Westslope Warmwater

GOCO Funded

Patrick J. Martinez
Principal Investigator

Thomas E. Remington, Director

Federal Aid in Fish and Wildlife Restoration

Job Progress Report

Colorado Division of Wildlife

Fish Research Section

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STATE OF COLORADO

Bill Ritter, Governor

COLORADO DEPARTMENT OF NATURAL RESOURCES

Sherman Harris, Executive Director

COLORADO DIVISION OF WILDLIFE

Thomas E. Remington, Director

WILDLIFE COMMISSION

AQUATIC RESEARCH STAFF

Mark S. Jones, General Professional VI, Aquatic Wildlife Research Leader
Arturo Avalos, Technician III, Research Hatchery
Rosemary Black, Program Assistant I
Stephen Brinkman, General Professional IV, F-243, Water Pollution Studies
Harry Crockett, General Professional IV, Eastern Plains Native Fishes
Matt Kondratieff, General Professional IV, Stream Habitat Restoration
Patrick Martinez, General Professional V, F-242, Coldwater Reservoir Ecology & GOCO - Westslope Warmwater
R. Barry Nehring, General Professional V, F-237, Stream Fisheries Investigations
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George Schisler, General Professional IV, F-394, Salmonid Disease Investigations
Kevin Thompson, General Professional IV, F-427, Whirling Disease Habitat Interactions and GOCO – Boreal Toad
Harry Vermillion, Scientific Programmer/Analyst, F-239, Aquatic Data Analysis
Nicole Vieira, Physical Scientist III, Water Quality Studies

Paula Nichols, Federal Aid Coordinator

Prepared by: ____

Patrick J. Martinez, GP V, Aquatic Researcher

Approved by: ____

Mark S. Jones, Aquatic Wildlife Research Leader

Date: ____________________________

The results of the research investigations contained in this report represent work of the authors and may or may not have been implemented as Division of Wildlife policy by the Director or the Wildlife Commission.

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Title: Westslope Warmwater Fisheries

Period Covered: July 1, 2006 to June 30, 2007

Principal Investigator: Patrick J. Martinez

STUDY OBJECTIVE: To evaluate, monitor and recommend select nonnative fish control strategies that fulfill commitments for recovery efforts for the "big river" endangered fishes and to provide guidance for maximizing angling opportunity for nonnative warmwater sport fishes within the regulatory, cooperative, and ecological constraints of protecting the "big river" native fish assemblage in the rivers of western Colorado.

OBJECTIVE 1: WARMWATER FISHERY ENHANCEMENT AND NONNATIVE FISH CONTROL STRATEGIES

To evaluate, facilitate and/or recommend nonnative fish control practices to foster/secure progress/compliance toward sufficient progress for recovery, for stocking agreements and regulations, and acceptable monitoring protocols necessary to perpetuate, expand or replace warmwater sport fisheries on Colorado's west slope.

Segment Objective 1: Push for adoption of stricter, harsher regulations for illicit fish introductions in western Colorado, including increased surveillance, increased incentives for informants, more severe penalties including higher fines, restitution and environmental rehabilitation as warranted (removal of unauthorized fishes).

INTRODUCTION

The Colorado Division of Wildlife (CDOW) lacks a comprehensive strategy to control or combat the practice of illicit fish stocking by well-intentioned, inadvertent or malicious acts of individuals. Martinez (2006) described the large scale ecological consequences to both sport and native fishes due to basin-wide proliferation of illicitly introduced fishes. In addition, Martinez (2006) also provided preliminary information regarding the proliferation of verile crayfish *Orconectes virilis* in the Yampa River and the evidence that this nonnative crustacean is now a major component of the river's food web included in the diets of nonnative predacious fishes (channel catfish, northern pike and smallmouth bass). The native fish of western Colorado River Basin appear to be especially vulnerable to the invasive effects of introduced aquatic species (Appendix A). Further, efforts focusing on the control of the illicit and invasive spread of nonnative aquatic species that pose a threat to the state's native fishes in western Colorado would also benefit the stability of sport fisheries.

Fundamentally, to protect its aquatic resources and to allow professional management strategies to prevail, CDOW should change its overall response to illicit fish introductions from one ranging from tolerance and acceptance to one of discouragement and prevention. Martinez (1997) raised concern that the incidence of illicit fish introductions had reached epidemic proportions just as the states of Colorado, Utah, and Wyoming had reached an agreement in 1996 regarding the stocking of nonnative fishes in the Upper Colorado River Basin along with the U.S Fish and Wildlife Service. This agreement entitled, Procedures for Stocking Nonnative Fishes in the Upper Colorado River Basin, was adopted to ensure that all future stocking of nonnative fishes would be consistent with recovery of endangered fishes within the Upper Colorado River Basin (CDOW et al. 1996). Obviously, illicit stocking circumvents the provisions of this agreement and may ultimately undermine the state's ability to protect and preserve its native fishes and further, may preclude the recovery of endangered ones.

METHODS and MATERIALS

I participated in discussions regarding the illicit fish introduction problem in western Colorado at a meeting with CDOW Northwest Region personnel regarding warmwater reservoir resources in Grand Junction in August 2006, and at the Colorado-Wyoming Chapter of the American Fisheries Society (CO-WY AFS) Annual Meeting in Fort Collins, in February 2007. Data on reservoir thermal conditions and ages of warmwater fishes in northwest Colorado are from data I had collected and analyzed in the 1980s. Data for comparison of fish ages in other waters are from Stroud and Clepper (1975), Carlander (1977) and Burdick (1979).

RESULTS and DISCUSSION

The discussion regarding warmwater reservoir resources in northwestern Colorado focused on options for managing warmwater fish species in individual waters. Appendix B contains information used in this discussion on reservoir size, thermal conditions, fish species composition, fish age and growth, angler preferences and the effects of illicitly introduced fish in achieving management goals for sport and native fish. The illicit fish issue was also discussed in the continuing education workshop offered at the CO-WY AFS meeting entitled Ecology and Management of Great Plains Stream Fishes. My contribution to this workshop, entitled Designating Conservation Areas to Prioritize, Publicize, Popularize and Optimize Nonsalmonid Native Fish Protection and Preservation, stressed the need to maximize the prospects of perpetuating native fishes, including addressing the expanding problem of illicit fish introductions (Appendix A).

Segment Objective 2: Lead effort to establish methodology for standardization of Upper Colorado River Basin Recovery Program's electrofishing fleet.

INTRODUCTION

Appendix C describes the impetus for evaluating the electrofishing fleet of aluminum-hulled electrofishing boats used by participants in the Upper Colorado River Basin Recovery

Program. The Recovery Program's electrofishing fleet consists of six separate stations consisting of several boats per station staffed by personnel from four agencies. These include:

1) Colorado Division of Wildlife in Grand Junction, CO, electrofishing in the Colorado and Yampa rivers in Colorado,
2) Colorado State University, Larval Fish Laboratory in Fort Collins, CO, electrofishing on the Yampa River in Colorado,
3) U.S. Fish and Wildlife Service, Colorado River Fishery Project in Grand Junction, CO, electrofishing on the Gunnison and Colorado Rivers in Colorado and Utah,
4) U.S. Fish and Wildlife Service, Colorado River Fishery Project in Vernal, UT, electrofishing on the Duschene, Green, and White Rivers in Utah and Colorado,
5) Utah Division of Wildlife Resources in Vernal, UT, electrofishing on the Duschesne, Green and White Rivers in Utah, and
6) Utah Division of Wildlife Resources, Moab UT, electrofishing on the Colorado, Dolores and Green Rivers in Utah.

The concept and benefits of standardizing a fleet of electrofishing boats of various dimensions and configurations deployed in rivers of differing conductivities are also described in Appendix C.

METHODS and MATERIALS

Appendix C provides a description of determining the electrical resistance of a "standard boat" to which other boats in the Recovery Program Fleet would be compared. Appendix D reports that the criteria for the "standard boat" were developed, but this topic will not be covered in detail in this report until comparisons to other boats in the electrofishing fleet are made. This report focuses on that aspect of Appendix C concerning the response of electofishers operated at their various control settings while subjected to static electrical loads that were adjusted to simulate different water conductivities (Appendices C and D). Figure 1 shows the locations of USGS stream gages in proximity to the river reaches typically sampled by Recovery Program crews electrofishing in the rivers of western Colorado and eastern Utah where measurements of specific conductance have been made during the 10-year period from 1997-2006. However, due to the need for water temperature records to convert specific conductance to ambient conductivity, ambient conductivity could only be calculated through 2005 (Appendix Tables E1-E21). Recovery Program crews typically electrofish with aluminum boats during a five month period in spring and summer, March–July, when flows in specific reaches facilitate navigable conditions using these craft. Thus, the Recovery Program's electrofishing fleet could be expected to encounter ambient water conductivities in these rivers typically ranging from about 100 to 1,000 µS/cm, with only a few exceptions in some months (Figures 2 and 3).

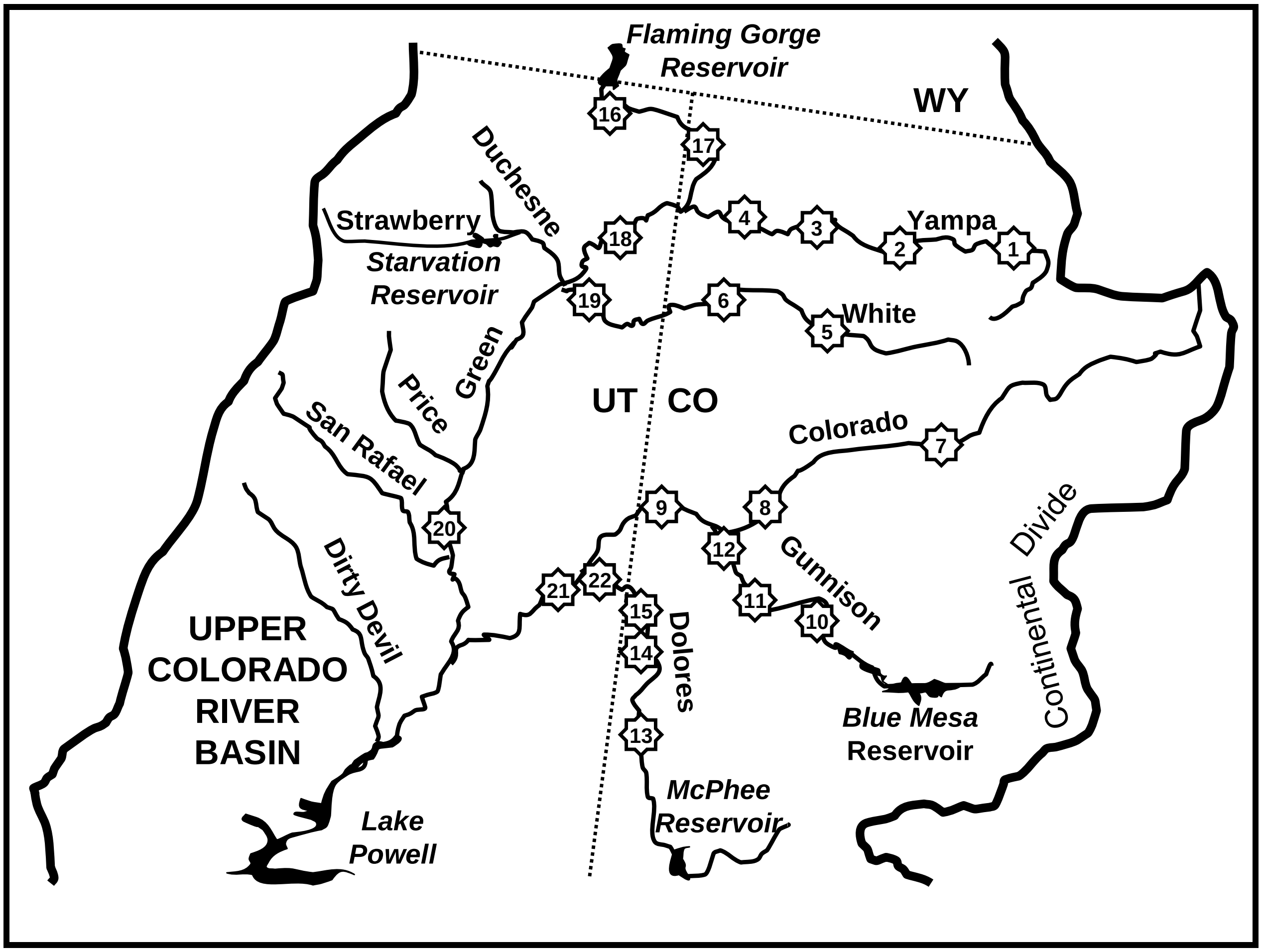

Figure 1. Major rivers in the Upper Colorado River Basin below Flaming Gorge Reservoir and above Lake Powell. Numbers denote stream gaging stations where measurements of specific conductance (µS/cm @ 25 C) and water temperature allowed calculation of ambient conductivity (µS/cm) during the years 1997-2005. Stream gages are identified by river: Yampa River - 1) Steamboat Springs, 2) Craig, 3) Maybell and 4) Deerlodge Park; White River - 5) Meeker, 6) Rangely and 19) Watson; Colorado River - 7) Glenwood Springs, 8) Cameo, 9) Colorado-Utah Stateline and 21) Cisco; Gunnison River - 10) Gunnison Tunnel, 11) Delta and 12) Grand Junction; Dolores River - 13) Slickrock, 14) Bedrock, 15) near Bedrock and 22) Cisco; Green River - 16) Greendale, 17) Gates of Ladore, 18) Jensen and 20) Green River.

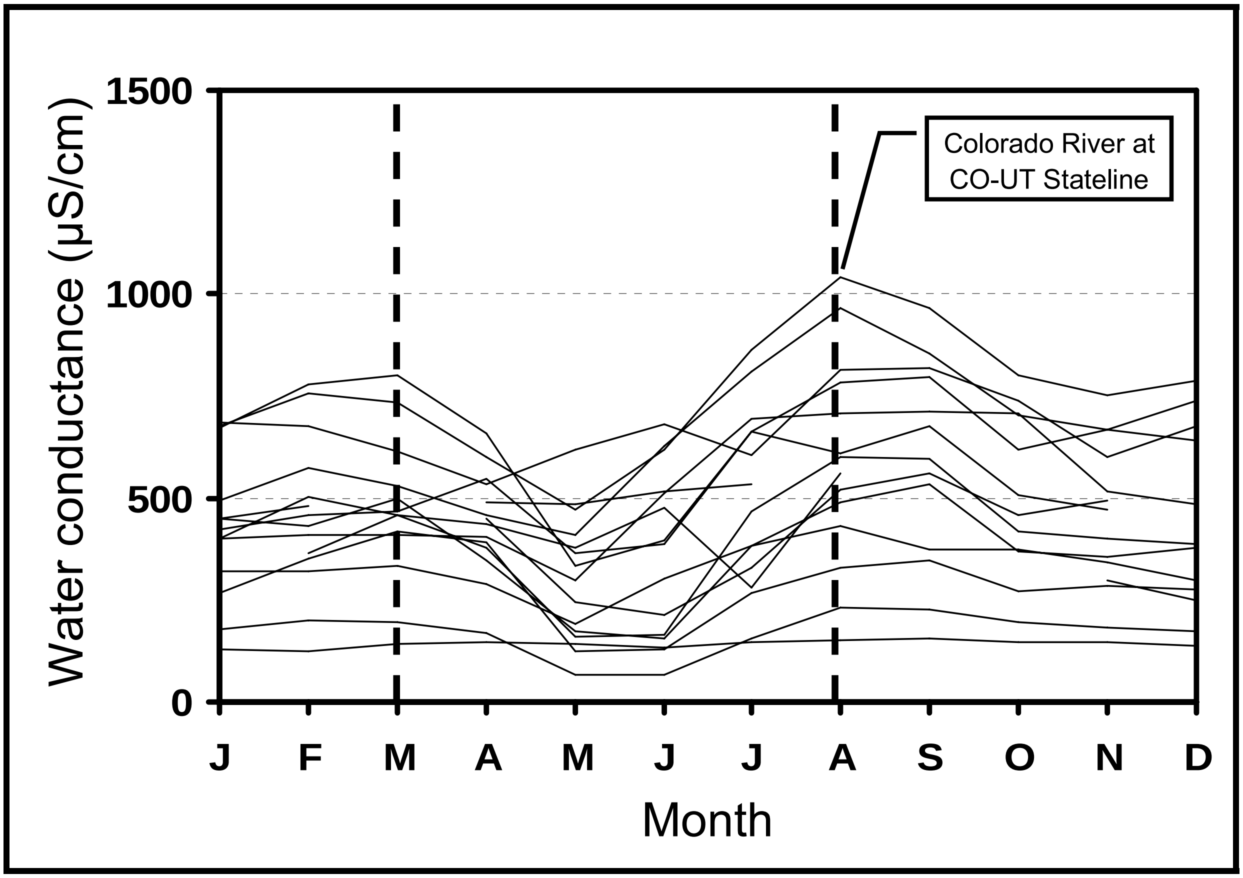

Figure 2. Ambient conductivity (µS/cm) at 16 stream gage stations in western Colorado, 1997-2005 (see Figure 1). Vertical dashed lines delineate the five-month period from March through July, the time of year when stream flows permit widespread use of aluminum-hulled electrofishing boats in rivers of the Upper Colorado River Basin. The mean monthly ambient conductivity in July in the Colorado River at Colorado-Utah Stateline is the only gage to exceed 1000 µS/cm.

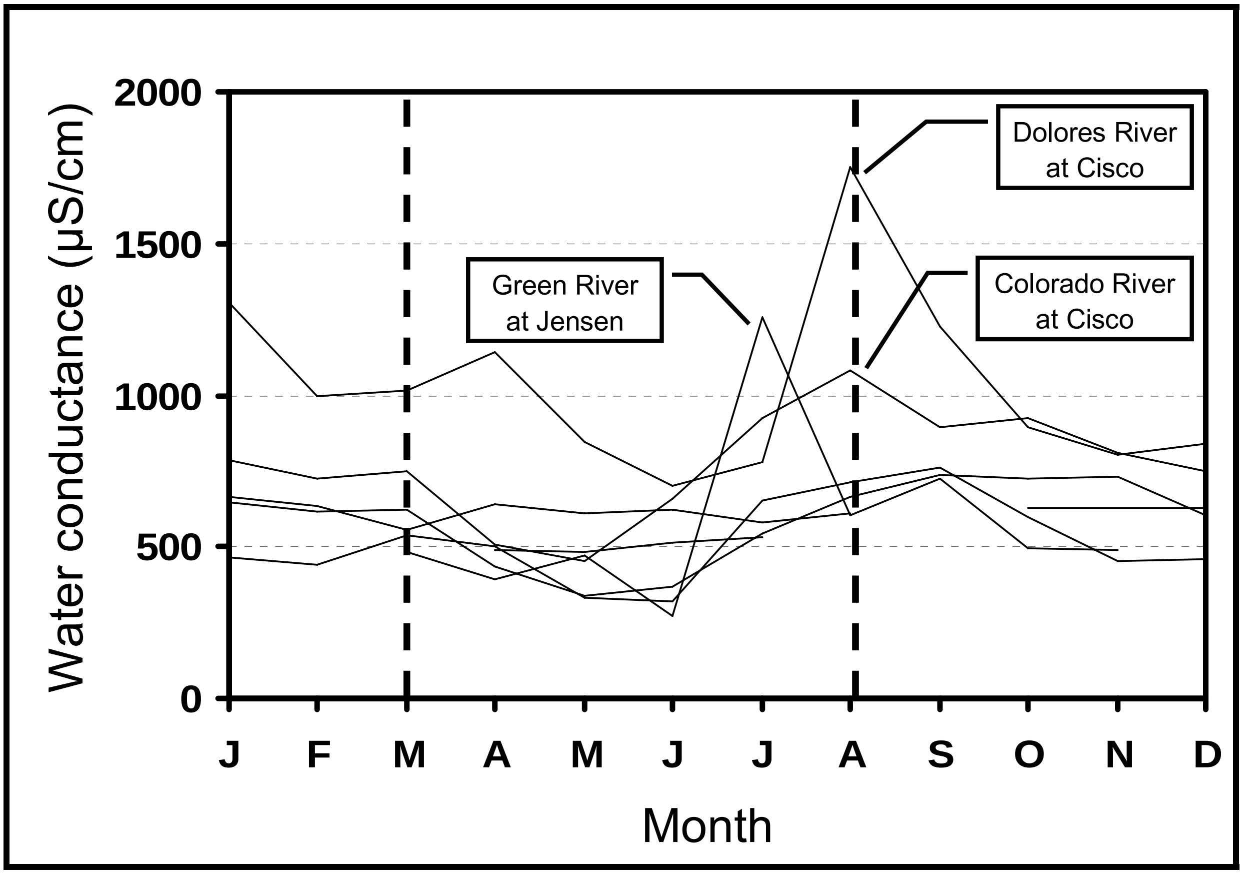

Figure 3. Ambient conductivity (µS/cm) at six stream gage stations in eastern Utah, 1997-2005. Vertical dashed lines delineate the months from March through July, the time of year when stream stream flows permit widespread use of aluminum-hulled electrofishing boats in rivers of the Upper Colorado River Basin. The mean monthly ambient conductivity at three stream gages, Colorado River at Cisco, Dolores River at Cisco and Green River at Jensen (Figure 1), exceed 1000 µS/cm at times during the five-month period.

This range of water conductivity, 100 to 1,000 µS/cm, was used to calculate the theoretical resistance of stainless steel spherical anodes ranging in diameter from 5 to 11 inches, sizes that might be used by Recovery Program personnel. Based on these calculations, electrical resistance was determined to range from 125 ohms for a single 5-inch sphere at 100 µS/cm to 5.7 ohms for a single 11-inch sphere at 1000 µS/cm (Figure 4). The output characteristics for three Smith-Root Model 5.0 GPP electrofishers were then measured while connected to static electrical loads having resistance values of 5.9, 9.6, 19.5, and 114 ohms.

For these static tests, the aluminum-hulled boat remained on its trailer in a parking lot, and three GPP electrofishing units were sequentially installed for electrical load measurements. A Smith-Root proprietary five kilowatt generator supplied power for the electrofishing units.

The electrofishing boat's two booms (anodes) were wired to an isolation strip that facilitated adjustment of the number of electrical loads needed to simulate four water conductivities: 100, 400, 700 (Figure 5) and 1,000 µS/cm (Figure 6). Electrical loads were CADET Model 4F1000W (Part #09954) 48"L x 6 ¾" H x 3 ¾" D, 4.2 amp, 240 volt, 1000 watt electric baseboard heaters wired in parallel or series. The boat hull was connected to the negative terminal of the electrofishing unit and the boat hull was grounded to a metal post driven into the soil for personnel safety (Figures 5 and 6).

Figure 7 shows the control panel of a Smith-Root Model 5.0 GPP electrofisher. Tests were performed at the simulated levels of water conductivity with three 5.0 GPPs, all operated on the pulsed direct current (PDC) MODE. For each RANGE setting of 500 or 1,000 volts, an electrofisher was operated incrementally at all combinations of its PERCENT OF RANGE (POR = pulse width) and PULSES PER SECOND (PPS = pulse frequency or Hz) settings. A FLUKE Model 99B digital oscilloscope using a Model 1000s current probe provided measurements of peak volts and peak amps at the electrical load. These values were used to calculate the resistance of the electrical load and peak power output for the individual electrofishers. The values for individual units were averaged for the three electrofishers to plot the relationship between the various combinations of electrofisher setting and the electrical loads simulating the four levels of water conductivity. Two of the electrofishing units had just been calibrated by Smith-Root. The third unit was judged to be fully functional, but it was returned to the field before a complete measurement series could be performed.

