Creek drainage, Yellowstone National Park, Bridger-Teton Wilderness, Wyoming. Yellowstone River segments are based on gradient changes through the main stem river.

Habitat Component	River Segment I	II	III	IV	V	Mountain Creek
Gradient (m/km)	0.5	0.9	1.7	0.2	1.3	17.0
Wetted Width (m)	51.1	37.5	44.7	33.6	34.2	7.2
Slow Water Habitat (%)	40.0	12.5	13.8	19.3	28.5	4.7
LWD (% coverage)	0.0	5.5	2.3	1.9	3.0	26.1[a]

[a] LWD for Mountain Creek drainage reported as m/100 m.

Table 3.5. Regression statistics for cutthroat trout relative abundance and habitat features in the five river segments in the main-stem upper Yellowstone River, Yellowstone National Park, Wyoming. Surveys were conducted in 2006 and 2007.

Cutthroat Trout Size Class	Wetted Width		Slow Water Habitat		Large Woody Debris		Gradient	
	r^2	p-value	r^2	p-value	r^2	p-value	r^2	p-value
<70 mm	0.34	0.31	0.00	0.94	0.25	0.39	0.21	0.43
70-150 mm	0.33	0.31	0.46	0.21	0.31	0.33	0.47	0.20
150-330 mm	_	_	_	_	_	_	_	_
>330 mm	0.50	0.18	0.47	0.20	0.46	0.21	0.01	0.61
All Fish	0.73	0.07	0.20	0.36	0.61	0.12	0.11	0.58

Table 3.6. Welch's two sample t-test statistics for comparison of cutthroat trout relative abundance in areas where large woody debris present or absent or slow water habitat was present or absent.

Cutthroat Trout Size Class	Large Woody Debris			Slow Water		
	p-value	t	df	p-value	t	df
<70 mm	0.70	0.39	39	0.54	0.62	39
70-150 mm	0.11	1.62	39	0.50	0.69	39
150-330 mm	_	_	_	_	_	_
>330 mm	0.97	-0.04	39	0.28	1.10	39
All Fish	0.34	0.96	39	0.17	1.39	39

Table 3.7. Regression statistics for cutthroat trout relative abundance and habitat features in the Mountain Creek drainage, Yellowstone National Park and Bridger-Teton Wilderness, Wyoming. Surveys were conducted in 2006 and 2007.

Cutthroat Trout Size Class	Wetted Width		Slow Water Habitat		Large Woody Debris		Gradient	
	r^2	p-value	r^2	p-value	r^2	p-value	r^2	p-value
<70 mm	0.01	0.49	0.00	0.95	0.00	0.82	0.30	0.30
70-150 mm	0.00	0.74	0.01	0.65	0.03	0.33	0.00	0.78
150-330 mm	0.09	0.07	0.04	0.27	0.00	0.90	0.06	0.14
>330 mm	–	–	–	–	–	–	–	–
All Fish	0.00	0.75	0.00	0.93	0.01	0.68	0.01	0.61

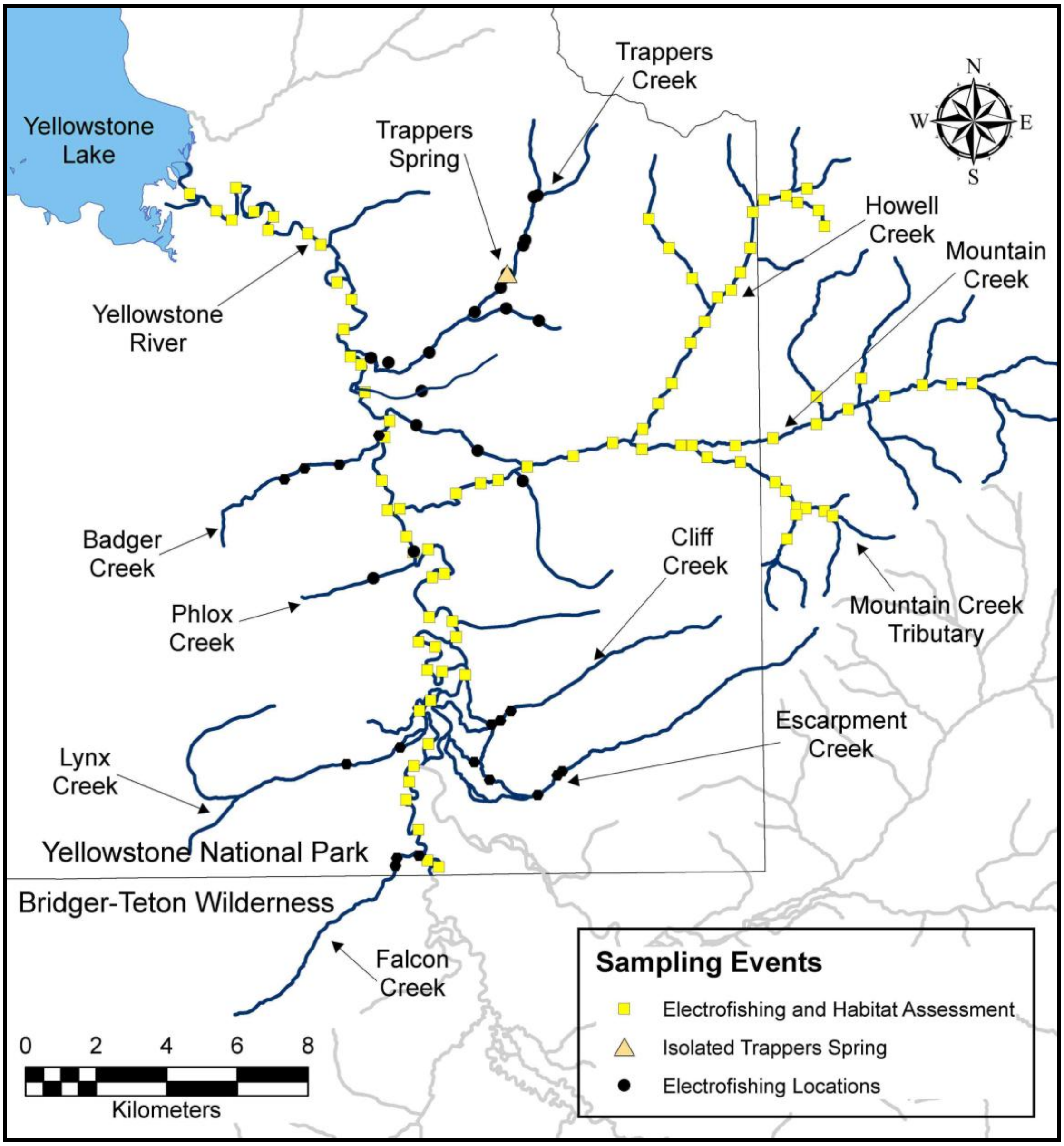

Figure 3.1. Upper Yellowstone River fish distribution and habitat assessment study area, and sampling reaches, Yellowstone National Park and Bridger Teton Wilderness, Wyoming. Reaches (500 m) were sampled in each km of the main-stem Yellowstone River, 100 m reaches were sampled in each km of tributary streams.

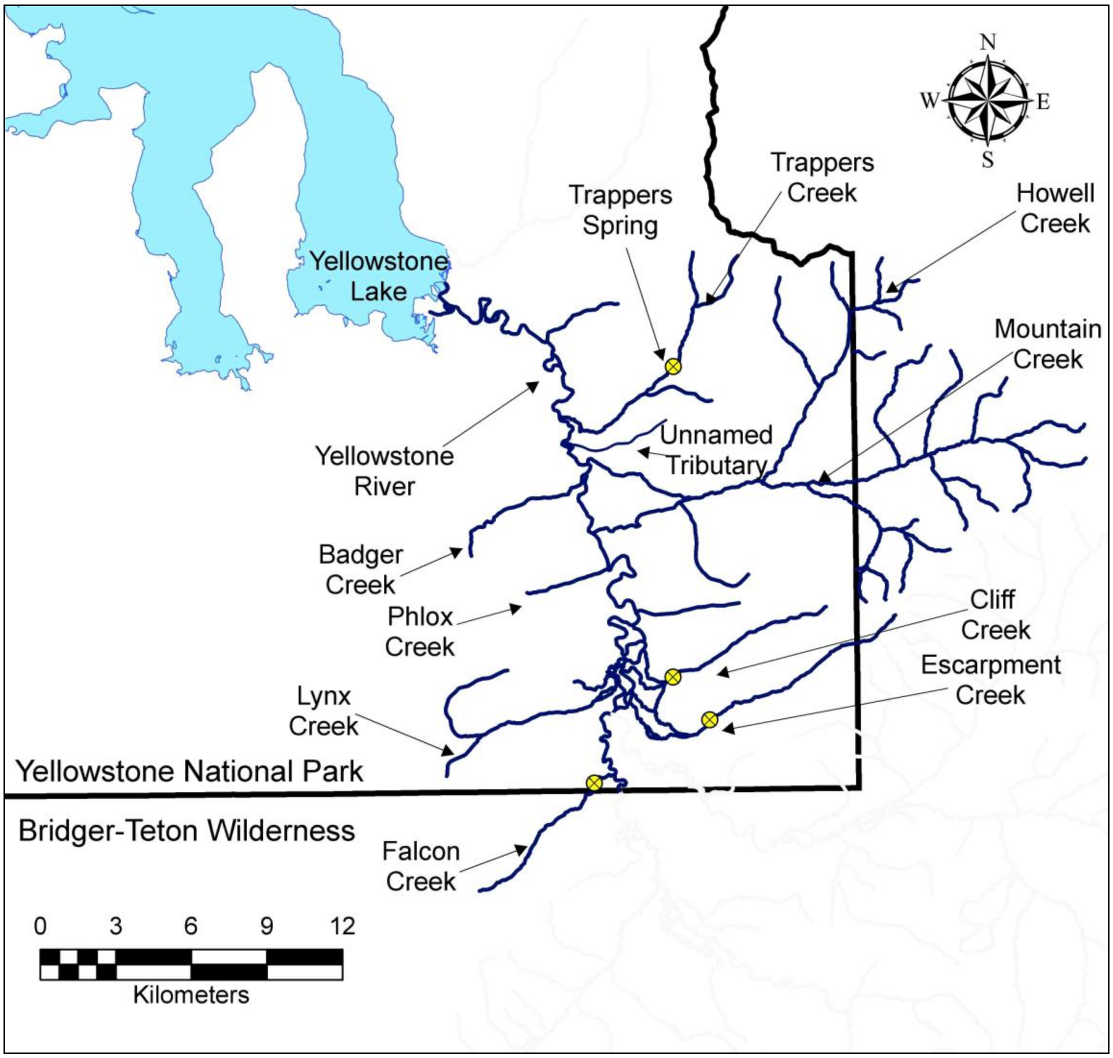

Figure 3.2. Locations of waterfalls on tributaries of the upper Yellowstone River. Cutthroat trout were identified above the falls on Trappers Spring, but not in the other three locations.