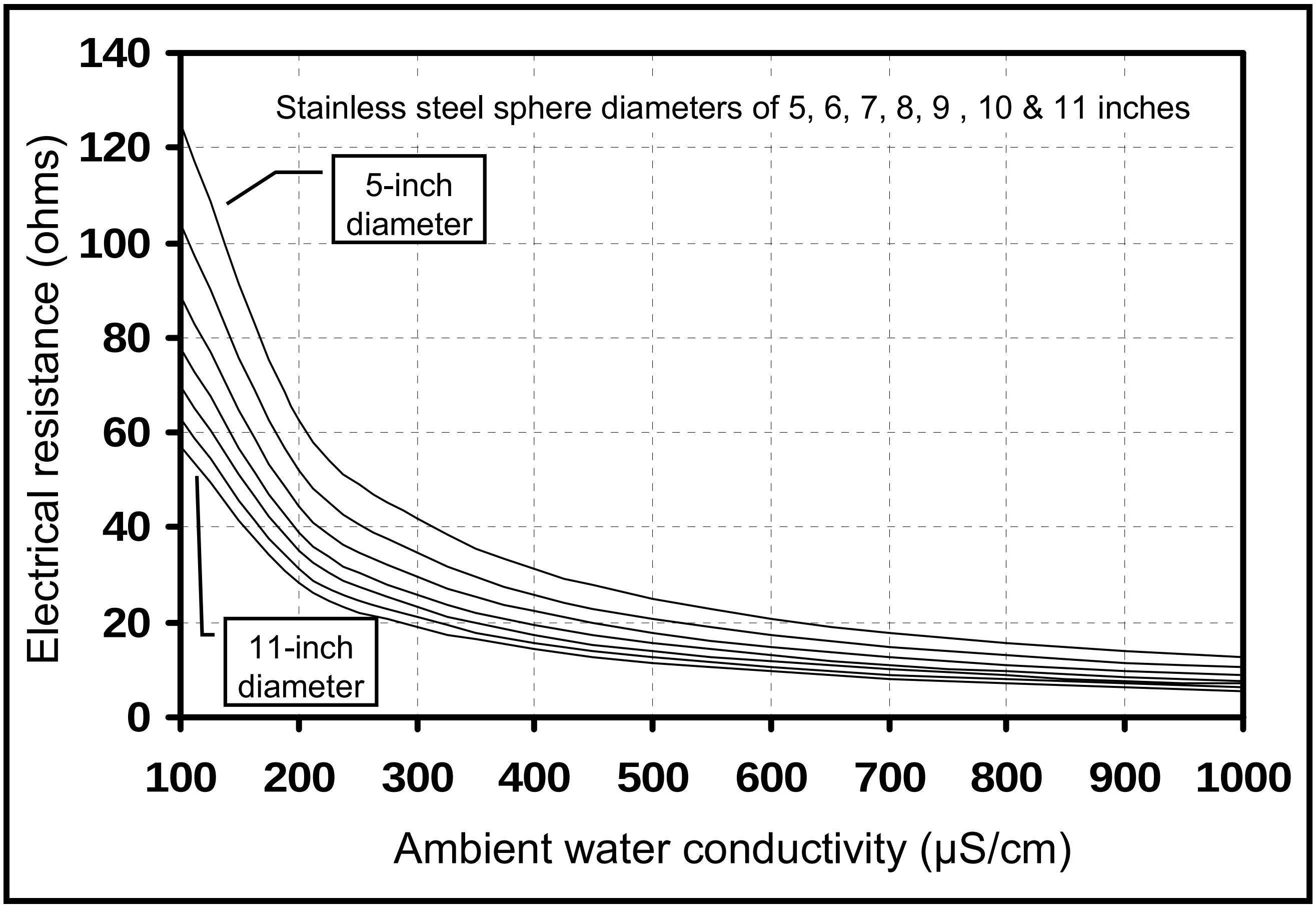

Figure 4. Theoretical electrical resistance of stainless steel spheres of 5, 6, 7, 8, 9, 10, and 11 inches in diameter at water conductivities ranging from 100 to 1000 µS/cm.

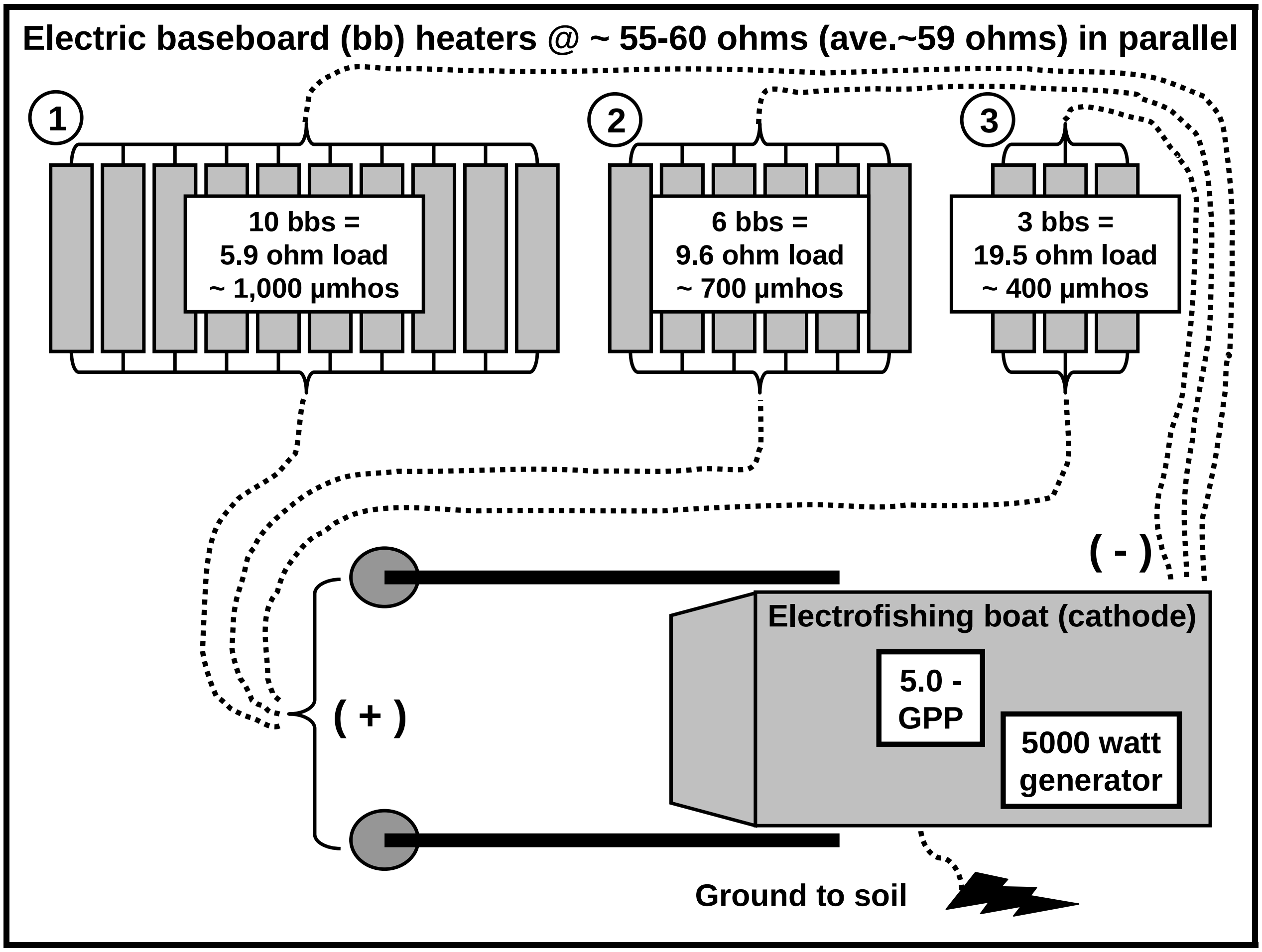

Figure 5. Diagram of set-up for subjecting a Smith-Root Model 5.0-GPP electrofisher to three levels of electrical resistance, 1) 5.9, 2) 9.6, and 3) 19.5 ohms, by using varying arrays of baseboard heaters to simulate water conductivities of 1,000, 700, and 400 µmhos, respectively.

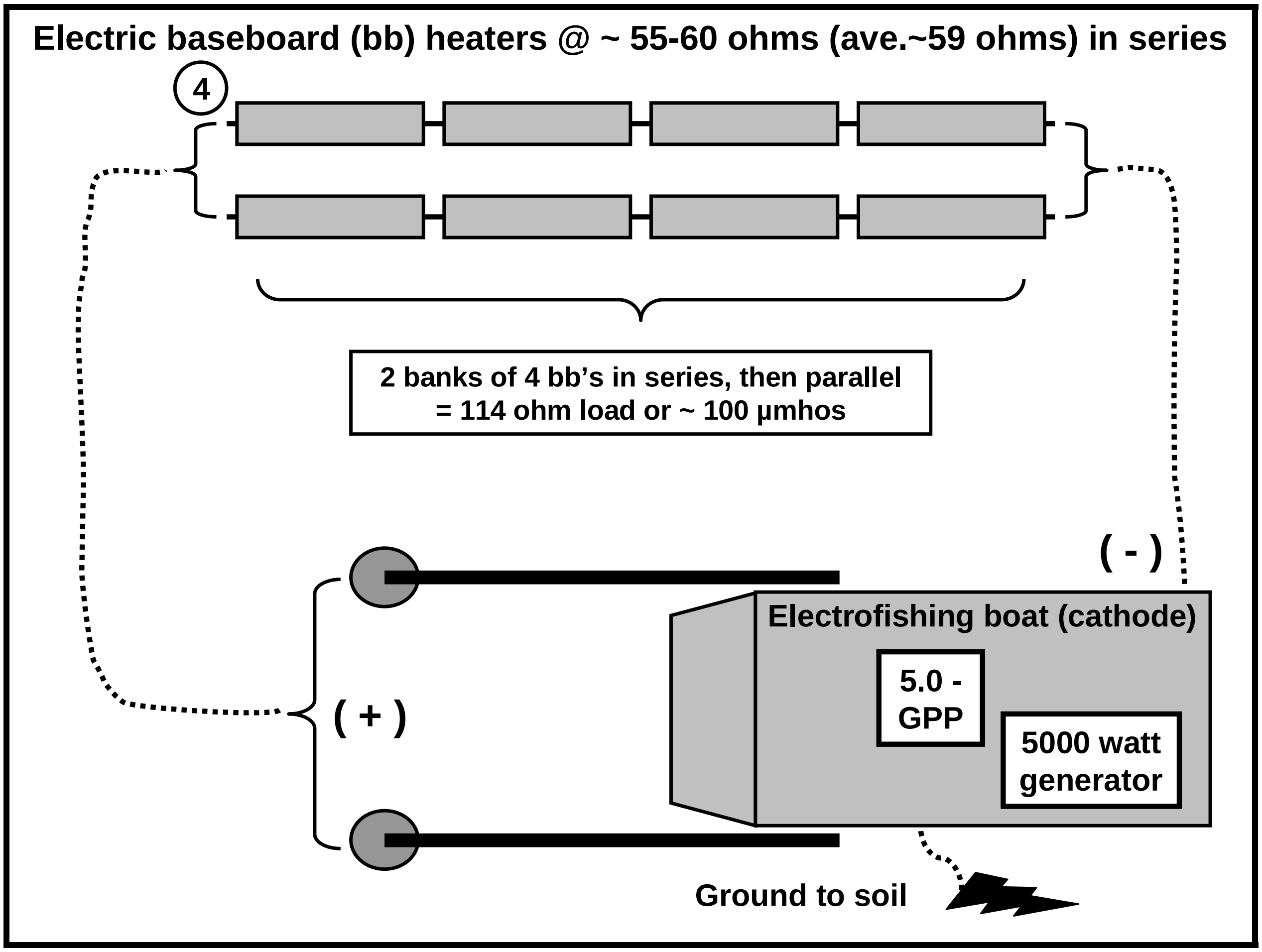

Figure 6. Diagram of set-up for subjecting a Smith-Root Model 5.0-GPP electrofisher to a fourth level of electrical resistance of 114 ohms using two arrays of four baseboard heaters in series, then parallel, to simulate a water conductivity of 100 µmhos.

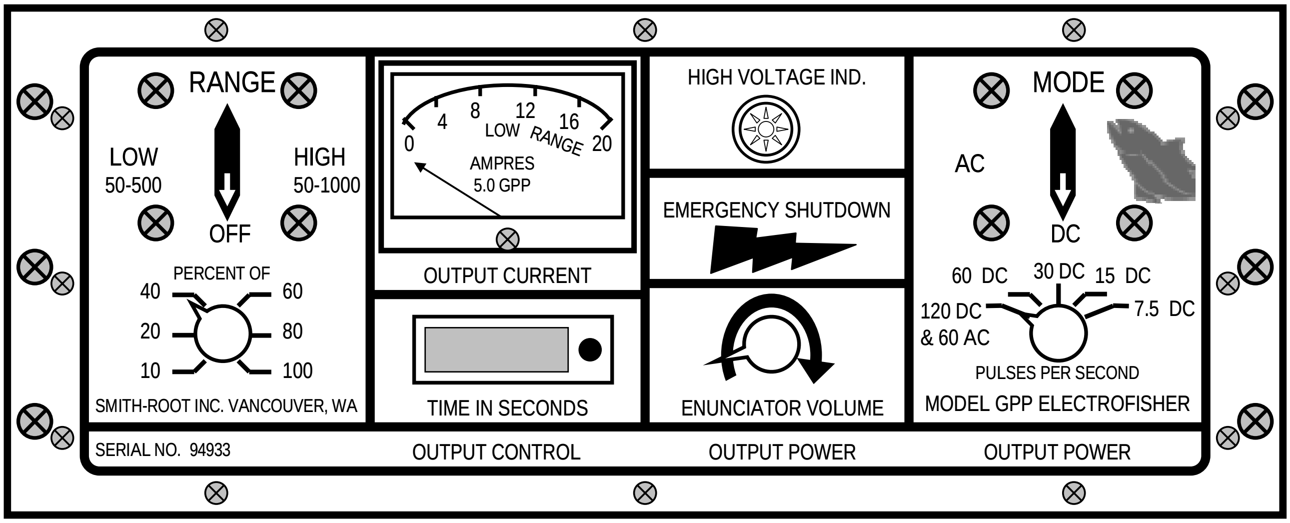

Figure 7. Control panel of Smith-Root Model 5.0-GPP electrofisher.

RESULTS and DISCUSSION

The controls for the 5.0 GPP are designed such that the output voltage and power will increase in a near linear fashion as the POR is increased from 10 to about 50 % and then the power remains almost constant from 50 to 100 %. This latter adjustment to 100% actually increases the time duration of the pulse (pulse width) but does not increase the pulse amplitude. Figure 8 demonstrates this characteristic for the GPPs operating on the 500 V RANGE while connected to an electrical load of 114 ohms. Note that all five PPS frequencies (7.5, 15, 30, and 60 Hz) exhibit essentially the same response, and the maximum power is less than 3 kW.

In comparing Figure 8 to Figures 9, 10 and 11, the power limitations of the GPP units become evident as the electrical loads are changed to 19.5, 9.6, and 5.9 ohms, the equivalent of electrofishing in higher conductivity water, respectively. The GPPs are simply incapable of producing a consistent maximum power at all five frequency settings when operating under heavy load conditions, and the individual frequency plots are shown to separate. This separation is explained by noting that the higher operating frequencies at a given pulse width necessitates an increase in the pulse duty cycle, and this limits the available output power. Of particular significance are those plots in Figures 10 and 11 where the power for 60 and 120 Hz actually reverse and decrease when the POR exceeds 80. Unfortunately, this reduction in power cannot be recognized by the equipment operators because the readings of the GPP's AC current meter is not a reliable indicator for the actual output power. In fact, during these tests, the AC current readings could not be correlated with the output voltage, current, or power.

The previous discussion for Figures 8 thru 11 applies equally to Figures 12 thru 15 for the GPPs operating on the 1,000 V RANGE. However, the power limitations are noticeably more severe as the power requirements are increased. This implies that as water conductivity increases the GPPs become progressively less able to support the power requirements at the higher POR and PPS settings (Figures 13-15). Thus, the use of the 1,000 V RANGE would be reserved only for waters of lower conductivity.

In addition to striving to standardize electrofishing capture efficiency and optimize fish capture, another factor of concern is damage to fish (Appendix C). Kolz et al. (1998) describes the pulsed DC waveform as having three key parameter including the pulse amplitude (voltage), pulse frequency (pulses per second or Hz), and pulse width (milliseconds). Pulse frequency is believed to be the most serious factor associated with damage to fish during electrofishing. Pulse width is considered to be next in importance in this regard, with voltage being the least damaging (Kolz et al. 1998). Miranda and Dolan (2004) suggested that a minimal duty cycle (% of time a field is energized) of 10% was needed to immobilize fish and that peak power requirements for fish immobilization increased greatly below this threshold. Duty cycles of 10-50% required the least peak power to immobilize fish and as a consequence may be less injurious to fish. This suggests that electrofishing with intermediate to high duty cycles may improve electrofishing effectiveness (Miranda and Dolan (2004).

Miranda and Spencer (2005) contend that confusion exists among fishery biologists with regard to the operation of Smith-Root GPPs, particularly the POR control. In their tests with a Smith-Root Model 7.5 GPP, they indicated that pulse widths less than 20 on the POR control did not provide a duty cycle of least 10% at PPS settings of 25 and 60 HZ. However, at a POR setting of 120 Hz, duty cycle ranged from about 15-50%. Thus, testing the outputs of electofishers becomes important for understanding how the controls actually affect power output as well as relating control setting to their electrical properties that would influence capture efficiency and injury of fish. Combining this information on GPP performance and standardization of electrofishing boats is intended to maximize capture efficiency of target species, facilitate comparison of capture data among boats, rivers and conductivities, and to minimize injury to captured fishes or those exposed to the electrical field.

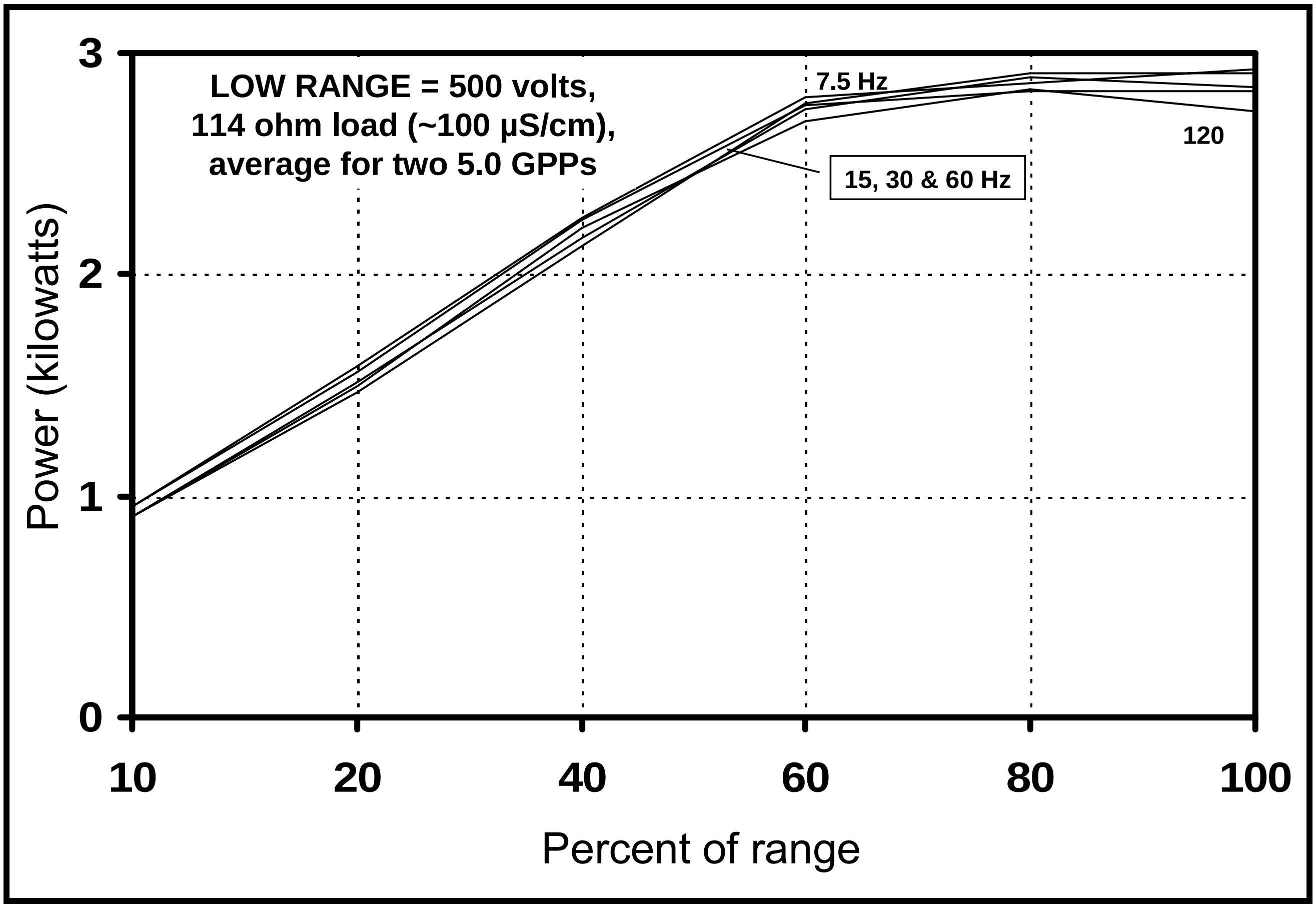

Figure 8. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for two units, operating at the LOW RANGE 500 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 114 ohms simulating an approximate water conductivity of 100 µS/cm, as illustrated in Figure 4, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

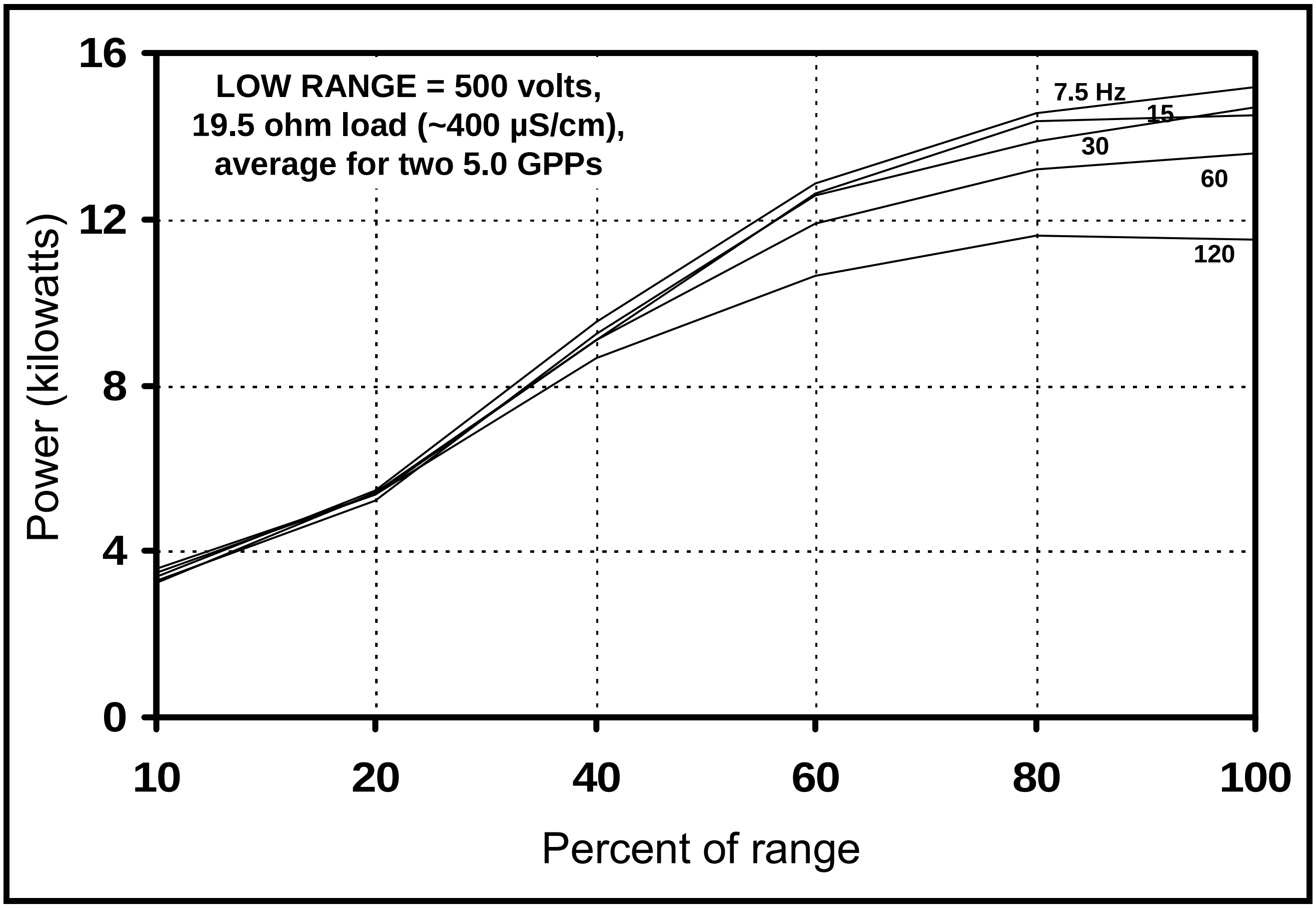

Figure 9. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for two units, operating at the LOW RANGE 500 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 19.5 ohms simulating an approximate water conductivity of 400 µS/cm, as illustrated in Figure 3, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