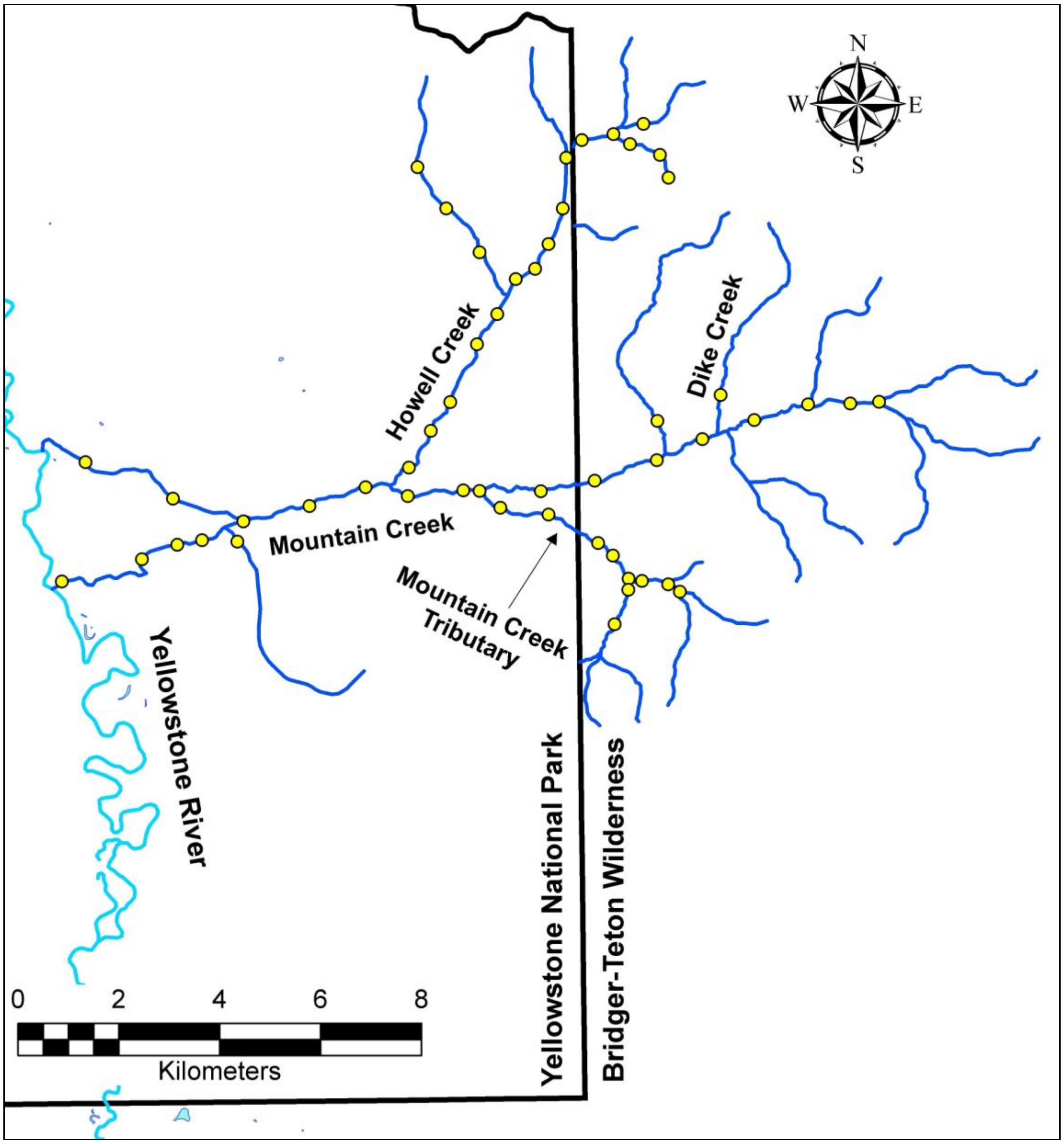

Figure 3.3. Mountain Creek drainage Yellowstone National Park and Bridger-Teton Wilderness, Wyoming. Electrofishing surveys were performed in randomly chosen 100 m reaches within each 1 km of stream in 2006. Fish habitat assessments were conducted on Mountain Creek, Howell Creek, and Mountain Creek Tributary.

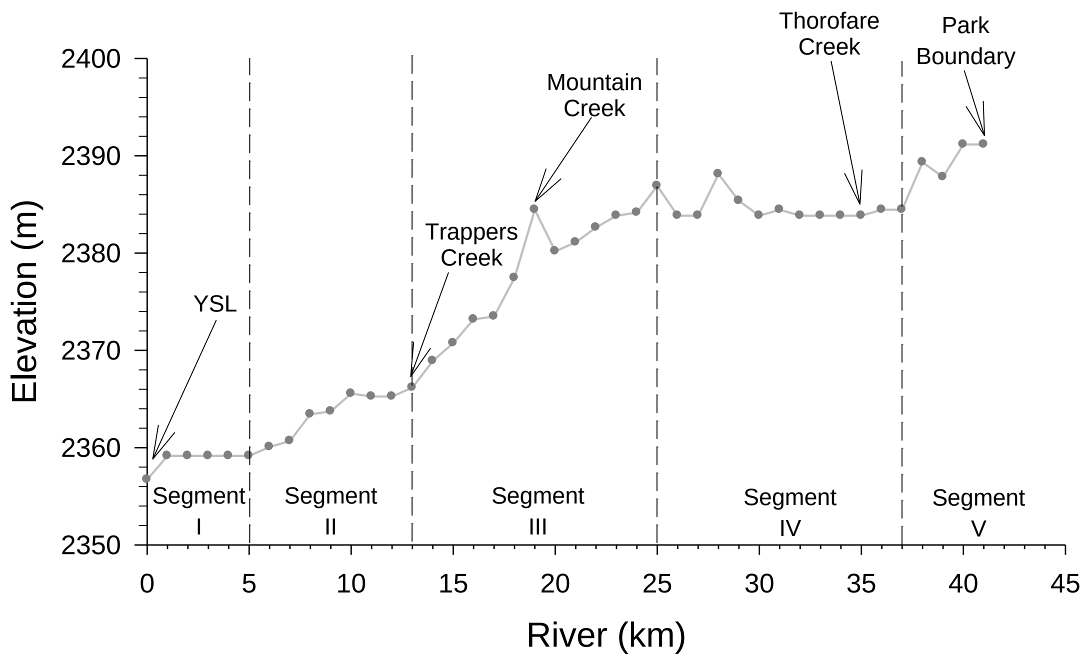

Figure 3.4. Profile of the main-stem Yellowstone River from Yellowstone Lake to the Yellowstone National Park south boundary, Wyoming. River segments were defined by changes in stream gradient.

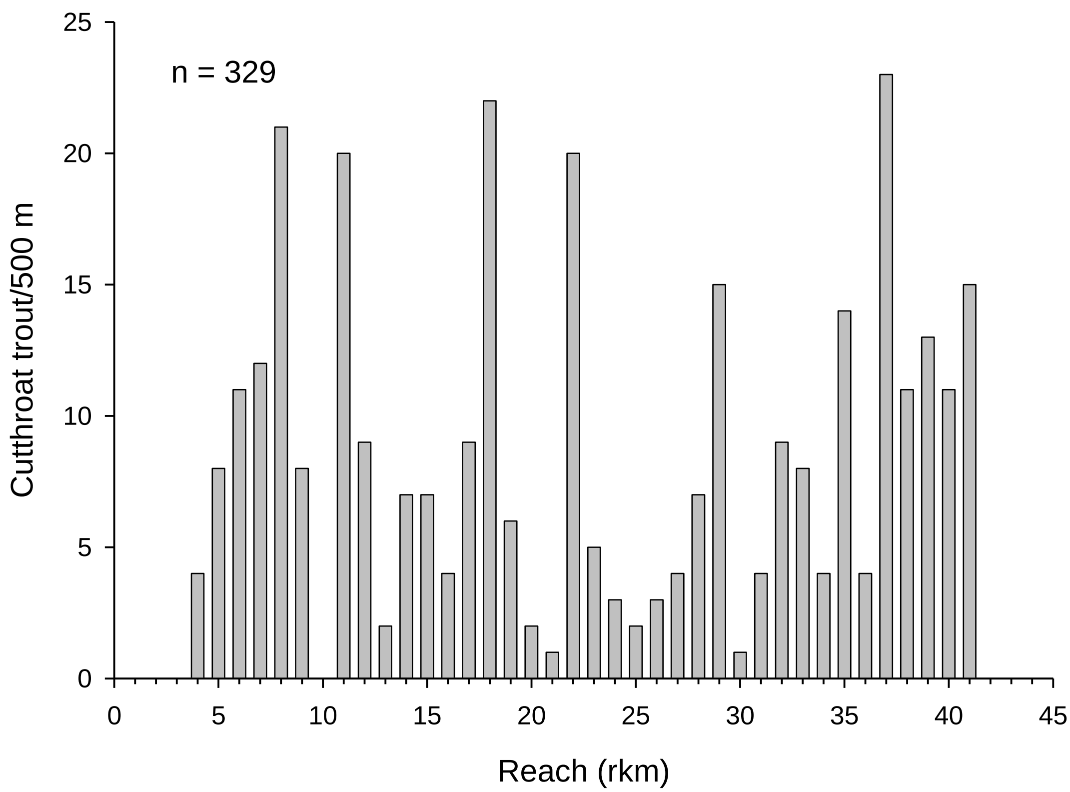

Figure 3.5. Cutthroat trout observed/sampled during underwater counts and electrofishing surveys of the main-stem Yellowstone River, September 2006. .

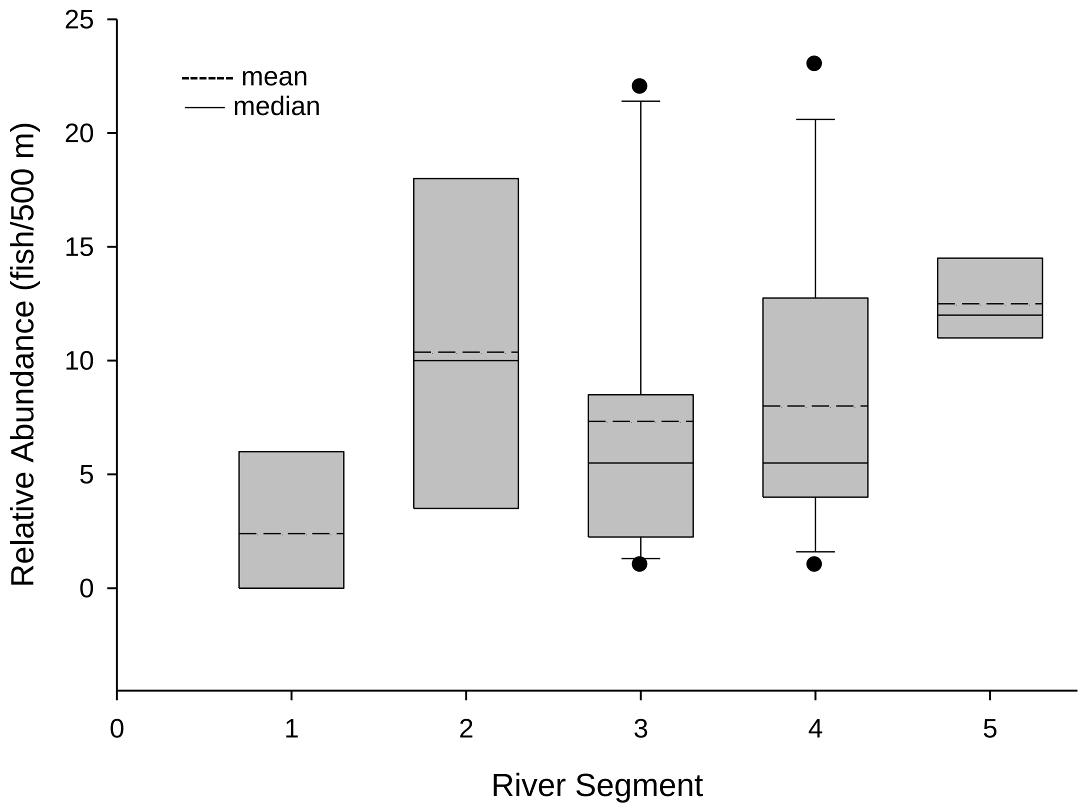

Figure 3.6. Box plots of cutthroat trout relative abundance (fish/500 m reach) in the five river segments of the main-stem upper Yellowstone River, September 2006.

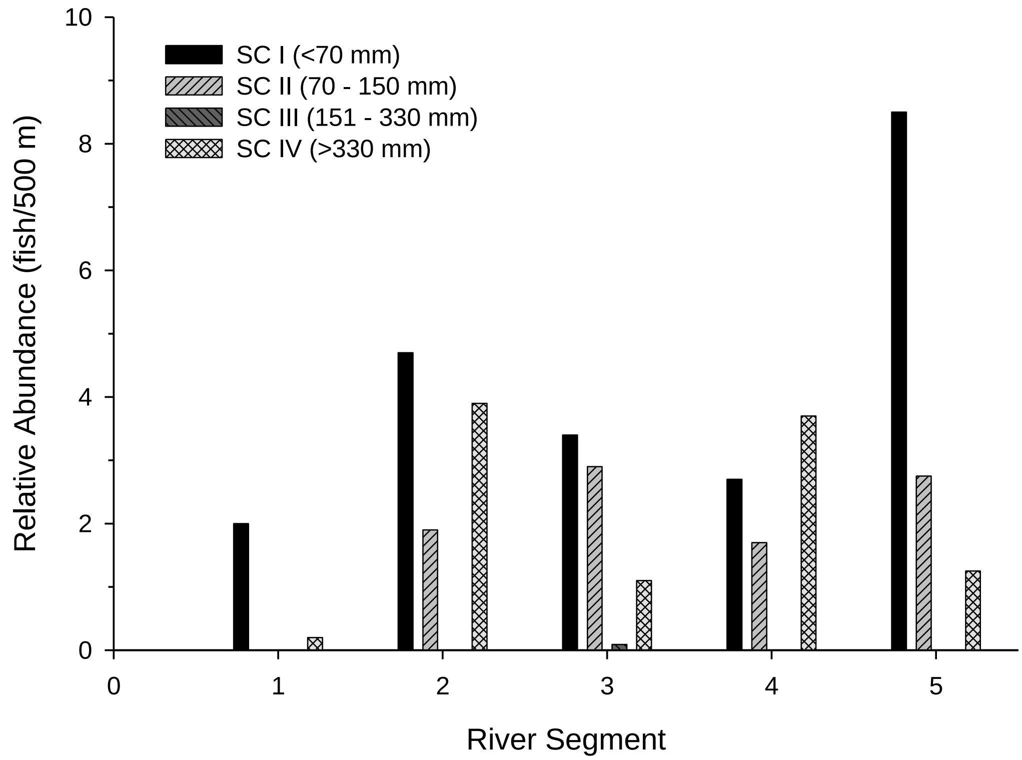

Figure 3.7. Cutthroat trout relative abundance by size category classification in the five river segments of the main-stem upper Yellowstone River, September 2006, Yellowstone National Park, Wyoming.

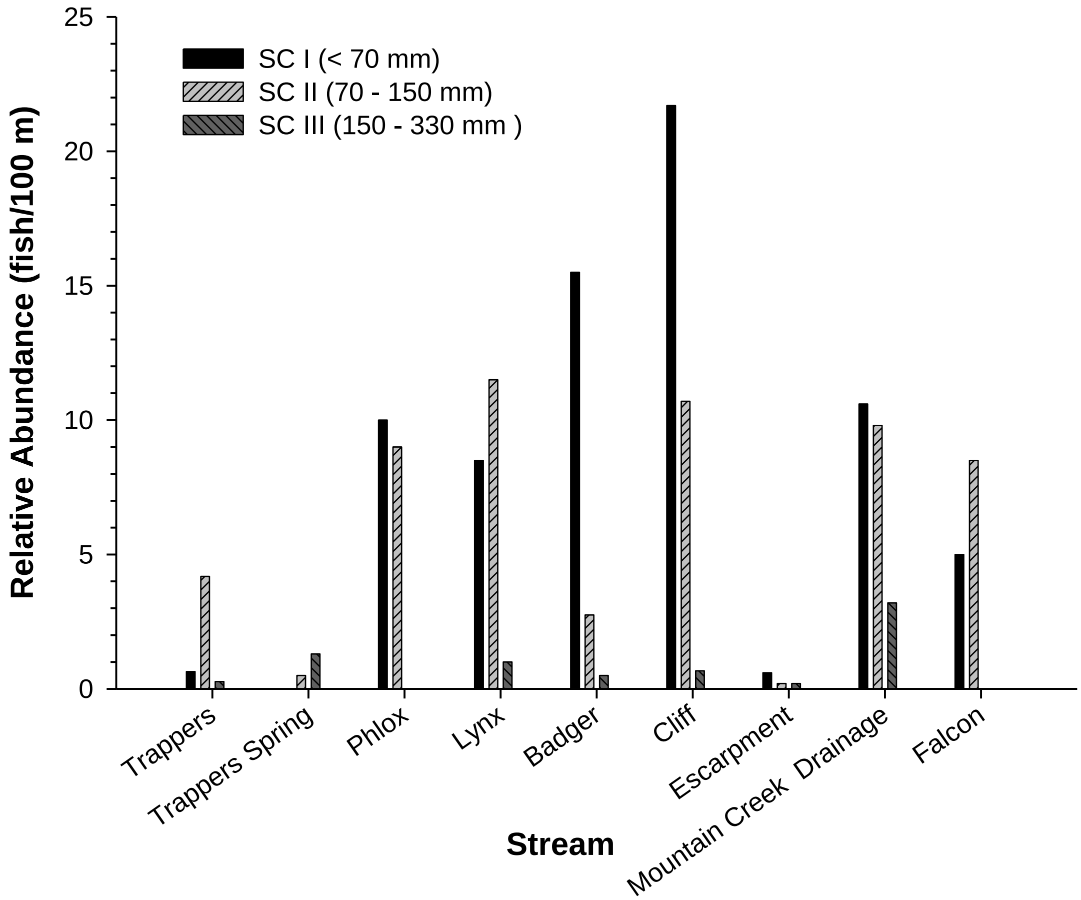

Figure 3.8. Relative abundance (fish/100 m) of cutthroat trout sampled in tributary streams of the upper Yellowstone River during electrofishing surveys, 2005-2007, Yellowstone National Park, Wyoming.

Literature Cited

Ball, O.P. 1955. Some aspects of homing in cutthroat trout. Proceedings Utah Academy of Science, Arts, and Letters, 32:75-80.

Ball, O.P., and O.B. Cope. 1961. Mortality studies on cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Research Report 55.

Bateman, D.S., R.E. Gresswell, and C.E. Torgersen. 2005. Evaluating single-pass catch as a tool for identifying spatial pattern in fish distribution. Journal of Freshwater Ecology 20:335-345.

Behnke, R.J. 2002. Trout and salmon of North America. New York: The Free Press.

Benson, N.G. 1960. Factors influencing production of immature cutthroat trout in Arnica Creek, Yellowstone Park. Transactions of the American Fisheries Society 89:168-175.

Benson, N.G., and R.V. Bulkley. 1963. Equilibrium yield management of cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Research Report 62.

Bernard, D.R., and E.K. Israelsen. 1982. Inter- and intrastream migration of cutthroat trout (*Salmo clarki*) in Spawn Creek, a tributary of the Logan River, Utah. Northwest Science 56:148-158.

Bircher, C.L., and E.F. Benfield. 2006. Physical and biological responses of streams to suburbanization of historically agricultural watersheds. Journal of the North American Benthological Society 25:356-369.

Bowlby, J.N., and R.C. Roff. 1986. Trophic structure n southern Ontario streams. Ecology 67:1670-1679.

Bozek, M.A., and W.A. Hubert. 1992. Segregation of resident trout in streams as predicted by three habitat dimensions. Canadian Journal of Zoology 70:886-890.

Brenkman, S.J., G.L. Larson, and R.E. Gresswell. 2001. Spawning migration of lacustrine-adfluvial bull trout in a natural area. Transactions of the American Fisheries Society 130:981-987.

Bryant, M.D., N.D. Zymonas, and B.E. Wright. 2004. Salmonids on the fringe: Abundance, species composition, and habitat use of salmonids in high-gradient streams, southeast Alaska. Transactions of the American Fisheries Society 133:1529-1538.

Bulkley, R.V., and N.G. Benson. 1962. Predicting year-class abundance of Yellowstone Lake cutthroat trout. U.S. Fish and Wildlife Service Research Report 59.

Byorth, P.A. 1990. An evaluation of Yellowstone cutthroat trout production in three tributaries of the Yellowstone River, Montana. Master's thesis, Montana State University, Bozeman, Montana.

Catalano, M.J., M.A. Bozek, and T.D. Pellett. 2007. Effects of dam removal on fish assemblage structure and spatial distributions in the Baraboo River, Wisconsin. North American Journal of Fisheries Management 27:519-530.

Chisholm, I.M., and W.A. Hubert. 1986. Influence of stream gradient on standing stock of brook trout in the Snowy Range, Wyoming. Northwest Science 60:137-139.

Coleman, M.A., and K.D. Fausch. 2007. Cold summer temperature limits recruitment of age-0 cutthroat trout in high-elevation Colorado streams. Transactions of the American Fisheries Society 136:1231-1244.

Devore, J., and R. Peck. 2005. Statistics: The exploration and analysis of data. Fifth edition. Brooks/Cole. United States.

Dolloff, A., J.L. Kershner, and R. Thurow. 1996. Underwater observation. In; B.R. Murphy and D.W. Willis editors. Fisheries Techniques, 2nd edition. Bethesda, MD; American Fisheries Society; 533-554.

Dunham, J.B., G.L. Vinyard, and B.E. Rieman. 1997. Habitat fragmentation and extinction risk of Lahontan cutthroat trout. North American Journal of Fisheries Management 17:1126-1133.

Flebbe, P.A., and C.A. Dolloff. 1995. Trout use of woody debris and habitat in Appalachian wilderness streams of North Carolina. North American Journal of Fisheries Management 15:579-590.

Fraley, J.J., and B.B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout (*Salvelinus confluentus*) in the Flathead Lake and river system, Montana. Northwest Science 63:133-143.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management 10:199-214.

Gowan, C., and K.D. Fausch. 1996. Mobile brook trout in two high-elevation Colorado streams: reevaluating the concept of restricted movement. Canadian Journal of Fisheries and Aquatic Sciences 53:1370-1381.

Gowan, C., and K.D. Fausch. 2002. Why do foraging stream salmonids move during summer? Environmental Biology of Fishes 64:139-153.

Gresswell, R.E., W.J. Liss, and G.L. Larson. 1994. Life-history organization of Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 51:298-309.

Gresswell, R.E. 1995. Yellowstone cutthroat trout. Pages 36-54 *in* M.K. Young, editor. Conservation assessment for inland cutthroat trout. U.S. Forest Service General Technical Report RM-GTR-256.

Gresswell, R.E., W.J. Liss, G.L. Larson, and P.J. Bartlein. 1997. Influence of basin-scale physical variables on life history characteristics of cutthroat trout in Yellowstone Lake. North American Journal of Fisheries Management 17:1046-1064.

Harig, A.L., and K.D. Fausch. 2002. Minimum habitat requirements for establishing translocated cutthroat trout populations. Ecological Applications 12:535-551.

Houde, E.D. 2002. Mortality. Pages 64-87. in L.A. Fuiman, and R.G. Werner editors. Fishery Science. The unique contributions of early life stages. Blackwell Scientific Publications, Oxford, UK.

Jakober, M.J., T.E. McMahon, R.F. Thurow, and C.G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223-235.

Jones, R.D., D.G. Carty, R.E. Gresswell, C.J. Hudson, L.D. Lentsch, and D.L. Mahony. 1986. Fishery and aquatic management program in Yellowstone National Park. U.S. fish and wildlife Service, Technical Report for 1985, Yellowstone National Park, Wyoming.

Kaeding, L.R., G.D. Boltz, and D.G. Carty. 1996. Lake trout discovered in Yellowstone Lake threaten native cutthroat trout. Fisheries 21(3):16-20.

Kaeding, L.R., and G.D. Boltz. 2001. Spatial and temporal relations between fluvial and allacustrine Yellowstone cutthroat trout, *Oncorhynchus clarki bouvieri*, spawning in the Yellowstone River, outlet stream of Yellowstone Lake. Environmental Biology of Fishes 61:395-406.

Kershner, J.L., C.M. Bischoff, and D.L. Horan. 1997. Population, habitat, and genetic characteristics of Colorado River cutthroat trout in wilderness and nonwilderness stream sections in the Uinta Mountains of Utah and Wyoming. North American Journal of Fisheries Management 17:1134-1143.

Knight, C.A., R.W. Orme, and D.A. Beauchamp. 1999. Growth, survival, and migration patterns of juvenile adfluvial Bonneville cutthroat trout in tributaries of Strawberry Reservoir, Utah. Transactions of the American Fisheries Society 128:553-563.

Koel, T.M., P.E. Bigelow, P.D. Doepke, B.D. Ertel, and D.L. Mahony. 2005. Nonnative lake trout result in Yellowstone cutthroat trout decline and impacts to bears and anglers. Fisheries 30(11):10-19.

Koel, T.M., J.L. Arnold, P.E. Bigelow, P.D. Doepke, B.D. Ertel, and M.E. Ruhl. 2010. Yellowstone Fisheries and Aquatic Sciences: Annual Report, 2008. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, YCR-2010-03.

Kozel, S.J., and W.A. Hubert. 1989. Factors influencing the abundance of brook trout (*Salvelinus fontinalis*) in forested mountain streams. Journal of Freshwater Ecology 5:113-122.

Kozel, S.J., W.A. Hubert, and M.G. Parsons. 1989. Habitat features and trout abundance relative to gradient in some Wyoming streams. Northwest Science 63:175-182.

Kruse, C.G., W. A. Hubert, and F.J. Rahel. 1997. Geomorphic influences on the distribution of Yellowstone cutthroat trout in the Absaroka Mountains, Wyoming. Transactions of the American Fisheries Society 126:418-427.

Kruse, C.G., W. A. Hubert, and F.J. Rahel. 1998. Single pass electrofishing predicts trout abundance in mountain streams with sparse habitat. North American Journal of Fisheries Management 1:940-946.