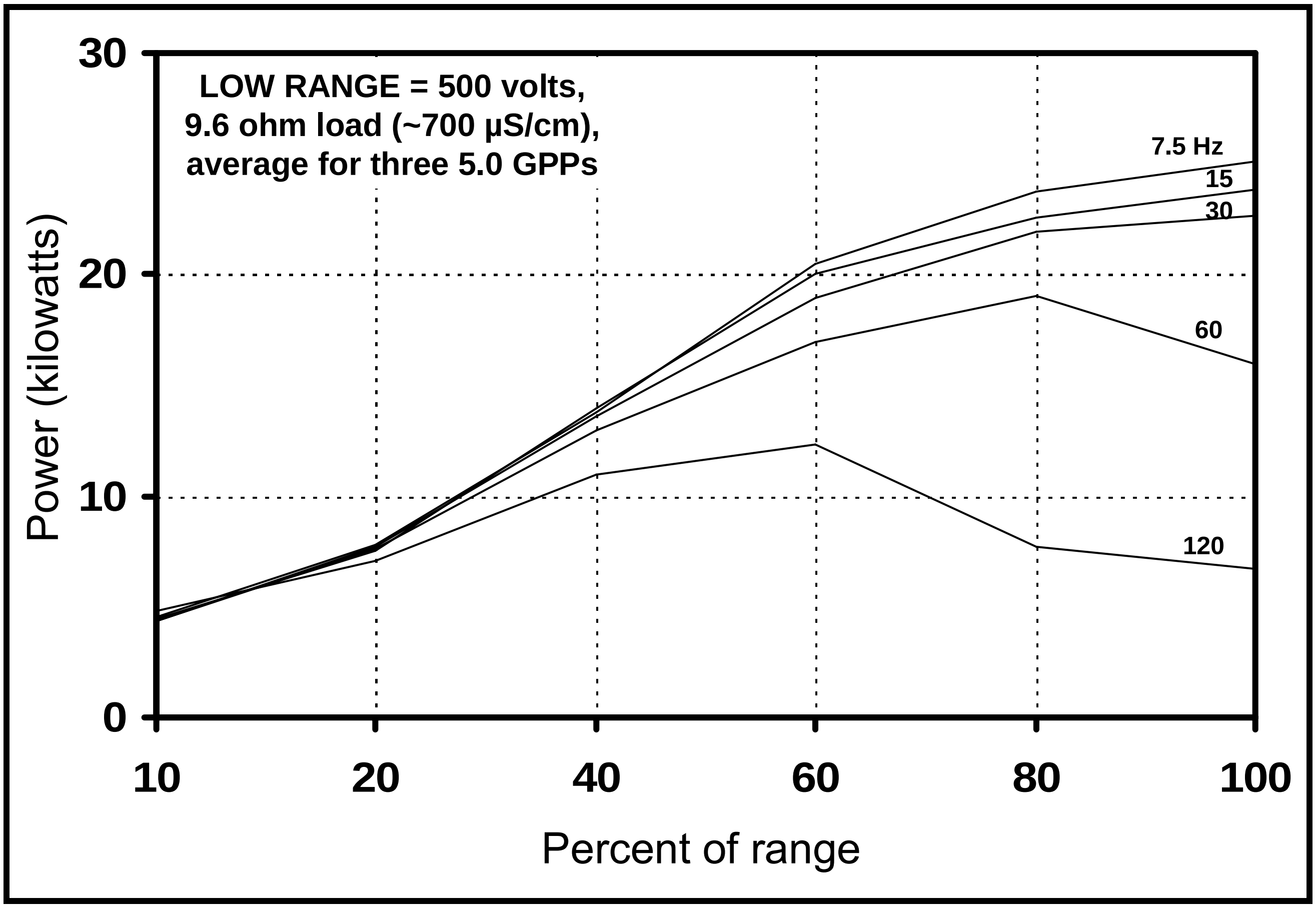

Figure 10. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for three units, operating at the LOW RANGE 500 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 9.6 ohms simulating an approximate water conductivity of 700 µS/cm, as illustrated in Figure 3, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

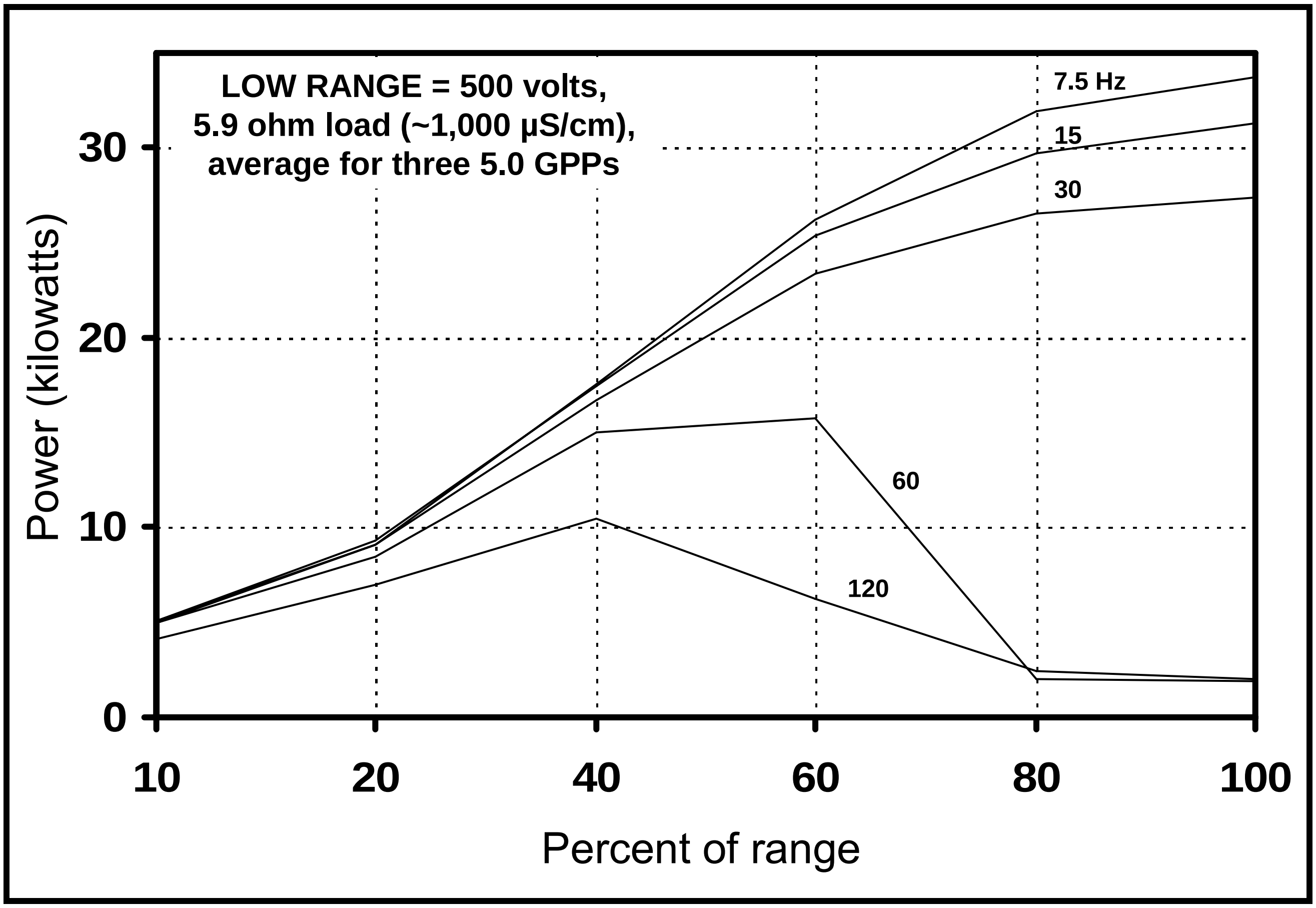

Figure 11. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for three units, operating at the LOW RANGE 500 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 5.9 ohms simulating an approximate water conductivity of 1,000 µS/cm, as illustrated in Figure 3, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

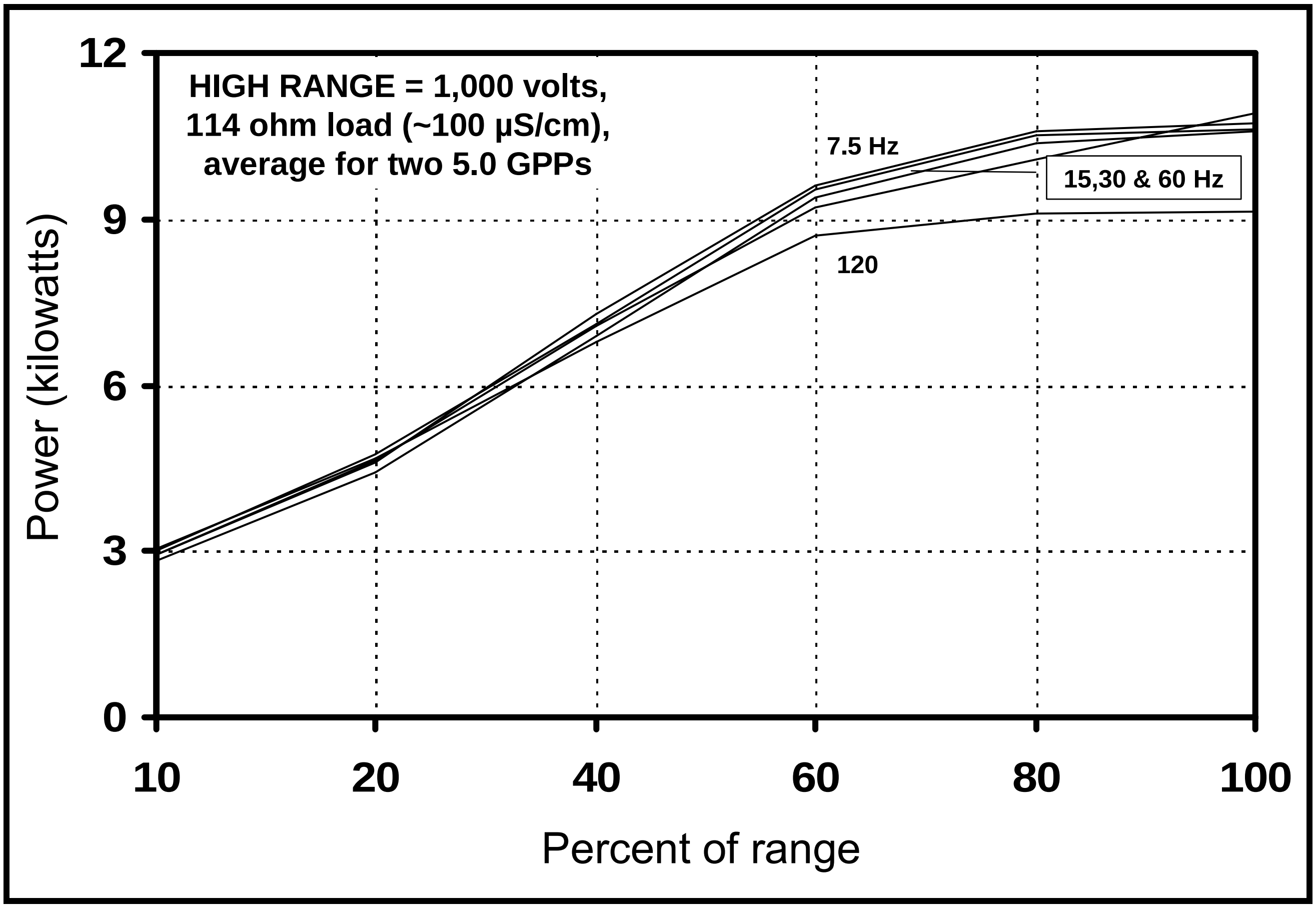

Figure 12. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for two units, operating at the HIGH RANGE 1,000 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 114 ohms simulating an approximate water conductivity of 100 µS/cm, as illustrated in Figure 4, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

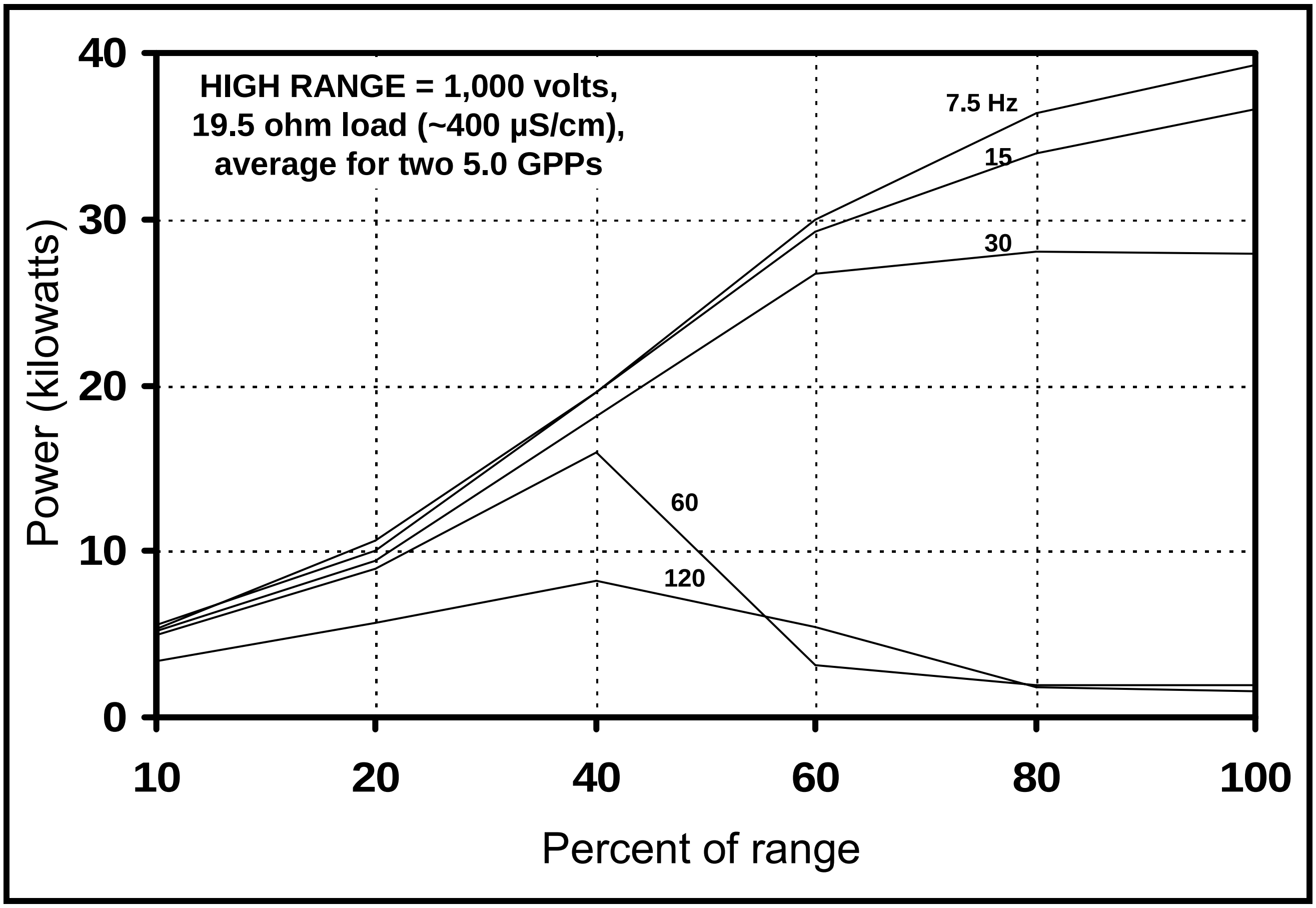

Figure 13. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for two units, operating at the HIGH RANGE 1,000 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 19.5 ohms simulating an approximate water conductivity of 400 µS/cm, as illustrated in Figure 3, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

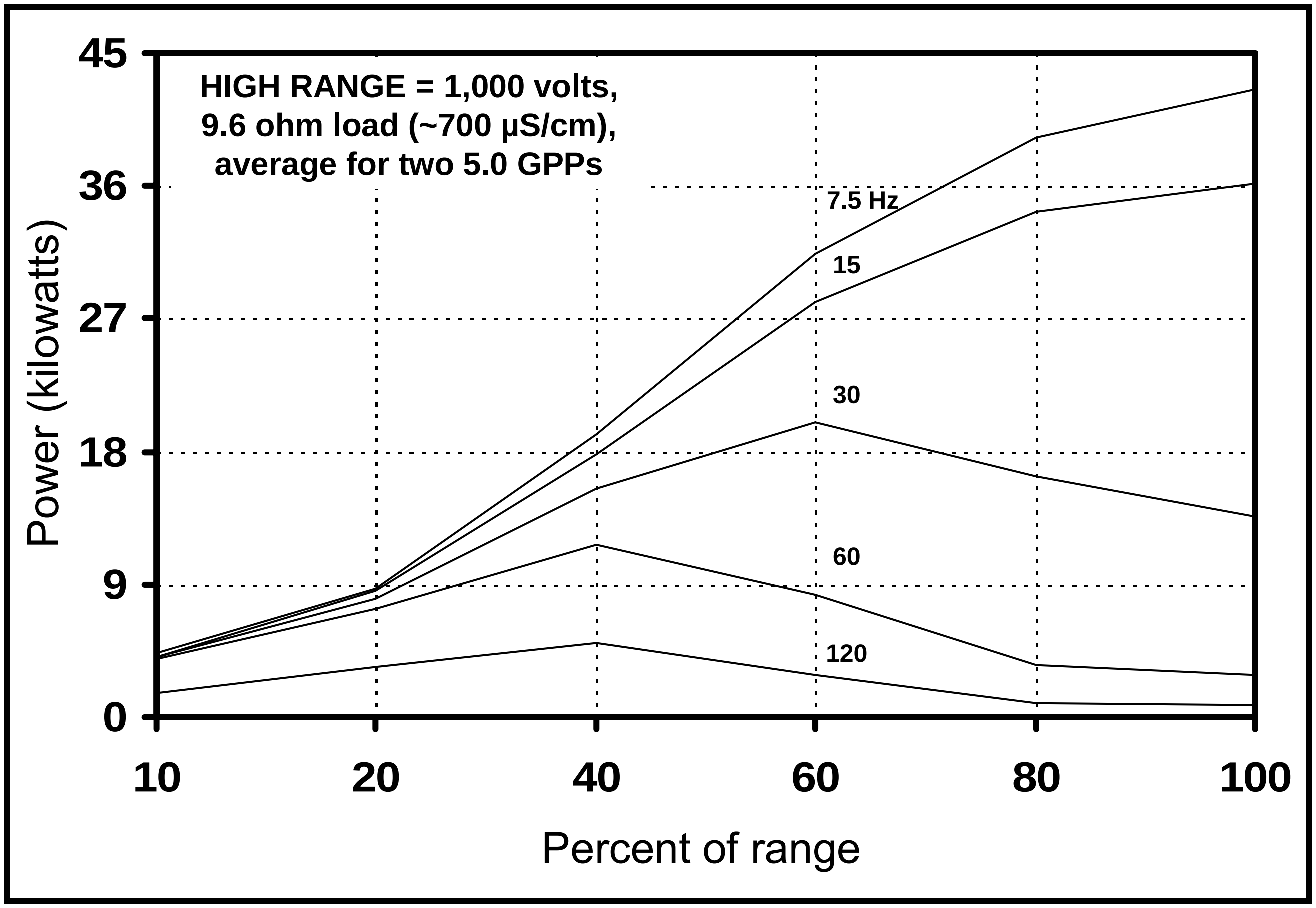

Figure 14. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for two units, operating at the HIGH RANGE 1,000 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 9.6 ohms simulating an approximate water conductivity of 700 µS/cm, as illustrated in Figure 3, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

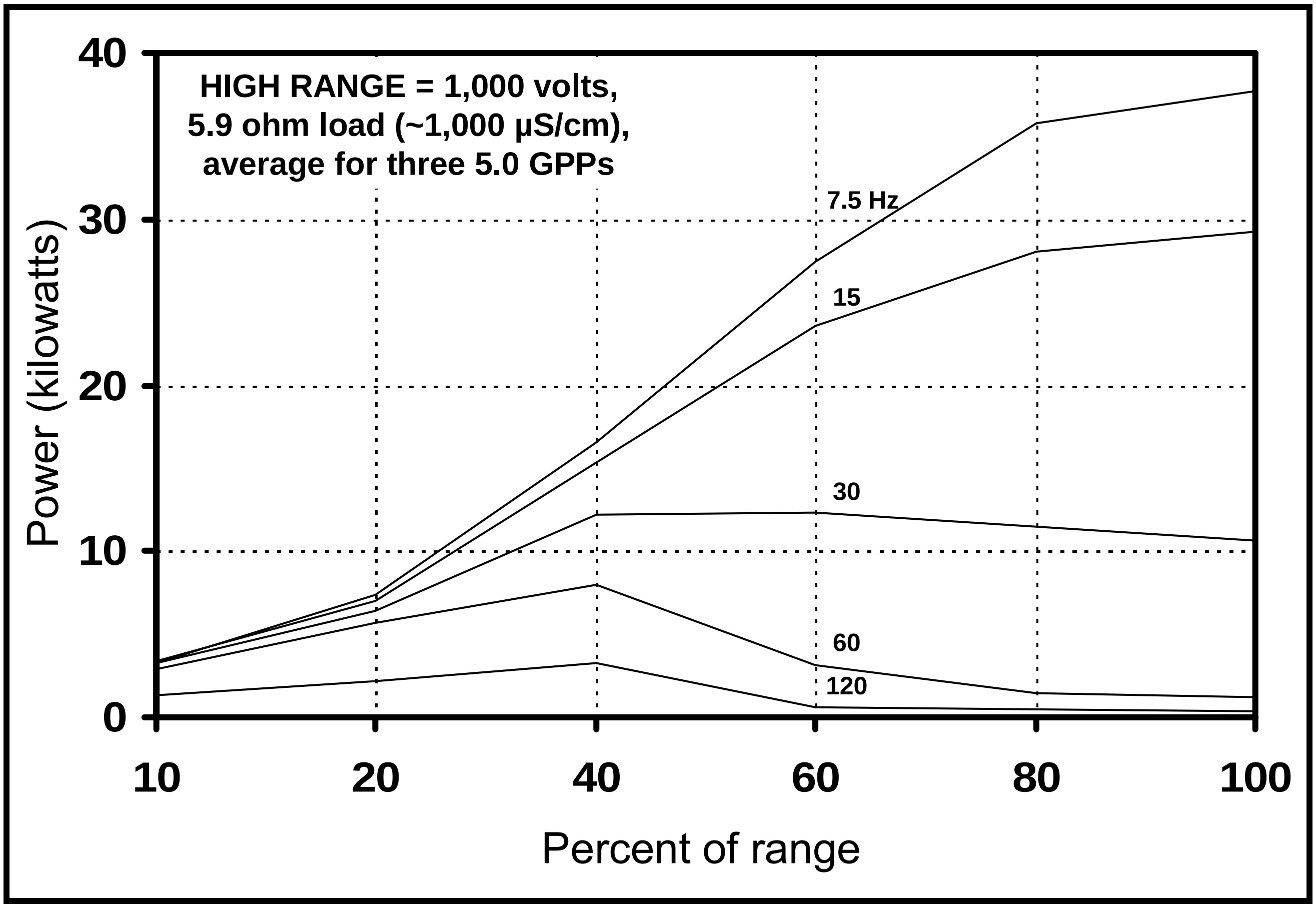

Figure 15. Power output for Smith-Root Model 5.0 GPP electrofisher, averaged for three units, operating at the HIGH RANGE 1,000 volt setting in the DC mode (Figure 1). Electrofishers were subjected to an electrical load of 5.9 ohms simulating an approximate water conductivity of 1,000 µS/cm, as illustrated in Figure 3, and operated at percent of range settings of 10, 20, 40, 60, 80 and 100 at pulse per second settings of 7.5, 15, 30, 60 and 120 Hz.

Segment Objective 3: Participate in/lead inter-agency effort to identify strategies to improve prospects for control of select nonnative fishes in the upper Colorado River basin rivers via their life history, control of their escapement from reservoirs, removal strategies, or environmental manipulations to reduce their abundance and negative ecological impacts in riverine habitats.

INTRODUCTION

In early 2006, the Biology Committee of the Upper Colorado Endangered Fish Recovery Program discussed the need to update the existing knowledge about the operations of reservoirs which may be sources of nonnative, warmwater fishes entering critical habitat for endangered fishes. Ultimately, this review fell to George Smith with the Recovery Program and me. Summarizing information about reservoir configurations, their operations and their dam's features would provide basic information needed to evaluate or forecast the potential for the escapement of primarily nonnative cool- and warmwater sport fish. Further, this effort would provide valuable information for the reservoir fingerprinting investigation described in Martinez (2006) with regard to the potential influence of reservoir operations on both water and otolith microchemistries.

At the Upper Colorado River Endangered Fish Recovery Program's Nonnative Fish Management Workshop held December 11-13, 2006 in Grand Junction, I was asked to provide an overview entitled Smallmouth Bass Life History-Know Thy Enemy. As part of this presentation, I covered the prospects of angling by the public or of organized events as viable means of exerting removal pressure on smallmouth bass in the Yampa River.

METHODS, MATERIALS, RESULTS and DISCUSSION

Appendix F provides the annual report for the reservoir fingerprinting investigation submitted to the Recovery Program. Significant events in 2006 for this project were the hiring of Master's candidate, Philip Brinkley, and the receiving of fish samples from key waters in Colorado and Utah for preliminary analyses.