Kruse, C.G., W.A. Hubert, and F.J. Rahel. 2000. Status of Yellowstone cutthroat trout in Wyoming waters. North American Journal of Fisheries Management 20:693-705.

Kruse, C.G., and W.A. Hubert. 2001. An assessment of headwater isolation as a conservation strategy for cutthroat trout in the Absaroka Mountains of Wyoming. Northwest Science 75:1-11.

Kutner, M.H., C.J. Nachtsheim, J. Neter, and W. Li. 2005. Applied linear statistical models. Fifth edition. McGraw-Hill. United States.

Latterell, J.J. R.J. Naiman, B.R. Fransen, and P.A. Bisson. 2003. Physical constraints on trout (*Oncorhynchus spp.*) distribution in the Cascade Mountains: a comparison of logged and unlogged streams. Canadian Journal of Fisheries and Aquatic Sciences 60:1007-1017.

Lindstrum, J.W., and W.A. Hubert. 2004. Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream. North American Journal of Fisheries Management 24:1341-1352.

Lonzarich, D.G., M.E. Lonzarich, and M.L. Warren. 2004. Using snorkeling to quantify fish assemblage structure in Arkansas streams. United States Forest Service General Technical Report SRS-74. Asheville, North Carolina.

Murphy, M.L., J. Heifetz, S.W. Johnson, D.V. Koski, and J.F. Thedinga. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences 43:1521-1533.

Nelson, M.L., T.E. McMahon, and R.F. Thurow. 2002. Decline of the migratory form of bull char, *Salvelinus confluentus*, and implications for conservation. Environmental Biology of Fishes 64:321-332.

Overton, C.K., S.P. Wollrab, B.C. Roberts, and M.A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) Fish and fish habitat standard inventory procedures handbook. United States Forest Service. General Technical Report INT-GTR-346.

Paul, A.J., and J.R. Post. 2001. Spatial distribution of native and nonnative salmonids in streams of eastern slopes of the Canadian Rocky Mountains. Transactions of the American Fisheries Society 130:417-430.

Rieman, B.E., and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society 124:25-296.

Roni, P., and T.P. Quinn. 2001. Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. Canadian Journal of Fisheries and Aquatic Sciences 58:282-292.

Rosenfeld, J., M. Porter, and E. Parkinson. 2000. Habitat factors affecting the abundance and distribution of juvenile cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences 57:766-774.

Rosenfeld, J.S., S. Macdonald, D. Foster, S. Amrhein, B. Bales, T. Williams, F. Race, and T. Livingston. 2002. Importance of small streams as rearing habitat for coastal cutthroat trout. North American Journal of Fisheries Management 22:177-187.

Sanderson, T.B., and W.A. Hubert. 2009. Movements by adult cutthroat trout in a lotic system: implications for watershed-scale management. Fisheries Management and Ecology 16:329-336.

Scarnecchia, D.L., and E.P. Bergersen. 1987. Trout production and standing crop in Colorado's small streams, as related to environmental features. North American Journal of Fisheries Management 7:315-330.

Schill, D.J., and J.S. Griffith. 1984. Use of underwater observations to estimate cutthroat trout abundance in the Yellowstone River. North American Journal of Fisheries Management 4:479-487.

Schlosser, I.J. 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecological Monographs 52:395-414.

Shuter, B.J., and J.R. Post. 1990. Climate, population viability, and zoogeography of temperate fishes. Transactions of the American Fisheries Society 119:314-336.

Simberloff, D. 2001. Biological invasions – how are they affecting us, and what can we do about them? Western North American Naturalist 63:308-315.

Slaney, P.A., and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. North American Journal of Fisheries Management 7:117-122.

Slawski, T.M., F.M. Veraldi, S.M. Pescitelli, and M.J. Pauers. 2008. Effects of tributary spatial position, urbanization, and multiple low-head dams on warm water fish community structure in a Midwestern stream. North American Journal of Fisheries Management 28:1020-1035.

Stonecypher, R.W. Jr., W.A. Hubert, and W.A. Gern. 1994. Effect of reduced incubation temperatures on survival of trout embryos. Progressive Fish-Culturist 56:180-184.

Thurow, R.F., C.E. Corsi, and V.K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in the upper Snake River drainage, Idaho. American Fisheries Society Symposium 4:25-36.

Varley, J.D., and R.E. Gresswell. 1988. Ecology, status, and management of Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Verro, R., A. Finizio, S. Otto, and M. Vighi. 2009. Predicting pesticide environmental risk in intensive agricultural areas. II: Screening level risk assessment of complex mixtures in surface waters. Environmental Science and Technology 43:530-537.

Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. Transactions of the American Fisheries Society 120:98-105.

Young, M.K. 1995. Conservation assessment for inland cutthroat trout. U.S. Forest Service, General Technical Report RM-GTR-2565, Fort Collins, Colorado.

Zubik, R.J., and J.J. Fraley. 1988. Comparison of snorkel and mark-recapture estimates for trout populations in large streams. North American Journal of Fisheries Management 8:58-62.

CHAPTER 4

AGE STRUCTURE AND GROWTH OF VARIOUS LIFE-HISTORY FORMS OF YELLOWSTONE CUTTHROAT TROUT IN THE UPPER YELLOWSTONE RIVER BASIN, WYOMING

Introduction

Salmonid species often display a wide variety of life-history forms both among and within drainages (Riget et al. 1986; L'Abee-Lund et al. 1989; Gresswell et al. 1994; Northcote 1997; Hogen and Scarnecchia 2006). Life-history form is determined by a combination of biotic and abiotic factors acting at different periods during a fish's lifetime (Meyer et al. 2003; Coleman and Fausch 2007). Life-history form can often be distinguished by differences in age of maturation, body size, growth rate, and migration patterns (Hutchings 2002).

Differences in growth rate and body size are important determinants of life-history form because of their influence on fecundity, migration potential, and survival (Stearns 1992; Okland et al. 1993; Hutchings 2003). Individuals that mature quickly gain fitness advantages through shorter generation times and decreased likelihood of mortality before spawning (Morita and Morita 2002). However, benefits of early maturation can be offset by costs associated with smaller body size and lower fecundity. Small size and early maturation are life-history characteristics common to resident salmonids residing in headwater streams (Northcote 1997). In contrast, delayed maturation provides fitness benefits associated with larger size and increased fecundity, but in turn, there are costs associated with longer generation times, specifically, an increased risk of mortality prior to spawning (Morita and Morita 2002). Among salmonids, differences in life-history forms have been classified as resident (fluvial) or migratory (fluvial-adfluvial, lacustrine-adfluvial, or allacustrine) forms (Varley and Gresswell 1988; Gresswell et al. 1997).

Life history differences can often be distinguished by examination of scales and other hard parts of fish. Scale circuli patterns can provide valuable insight into age, growth, and movement of a fish throughout its lifetime (Ogle and Spangler 1996; Weisberg 1993). Fish reared in different environments often develop recognizable patterns on their scales as they form (Bigelow and White 1996). In some systems, fisheries managers have been able to use scale pattern analysis to differentiate lacustrine versus stream dwelling fish (Hutchings 1986; Dempson et al. 1996).

The pattern of spacing between circuli is directly related to the growth of a fish at that time (Francis 1990). Changes in growth rates are typically brought about by changes in temperature and diet associated with changes in season or through migration. Wider spaced circuli typically form during the summer growing season and in more productive environments, and narrower spaced or incomplete circuli form during the colder seasons and less productive environments. This pattern often provides an accurate format for ageing fish and determining migration and life-history patterns (Brown and Bailey 1952; Laakso and Cope 1956; Pikitch and Demory 1988).

Ageing fish with scales presents several common problems. Scales can be regenerated by a fish in areas where scale have been damaged or removed. Newly formed scales will not yield accurate age. Also, scales of fish found in headwater locations or environments with short growing seasons will often fail to produce an annulus mark during their first year (Laakso 1955; Regier 1962). This is particularly true for Yellowstone cutthroat trout in many Yellowstone waters because of their late emergence and subsequent slow growth during October as temperatures and productivity decline (Laakso and Cope 1956). Brown and Bailey (1952) found that cutthroat trout had highly variable levels of scale formation at the end of their first growing season. Laakso and Cope (1956) reported that approximately 33% of cutthroat trout examined from the Yellowstone Lake basin did not form scales during their first summer post-emergence, and only 31.5% that did show signs of squamation formed a first year annulus mark.

Cutthroat trout within the Yellowstone Lake drainage display all four life-history forms, but the lacustrine-adfluvial life history is by far the predominant form among tributaries studied (Varley and Gresswell 1988; Gresswell et al. 1994; Kaeding and Boltz 2001). These fish spawn in lake tributaries with juvenile outmigration typically occurring during their first summer, shortly after emergence (Ball and Cope 1961; Varley and Gresswell 1988; Gresswell et al. 1994). In contrast, the fluvial, fluvial-adfluvial, and allacustrine life-history forms are rare in the tributaries to Yellowstone Lake (Varley and Gresswell 1988; Gresswell et al. 1994; Kaeding and Boltz 2001). However, there has been no comprehensive fisheries assessment conducted in the upper Yellowstone River, the largest tributary to Yellowstone Lake, and its extensive network of tributary drainages. This large fluvial environment may facilitate the occurrence of fluvial or fluvial-adfluvial life-history types.

Typical of many salmonids, growth rates of Yellowstone cutthroat trout vary by life-history type both among and within drainages across its range (Thurow et al. 1988; Gresswell et al. 1994; Behnke 2002; Meyer et al. 2003). Headwater resident cutthroat trout may reach lengths of 250 mm, whereas migratory, lacustrine-adfluvial cutthroat trout may reach lengths of up to 600 mm or greater (Behnke 2002). Fluvial trout in headwater environments tend to grow at much slower rates because of the colder or less productive environments in which they typically reside (Behnke 2002). It is rare for a fluvial cutthroat trout to live more than 3-5 years, while fish in Yellowstone Lake have been known to live 9 years or more (Gresswell and Varley 1988; Varley and Gresswell 1988; Behnke 2002). Although headwater resident cutthroat trout grow at a slower rate and live shorter lives on average, they have evolved to mature at a younger age then fluvial-adfluvial or lacustrine-adfluvial fish (Behnke 2002). Determining if multiple life-history types are present within the upper Yellowstone River drainage would show that the area contains life-history forms that rarely occur elsewhere in the lake basin. It could also indicate that there are distinct spawning populations present in various parts of the drainage.

The primary objective of this study was to assess if different life-history forms that occur in Yellowstone cutthroat trout in the upper Yellowstone River Drainage could be differentiated between based on scale circuli patterns. I used age structure and growth patterns from scale samples to identify if fluvial, fluvial-adfluvial, and lacustrine-adfluvial life-history forms were present in the drainage. Identification of unique life-history types is important as different life histories may represent different genotypes within a species (Healey and Prince 1995). A greater understanding of unique life-history forms that may be present in the upper Yellowstone River basin will aid management and regulatory decisions for this large drainage and Yellowstone Lake. I hypothesized that fluvial or fluvial-adfluvial fish, if present, would display slower growth rates than lacustrine-adfluvial migrants and these fish could be distinguished by distinctive differences in scale patterns and growth.

Study Area

The study area consisted of the upper Yellowstone River from its headwaters near Younts Peak to Yellowstone Lake (Figure 4.1). The Yellowstone River flows just over 80 kilometers from its headwaters to its mouth at Yellowstone Lake. The drainage contains over 200 km of tributary streams, covers an area of 1,244 square kilometers, and drains about 42% of the Yellowstone Lake basin. It is one of 68 of 124 Yellowstone Lake tributaries known to contain a spawning run of Yellowstone cutthroat trout (Jones et al. 1986; Kaeding and Boltz 2001). Scale collection took place on the main-stem Yellowstone River, Trappers, Mountain, Howell, Cliff, Escarpment, Thorofare, Phlox, and Badger creeks.

The headwater reaches of the main-stem upper Yellowstone River consists of riffle-pool complexes that flow through steep forested slopes of lodgepole pine *Pinus contorta*, whitebark pine *Pinus ablicaulis*, limber pine *Pinus flexilis*, blue spruce *Picea pungens*, and douglas fir *Psuedotsuga menziesii* trees. From the headwaters to Castle Creek, the river gradient is 11.6 m/km and substrate is dominated by boulders and cobble.

From Castle Creek to Yellowstone Lake, gradient flattens to 0.96 m/km and the river consists of long runs, glides, and a few large pools. Substrate is dominated by gravel, cobble, and sand. The over-story is similar in structure to the upper reaches, but is more heavily dominated by lodgepole pine. The understory includes fields of willow *Salix spp.* and grasses *Bromus spp.* and *Phleum spp.* Wildfires have occurred in recent decades and large burned areas are common in the watershed.