In September 2006, I hired Ellen Hamann as a Technician to gather and compile information on the primary reservoirs of concern regarding fish escapement. These waters are also part of Phil Brinkley's graduate research at Colorado State University. Table 1 provides preliminary information on these waters.

Appendix G contains the PowerPoint presentation entitled <u>The Use of Water Temperature, Discharge & Turbidity to approximate the duration of Optimal Conditions for Smallmouth Bass Angling in the Yampa River</u>. This analysis relies on reactive distance of rainbow trout (Barrett et al. 1992) and smallmouth bass (Sweka and Hartman 2003) in conjunction with sediment data for the Yampa River (Elliot and Anders 2005) to estimate a timeframe for smallmouth bass catchability. Based on this analysis of mean conditions in the Yampa River, the period for optimal smallmouth bass fishing is short, particularly for boats (5 weeks), and turbidity due to summertime storms would further limit angling (Appendix G).

Table 1. Specifications for 15 reservoirs being examined for potential escapement of nonnative warmwater sport fish in western Colorado and eastern Utah.

Reservoir: Bottle Hollow Surface area (full pool): 420ac Max depth: 50ft Storage capacity: 11,100af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: capacity = 210cfs, canal = 30cfs Spillway (frequency of operation): rare Hydropower (yes/no): no Screened outlet: screen at Elders Pond	**Reservoir: Hallenbeck (Purdy Mesa)** Surface area (full pool): 62ac Max depth: 46ft Storage capacity: 659af **Dam:** Outlet type (fixed/variable): Outlet depth: Spillway (frequency of operation): rare Hydropower (yes/no): no Screened outlet: yes
Reservoir: Crawford Surface area (full pool): 400ac Max depth: 120ft Storage capacity: 14,395af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: capacity = 125cfs Spillway (frequency of operation): frequently Hydropower (yes/no): no Screened outlet: no	**Reservoir: Harvey Gap** Surface area (full pool): 196ac Max depth: 41ft Storage capacity: 5,858af **Dam:** Outlet type (fixed/variable): Outlet depth: Spillway (frequency of operation): rare Hydropower (yes/no): no Screened outlet: no
Reservoir: Elkhead Surface area (full pool): 900ac Max depth: 80ft Storage capacity: 24,778af **Dam:** Outlet type (fixed/variable): Outlet depth: spillway capacity = 28,000cfs Spillway (frequency of operation): rare Hydropower (yes/no): no Screened outlet: screens on towers	**Reservoir: Juniata** Surface area (full pool): 144ac Max depth: 113ft Storage capacity: 6,868af **Dam:** Outlet type (fixed/variable): Outlet depth: Spillway (frequency of operation): rare Hydropower (yes/no): no Screened outlet: no
Reservoir: Flaming Gorge Surface area (full pool): 42,020ac Max depth: 436ft Storage capacity: 3,788,900af **Dam:** Outlet type (fixed/variable): penstocks & outlet tubes = 8,600cfs Outlet depth: Spillway (frequency of operation): rare Hydropower (yes/no): yes Screened outlet: no	**Reservoir: Kenny** Surface area (full pool): 615ac Max depth: 71ft Storage capacity: 27,600af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: outlet works capacity = 1450cfs Spillway (frequency of operation): yearly Hydropower (yes/no): yes Screened outlet: no

Table 1. (continued) Specifications for 15 reservoirs being examined for potential escapement of nonnative warmwater sport fish in western Colorado and eastern Utah.

Reservoir: McPhee Surface area (full pool): 4,606ac Max depth: 262ft Storage capacity: 381,151af **Dam:** Outlet type (fixed/variable): gated Outlet depth: capacity = 5,275cfs Spillway (frequency of operation): rare Hydropower (yes/no): yes Screened outlet: no	**Reservoir: Rio Blanco** Surface area (full pool): 116ac Max depth: 18ft Storage capacity: data pending, CDOW **Dam:** Outlet type (fixed/variable): stoplog structure Outlet depth: Spillway (frequency of operation): occasional Hydropower (yes/no): no Screened outlet: pike exclusion device
Reservoir: Paonia Surface area (full pool): 400ac Max depth: 120ft Storage capacity: 17,461af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: capacity = 1,130cfs Spillway (frequency of operation): frequent and long duration Hydropower (yes/no): no Screened outlet: no	**Reservoir: Stagecoach** Surface area (full pool): 775ac Max depth: 130ft Storage capacity: 33,275af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: Spillway (frequency of operation): yearly Hydropower (yes/no): yes Screened outlet: no
Reservoir: Ridgway Surface area (full pool): 1,000ac Max depth: 80ft Storage capacity: 84,410af **Dam:** Outlet type (fixed/variable): uncontrolled crest, morning glory Outlet depth: capacity = 1,400cfs Spillway (frequency of operation): 1-3 years to clear spillway Hydropower (yes/no): no Screened outlet: no	**Reservoir: Starvation** Surface area (full pool): 2760ac Max depth: 154.9ac Storage capacity: 162,798af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: capacity = 1,000+cfs Spillway (frequency of operation): rare Hydropower (yes/no): no Screened outlet: no
Reservoir: Rifle Gap Surface area (full pool): 400ac Max depth: 87ft Storage capacity: 13,602af **Dam:** Outlet type (fixed/variable): uncontrolled crest Outlet depth: capacity = 144cfs Spillway (frequency of operation): frequent Hydropower (yes/no): no Screened outlet: no	

Temperature and dissolved oxygen profiles were again monitored at Highline Lake in 2006 (Appendix H). This sampling, in addition to providing training for my crew working on reservoirs, provides information to State Parks so that they can perform their annual maintenance release of water from the reservoirs's outlet when oxygen depletion at depth minimizes the escapement of fish (Martinez 2003). This sampling was conducted on three dates in 2006, 15 May, 1 June, and 28 July (Appendix Table H-1). Dissolved oxygen was less than 2 ppm below 6-m depth on 28 July and State Parks was informed that conditions were suitable for the unscreened release from the outlet. Zooplankton was collected on one date each in 2005 and 2006 in Highline Lake, as described in Martinez (2000), and the results of this sampling is reported in Appendix Tables H-2 and H-3. Daphnia were abundant on both dates, but as has been reported in the past, the majority of the zooplankters were small, generally averaging < 1.0 mm in length (Martinez 2000 and 2003).

OBJECTIVE 2: TROPHIC AND BIOENERGETICS INVESTIGATIONS FOR WARMWATER FISH MANAGEMENT

To improve/identify methods to evaluate/pin-point sources, species, life-stages of nonnative fishes that are most problematic to facilitate efficient control of nonnative fish, to protect/recover native fish, and to facilitate continued or expanded stocking/translocation/management of warmwater sport fish on Colorado's western slope.

Segment Objective 1: Estimate density and size structure of verile crayfish *Orconectes virilis* in Yampa river.

INTRODUCTION

Martinez (2006) discussed the impetus to examine the verile crayfish population in the Yampa River and the role this nonnative crustacean may have in fueling nonnative piscivores, channel catfish, northern pike and smallmouth bass, and posing a competitive threat to native fishes. Crayfish density was deemed high in 2005 at an estimated 6.7 individuals/ m^2 constituting a biomass of 9 g/m^2 (Martinez 2006). Crayfish sampling in the Yampa River was repeated in 2006 to further document their density, biomass and size structure.

METHODS and MATERIALS

Martinez (2006) provides details for the collection, measurement and sex determination of verile rayfish captured in the Yampa River in 2005 and 2006. Crayfish were sampled during late August when river flow would be low enough to allow access by wading across the entire channel and water clarity would allow unhindered visual detection of crayfish. In addition, this time of year would allow both air and water temperatures to be tolerated by crew members searching for crayfish in the river. Lastly, annual crayfish reproduction would be complete facilitating the sampling of a crayfish standing crop that would be representative of the density and biomass of crayfish available to fish as prey during the growing season.

Sampling stations were chosen to represent the various habitat types in the Middle Yampa River and to provide assess by vehicle for long-term monitoring of crayfish. Due to local sensitivities about agency trespass on private lands, random selection of stations may have exposed one or more stations to denied access in the future on private land. Further, low stream flows in late August limit the use of watercraft and unimproved roads in the area may also preclude station access. Thus, it was decided that sampling for crayfish would occur at boat launch sites where long-term access was likely. In addition, sampling for crayfish at these sites would occur upstream of the boat launch areas to avoid those portions of the river's shoreline and channel heavily disturbed by boat, vehicle or human activity.

Figure 16 provides the location and GPS coordinates of the three sampling stations at Juniper Springs and Morgan Gulch boat ramps and the Milk Creek boat access. At each station a reach of the river upstream of the boat launch was marked every 10 m from 0 m to 50 m with flagging tape affixed to the shoreline to denote six potential transects spanning the river channel, perpendicular to the flow. A die was rolled to randomly select two of the six transects for sampling of crayfish. Crayfish were sampled within a 1-m square plot fabricated from 2-inch diameter, Schedule 40 (thick wall) PVC pipe (Martinez (2006). Prior to final assembly of the PVC pipes and elbows, it was filled with sand to provide weight to make it demersal, yet portable.

At the start of each transect, a die was rolled to determine if the first plot would be placed 1-m or 5-m offshore, to randomly account for the scarcity or abundance of crayfish near shore. Once this selection was made, the plot was placed in the water, taking care to count any fleeing crayfish. A Nikon Laser 440 compact rangefinder was used to space subsequent plots 5-m apart along the transect for the entire width of the river. Crayfish were handpicked by two people from within each plot, taking care to again account for emigration or immigration from the plot while it was thoroughly searched for crayfish. A third person held a seine with 0.25 inch Ace mesh, which served as a block-net downstream of the plot, while assisting with crayfish collection or monitoring crayfish escape. On plots with larger-sized gravel to cobble substrate, the plot was raked once in an effort to account for all crayfish in the plot. Crayfish captured in each plot were placed in Zip-loc or Whirl-pac bags, and labeled to denote the station, transect and plot from which they were sampled. They were then stored on ice for transport to the lab.

Additional data collected at each transect included water temperature and channel width. Within each plot, other measurements included water depth, water velocity (measured at 0.6 of total depth from the water surface) measured with a Marsh-McBirney Model 2000 portable flow-meter, and substrate type. Substrate types included silt, sand, gravel, cobble, and rock, where gravel was stones < 150 mm, cobble included stones 150-250 mm and rocks were > 250 mm. The two dominant substrate types at each station were used to characterize the habitat for that reach of river. The flow at the Maybell USGS stream gaging station (Figure 16) was also recorded for the dates of sampling in 2005 and 2006.

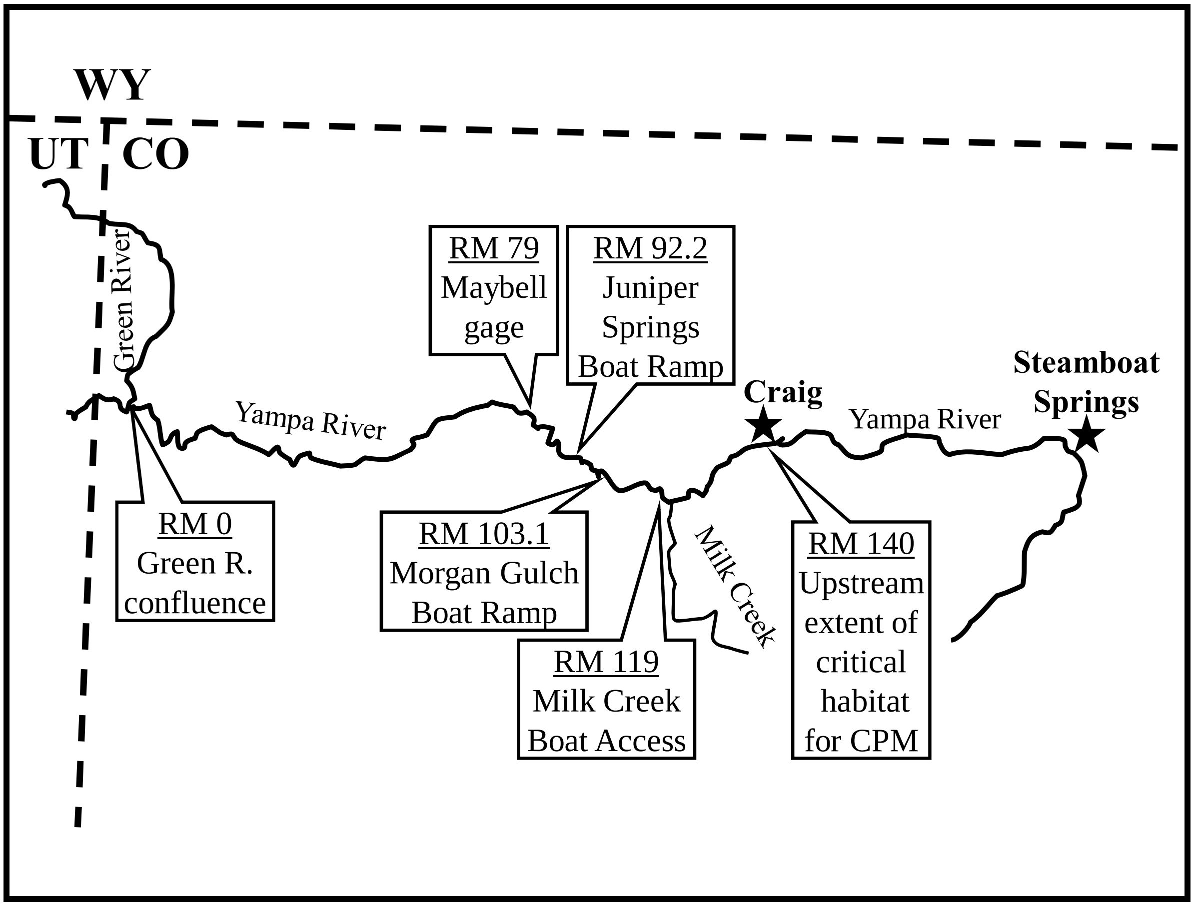

Figure 16. Map of Yampa River showing sampling stations sampled for verile crayfish, Juniper Springs Boat Ramp, Morgan Gulch Boatramp, and Milk Creek Boat Access, in 2005 and 2006. GPS coordinates were 13T 0248608 UTM 4484666 at Juniper Springs, 13T 0256653 UTM 4478090 at Morgan Gulch, and 13T 0265404 UTM 4475627 at Milk Creek.

Data recorded in the field for crayfish at each plot included number captured and number escaped. In the lab, the sex of each crayfish was determined, their carapace length (CL) was measured to the nearest mm with digital calipers, and they were weighed. In 2005, the sex of 44 crayfish < 20 mm was not determined. In 2005, crayfish larger than 20 mmCL were weighed to the nearest 0.5 gram with an Accu-Weigh 2500 platform scale. However, crayfish smaller than 20 mmCL were pooled before being weighed due to the scale's inability to provide individual weights of the smallest crayfish. Crayfish in three groups, $\leq$ 10 mmCL, 11-15 mmCL and 16-20 mmCL were weighed together and this weight was divided by the number of crayfish in the pool to estimate individual weight. In 2006, crayfish were weighed to the nearest 0.1 gram with an Accu-Weigh PLS-500 platform scale.

Channel width measurements at the three stations averaged 59.9 m in 2005 and 62.5 m in 2006. A mean channel width of 60 m was chosen to represent 130 km (80 miles) of the Yampa River from RM 45-125. These distances represent approximately 7.8 million m^2 of stream area which was used with the mean density of crayfish/m^2 in each year to estimate crayfish abundance. Using the mean length of crayfish in each year in conjunction their respective length-weight regression equations allowed estimation of the biomass of crayfish/m^2. These values ultimately allow the estimation of crayfish density, abundance or biomass per unit area.

RESULTS and DISCUSSION

Table 2 summarizes the stream channel characteristics and measurements at the three crayfish sampling stations in the Yampa River in 2005 and 2006. Table 3 provides the total number of crayfish in each 1 m^2 plot, and shows the total numbers of crayfish that were either captured or missed in each transect. Sampling accounted for 631 crayfish in 2005, of which 23% were counted as missed. In 2006, sampling accounted for 566 crayfish of which 22% were counted as missed. Figure 17 shows the length frequency of verile crayfish captured at the three sampling stations. Figure 18 provides a length frequency comparison of female and male crayfish sampled in 2005 and 2006. Both figures indicate a larger size structure of crayfish captured in 2006. Figure 19 shows length-weight relationships for the crayfish captured at the three sampling stations in 2005 and 2006.

Table 4 shows the mean density and mean carapace length (CL) of verile crayfish at the three sampling stations in the Yampa River in 2005 and 2006. Using criteria from Anderson (2003), the river at Juniper Springs was generally characterized as a run, Morgan Gulch as a pool, and Milk Creek as a deep riffle. Anderson (2003) estimated the proportion of each habitat type in this vicinity of the Yampa River to be 64% runs, 30% pools and 6% riffles. These percentages were applied to both the crayfish densities and CLs to establish weighted means for these values. The weighted carapace lengths from each year were used with their respective length-weight regressions to determine a mean crayfish weight for each year.

Weighted crayfish density was higher in 2006, 9.0/m^2, than in 2005, 6.7/m^2 (Table 4). Weighted mean CL was also higher in 2006, 18.5 mm, than in 2005, 17.2 mm (Table 4). These values were used in Table 13 to develop indices of crayfish abundance and biomass in the 130 km reach of the Yampa River from RM 145-RM125 (80 miles). The higher mean density and CL of crayfish in 2006 greatly increased the estimate of crayfish abundance and biomass over 2005. While the estimate of crayfish abundance increased about 26% from 2005 to 2006, the estimate of crayfish biomass increased by about 44%. As reported in Martinez (2006), these estimates of crayfish biomass, when annual production is accounted for, exceed the estimates of fish standing crop and its annual production.

Martinez (2006) discussed the likelihood that these densities of crayfish in the middle Yampa River were providing ample prey to nonnative predators including channel catfish, smallmouth bass and northern pike and that crayfish may affect native suckers and chubs through interference competition via their agnostic or territorial behavior (Carpenter 2005). The evidence provided herein of the capacity of nonnative verile crayfish to attain high density and biomass suggests that crayfish stocking activity must be reviewed and likely ceased in western Colorado. New policies and regulations are needed to prevent the inadvertent, illicit or intentional spread of verile crayfish or any new crayfish species that pose a threat to native fishes.

Table 2. Summary of stream channel physical characteristics and measurements at three stations sampled for verile crayfish in the Yampa River in 2005 and 2006. Flow @ Maybell refers to the mean daily streamflow measured that the USGS gage station.

Station parameters	**Juniper Springs** **rivermile 92.2**	**Morgan Gulch** **rivermile 103.1**	**Milk Creek** **rivermile 118.6**
22-24 August 2005			
Habitat	Run	Pool	Riffle
Channel width (m)	61 & 56	62 & 72	40 & 39
Flow (cfs) @ Maybell	151	148	165
Temperature (^{o}C)	19.9	21.1	21.4
Mean depth (cm)	33	46	45
Mean velocity (ft./sec.)	1.24	0.63	1.47
Primary substrate	GR/CB	GR/SA	CB/RK
28-29 August 2006			
Habitat	Run	Pool	Riffle
Channel width (m)	57 & 67	64 & 71	47 & 39
Flow (cfs) @ Maybell	165	163	166
Temperature (^{o}C)	21.3	19.6	19.9
Mean depth (cm)	34	53	41
Mean velocity (ft./sec.)	1.26	0.57	1.54
Primary substrate	GR/SA	SA/GR	GR/CB

Table 3. Summary of the numbers of verile crayfish captured in 1-m square plots at three stations from six randomly selected transects (two transects per station) situated perpendicular to the flow in the Yampa River in 2005 and 2006.

2005																
Tran-sect	**Sample plot**													**Caught**	**Missed**	**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**			
Juniper Springs																
T2	0	0	0	0	0	4	5	2	3	14				25	3	**28**
T5	4	0	1	2	1	4	2	2	4	24				40	4	**44**
Morgan Gulch																
T1	16	13	20	9	0	0	0	0	1	3	1			35	28	**63**
T6	108	4	5	7	26	4	6	7	3	3	4	6	3	157	29	**186**
Milk Creek																
T2	85	29	20	7	4	0	2							110	37	**147**
T3	77	26	9	2	5	0	44							116	47	**163**
All Stations →														**483**	**148**	**631**

2006																
Tran-sect	**Sample plot**													**Caught**	**Missed**	**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**			
Juniper Springs																
T2	7	2	1	0	2	8	6	14	12	24	22			71	25	**98**
T5	8	2	1	5	7	13	11	16	10	30				88	15	**103**
Morgan Gulch																
T1	23	3	8	27	22	3	4	2	2	1	3			66	32	**98**
T4	15	2	6	7	16	1	3	2	4	2	8			56	10	**66**
Milk Creek																
T1	37	20	9	15	4	6	6	18						87	28	**115**
T3	10	36	11	7	9	3	10							70	16	**86**
All Stations →														**438**	**126**	**566**

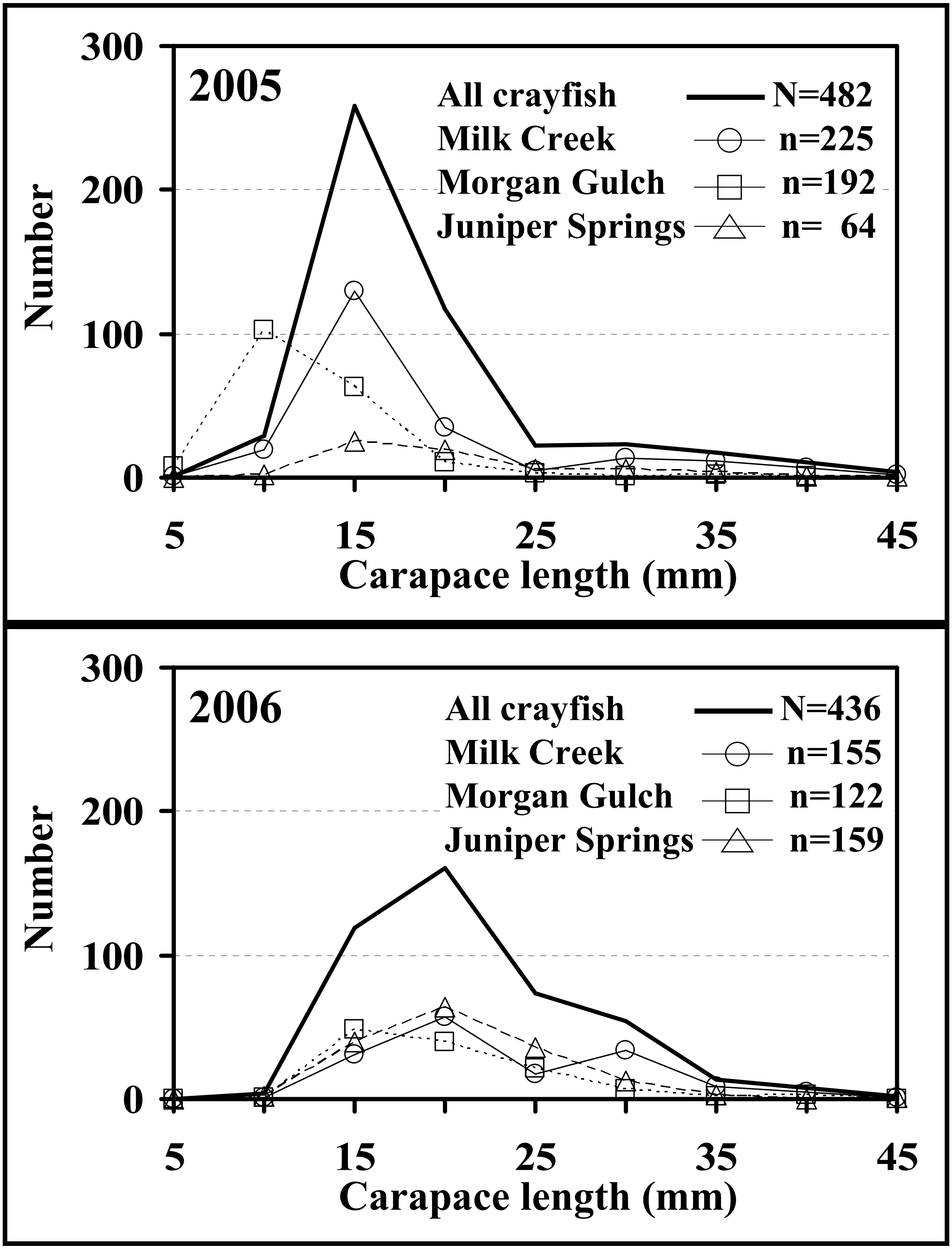

Figure 17. Length frequency of verile crayfish sampled at three stations in the Yampa River in 2005 and 2006.

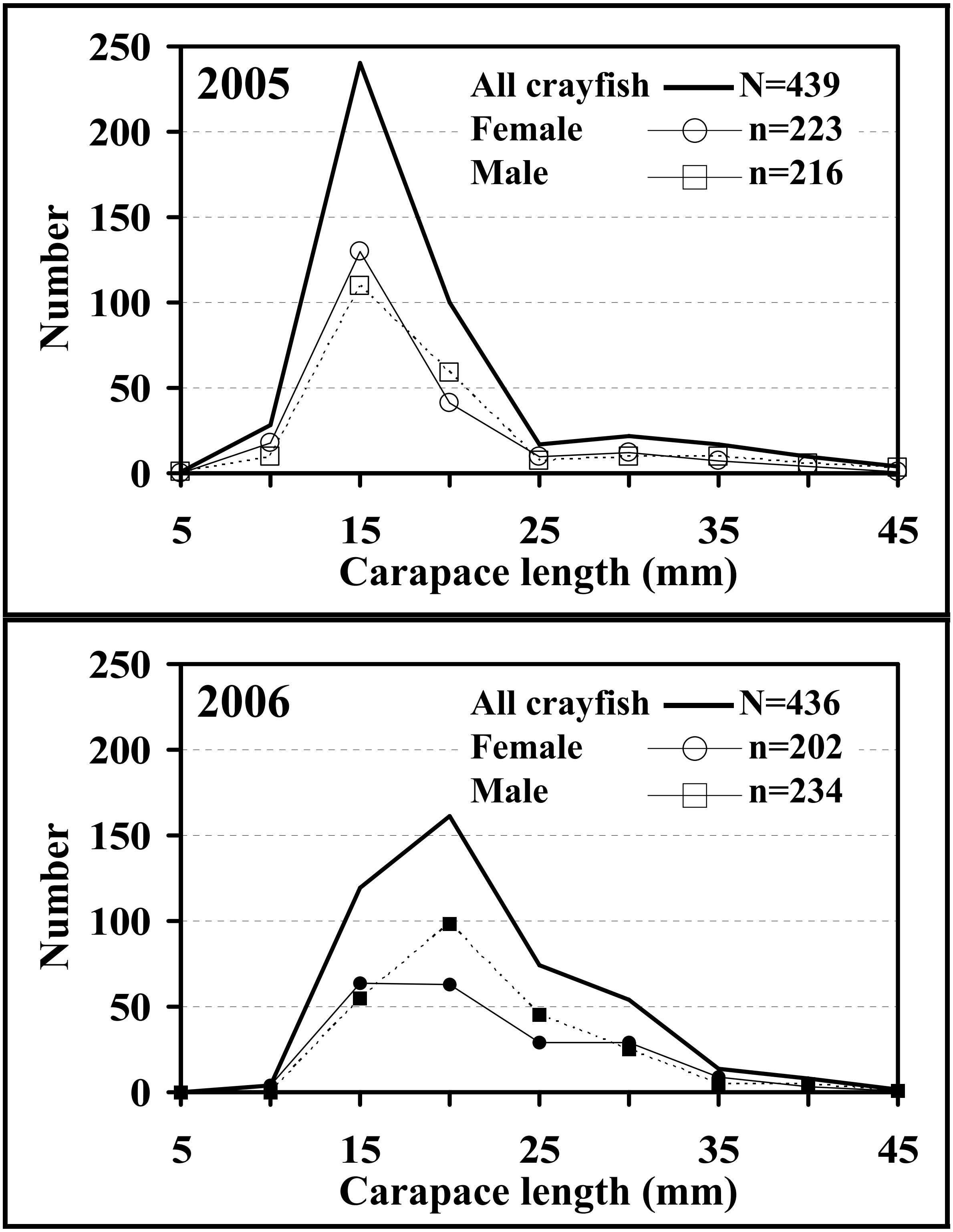

Figure 18. Length frequency of female and male verile crayfish sampled in the Yampa River in 2005 and 2006.

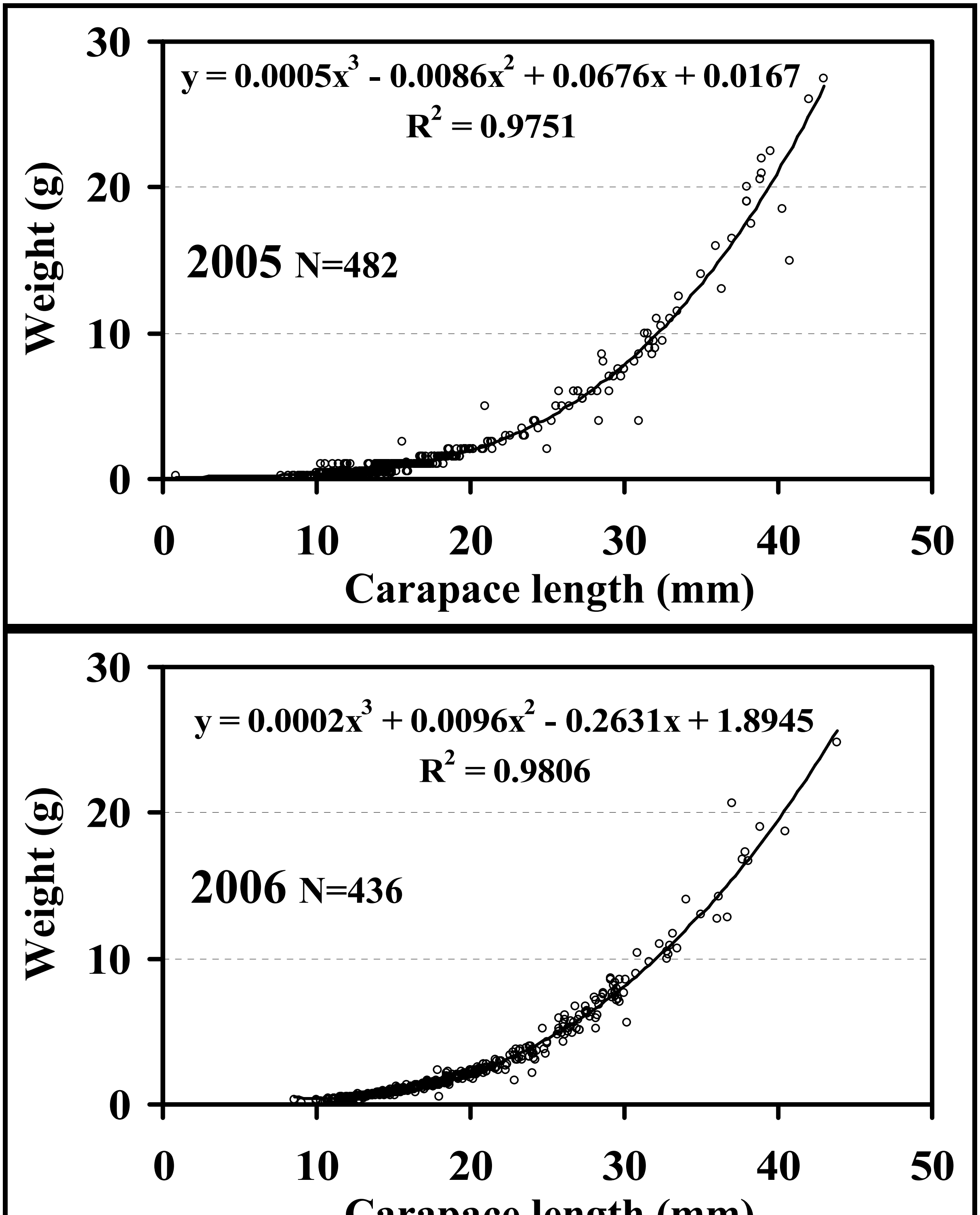

Figure 19. Length-weight relationships for verile crayfish sampled in the Yampa River in 2005 and 2006. Equation combining length-weight of crayfish for both years is $y = 0.1638x^2 - 1.122x + 2.1518$, $R^2 = 0.9653$.

Table 4. Mean density and carapace length of verile crayfish at three stations representing three habitat types in the Yampa River in 2005 and 2006. Mean values were multiplied by the percentage of each habitat type (Anderson 2003) to estimate weighted mean crayfish density and carapace length.

Habitat	Percent	No./m2	Weighted density	Mean carapace length (mm)	Weighted carapace length (mm)
2005					
Juniper Springs					
RUN	64%	3.6	2.3	18.2	11.7
Morgan Gulch					
POOL	30%	10.4	3.1	15.1	4.5
Milk Creek					
RIFFLE	6%	22.1	1.3	16.3	1.0
100%		Weighted no./m2 = 6.7		Weighted CL = 17.2	
2006					
Juniper Springs					
RUN	64%	9.6	6.1	18.6	11.9
Morgan Gulch					
POOL	30%	7.1	2.1	17.7	5.3
Milk Creek					
RIFFLE	6%	13.4	0.8	21.0	1.3
100%		Weighted no./m2 = 9.0		Weighted carapace length = 18.5	

Table 5. Weighted mean abundance and size of verile crayfish sampled in the Yampa River in 2005 and 2006 (Table 12) expanded to indices of crayfish abundance and biomass. Equations for calculating the weight of crayfish provided in Figure 43.

Channel		**Area**		**Weighted crayfish abundance**				**Weighted crayfish biomass**			
Length in km	**Width in m**	**m^2**	**ha**	**No./m^2**	**Population estimate**	**Nunber/ kilometer**	**Number/ hectare**	**Weight in grams**	**Grams/ m^2**	**Kilograms/ kilometer**	**Kilograms/ hectare**
2005: weighted mean crayfish carapace length = 17.2											
130	60	7.8M	780	6.7	52,260,000	402,000	67,000	1.2	8.0	480	80
2006: weighted mean crayfish carapace length = 18.5											
130	60	7.8M	789	9.0	70,200,000	540,000	90,000	1.6	14.4	864	144

Segment Objective 2: Continue to establish data set needed for bioenergetics evaluation of piscivory by centrarchids in backwaters within critical habitat for endangered fishes in the Colorado River.

INTRODUCTION, METHODS, MATERIALS, RESULTS and DISCUSSION

Analysis of nitrogen isotopes of centrarchids from the Colorado River near Grand Junction showed that largemouth bass, black crappie and green sunfish occupied top trophic positions among fishes collected in backwaters (Martinez et al. 2001). To follow-up on this finding, detailed bioenergetic modeling of their prey consumption will be performed upon completion of the various data sets required for this analysis. As indicated in Appendix I, this analysis has awaited the completion of a large number of diet samples. This and other analyses are now available for this bioenergetics evaluation to be performed by Dr. Brett Johnson at CSU.

Segment Objective 3: Examine demographics of channel catfish in the Colorado River.

INTRODUCTION

Channel catfish were introduced into the Colorado River in the late 1800s and early 1900s (Wiltzius 1985) and were well established by the 1950s (Lemons 1954). A preliminary examination of channel catfish in western Colorado rivers suggested that growth was slow, with channel catfish from the Colorado River reaching 16.9 inches by age 8 and 22.6 inches by age 10 (Lynch and Lemons 1956). Nonnative channel catfish remain a concern with regard to the preservation of native fishes and recovery of endangered ones in the upper Colorado River basin (Tyus and Saunders 2000).

METHODS and MATERIALS

Channel catfish were obtained from 2004 to 2006 in conjunction with USFWS electrofishing efforts for smallmouth bass in the 18-mile reach of the Colorado River (river miles 152-170) below the confluence with the Gunnison River. These channel catfish were subsampled from those collected by the USFWS crew in an attempt to represent the size structure from intensive sampling of channel catfish performed by the USFWS in 2003 (Burdick 2003). Only those channel catfish captured by USFWS in the 18-mile reach in 2003 are used for comparison with our 2004-2006 samples. Our channel catfish were measured for total length in mm, weighed to the nearest 2-g, their stomachs were preserved for content analysis, a sample of dorsal muscle was removed for isotopic analyses and saggital otoliths were taken for sectioning and aging.

A sample of channel catfish from the Yampa River was also obtained from CDOW (Lori Martin) and CSU (John Hawkins) crews in 2005 and 2006 for comparison to channel catfish in the Colorado River. These fish have also been used in bioenergetics comparisons to northern pike and smallmouth bass in the Yampa River (Appendix I). Appendix I provides an update on collaborative efforts to publish findings from joint research on nonnative fishes in the upper Colorado River Basin.

RESULTS and DISCUSSION

A total of 252 channel catfish (33 in 2004, 107 in 2005, and 112 in 2006) were obtained from the Colorado River for detailed analysis of their size, growth and diet. Information on their size is presented here pending review of their age and diet information. The goal of obtaining channel catfish in 2004-2006 spanning the length range seen in the USFWS 2003 sample was achieved (Figure 20). Figure 21 shows the relative weights of channel catfish from the Colorado (2004-2006, n=172) and Yampa (2005-2006, n=41) rivers. Channel catfish in the Colorado River display relative weights primarily below 100%, except for some of the larger specimens over 450 mmTL. Channel catfish in the mid-Yampa River are primarily larger fish > 450 mmTL, but these fish display higher relative weight (Figure 21). This notable difference in relative weights between the two rivers has been attributed to the high incidence of verile crayfish in the diets of channel catfish in the middle Yampa River (Martinez 2006).

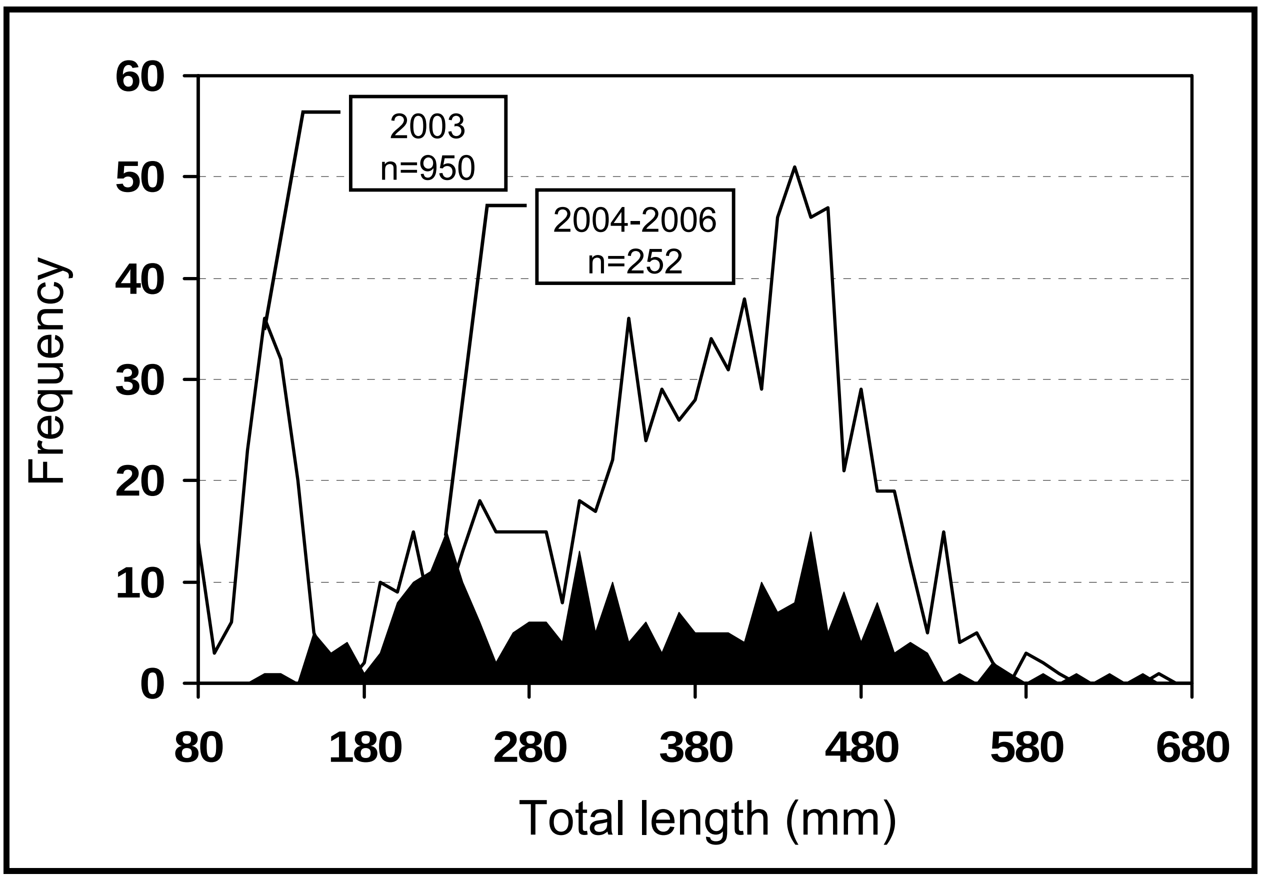

Figure 20. Comparison of length distributions for channel catfish captured in the 18-mile reach of the Colorado River below the Gunnison River confluence (rivermiles 152-170) in 2003 and from 2004 to 2006.

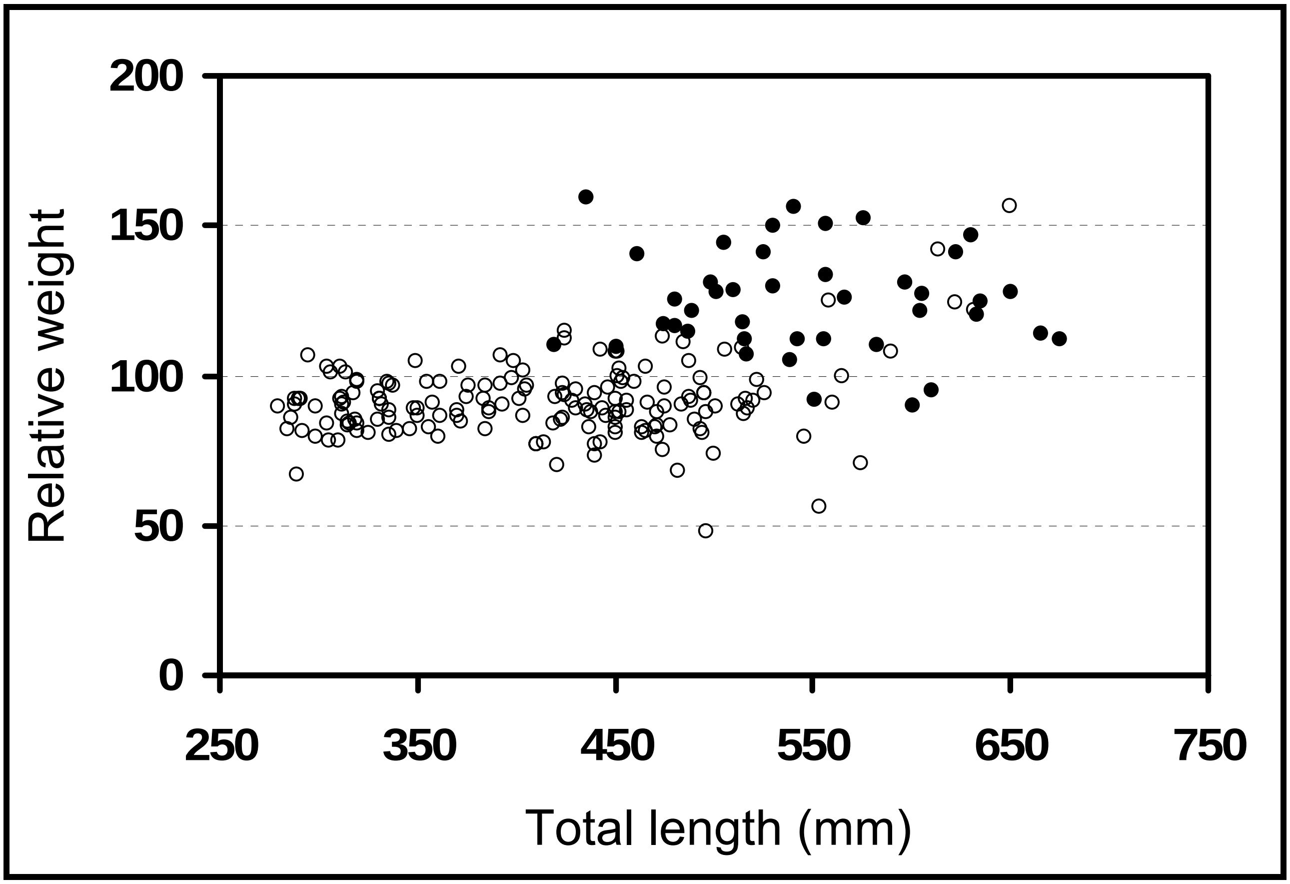

Figure 21. Comparison of relative weights for channel catfish > 280 mm total length captured in the Colorado River in the 18-mile reach (rivermiles 152-170, n=172) and in the Yampa River from rivermiles 60-120 (n=41).

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APPENDIX A

POWERPOINT PRESENTATION: DESIGNATING CONSERVATION AREAS TO PRIORITIZE, PUBLICIZE, POPULARIZE AND OPTIMIZE NONSALMONID NATIVE FISH PROTECTION AND PRESERVATION, GIVEN AT COLORADO-WYOMING CHAPTER OF THE AMERICAN FISHERIES SOCIETY CONTINUING EDUCATION WORKSHOP IN FORT COLLINS, FEBRUARY 2007

Designating Conservation Areas to Prioritize, Publicize, Popularize and Optimize Nonsalmonid Native Fish Protection and Preservation

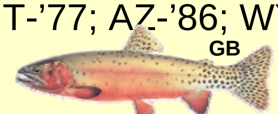
Patrick J. Martinez, Aquatic Researcher
Colorado Division of Wildlife, Grand Junction

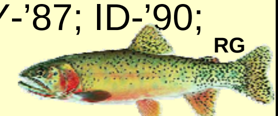
Fishes: Tomerelli et al.   P.J. Martinez-CO Div. Wildl.-2007   1

Native Salmonid Conservation & Recognition

- Cutt-Slam, WY

- Yellowstone Lake cutthroat trout plight: lake trout & whirling disease
- State Fish: NM-’55; MT-’77; AZ-’86; WY-’87; ID-’90; CO-’94; UT-’97





- Angling & stocking exclusions for designated cutthroat trout waters: recovery, genetics, competition & disease
- Cutthroat trout often provide “Watchable” opportunities in shallows of streams or shoals due water clarity & feeding or spawning aggregations (YNP, TNP, RMNP)

Fishes: Tomerelli et al.   P.J. Martinez-CO Div. Wildl.-2007   2

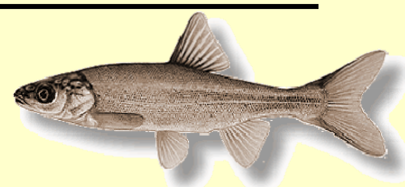
Western vs. Eastern U.S. Fishes

- Nonnatives~10% of fish spp.east of Rocky Mtns. where native fish evolved in complex & shifting assemblages
- Nonnatives, mostly eastern spp. comprise 30-60% of fish west of the Rocky Mtns. where local native fish communities were comparatively simple
- Colorado River Basin has highest level of endemism (74%) of any major drainage in North America
- Colorado River Basin is highly susceptible to establishment of nonnative fishes due to its low diversity of native fishes & highly altered habitats
- Nonnatives comprise about ~57% of fish fauna in CO east of Continental Divide & ~75% in western CO

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 3

Native Fish Conservation Areas

Objectives:



1. Impetus & rationale
2. Administrative guidance & framework
3. Components of designation
4. Analogous conservation designations
5. Identify candidate conservation areas
6. Expected benefits of designation

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 4

1. Impetus & rationale

- Model of sportsman license fees, excise tax revenues & agency & wildlife organization enthusiasm & dedication for restoring, managing & protecting select fish & wildlife species & their habitats is remarkable in its success (e.g. RMEF, TU, DU, PF, etc.); spin-off benefits for native, non-sport wildlife species
- This model begins to fall short for native species with modest or no sporting qualities, minimal or no economic value, or of limited range, abundance or recognition (e.g. small mammals, dickie-birds, herps, invertebrates, non-game fishes – "trash fish")
- State agencies often rely on license buyer perception regarding worthiness of native species & programs for their restoration, management & protection, even when the bulk of funding for some native species programs come from non-license revenues such as tax-payers, power revenues, lottery allocations

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 5

Sport Fish Tradition vs. Native Fish Conservation

- habitats capable of sustaining any sport fish species must be managed as sport fishery (license contract = mineral right?)
- intermittent, ephemeral, small or marginal habitats with low sport fish value relinquished for possible native fish emphasis
- sport fish populations ill-advisedly, invasively or illicitly established often viewed as warranting perpetuation
- native fish assemblages subject to "open range" displacement or replacement by nonnative fishes intentionally or inadvertently introduced into drainages, escaping from impoundments, or invading new stream reaches
- establishment of nonnative prey/sport species in a drainage often viewed as sufficient precedent to warrant their continued stocking, expanded distribution, or perpetuation

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 6

<u>Biodiversity</u>: large variety of native species sustained by a variety of quality habitats suitable for these species