Native fish species in the Yellowstone River include Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae*. Nonnative species include redside shiner *Richardsonius balteatus,* and longnose sucker *Catostomus catostomus*. Although not documented in the Yellowstone River, lake chub *Couesius plumbeus,* and lake trout have been documented in Yellowstone Lake.

Methods

Scale samples were collected during two different sampling events: radio transmitter implantation trips for spawning adults (chapter 2) and electrofishing surveys (chapter 3). During implantation trips fish were collected by angling from May through mid-July 2003–2005. Additional trips were made in August and October of 2003. These trips produced few fish and were not continued in following years. Scale samples were taken from all fish captured during this time with the exception of males whose scales had become too embedded to remove, or female fish who released gametes when handled. All scales were collected from the left side of the fish, above the lateral line, between the dorsal and adipose fins. Scales were placed on glue-cards for later processing. During implantation efforts, no fish <400 mm in total length were collected with the exception of 2 fish from a small isolated spring tributary of Trappers Creek (Trappers Spring). Scales collected during implantation trips were used to develop age and growth standards for the lacustrine-adfluvial life-history form in this drainage to compare with fish collected during later electrofishing surveys of the region.

Electrofishing surveys took place from August through September each year from 2004–2007 on the main-stem Yellowstone River and several tributary streams (Table 4.1). Scale samples were collected from up to 10 fish in 10 mm size class increments in each stream sampled. Additional samples were taken in headwater or isolated reaches where the possibility of sampling fluvial or fluvial-adfluvial cutthroat trout was greatest. The main-stem Yellowstone River was sampled using an approximately 5-m raft outfitted with electrofishing equipment. The river was divided into 1-km sampling sections and a 500-m reach was sampled within each section. Each reach was sampled on two occasions in September of 2006. Tributaries were sampled using a Smith-Root model LR-24 backpack electrofishing unit. Each tributary was divided into 1-km sections and a 100-m reach in each km was randomly selected and sampled. All tributaries were sampled until two consecutive sections were sampled without collecting a fish. If a possible barrier to upstream movement was identified, at least one section above the barrier was sampled if no fish were present.

Scale impressions were made on a 0.5-mm thick, clear acetate card using a Carver laboratory press. Press plates were heated to 200^{o}F and cards were pressed under 10,000 pounds of pressure for 60 seconds. Scale impressions were read using an Eberbach frontal projector. For each scale sample readers recorded scale radius, focus radius, annulus radius, and circuli counts for the first and second annuli. Measurements were taken along the major axis (Laakso and Cope 1956) directly from the projected image (Figure 4.2). All scale images were read under the same magnification. Annuli were identified by circuli spacing and completeness of circuli rings on the scale (DeVries and Frie 1996). Because not all cutthroat trout form scales before their first winter, samples with more than 7 circuli before their first annulus were not considered to have formed an annulus during their first growing season (Laakso 1955; Laakso and Cope 1956; Lentsch and Griffith 1987) (Figure 4.3). Such scales, along with those showing evidence of regeneration or lacking clearly defined annuli were removed from age and growth analysis.

Scale samples were independently aged by two trained readers. To eliminate bias in interpretation, readers were unaware of fish capture location, capture date, sex, or total length. Reader 1 read all scales on two different occasions and reader 2 read each scale once. Multiple scales from each fish were read to ensure accuracy of age estimations and measurements. If age readings did not agree, either between readers or between scales from an individual fish, samples were removed from further analysis. Because of the "Species of Special Concern" status of Yellowstone cutthroat trout in Montana, lethal sampling for otoliths was not conducted. However, previous studies have verified that scales of cutthroat trout yield consistent age estimates provided that those with and without a perceptible first annulus were accurately characterized (Brown and Bailey 1952; Laakso 1955). Otolith and scale comparison indicated that otoliths yielded age estimates one to two years greater than with scales (Hubert et al. 1987; Kruse et al. 1997). Age underestimation using scales was attributed to lack of annulus formation on scales during the first growing season and reader error due to obscure annuli or scale erosion.

For this study, age structure and growth were compared among four different stream categories in the upper Yellowstone drainage based on relative stream size: main stem, large tributaries, small tributaries, and isolated waters (Table 4.1). Length-at-age was compared to determine if different life-history types were present in the basin and if present, if differences in growth rate and age structure occur among stream size categories. Higher lengths-at-age have been reported in lacustrine-adfluvial versus fluvial or fluvial-adfluvial fish in several systems (Hutchings 1986, Dempson et al. 1996, Behnke 2002). Therefore, fish with significantly lower length at age may be evidence of fluvial or fluvial-adfluvial cutthroat populations in the upper Yellowstone River system. Age structure and mean length at age for all categories were compared using Welch's two-sample t-test ($\alpha = 0.05$) or Kruskal Wallis test ($\alpha = 0.05$) (Kutner et al. 2005).

Results

Scale samples were collected from 65 of the 219 Yellowstone cutthroat trout sampled during radio-tagging of large spawning adults. Of the 65 samples collected, only 29 provided readable scale samples. The majority of rejected scale samples (86%) contained regenerated areas that distorted the area around the scale focus making them unreadable (Figure 4.3c). Twenty-two samples formed an annulus during their first growing season based on ≤ 7 circuli prior to the first annulus mark. These fish ranged in age from 4 to 7 years with a mean of 5.1 years (median 5, SE 0.21) (Figure 4.4). No fish were collected from isolated streams.

Electrofishing of Yellowstone cutthroat trout of all sizes yielded readable samples from 309 fish. Of these, it was determined that 252 (81.6%) fish produced an annulus mark during their first growing season. This percentage was much higher than the 31.5% previously reported for cutthroat trout from tributaries of Yellowstone Lake (Laakso and Cope 1956).

Not all age classes were collected in all stream categories. Age 0-2 fish were collected throughout all waters sampled with the exception of isolated waters where no age 0 fish and only one age 1 fish were sampled. Age-3 fish were collected only in a few locations in large tributaries and isolated waters. Age-4 fish were collected in the main stem and large tributaries. Age-5 and 6 fish were collected only in the main stem. For all waters cutthroat trout age ranged from zero to six years of age with a mean age of 1.2 (Median 1, SE 0.06) (Figure 4.5, Table 4.2). Median age differed significantly between the four categories of stream (Kruskal Wallis, $F = 56.4$, $p < 0.0001$, $df = 3$). Pairwise comparison of median age for the four categories showed that significant differences occurred between all categories. Age 1 was the dominant age class in all streams except isolated waters where age-2 and 3 fish were most abundant (Figure 4.6).

Length at age was significantly different for certain age classes of fish in the different stream categories (Table 4.3). Total length of age zero fish was significantly different between the stream categories (Kruskal Wallis, $F = 11.0$, $P = 0.004$, $df = 2$). Tukey's post-hoc multiple comparison tests showed that length at age zero was significantly different for fish in the main stem versus small tributaries. Mean total length of age 0 fish was longer in small tributaries than in large tributaries or the main stem river (Table 4.3). No significant differences in total length were detected in age classes 1 or 2 (Kruskal Wallis F = 6.6, $P = 0.084$, df = 3 (age 1) and f = 3.6, $P = 0.31$, df = 3 (age 2)) for any stream categories. Significant differences were detected in age-3 fish (Welch's two sample t-test, t = -4.8. $P = 0.001$, df = 9). These fish were collected only in two categories, large tributaries and isolated waters. Cutthroat trout from large tributaries were significantly larger than those captured in isolated waters (Table 4.3). Age-4 fish were collected in low numbers in the main stem and large tributaries. Age-4 fish from the main stem were nearly 200-mm longer than those from large tributaries (Table 4.3). Age-5 and 6 fish were not tested as they were only collected in the main stem.

Discussion

Age and growth analysis supported the hypothesis that varying life-history forms of Yellowstone cutthroat trout are found in the upper Yellowstone River basin. The difference in total length of adult fish captured in the Mountain Creek drainage (large tributary) during autumn electrofishing surveys was significantly different than that of adult fish captured during spring spawning migrations in the drainage. The smaller size of adult fish in Mountain Creek as well as those from Trappers Spring (isolated water) in comparison to lacustrine-adfluvial fish captured during spring surveys indicates that fluvial fish are present in this drainage and can be distinguished from lacustrine-adfluvial fish based on total length at age for age-3 and older fish.

Cutthroat trout captured in the upper Yellowstone River basin during implantation efforts were similar in age to those captured in other tributary streams of Yellowstone Lake and the Yellowstone River outlet. Mean age of 5.1 years was similar to that of fish aged from Clear Creek (5.3, in 1984) (Gresswell and Varley 1988), and the Yellowstone River outlet (5.2, in 1998) (NPS, unpublished data). Mean total length of cutthroat trout sampled in the upper Yellowstone River system (460 mm) was significantly different (Kruskal-Wallis, $p < 0.000$) than that of spawning cutthroat trout in Clear Creek (523 mm, 2007) and Arnica Creek (370 mm, 1998) (NPS, unpublished data). The fact that the mean length of fish sampled in the upper Yellowstone River falls between the mean length of fish in other spawning tributaries of Yellowstone Lake indicates that estimates are most likely reflective of lacustrine-adfluvial fish from the lake. The relatively small sample size of 219 fish and use of angling as a capture technique may have biased this result.

The majority of fish captured in all waters, other than Trappers Spring, during electrofishing surveys were age 0 or 1 (Figure 4.6). This indicates that most cutthroat trout migrate downstream to Yellowstone Lake shortly after hatching or at age one and return later to spawn. This pattern of movement is similar to that seen in other tributary streams of Yellowstone Lake (Gresswell et al. 1994) indicating that the lacustrine-adfluvial life history is also dominant in the upper Yellowstone River drainage. Further evidence of the lacustrine-adfluvial life history can be drawn from the lack of age 3 fish in all areas with the exception of the upper reaches of the Mountain Creek drainage and Trappers Spring. The low numbers of adult fish captured during electrofishing surveys indicate that fluvial or fluvial-adfluvial life histories are extremely rare in this drainage. Fluvial or fluvial-adfluvial life histories have only been documented in one other tributary to Yellowstone Lake, Sedge Creek, where fish have been isolated from Yellowstone Lake by a thermal barrier for over 8,000 years (Varley and Gresswell 1988; Gresswell et al. 1994).

The presence of age 0 and 1 cutthroat trout in all waters sampled indicates that migratory adults may enter all streams without barriers to upstream movement during spring spawning migrations. The occurrence of large (>400 mm) spawning adults, in all areas with the exception of Trappers Spring, supports this assertion. The presence of both migratory and resident adults in the upper Mountain Creek drainage indicates that there is no migratory barrier in the system and visual accounts of small (<300 mm) fish attempting to spawn with large (>400 mm) fish indicates that there is likely temporal overlap in spawning periods of fish within these size groups as well (personal observations). The low numbers of age 3 and older fish throughout the majority of the system is evidence that the lacustrine-adfluvial life-history form is predominant in the upper Yellowstone River system. In contrast, only a few fluvial cutthroat trout were present in the system. Though rare, the existence of the true fluvial cutthroat trout in the Mountain Creek drainage is the first documented case of this life history in any Yellowstone Lake tributary that is not isolated above a migration barrier.

Fluvial fish isolated above migration barriers, like those found in Trappers Spring, have been documented only in Sedge Creek (Gresswell et al. 1994) and the South Fork of the Yellowstone River (Wyoming Game and Fish Department unpublished data). The presence of multiple age classes of fish in Trappers Spring is evidence that this is a self-sustaining population, although in very low numbers. To help determine population and genetic status of these fish, they should be studied in more detail.

The paucity of true resident or fluvial populations within the Yellowstone Lake drainage distinguishes these as unique populations and should be protected. The current regulations within Yellowstone National Park call for complete closure to fishing prior to July 15, and catch-and-release fishing for Yellowstone cutthroat trout thereafter. To help protect these populations, this regulation should be adapted in waters outside the park boundary where it is currently legal to keep two cutthroat trout throughout the season. With Yellowstone cutthroat trout numbers showing marked declines range-wide and particularly within the Yellowstone Lake drainage, these populations could be of great importance to the conservation of these unique metapopulations.

Table 4.1. Waters included under each stream category. Tributary classifications are based on stream size of the tributary as it enters the Yellowstone River. For example Howell Creek is classified in the Large Tributares category because it flows into Mountain Creek before entering the Yellowstone River.