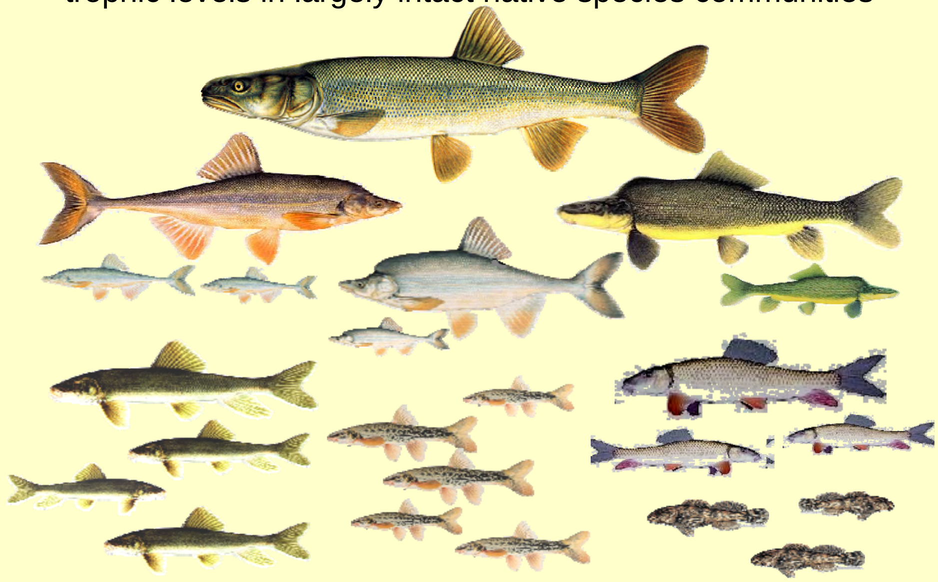
Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 7

Designating Aquatic Habitats for the Conservation of Nonsalmonid Native Fishes

- Aquatic habitats identified as sanctuaries for nonsalmonid native fishes to emphasize, publicize & institutionalize ecological concepts & management priorities necessary to perpetuate native fish existence, distribution & numbers
- As sacred sites for the preservation of native fishes, agencies & the public will be more aware of, or demand, restoration of ecological function among native species in aquatic habitats
- Agencies & public will become predisposed to select & apply conventional habitat/population techniques applied to salmonids: e.g. riparian protection, stream restoration, spp. reintroductions
- Agencies & public will become more receptive to envision & support potentially controversial management strategies: e.g. nonnative removals, chemical reclamations, new innovations

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 8

Ecological function: native species occupying niches & trophic levels in largely intact native species communities



Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 9

2. Administative guidance & framework

CDOW Strategic Plan 2002-2007:

- recover endangered species
- prevent further listings
- ***perpetuate native wildlife***

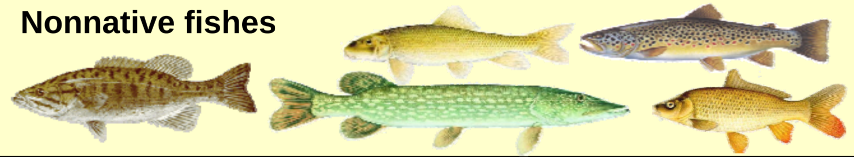
CDOW Admin. Dir. W-6: Fish Mgmt & Stocking (1999):

- ***Non-salmonid Native Fish Recovery & Conservation Water***
- aid recovery & conservation of T&E & native fish
- stocking of nonnative fish & sport fish recreation may be restricted

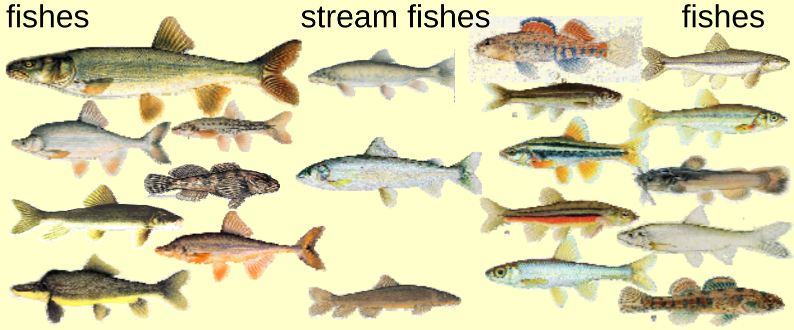
Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 10

Ecological dysfunction: habitat degradation which diminishes conditions for native species & nonnative species which displace native species or compete for or replace their roles in food webs

Nonnative fishes



"Big River" fishes — Mountain lake & stream fishes — "Plains Stream" fishes



Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 11

3. Components of designation

- publicize priority of native over nonnative species (Native Spp. Roundtables *a la* Angler's Roundtables)
- sportfishing allowed & regulated for native sport fish
- bag & size limits removed for nonnative species
- inform anglers nonnative sport fish may be reduced
- take of native species prohibited as warranted

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 12

3. Components of designation (con't)

- penalties for harming native species increased 10x+
- innovations to control nonnative species
- fund easements: access to private lands for management of natives, nonnatives & habitat
- incentives: protect riparian, in-stream & lentic habitats
- encompass area occupied by mobile/migratory fish

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 13

4. Analogous designations

WLC Policy D-6 (1992) & Admin. Dir. W-6 (1999)

- **Gold Medal Waters** – CDOW – quality trout >14"

- **Wild Trout Water** – CDOW – naturally sustained trout

- **Native Cutthroat Water** - CDOW, USFS, BLM, NPS

- promote protection/enhancement of aquatic/terrestrial habitat

- designation loss/degradation due to man requires mitigation

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 14

Arizona

<u>San Pedro Riparian National Conservation Area, BLM</u>:
40 streammiles; formerly 14 NTF, only longfin dace & desert sucker remain – replaced by NNF, primarily common carp, yellow bullhead & mosquitofish http://www.mountainvisions.com/Aurora/spedrnca.html

<u>Las Cienegas National Conservation Area, BLM</u>: Cienega Creek; Gila topminnow (endg.), Gila chub (endg. cand.) & longfin dace
http://gorp.away.com/gorp/location/az/az_empi.htm

Missouri

<u>River Bends Conservation Opportunity Area</u>: protect & enhance swamp habitats for mussels, native fish & invertebrates
http://www.mdc.mo.gov/documents/coa/33.pdf

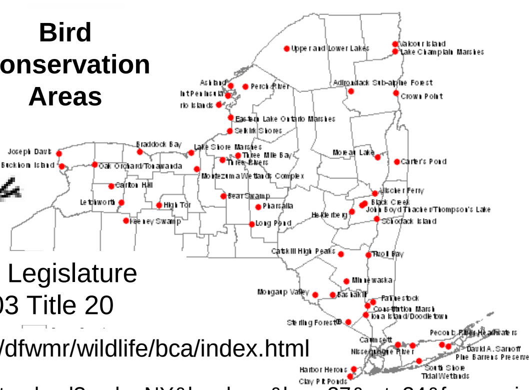
Ontario

<u>Hampton Conservation Area</u>: stream barrier preserves native brook trout from nonnative fishes (rainbow trout & salmon spp.)
http://www.cloca.com/con_areas/otherareas.php

Minnesota

<u>Bird Conservation Area Concept</u>: tallgrass prairie; heavily wooded vegetation which can harbor predators & brood parasites are considered "hostile habitat"
http://www.npwrc.usgs.gov/resource/birds/bca1998/index.htm

New York **Bird Conservation Areas**



- Enacted in 1997 by State Legislature SCL §11-2001& § 11-2003 Title 20

http://www.dec.state.ny.us/website/dfwmr/wildlife/bca/index.html

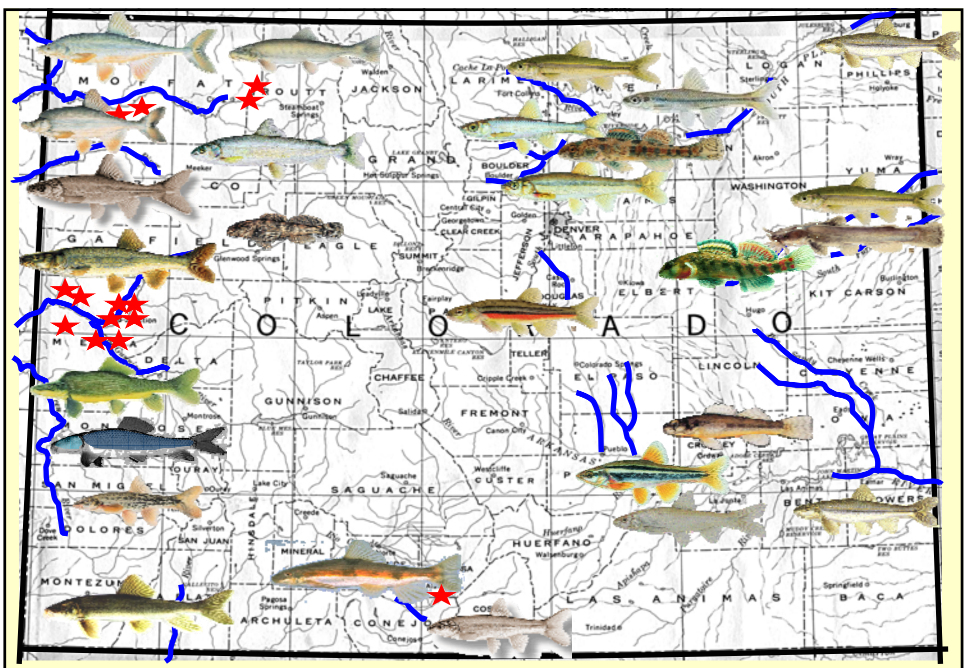
http://caselaw.lp.findlaw.com/scripts/getcode.pl?code=NY&ls=claws&law=37&art=34&frame=right2

http://www.fs.fed.us/psw/publications/documents/psw_gtr191/Asilomar/pdfs/208-212.pdf

5. Identify candidate conservation areas

NY Bird Conservation Area Program: Categories	Native nonsalmonid Aquatic Spp. Cons. Area: Categories
1. Waterfowl Conc. Site	1. “Big River” fish Cons. Area
2. Pelagic Seabird Site	2. “Foothills” fish Cons. Area
3. Shorebird Conc. Site	3. “Plains stream” fish Cons. Area
4. Wading Bird Conc. Site	4. Natural Lake Cons. Area
5. Migratory Conc. Site	5. High-Mtn. Lake-NO FISH
6. Diverse Spp. Conc. Site	6. Diverse Spp. Conc. Site
7. Individual Spp. Conc. Site	7. Individual Spp. Conc. Site
8. Species at Risk Site	8. Species at Risk Site
9. Bird Research Site	9. Aquatic Spp. Research Site

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 17



Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 18

1. **“Big River” fish Cons. Area**: Green, Gunnison, Colo., Dolores, San Juan, White, Yampa rivers; CO/NM/UT/WY
2. **“Foothills” fish Cons. Area**: Boulder, Fountain, Plum & Hot creeks, CO
3. **“Plains Stream” fish Cons. Area**: Arikaree R., Chico & Rush creeks, CO; Big Horn, Niobrara, Powder, Tongue rivers, WY
4. **Natural Lake Cons. Area**: Bear Lake, UT/ID
5. **High Mtn. Lake-NO FISH**: Flattops, CO; see Kevin Rogers
6. **Diverse Spp. Conc. Site**: St. Vrain Creek, CO
7. **Individual Spp. Cons. Site**: Pupfish, CA; Kendall Warm Springs dace, WY
8. **Spp. at Risk Site**: Molluscs, crayfish?
9. **Aquatic Spp. Research Site**: 3-Species, Muddy Cr., WY

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 19

6. Benefits of designation

- awareness of nonsalmonid native fish communities & their ecological & conservation needs
- understanding of urgency for actions to benefit native fishes
- instilling concept of refuge/sanctuary for native aquatic species
- agency/public share goal of optimizing native fish communities
- acceptance of/expectation for controversial mgmt. actions

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 20

6. Benefits of designation (con't)

- long-term access to private lands for habitat & species mgmt.
- "Good Neighbor" policy emphasizing native species to promote success of native fish interstate agreements/T&E fish recovery
- reduce risk of future listing, extirpation or extinction
- restore ecological function to allow evolutionary processes to occur within & among native aquatic species
- expedite recovery, protection & perpetuation of native fish

Fishes: Tomerelli et al. P.J. Martinez-CO Div. Wildl.-2007 21

APPENDIX B

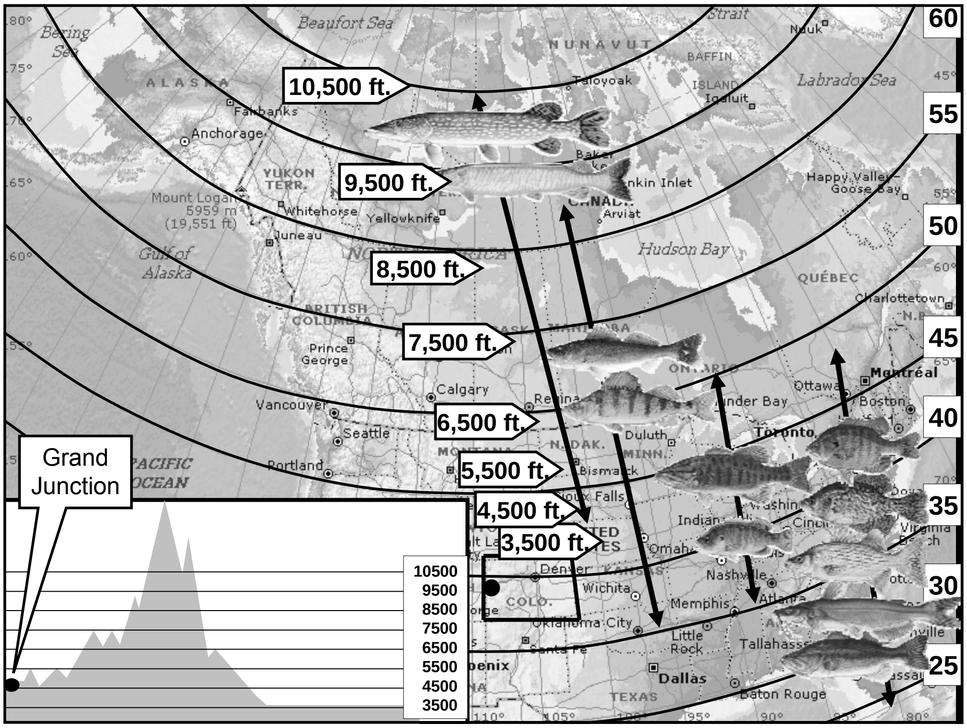
POWERPOINT PRESENTATION:
OVERVIEW OF NW COLORADO WARMWATER FISHERY RESOURCES
DISCUSSED 7 AUGUST 2006 IN GRAND JUNCTION

Overview of NW CO Warmwater Fishery Resources

1. Thermal categories of sport fish
2. NW CO warmwater ponds and reservoirs
3. NW CO warmwater pond & reservoir thermal conditions
4. Warmwater fish growth in NW CO vs. other waters
5. Angler surveys and preferences
6. Warmwater sport fish attributes & limitations
7. Recommendations for warmwater & native fish management

1. Thermal categories of sport fish

Thermal category	Fish species	Growth vs. water temperature			Lethal temperature
		Minimum	Optimum	Maximum	
COLD	trout salmon char	40	60	70	75
COOL	pike walleye perch	50	70	80	85
WARM	bass sunfish catfish	60	80	90	95



2. NW CO warmwater ponds and reservoirs

Fishing boat accessible:

Reservoir	Maxima		
	Acres	**Elevation**	**Depth**
Elkhead	440	6,400	55
Harvey Gap	190	6,400	40
Highline	140	4,700	50
Kenney	400	5,300	50
Rifle Gap	400	6,000	90
Rio Blanco	100	5,800	20
TOTAL ACREAGE	**1,670**		
Pelican Lake (UT)	1,700	4,800	15
Elkhead enlarged	1000	6,400	80

2. NW CO warmwater ponds and reservoirs

Other reservoirs > 25 SA:

Reservoir	Maxima		
	Acres	Elevation	Depth
Axial Basin	25	6,500	15
Hollenbeck	60	5,600	25
Jerry Creek 1	150	5,700	20
Jerry Creek 2	260	5,700	30
Juniata	160	5,700	55
Mack Mesa	30	4,700	20
TOTAL ACREAGE	**685**		

2. NW CO warmwater ponds and reservoirs

Ponds < 25 SA:

Pond	Maxima		
	Acres	Elevation	Depth
Connected Lakes-3	45	4,600	10
Corn, 30 Road-Wildlife Area, Fruita Shadow, Skippers	55	4,600	15
Divide Creek	10	5,700	15
Parachute, Rifle	5	5,000	10
Yampa SWA-2, Loudy Simpson, Craig Justice Cntr.	25	5,800	10
TOTAL ACREAGE	**140**		

2. NW CO warmwater ponds and reservoirs

Salmonid reservoirs with northern pike:

Pond	**Maxima**		
	Acres	**Elevation**	**Depth**
Stagecoach	700	4,600	70
Williams Fork	1,600	4,600	170
TOTAL ACREAGE	**2300**		
Boat Accessible	1,670 (Elkhead enlarged)		
Reservoirs > 25 SA	685		
Ponds < 25 SA	140		
TOTAL ACREAGE – all NW warmwaters			**4,795**

2. NW CO warmwater ponds and reservoirs

Fishing boat accessible:

Reservoir	**Sport fish species (bold italics = illicit introduction)**											
	Cold		**Cool**			**Warm**						
	LOC	**RBT**	**NOP**	**WLY**	**YLP**	**BGL**	**BCR**	**CCF**	**GSF**	**LMB**	**SMB**	**TGM**
Elkhead		X	X			X	X	X		X	X	
Harvey Gap		X	***X***		X	X	X	X		X	X	X
Highline		X			***X***	X	X	X		X	***?***	
Kenney		X	***?***			***?***	***X***	X		***?***	***?***	
Rifle Gap	X	X	***X***	X	***X***		***X***				X	
Rio Blanco			X		***X***	X	X	X		X	?	
Number	1	4	4	1	4	4	6	5		4	3	1

2. NW CO warmwater ponds and reservoirs

Other reservoirs > 25 SA:

Reservoir	Sport fish species (bold italics = illicit introduction)											
	Cold		Cool			Warm						
	LOC	RBT	NOP	WLY	YLP	BGL	BCR	CCF	GSF	LMB	SMB	TGM
Axial Basin		X	X			X	X	X			X	
Hollenbeck		X				X				X	***?***	
Jerry Creek 1		X				X				X		
Jerry Creek 2						X				X		
Juniata	X	X		***X***							***X***	
Mack Mesa					***X***	**X**	**X**	**X**		**X**		
Number	1	4	3	1	4	4	4	5		3	2	

2. NW CO warmwater ponds and reservoirs

Ponds < 25 SA:

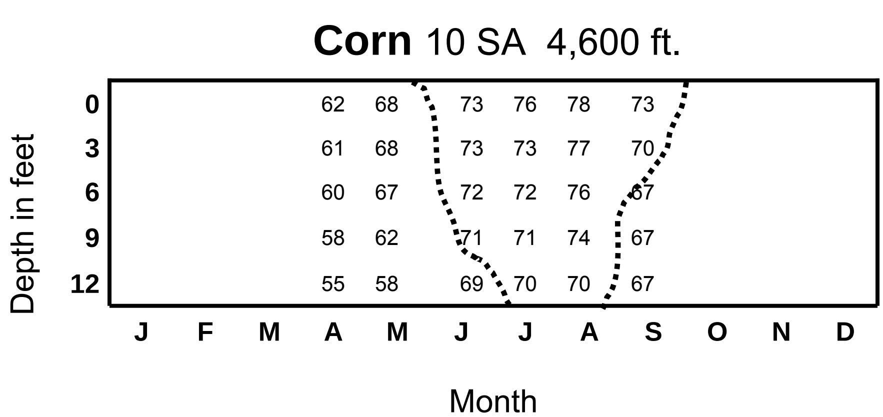
Reservoir	Sport fish species (bold italics = illicit introduction)											
	Cold		Cool			Warm						
	LOC	RBT	NOP	WLY	YLP	BGL	BCR	CCF	GSF	LMB	SMB	BBH
Connected Lakes-3				***X***		X	X			X		X
Corn, 30 Road-Wildlife Area, Fruita Shadow, Skippers		X		***X***		X				X		X
Divide Creek												X
Parachute, Rifle		X				X				X		
Yampa SWA-2, Loudy Simpson, Craig Justice Cntr.			X								X	
Number		2	1			3	1			3	1	3

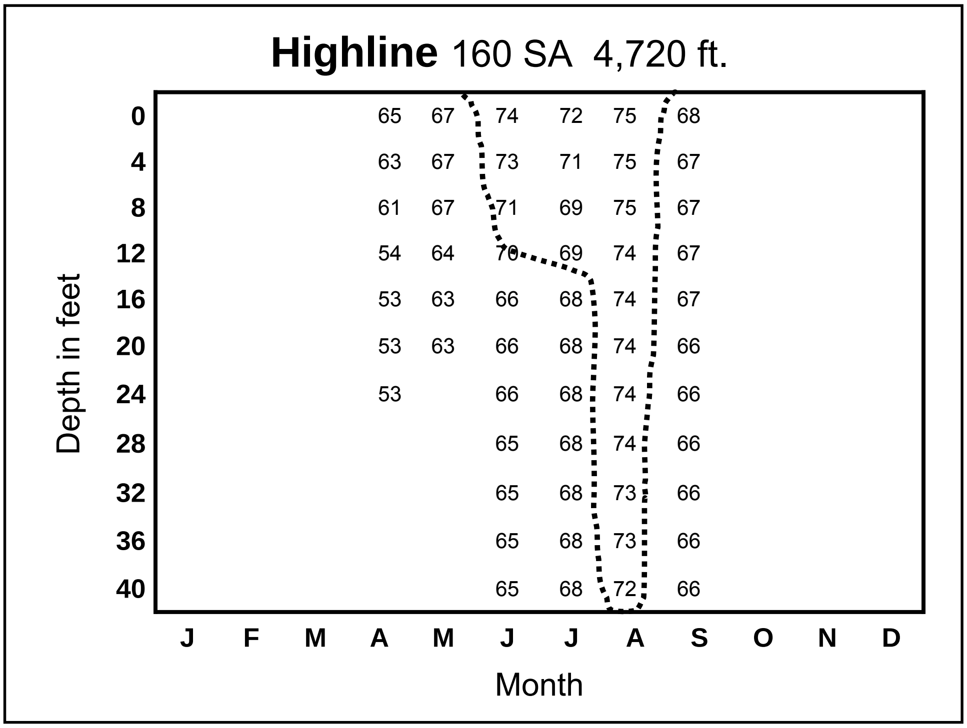
2. NW CO warmwater ponds and reservoirs

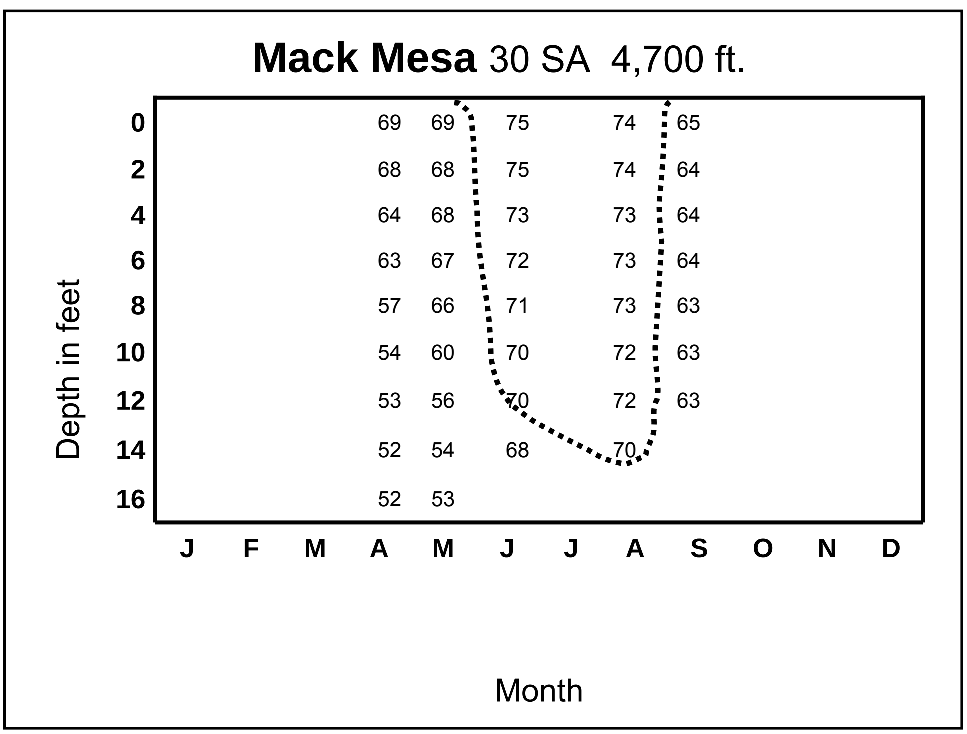
<u>Salmonid reservoirs with northern pike</u>:

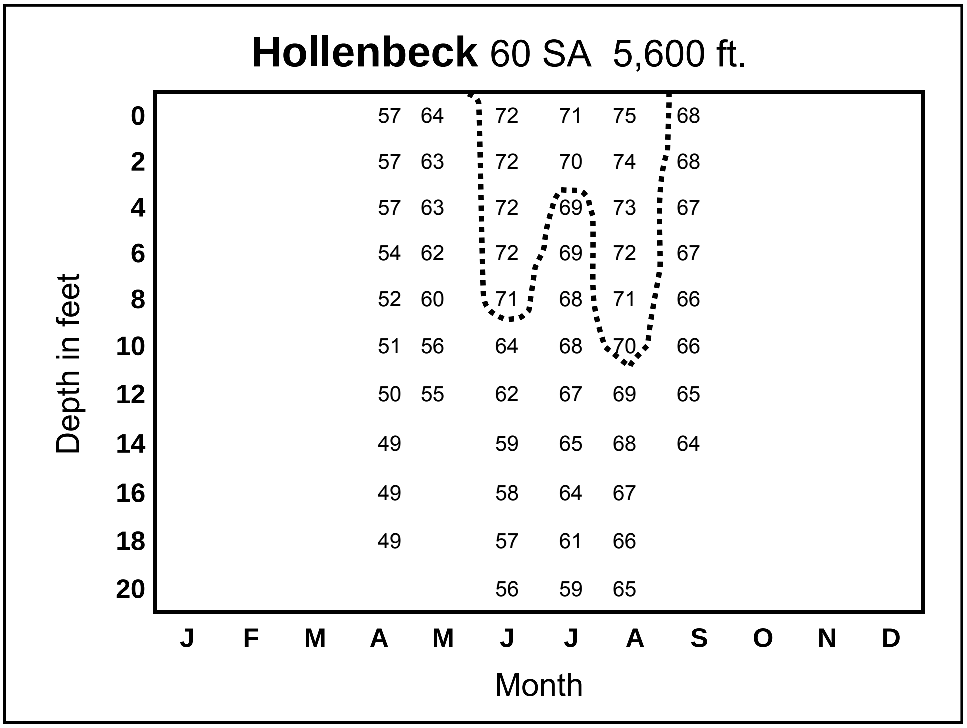
Reservoir	Sport fish species (bold italics = illicit introduction)								
	Cold					Cool			
	LOC	RBT	KOK	MAC	BRK	BCR	NOP	WLY	YLP
Stagecoach		X			X	***?***	***X***	***X***	
Williams Fork	X	X	X	X	X		X		
Number	1	2	1	1	2		2	1	

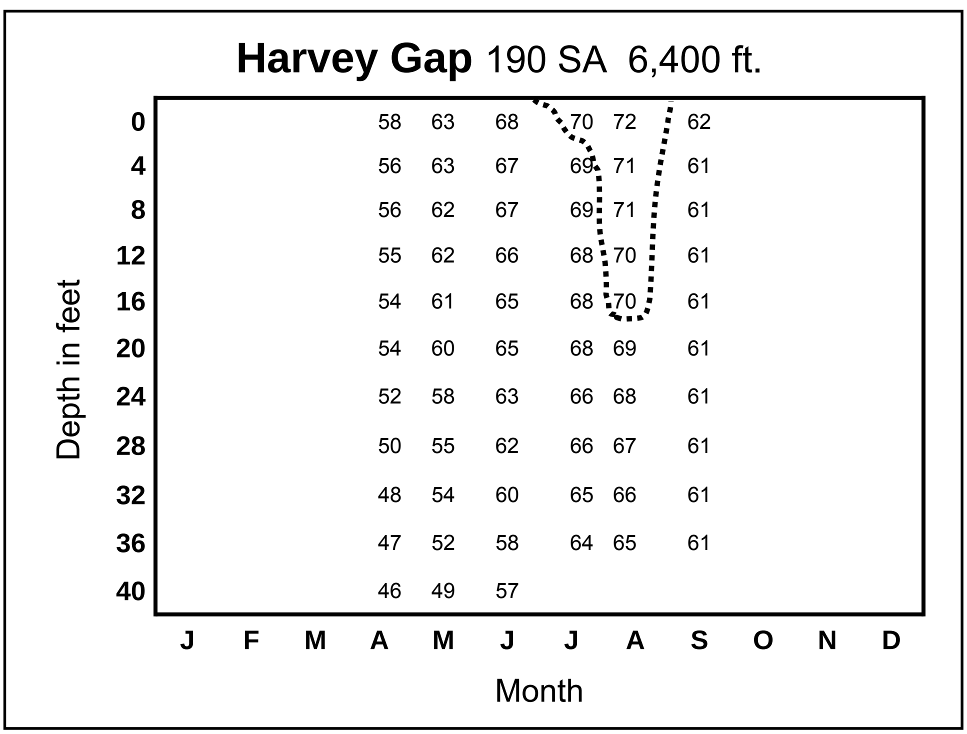
3. NW CO warmwater ponds & reservoir thermal conditions

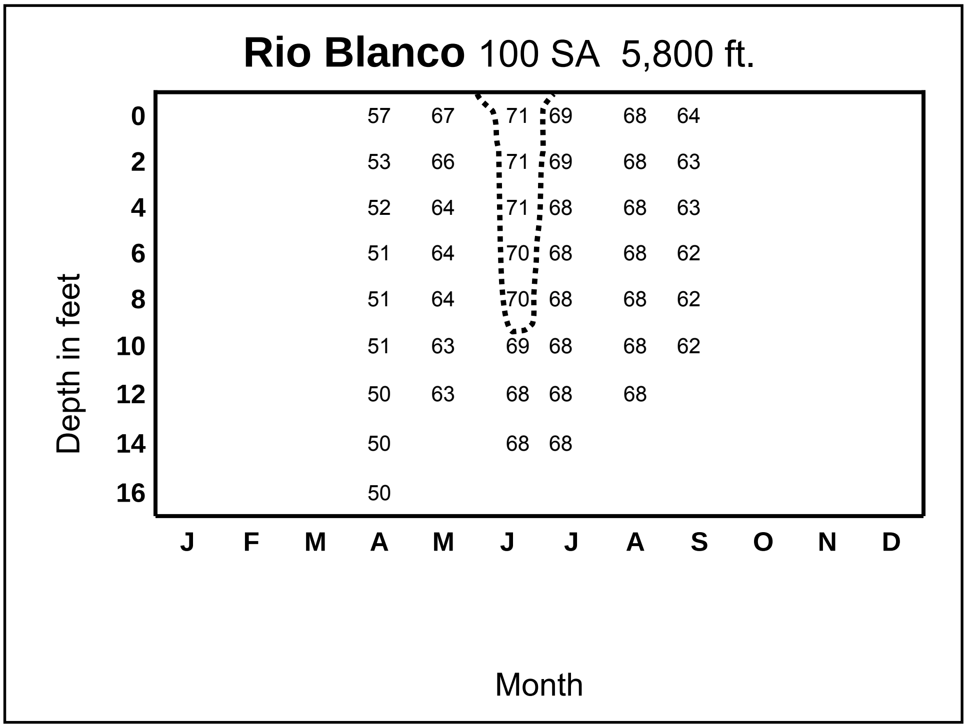


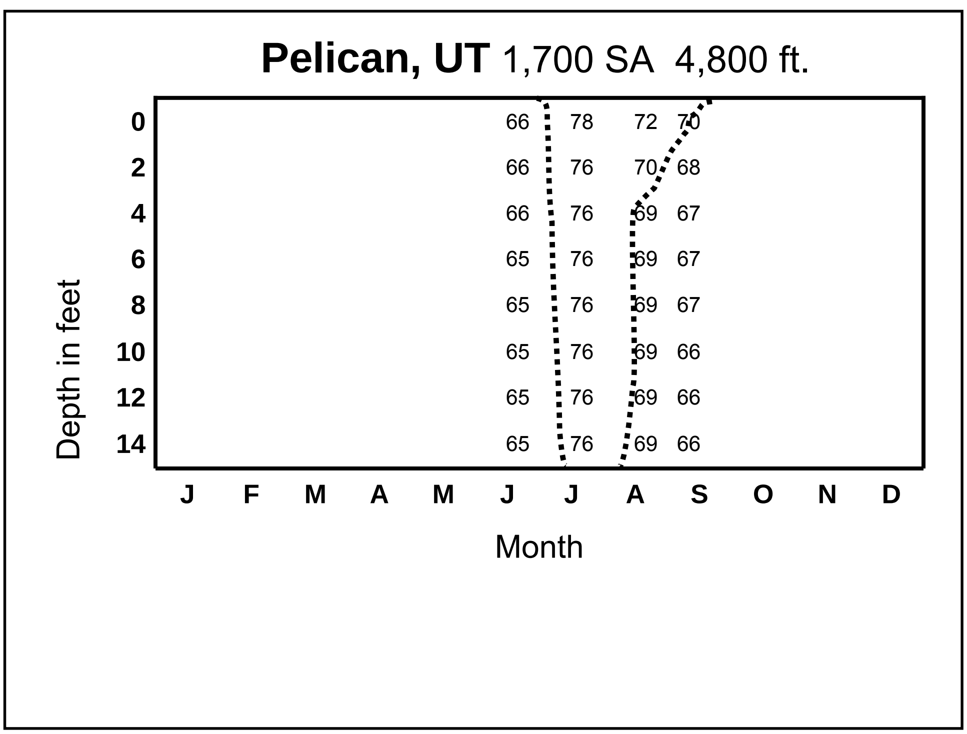

Highline 160 SA 4,720 ft.
Depth in feet
0 65 67 74 72 75 68
4 63 67 73 71 75 67
8 61 67 71 69 75 67
12 54 64 70 69 74 67
16 53 63 66 68 74 67
20 53 63 66 68 74 66
24 53 66 68 74 66
28 65 68 74 66
32 65 68 73 66
36 65 68 73 66
40 65 68 72 66
J F M A M J J A S O N D
Month

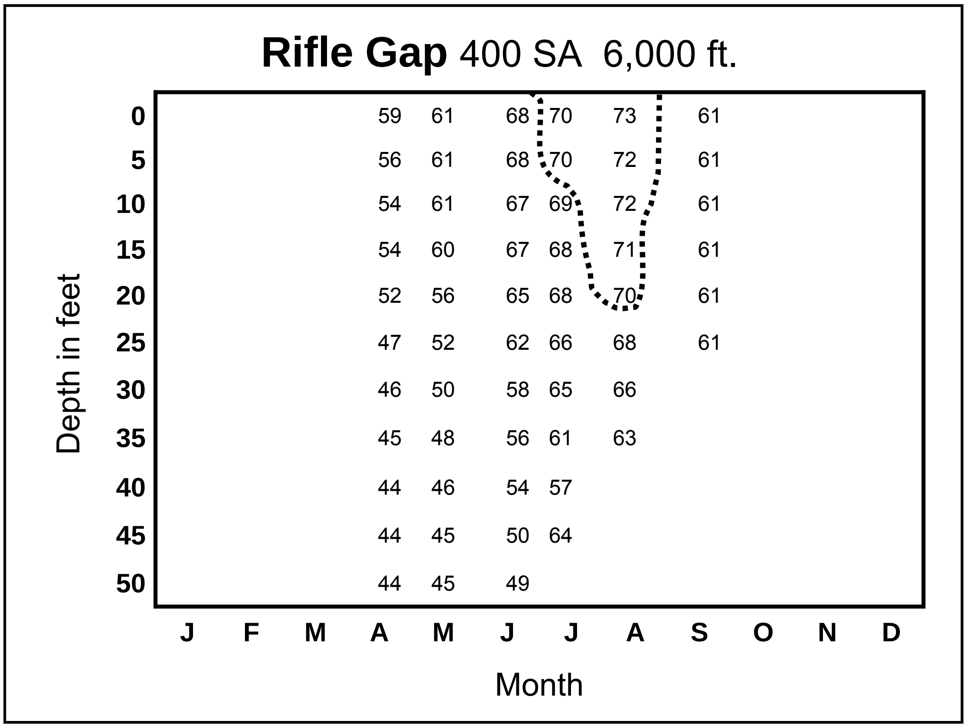

Mack Mesa 30 SA 4,700 ft.
Depth in feet
0 69 69 75 74 65
2 68 68 75 74 64
4 64 68 73 73 64
6 63 67 72 73 64
8 57 66 71 73 63
10 54 60 70 72 63
12 53 56 70 72 63
14 52 54 68 70
16 52 53
J F M A M J J A S O N D
Month

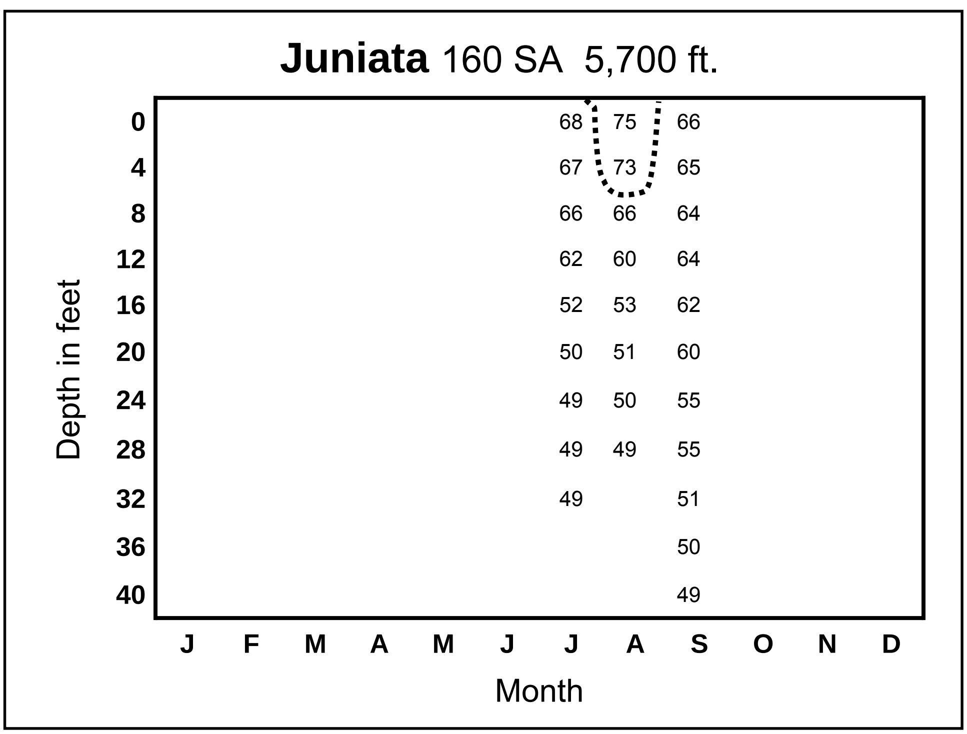

Hollenbeck 60 SA 5,600 ft.
Depth in feet
0 57 64 72 71 75 68
2 57 63 72 70 74 68
4 57 63 72 69 73 67
6 54 62 72 69 72 67
8 52 60 71 68 71 66
10 51 56 64 68 70 66
12 50 55 62 67 69 65
14 49 59 65 68 64
16 49 58 64 67
18 49 57 61 66
20 56 59 65
J F M A M J J A S O N D
Month

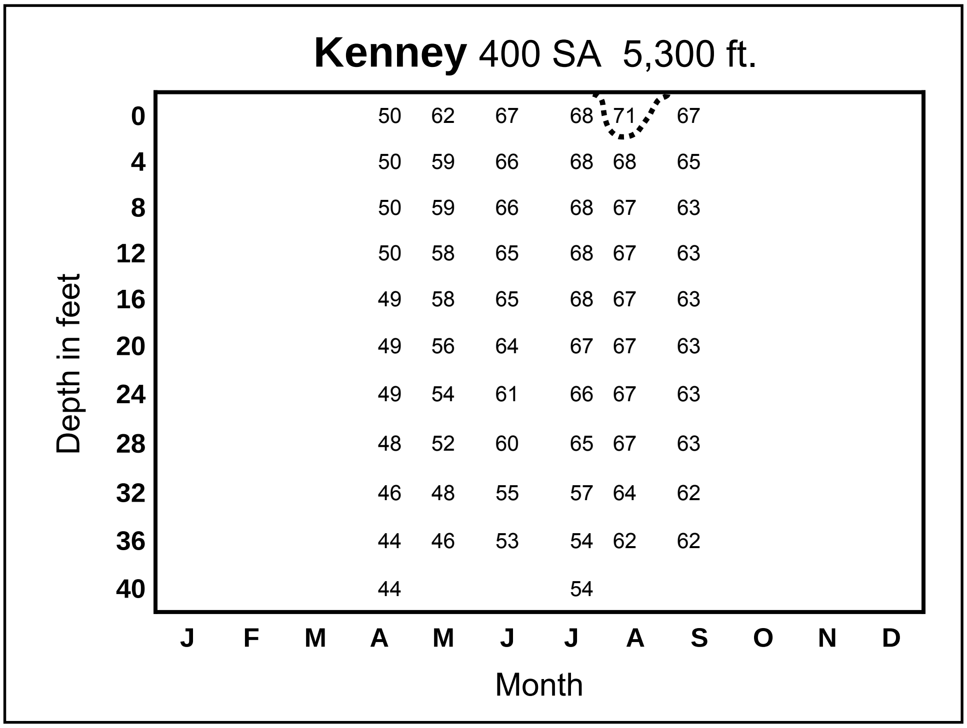

Harvey Gap 190 SA 6,400 ft.
Depth in feet
0 58 63 68 70 72 62
4 56 63 67 69 71 61
8 56 62 67 69 71 61
12 55 62 66 68 70 61
16 54 61 65 68 70 61
20 54 60 65 68 69 61
24 52 58 63 66 68 61
28 50 55 62 66 67 61
32 48 54 60 65 66 61
36 47 52 58 64 65 61
40 46 49 57
J F M A M J J A S O N D
Month

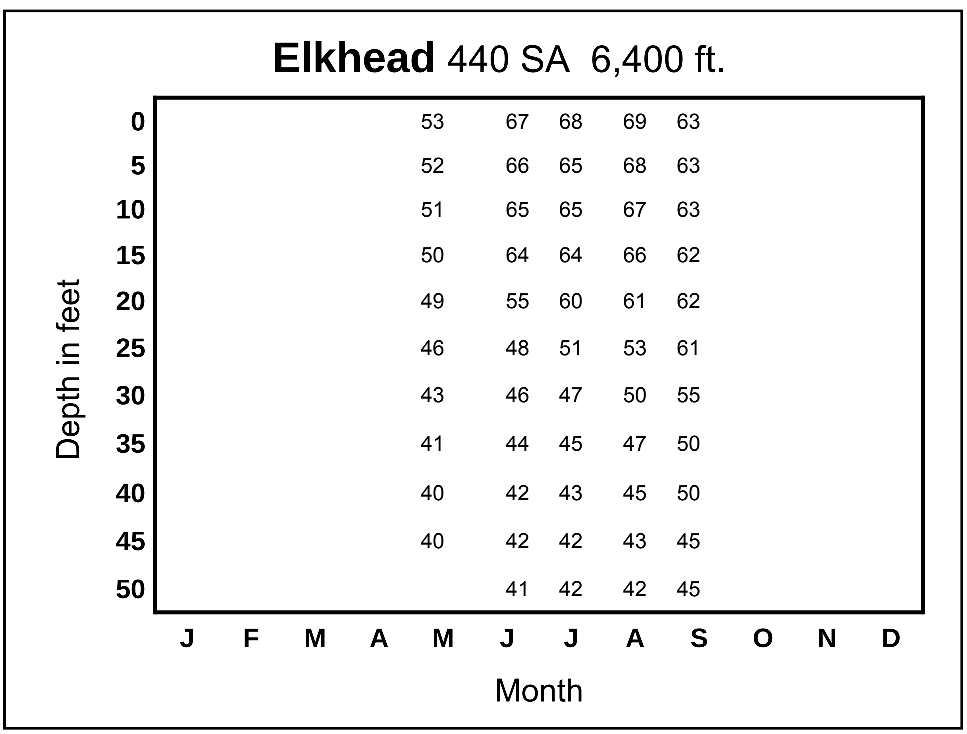

Rio Blanco 100 SA 5,800 ft.
Depth in feet
0 57 67 71 69 68 64
2 53 66 71 69 68 63
4 52 64 71 68 68 63
6 51 64 70 68 68 62
8 51 64 70 68 68 62
10 51 63 69 68 68 62
12 50 63 68 68 68
14 50 68 68
16 50
J F M A M J J A S O N D
Month


Pelican, UT 1,700 SA 4,800 ft.
Depth in feet
0 66 78 72 70
2 66 76 70 68
4 66 76 69 67
6 65 76 69 67
8 65 76 69 67
10 65 76 69 66
12 65 76 69 66
14 65 76 69 66
J F M A M J J A S O N D
Month

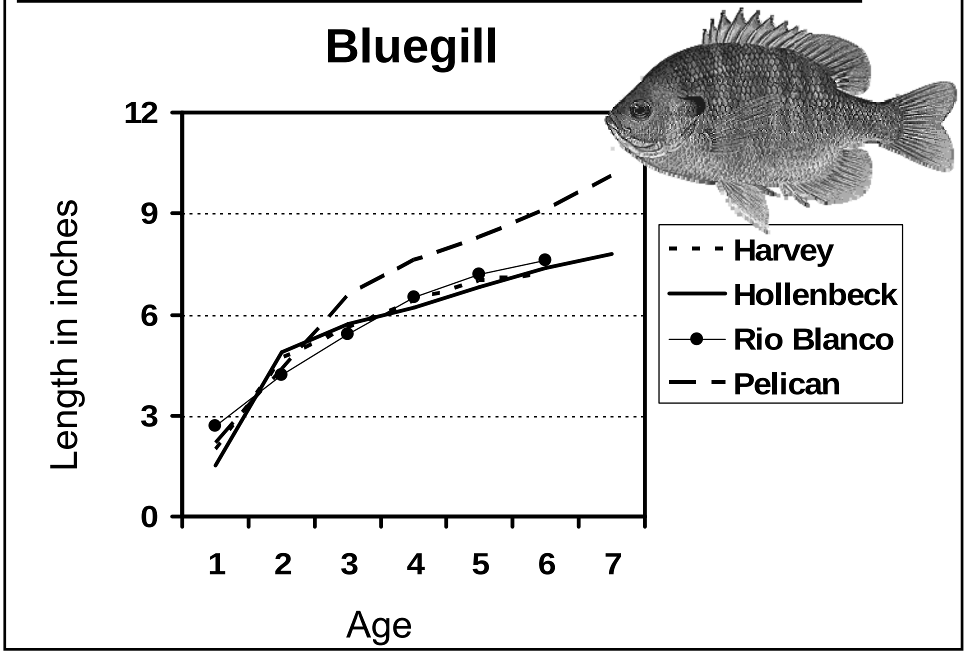

Rifle Gap 400 SA 6,000 ft.
Depth in feet
0 59 61 68 70 73 61
5 56 61 68 70 72 61
10 54 61 67 69 72 61
15 54 60 67 68 71 61
20 52 56 65 68 70 61
25 47 52 62 66 68 61
30 46 50 58 65 66
35 45 48 56 61 63
40 44 46 54 57
45 44 45 50 64
50 44 45 49
J F M A M J J A S O N D
Month

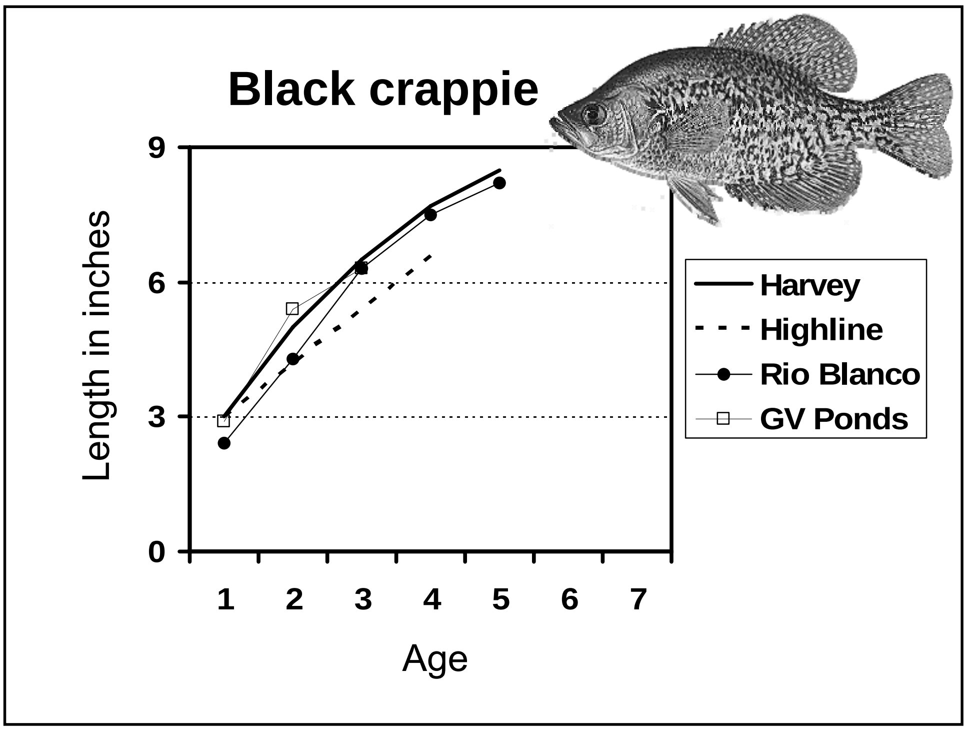

Juniata 160 SA 5,700 ft.
Depth in feet
0 68 75 66
4 67 73 65
8 66 66 64
12 62 60 64
16 52 53 62
20 50 51 60
24 49 50 55
28 49 49 55
32 49 51
36 50
40 49
J F M A M J J A S O N D
Month