Stream Category	Streams
Main Stem	Yellowstone River
Large Tributaries	Mountain Creek -Howell Creek* -Several unnamed streams*
Small Tributaries	Trappers Creek Cliff Creek Escarpment Creek Badger Creek Phlox Creek Falcon Creek
Isolated Waters	Trappers Spring

* Located within the Mountain Creek drainage.

Table 4.2. Percent of cutthroat trout (≥ 60 mm in total length) in each age group sampled during electrofishing surveys of the upper Yellowstone River basin, Yellowstone National Park, Bridger-Teton Wilderness, Wyoming. Breakdown based on age-length key created from fish sampled during electrofishing and tag implantations surveys. (MS = Yellowstone River main stem, LT = Large Tributaries, ST = Small Tributaries, and ISO = Isolated Waters).

		Age						
Category	n	0	1	2	3	4	5	6
MS	46	13.0	65.2	2.2	0.0	4.3	13.0	2.2
LT	138	10.9	68.8	16.7	2.9	0.7	0.0	0.0
ST	55	43.6	52.7	3.6	0.0	0.0	0.0	0.0
ISO	13	0.0	7.7	38.5	53.8	0.0	0.0	0.0

Table 4.3. Mean total length (mm) of cutthroat in different age groups from the main stem, large tributaries, and small tributaries of the Yellowstone River. Normal scales are those that contained less than 8 circuli before the formation of the first annulus. Category names are the same as Table 4.2.

Category	Scale	Age (n)						
	Type	0	1	2	3	4	5	6
MS	TL	64.3	109.0	108.0	-	471.5	463.3	455.0
	n	6	30	1	0	2	6	1
LT	TL	79.3	119.5	154.5	237.3	280.0	-	-
	n	15	95	23	4	1	0	0
ST	TL	85.7	116.6	173.5	-	-	-	-
	n	24	29	2	0	0	0	0
ISO	TL	-	104.0	156.3	190.1	-	-	-
	n	0	1	7	7	0	0	0

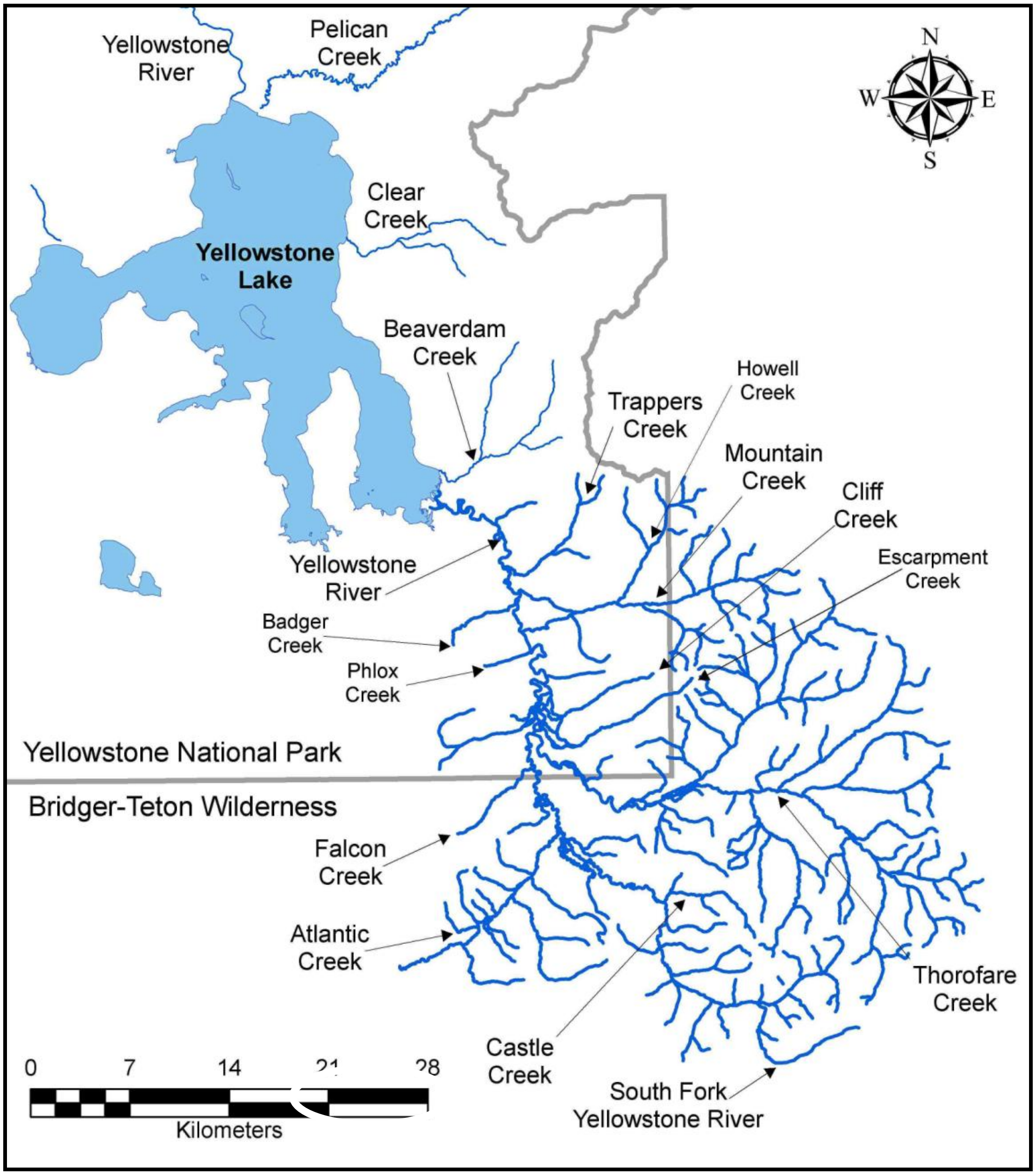

Figure 4.1. Location of scale sample collections within the upper Yellowstone River study area. Scales samples were collected from adult cutthroat trout throughout the basin during radio transmitter implantation trips from 2003–2005 and during electrofishing surveys from 2004–2007.

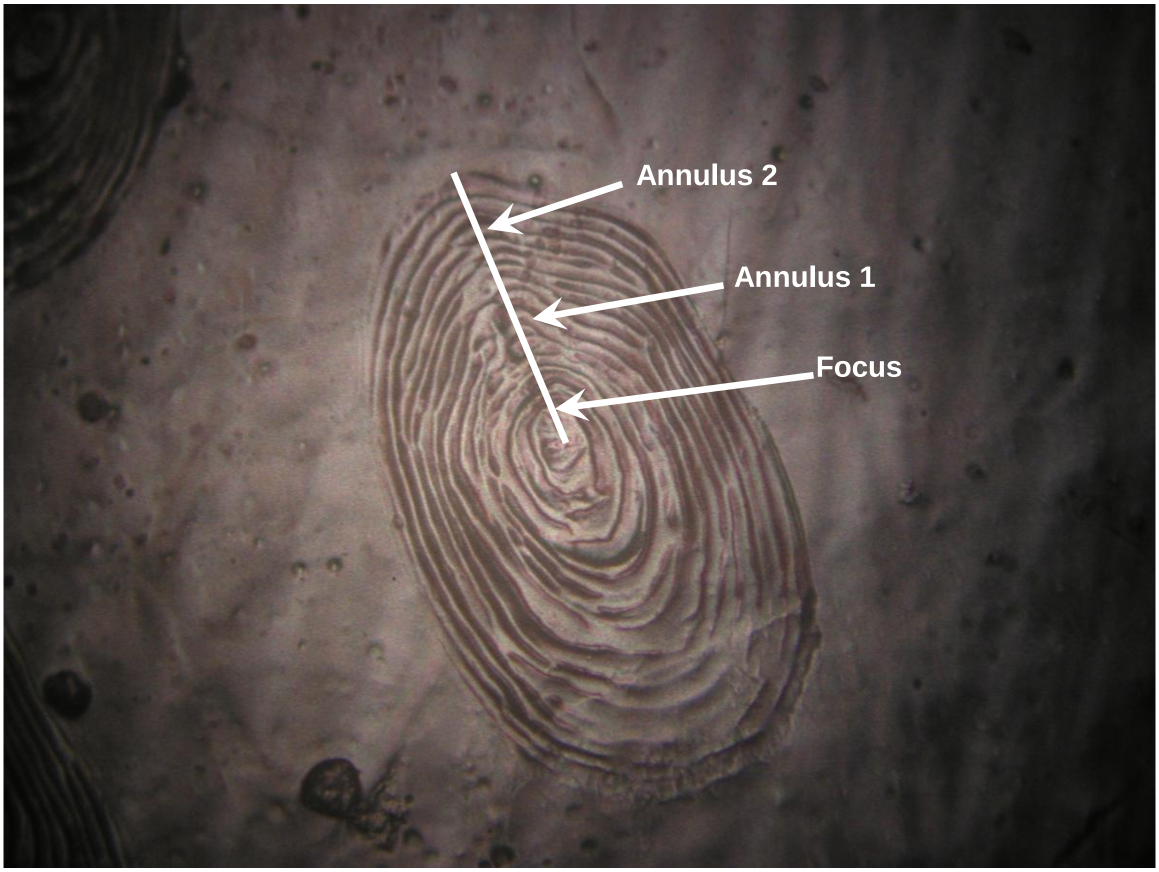

Figure 4.2. Measurement axis, focus, and annuli 1 and 2, for scale of a 108 mm TL, cutthroat trout collected from Mountain Creek, Bridger-Teton Wilderness, Wyoming, September 27, 2006.

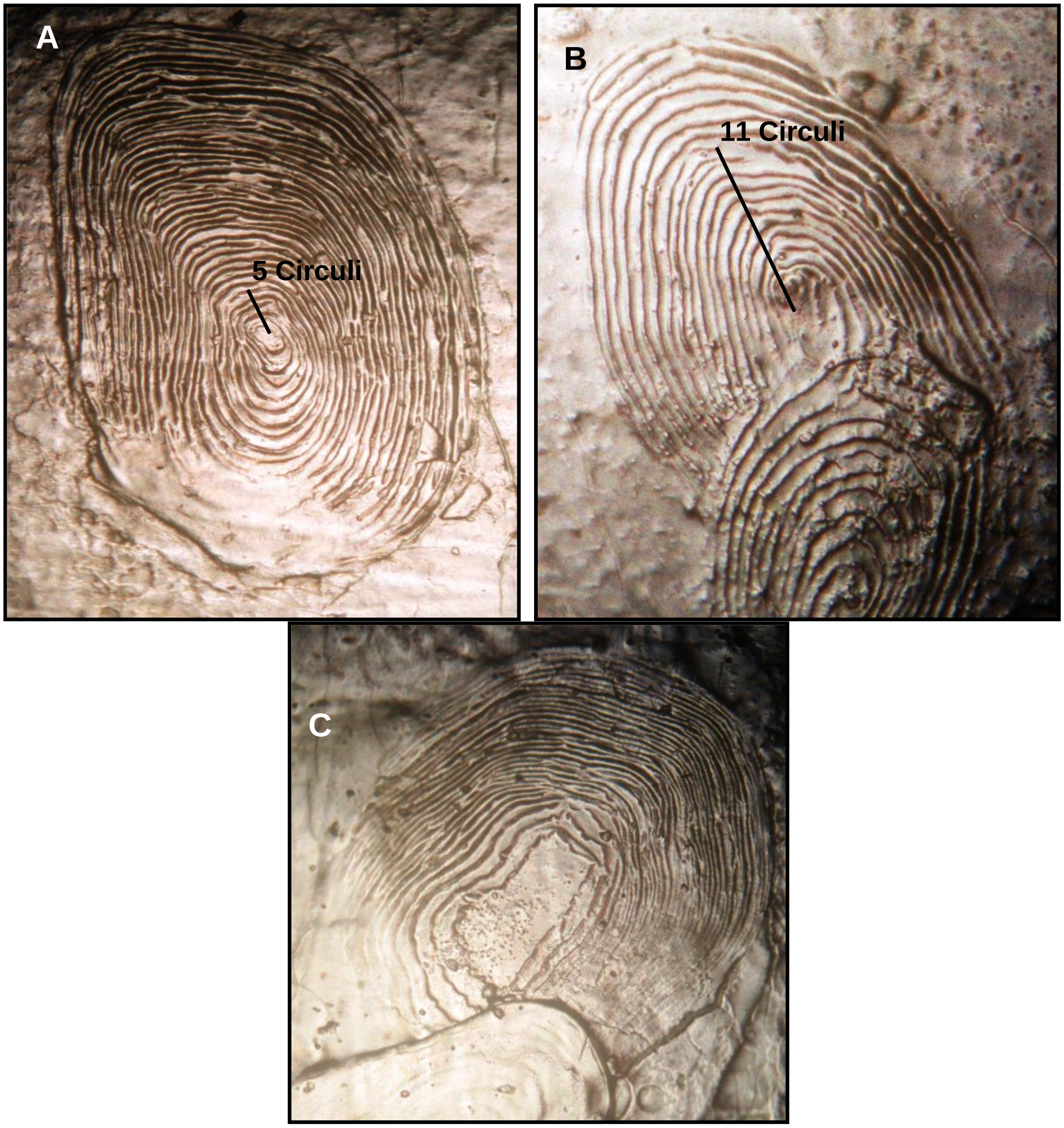

Figure 4.3. Scale of a 460 mm cutthroat trout (A) that formed a first year annulus. Notice the scale contains 5 circuli before the first annulus check. Scale of a 216 mm cutthroat trout (B) that did not form a first year annulus. Notice the scale contains 11 circuli before the first annulus check. Scale of a 439 mm cutthroat trout (C) that has regenerated its scale. Notice the distorted area around the scale focus.

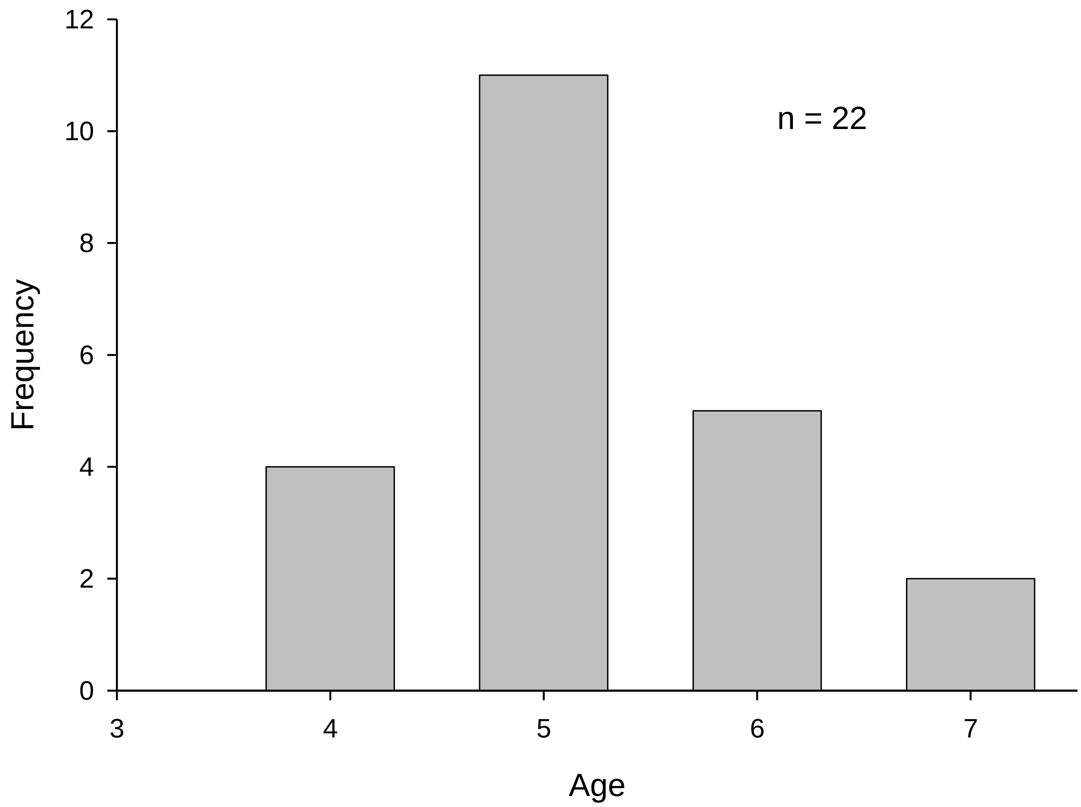

Figure 4.4. Frequency of cutthroat trout from each of the four age classes collected during radio transmitter implantation trips in the upper Yellowstone River basin, 2003–2005.

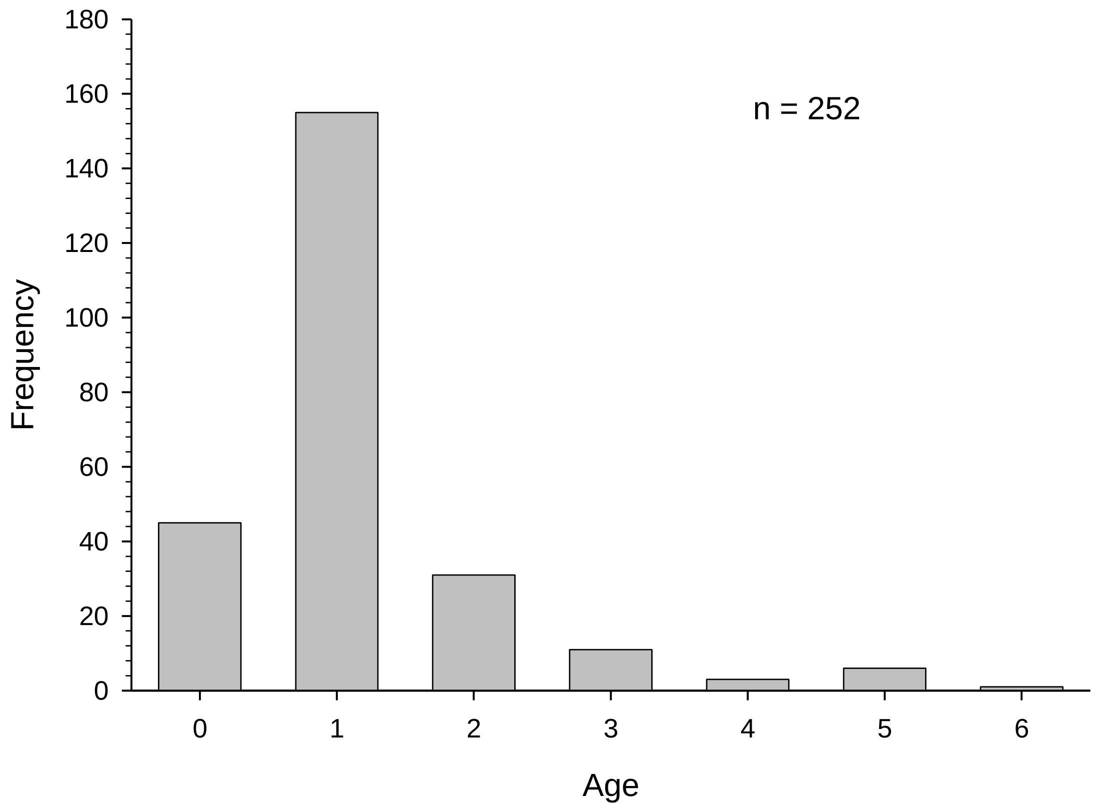

Figure 4.5. Age frequency of cutthroat trout sampled in all streams during electrofishing surveys of the upper Yellowstone River basin, 2004–2007.

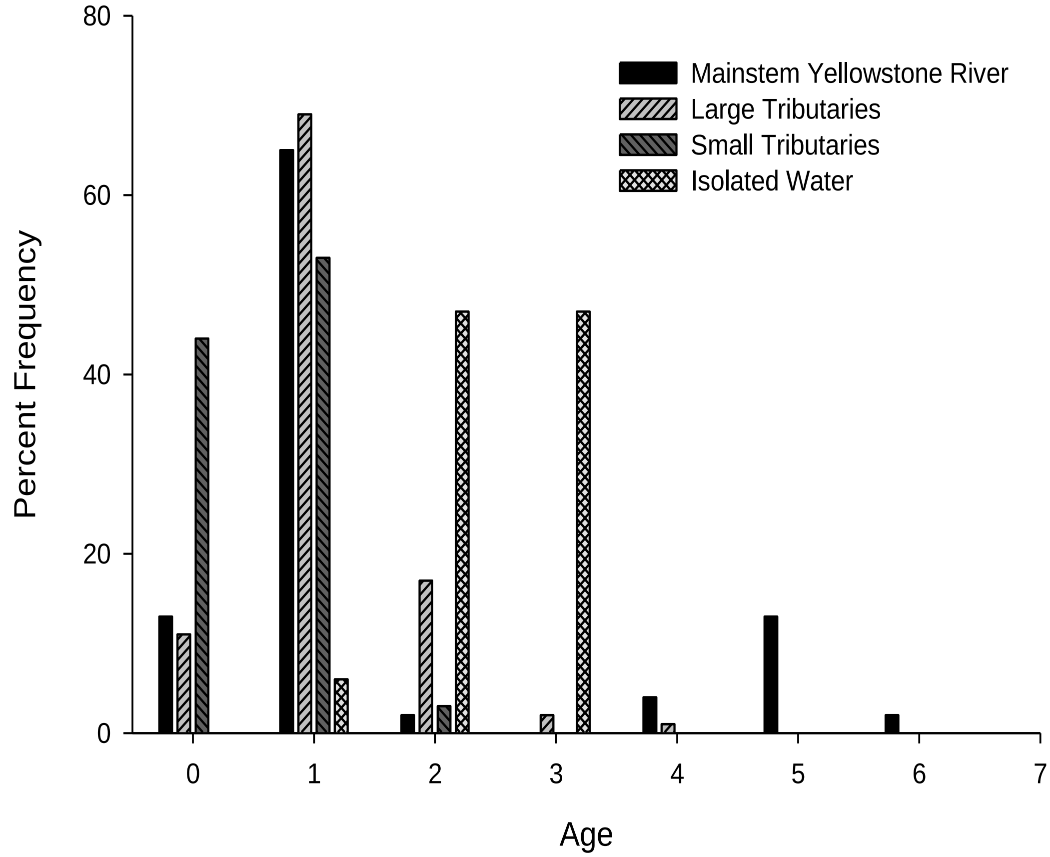

Figure 4.6. Percent frequency of each age class of cutthroat trout sampled in the four stream categories of the upper Yellowstone River basin, 2004–2007.

Literature Cited

Ball, O.P., and O.B. Cope. 1961. Mortality studies on cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Research Report 55.

Barlow, C.G., and B.A. Gregg. 1991. Use of circuli spacing on scales to discriminate hatchery and wild barramundi, *Lates calcarifer* (Bloch). Aquaculture and Fisheries Management 22:491:498.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, Maryland.

Behnke, R.J. 2002. Trout and salmon of North America. New York: The Free Press.

Bigelow, P.E., and R.G. White. 1996. Evaluation and growth interruption as a means of manipulating scale patterns for mass-marking hatchery trout. North American Journal of Fisheries Management 16:142-153.

Brown, C.J.D., and J.E. Bailey. 1952. Time and pattern of scale formation in Yellowstone cutthroat trout, *Salmo clarki lewisi*. Transactions of the American Microscopic Society 71:120-124.

Carlander, K.D. 1982. Standard intercepts for calculating length from scale measurements for some centrarchid and percid fishes. Transactions of the American Fisheries Society 111:332-336.

Coleman, M.A., and K.D. Fausch. 2007. Cold summer temperature limits recruitment of age-0 cutthroat trout in high-elevation Colorado streams. Transactions of the American Fisheries Society 136:1231-1244.

Dempson, J.B., M.F. O'Connell, and M. Shears. 1996. Relative production of Atlantic salmon from fluvial and lacustrine habitats estimated from analyses of scale characteristics. Journal of Fish Biology 48:32-341.

Devries, D.R., and R.V. Frie. 1996. Determination of age and growth. Pages 483-512 in B.R. Murphy and D.W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Gresswell, R.E., and J.D. Varley. 1988. Effects of a century of human influence on the cutthroat trout of Yellowstone Lake. American Fisheries Society Symposium 4:45-52.

Gresswell, R.E., W.J. Liss, and G.L. Larson. 1994. Life-history organization of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 51(supplement 1):298-309.

Gresswell, R.E., W.J. Liss, G.L. Larson, and P.J. Bartlein. 1997. Influence of basin-scale physical variables on life history characteristics of cutthroat trout in Yellowstone Lake. North American Journal of fisheries Management 17:1046-1064.

Healey, M.C., and A. Prince. 1995. Scales of variation in life history tactics of Pacific salmon and conservation of phenotype and genotype. American Fisheries Society Symposium 17:176-184.

Hogen, D.M. and D.L. Scarnecchia. 2006. Distinct fluvial and adfluvial migration patterns of relict charr, *Salvelinus confluentus*, stock in a mountainous watershed, Idaho, USA. Ecology of Freshwater Fish 15:376-387.

Hubert, W.A., G.T. Baxter, and M. Harrington. 1997. Comparison of age determinations based on scales, otoliths and fin rays fro cutthroat trout from Yellowstone Lake. Northwest Science 61:32-36.

Hutchings, J.A. 1986. Lakeward migrations by juvenile Atlantic salmon, *Salmo salar*. Canadian Journal of Fisheries and Aquatic Sciences 43:732-741.

Hutchings, J.A. 1993. Adaptive life histories effected by age-specific survival and growth rate. Ecology 74:673-684.

Ibanez, A.L., J.R. Britton, and I.G. Cowx. 2008. Relationship between scale growth checks, circuli formation rate and somatic growth in *Rutilus rutilus* (L.) a fish farm-reared cyprinid. Journal of Fish Biology 72:1023-1034.

Jensen, A. J. and B.O. Johnsen. 1982. Difficulties in aging Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*) from cold rivers due to lack of scales as yearlings. Canadian Journal of Fisheries and Aquatic Sciences 39:321-325.

Jones, R.D., D.G. Carty, R.E. Gresswell, C.J. Hudson, L.D. Lentsch, and D.L. Mahony. 1986. Fishery and aquatic management program in Yellowstone National Park. U.S. fish and wildlife Service, Technical Report for 1985, Yellowstone National Park, Wyoming.

Kaeding, L.R., and G.D. Boltz. 2001. Spatial and temporal relations between fluvial and allacustrine Yellowstone cutthroat trout, *Oncorhynchus clarki bouvieri*, spawning in the Yellowstone River, outlet stream of Yellowstone Lake. Environmental Biology of Fishes 61:395-406.

Kaplinski, M.A. 1991. Geomorphology and geology of Yellowstone Lake, Yellowstone National Park, WY. Thesis. Northern Arizona University, Flagstaff, Arizona, USA.

Koel, T.M., J.L. Arnold, P.E. Bigelow, P.D. Doepke, B.D. Ertel, and M.E. Ruhl. 2008. Yellowstone Fisheries & Aquatic Sciences: Annual Report, 2007. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, YCR-2008-02.

Kruse, C.G., W.A. Hubert, and F.J. Rahel. 1997. Using otoliths and scales to describe age and growth of Yellowstone cutthroat trout in a high-elevation stream system, Wyoming. Northwest Science 71:30-38.

Kutner, M.H., C.J. Nachtsheim, J. Neter, and W. Li. 2005. Applied linear statistical models. Fifth edition. McGraw-Hill. United States.

Laakso, M. 1955. Variability in scales of cutthroat trout in mountain lakes. Utah Academy Proceedings 32:81-87.

Laakso, M., and O.B. Cope. 1956. Age determination in Yellowstone cutthroat trout by the scale method. The Journal of Wildlife Management 20:138-153.

L'Abbe-Lund, J.H., B. Jonsson, A.J. Jensen, L.M. Saettem, T.G. Heggberget, B.O. Johnsen, and T.F. Naesje. 1989. Latitudinal variation in life history characteristics of sea-run migrant brown trout *Salmo Trutta*. Journal of Animal Ecology 58:525-542.

Lentsch, L.D., and J.S. Griffith. 1987. Lack of first year annuli on scales: Frequency of occurrence and predictability in trout of the western United States. Pages 177-188 in R.C. Summerfelt and G.E. Hall, editors. The age and growth of fish. The Iowa State University Press, Ames, Iowa.

Meyer, K.A., D.J. Schill, F. Steven-Elle, and J.A. Lamansky, JR. 2003. Reproductive demographics and factors that influence length at sexual maturity of Yellowstone cutthroat trout in Idaho. Transactions of the American Fisheries Society 132:183-195.

Morgan, L.A., W.C. Shanks, D.A. Lavalvo, S.Y. Johnson, W.J. Stephenson, K.L. Pierce, S.S. Harlan, C.A. Finn, G. Lee, M. Webring, B. Schulze, J. Duhn, R. Sweeney, and L. Balistrieri. 2003. Exploration and discovery in Yellowstone Lake: results from high-resolution sonar imaging, seismic reflection profiling, and submersible studies. Journal of Volcanology and Geothermal Research 122:221-242.

Morita, K., and S.H. Morita. 2002. Rule of age and size at maturity: individual variation in the maturation history of resident white-spotted charr. Journal of Fish Biology 61:1230-1238.

Northcote, T.G. 1997. Potamodromy in salmonidae-living and moving in the fast lane. North American Journal of Fisheries Management 17:1029-1045.

Ogle, D.H., and G.R. Spangler. 1996. Check formation on the scales of hatchery-reared lake trout prior to and soon after release into Lake Superior. North American Journal of Fisheries Management 16:896-904.

Okland, F. B. Jonsson, A.J. Jensen, and L.P. Hansen. 1993. Is there a threshold size regulating seaward migration of brown trout and Atlantic salmon? Journal of Fish Biology 42:541-550.

Pikitch, E.K., and R.L. Demory. 1988. Assessment of scales as a means of aging dover sole. Transactions of the American Fisheries Society 117:345-349.

Regier, H.A. 1962. Validation of the scale method for estimating age and growth of bluegills. Transactions of the American Fisheries Society 91:362-374.

Riget, F.F., K.H. Nygaard, and B. Christensen. 1986. Population structure, ecological segregation, and reproduction in a population of Arctic Char (*Salvelinus alpinus*) from Lake Taseruaq, Greenland. Canadian Journal of Fisheries and Aquatic Sciences 43:985-992.

Smedstad, O.M., and J.C. Holm. 1996. Validation of back-calculation formulae for cod otoliths. Journal of Fish Biology 49:973-985.

Stearns, S.C. 1992. The Evolution of Life Histories. Oxford: Oxford University Press.

Tattam, I.A., T.A. Whitesel, and Y. Pan. 2003. Scale pattern analysis of selected scale characteristics and the first annulus for distinguishing wild and hatchery steelhead in the Hood River, Oregon. North American Journal of Fisheries Management 23:856-868.

Thurow, R.F., C.E. Corsi, and V.K. Moore. 1988. Status, ecology, and management of Yellowstone cutthroat trout in the upper Snake River drainage, Idaho. Pages 25-36 in R.E. Gresswell, editor. Status and management of interior stocks of cutthroat trout. American Fisheries Society, Symposium 4, Bethesda, Maryland.

Varley, J.D. and R.E. Gresswell. 1988. Ecology, status, and management of Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.

Weisberg, S. 1993. Using hard-part increment data to estimate age and environmental effects. Canadian Journal of Fisheries and Aquatic Sciences 50:1229-1237.

CHAPTER 5

CONCLUSION

The purpose of this research was to determine the life-history forms, abundance, distribution, and habitat use of Yellowstone cutthroat trout in the upper Yellowstone River basin, Wyoming, a largely intact, but previously unexplored, native trout ecosystem. To accomplish this, a combination of radiotelemetry, underwater counts, electrofishing surveys, and habitat assessments were conducted throughout the region over a five year period.

The lacustrine-adfluvial life history is the dominant form displayed by Yellowstone cutthroat trout in the main-stem upper Yellowstone River. The dominance of this life-history type is similar to that observed previously in other tributary streams of Yellowstone Lake (Ball and Cope 1961; Varley and Gresswell 1988; Gresswell et al. 1994). Ninety-six percent of fish relocated during radiotelemetry surveys in this study were classified as lacustrine-adfluvial. Total lengths and age and growth rates of fish sampled during radio transmitter implantation trips, underwater counts, and electrofishing surveys also indicate the lacustrine-adfluvial life history is dominant in the main stem river.

The presence of large fluvial or fluvial-adfluvial populations in the main stem river below the South Fork falls seems unlikely. Just 4% (n = 4) of relocated fish during tracking surveys remained in the river after September 1, and fish >330 mm averaged just 4.4 fish/km during underwater counts and electrofishing surveys. The low numbers of fish >330 mm remaining in the system late in the season coupled with the fact that just one fish between 151-330 mm was observed during sampling events on the main stem river is strong evidence that fluvial or fluvial-adfluvial populations are not present.

There is another explanation for the presence of low numbers of fish >330 mm remaining in the system. Lacustrine-adfluvial fish that migrated into the system may have remained for an extended period. This behavior has been documented in Pelican Creek the second largest tributary to Yellowstone Lake (Varley and Gresswell 1988; Gresswell et al. 1994). Cutthroat trout which migrate into Pelican Creek to spawn occasionally overwinter within the stream. This behavior would explain the lack of age-2 and age-3 fish found in the upper Yellowstone River. It would also explain why growth rates of the apparent stream resident fish were similar to those of lacustrine-adfluvial migrants.

Tributary streams of the upper Yellowstone River were also dominated by lacustrine-adfluvial cutthroat trout. Just one fish implanted with a radio transmitter that moved into a tributary of the Yellowstone River remained in the system after August 1. This fish migrated into Thorofare Creek during the spawning period and returned to the main-stem Yellowstone River to overwinter. All other relocated fish tagged in the stream system returned to Yellowstone Lake before October each year.

However, an important finding of this study was the discovery of extant populations of Yellowstone cutthroat trout in the Mountain Creek drainage displaying fluvial and fluvial-adfluvial life history. Although occurring in low numbers these life-history forms have not been documented in other tributary streams of Yellowstone Lake that do not contain barriers to movement. Known fluvial populations in Sedge Creek and South Fork Yellowstone River are isolated by a thermal barrier and waterfall respectively. Resident fluvial fish were found in tributary streams and could be distinguished from lacustrine-adfluvial migrants based on length at age after age 2.

During electrofishing surveys of tributary streams, Yellowstone cutthroat trout were found in all waters sampled below barriers to upstream movement and in Trappers Spring above a barrier. Fluvial populations were identified in the Mountain Creek drainage and in Trappers Spring. While the majority of the Mountain Creek drainage was dominated by age 0 and age 1 fish that likely migrate downstream to Yellowstone Lake with the next season high flows, the upper reaches housed fish aged at 3 and 4. Mean length of an age three fish in the Mountain Creek drainage was 237 mm and in Trappers Spring 190 mm. No age 3 fish were sampled in the main-stem Yellowstone River, but in other tributaries and Yellowstone Lake, mean length of age three fish is 368 mm (NPS unpublished data). Age 4 fish sampled in the Mountain Creek drainage averaged 280 mm, in the main stem river mean length of a four year old fish was 471.5 mm. No age four fish were captured in Trappers Spring.

Habitat was not a limiting factor in the presence or distribution of fluvial or fluvial-adfluvial cutthroat trout in the upper Yellowstone River basin. Differences in the areas that contained fish and those that did not were minimal. Large areas containing adequate flow, substrate, and cover were found to be fishless throughout the drainage. Factors other than those measured in this study (e.g. overwintering habitat, prey availability) may be the reason so few adult fish are found in the system.

The findings of this study show Yellowstone cutthroat trout displaying a variety of life-history forms are present in the upper Yellowstone River basin. Although year-round residents in the stream system are rare, they may be an important source of genetic influx to lacustrine-adfluvial migrants. As cutthroat trout numbers in the lake continue to decline, fluvial or fluvial-adfluvial cutthroat trout populations may become important sources to repopulate the lower reaches of the drainage and possibly Yellowstone Lake.

Although stream resident fluvial cutthroat trout are abundant throughout their distribution, they are rare in the Yellowstone Lake drainage. Because of the presence of stream resident fish and the declining numbers of lacustrine-adfluvial migrants from Yellowstone Lake this region should be further protected from angler harvest. Currently, within the Yellowstone National Park boundary, angling is closed until July 15 each year, and anglers must release all cutthroat trout caught. Outside of the park, however, angling is legal during the spawning season and anglers are allowed to keep two cutthroat trout. To protect stream resident populations and lake migrants the results of this study support an angling closure of streams in the upper Yellowstone River drainage until after the spawning season (August 1), and catch and release of all cutthroat trout thereafter.

Literature Cited

Ball, O.P., and O.B. Cope. 1961. Mortality studies on cutthroat trout in Yellowstone Lake. U.S. Fish and Wildlife Service Research Report 55.

Gresswell, R.E., W.J. Liss, and G.L. Larson. 1994. Life-history organization of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 51(supplement 1):298-309.

Varley, J.D. and R.E. Gresswell. 1988. Ecology, status, and management of Yellowstone cutthroat trout. American Fisheries Society Symposium 4:13-24.