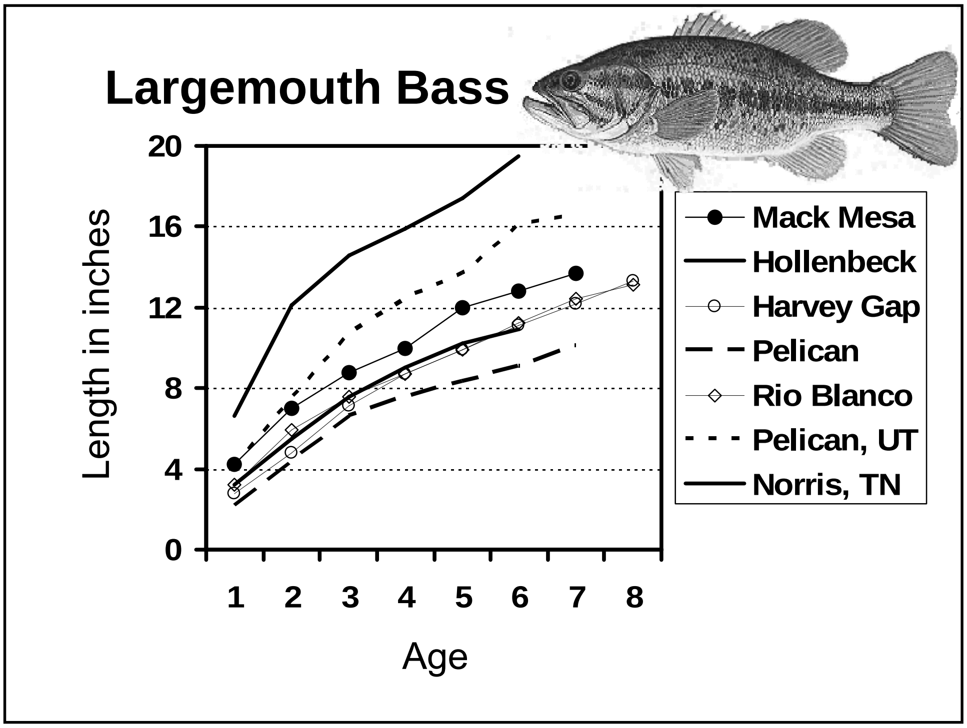

Kenney 400 SA 5,300 ft.
Depth in feet
0 50 62 67 68 71 67
4 50 59 66 68 68 65
8 50 59 66 68 67 63
12 50 58 65 68 67 63
16 49 58 65 68 67 63
20 49 56 64 67 67 63
24 49 54 61 66 67 63
28 48 52 60 65 67 63
32 46 48 55 57 64 62
36 44 46 53 54 62 62
40 44 54
J F M A M J J A S O N D
Month

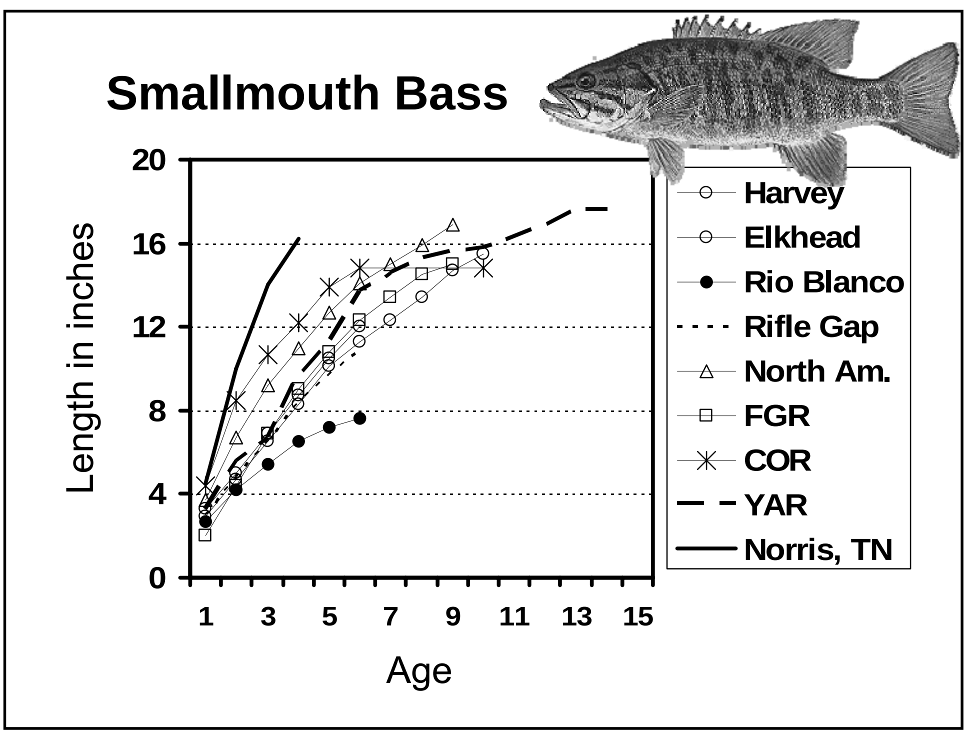

Elkhead 440 SA 6,400 ft.
Depth in feet
0 53 67 68 69 63
5 52 66 65 68 63
10 51 65 65 67 63
15 50 64 64 66 62
20 49 55 60 61 62
25 46 48 51 53 61
30 43 46 47 50 55
35 41 44 45 47 50
40 40 42 43 45 50
45 40 42 42 43 45
50 41 42 42 45
J F M A M J J A S O N D
Month

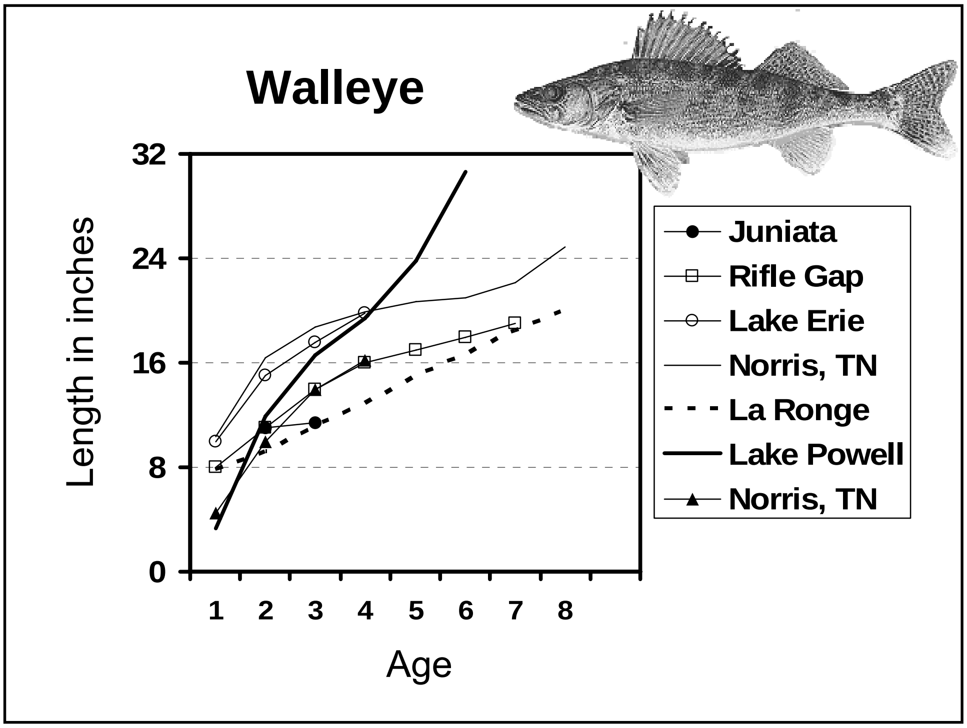
3. NW Warmwater fish growth in NW CO vs. other waters

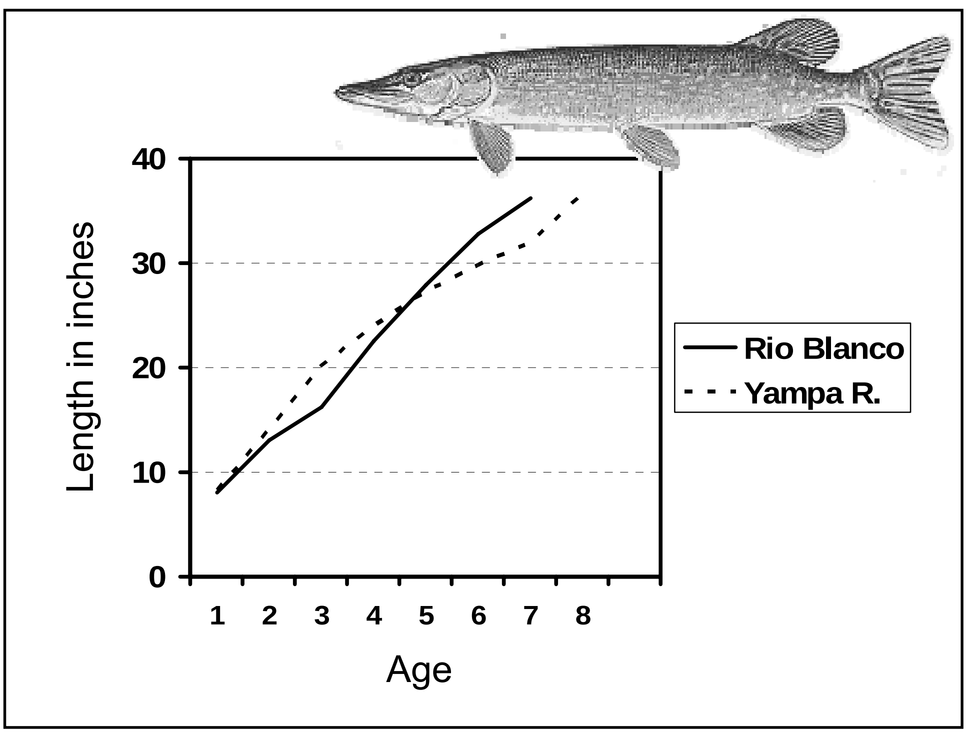





Largemouth Bass
20
16
12
8
4
0
Length in inches
1 2 3 4 5 6 7 8
Age
Mack Mesa
Hollenbeck
Harvey Gap
Pelican
Rio Blanco
Pelican, UT
Norris, TN


Smallmouth Bass
20
16
12
8
4
0
Length in inches
1 3 5 7 9 11 13 15
Age
Harvey
Elkhead
Rio Blanco
Rifle Gap
North Am.
FGR
COR
YAR
Norris, TN


Walleye
Length in inches
32
24
16
8
0
1 2 3 4 5 6 7 8
Age
Juniata
Rifle Gap
Lake Erie
Norris, TN
La Ronge
Lake Powell
Norris, TN


Length in inches
40
30
20
10
0
1 2 3 4 5 6 7 8
Age
Rio Blanco
Yampa R.

5. Angler preferences and surveys

CDOW. Results of a survey of CO warmwater anglers residing in Delta, Garfield, Mesa & Montrose counties. April 2006

1. Angler characteristics/preferences

- anglers fished 16.4 days/year; 4.4 days spent fishing warmwater
- CCF (36%); LMB (25%); BCR (9%); SMB (6%); BGL (5%)
- prefer to fish in large reservoirs (40%); COR (28%); small reservoirs (27%); ponds (22%); GUR (10%)
- want more fishing opportunity in large reservoir (44%); small reservoir (29%); ponds (21%)
- 63% satisfied with warmwater fishing locally
- how important is it to have warmwater fishing within one hour?
  very important 56%; somewhat important (36%)
- Restock after reclamation? vacant (8%); trout only (52%); LMB, BCR & BGL (75%)

CDOW. Inquiry into why CO anglers who bought a fishing license in 2001 either did not buy a license again in 2002 and 2003, or did not buy a license in 2002, but bought again in 2003. Aquatic Wildlife Section Special Report 05-1, December 2005

I. Anglers who did not purchase a license in either 2002 or 2003

- lack of time
- change in attitude or interest
- numbers or sizes of fish

II. Motivations for buying a license among anglers who did not purchase a license in 2002, but purchased a fishing license in 2003

- lack of time
- change in attitude or interest
- numbers or sizes of fish

III. Fishing behaviors of both lapsed and returning anglers

- trout (70%); walleye (9%); bass (6%)
- coldwater lakes/reservoirs (45%); coldwater streams/rivers (32%)
- fish from bank (59%); fish from boat (25%); fish any method (69)
- C&R sometimes (79%); C&R exclusively (31%)

CDOW. 2004 angler survey summary. Aquatic Wildlife Section Special Report 06-1, March 2006

1. **Angler characteristics**
   - start fishing at 11 year or younger
   - average angler has fished for 26 years
   - 75% buy fishing license every year

2. **Angler preferences**
   - trout (78%); walleye (6%); bass (3%)
   - **coldwater lakes/reservoirs in mountains (44%); coldwater streams/rivers (28%); coldwater lakes/reservoirs at low elevations (13%); warmwater lakes pons or reservoirs (11%)**
   - shore (57%); boat (20%); wade (19%)

3. **Fishing activity/opinions**
   - fish average of 20.7 days per year
   - 97% would buy license in 2005
   - 62% strongly or somewhat satisfied with fishing experience

6. Warmwater sport fish attributes & limitations

Species attributes & limitations: **Smallmouth bass**

▲ popular with some anglers; reach size of interest to anglers

▲ consume small-prey & crayfish in reservoirs

▲ often self-sustaining; two-story fishery in reservoirs

▼ highly invasive in mainstem-rivers, harmful to native fishes

▼ winter quiescent, no cold-weather or ice fishery; mercury?

▼ river fishery limited by temperature & turbidity

Species attributes & limitations: **Largemouth bass**

▲ popular with anglers; may reach trophy-size in some waters

▲ can provide angling in ponds & reservoirs

▲ available for stocking; routine under NNFSP

▼ thermally limited growth in NW CO; high mercury burden?

▼ highly invasive in river backwaters, harmful to native fishes

▼ functionally no fishery in rivers due to limited habitat

Species attributes & limitations: **Yellow perch**

▲ popular with some anglers; considered excellent eating

▲ typically easy to catch; high bag limits; low mercury burden

▲ seemingly non-invasive in rivers; low riverine abundance

▲ tolerate low winter oxygen levels

▼ smallish size often criticized; largest perch preferred by pike

▼ illicit introductions; high risk of damage to salmonid fisheries

▼ illicit establishment tends to incite further illicit introductions

Species attributes & limitations: **Walleye**

▲ popular with some anglers; considered excellent eating

▲ reach larger sizes

▲ may reduce sucker biomass

▼ difficult to catch; require abundant soft-rayed fish @ 4-in.

▼ establishment can reduce existing fisheries & angling

▼ increasing in UCRB rivers? – threat to trout & native fishes

▼ mercury consumption advisories

Fish spp.	In.	Hg-ppm	Group	Gen.	Trophic	Mgmt.
Kokanee	12-18	0.13	A	A-B	planktivores insectivores	basic yield liberal bag limits
Rainbow trout	6-12	0.11	A			
	12-18	0.20	B			
Yellow Perch	1-6	0.15	A			
	6-12	0.27	B			
Bullhead	9	0.17	A			
Common carp	18	0.24	B	B-C	benthivores omnivores	non-game & prey moderate bag limits
White sucker	12-18	0.19	A			
	18-24	0.45	C			
Channel catfish	12-18	0.20	B			
	18-24	0.36	C			
Smallmouth bass	1-6	0.28	B			
	6-12	0.37	C			
Black crappie	6-12	0.39	C	C-D	predators piscivores	protective length limits low bag limits
Walleye	16	0.29	C			
	19	0.40	C			
Largemouth bass	12-18	0.70	D			
Northern pike	12-24	0.20	B			
	24-36	0.39	C			
	36-42	0.73	D			

Vallecito Reservoir Mercury Advisory

-Northern pike over 27 inches: no meals for children 6 years and younger; one meal per month for the general population.

- Walleye larger than 18 inches: no meals for pregnant women, women who are nursing or women planning on becoming pregnant; no meals for children 6 years and younger; one meal per month for the general population.

- Walleye smaller than 18 inches: one meal per month for pregnant women, women who are nursing or women planning on becoming pregnant; one meal per month for children 6 years and younger; two meals per month for the general population.

7. Recommendations for warmwater & native fish management

- Advertise warmwater opportunities & improvements
- Restrict stocking of smallmouth bass in western CO
- Moratorium on predator stocking until mercury data available
- Encourage management of trout as feasible
- Pursue stocking of wipers & restrict stocking density
- Do not promote riverine warmwater fisheries
- Clarify/modify channel catfish elevation restriction in NNFSP
- Complete review of reservoir escapement potential
- Maximize message & penalties to combat illicit stocking

APPENDIX C

COLORADO RIVER RECOVERY PROGRAM
FY 2006-2007 SCOPE OF WORK
PROJECT NO.: _147_
STANDARDIZATION OF RECOVERY PROGRAM ELECTROFISHING FLEET

COLORADO RIVER RECOVERY PROGRAM Project No.:147

FY 2006-2007 SCOPE OF WORK

Standardization of Recovery Program Electrofishing Fleet

Lead Agency: Colorado Division of Wildlife

Submitted by: Patrick J. Martinez

Address: Colo. Div. of Wildlife, 711 Independent Ave., Gr. Jct. CO 81501
Phone: (970)255-6141
FAX: (970)255-6111
E-mail: martinez@state.co.us

Date: May 10, 2006 (minor edits by A. Kantola June 12, 2006)

Category:
____Ongoing
____Ongoing-revised project
__X_Requested new project
____Unsolicited proposal

Expected Funding Source:
____Annual funds
____Capital funds
__X_Other (Section 7)

I. Title of Proposal: *Standardization of Recovery Program Electrofishing Fleet*

II. Relationship to RIPRAP:

- General Recovery Program Support Action Plan
  - V.A. Measure and document population parameters to determine status and biological response to recovery actions.
  - V.A. 2. Evaluate population estimates.
  - V.C. Develop and enhance scientific techniques required to complete recovery actions.
  - V.D. Establish sampling procedures to minimize adverse impacts to endangered fishes.
  - V.D.2. Implement scientific sampling protocols to minimize mortality for all endangered fish.

III. Study Background/Rationale and Hypotheses:

The Colorado River Recovery Program consists of essentially six separate field stations conducting electrofishing in riverine critical habitat for endangered fishes and in adjacent river reaches. These stations include: U.S. Fish and Wildlife, Colorado River Fishery Project offices in Grand Junction, CO, and in Vernal, UT; Utah Division of Wildlife Resources offices in Moab and Vernal, UT; Colorado Division of Wildlife in Grand Junction, and the Larval Fish Lab at Colorado State University in Fort Collins. Table 1 shows that each station has two to four boats that operate on one or more rivers each year to capture endangered, native or nonnative fishes.

Kolz (1989) developed a model of the transfer of power from water to fish which compensated for the power needed to deliver constant electric power to fish in waters with differing conductivities. This model is being used as a basis to standardize electrofishing in fishery research and management programs (Burkhardt and Gutreuter 1995, Chick et al. 1999, Miranda 2005). Bonar and Hubert (2002) elaborated the benefits of standardization for fisheries programs, including minimizing variation in catchability and maximizing catch. Standardizing the electrofishing fleet within the Recovery Program would promote and facilitate comparison of catch data among rivers and reaches, and may maximize the catch of target native or nonnative fishes, thus benefiting stock assessments or removal of target fishes.

Standardization of electrofishing in waters having differing conductivities is essential when monitoring temporal and spatial differences in fish assemblages (Miranda and Dolan 2003). This scenario is characteristic of work performed by the Recovery Program for Endangered Fishes in the Upper Colorado River Basin where periodic estimates of fish density and abundance are derived by electrofishing in several rivers known to have different water conductivities. Standardization of the amount of electrical power transferred to fish can reduce the variability of survey data and potentially reduce injury to fish (Miranda 2005). Burkhardt and Gutreuter (1995) improved the predictability of their electrofishing catch rates by adopting an electrofishing standardization protocol. Snyder (1995) cautioned that electrofishing-induced injury and mortality in sampled fishes can often be linked to excessive power levels.

Standardization of electrofishing equipment requires adjusting power output to keep constant the amount of power transferred to fish in diverse water conditions; however, this relationship can be affected by differences in electrode arrays (Miranda 2005). Further, the Recovery Program electrofishing fleet has switched primarily to Smith-Root GPP-5.0 electroshockers (Table 1) and some confusion may exist about the use of the percent of range control (Miranda and Spencer 2005). While complete standardization of an electrofishing fleet may not be entirely feasible, standardization of variables that can be accommodated by a fleet remains advisable (Miranda 2005).

IV. Study Goals, Objectives, End Product:

Goal

The goal of this Scope-of-Work is to provide members of the Recovery Program's electrofishing fleet with guidelines for standardizing their boats and electrode arrays to facilitate standardization of the power output of their electrofishing boats. This standardization is focused on the aluminum boats in the fleet operating with boom electroshockers. Upon standardization of the electrofishing boats themselves, a model specific to the conductivity range encountered by the Recovery Program electrofishing fleet in the upper Colorado River Basin (100-1000 µmhos) will facilitate setting electroshocker controls to achieve recommended power output to maximize fish capture while minimizing the likelihood of fish injury or mortality. Additional benefits of this process should be to reduce catch variability among boats and rivers, to improve comparability of data across rivers, reaches and species, and to maximize the catchability of target fishes.

Objectives

1. Establish "standard" electrofishing boat to which other boats in the fleet will be compared to evaluate the equivalent resistance of their electrode arrays.

2. Recommend electrode deployment, including anode (sphere) and cathode (boat hull) configuration, size and spacing to facilitate standardized electrical field and power output that can be accommodated by all boats in the fleet.

3. Evaluate all aluminum boats with boom electroshockers in the fleet to identify the equivalent resistance of their electrodes and recommend maintenance, modification or repairs required for individual boats to conform to the "standard" boat.

4. Evaluate spherical anode size relative to power output capabilities of electroshockers and develop model to recommend conductivity thresholds for changing anode size to optimize power output of electroshocker.

5. Explore response of electroshockers and their control settings to variable loads representing changes in water conductivity to assess their maintenance of expected waveforms in an attempt to identify any current properties that could pose a threat to fish exposed to the electrical field.

End Products

1. Standardized guidelines for deployment of electrodes including spacing, style, size, submersion and maintenance.

2. An evaluation of the equivalent resistance of the fleet's individual aluminum boats operating with boom electroshockers and recommendations needed for individual boats to conform to the "standard".

3. A model specific to the conductivity range encountered by the fleet's boats in Upper Colorado River basin recommending conductivity thresholds at which adjustments of electroshocker control settings or a switch to different diameter spherical anodes would be made to optimize power output.

4. Issue an alert, if necessary, to the Upper Basin fleet and to electroshocker manufactures if the variable load assessment identifies deleterious current properties that could pose a threat to fish exposed to the electrical field.

V. Study Area:

Work to establish "standard" boat for evaluation of equivalent resistance of electrodes, compare spherical anode sizes to power capabilities of electroshockers, and examination of electroshocker current properties under variable load will be performed in Grand Junction. Evaluation of the fleet's individual boats will be performed either in Grand Junction or at the respective field stations.

VI. Study Methods/Approach:

Larry Kolz, retired engineer – USFWS, will make electrical measurements and calculations (Kolz 1993) using the 18-foot CLARK aluminum flat-bottom boat operated by Lori Martin, aquatic biologist-CDOW, to establish the "standard" boat using fully submerged spherical anodes. Larry will perform, or train a designee, to conduct the assessment of equivalent resistance of the individual boats in the fleet. The evaluation of individual boats will be performed in water of known conductivity, either in Grand Junction or at the Recovery program's stations in UT. A model specific to the conductivity range encountered by the fleet's boats in Upper Colorado River Basin recommending conductivity thresholds at which adjustments to electroshocker control settings or a switch to different sizes spherical anodes would be made to optimize power output. Larry will also simulate changes in water conductivity via incremental addition of resistors to examine current properties vs. the control settings of an electroshocker under load. This evaluation will allow examination of power output, but will also identify any changes in electrical waveforms that may deviate from specifications or that may be harmful to fish.

VII. Task Description and Schedule

Description

1. Establish "standard" electrofishing boat.

2. Recommend electrode deployment that can be accommodated by all boats in the fleet.

3. Evaluate electrofishing fleet for the equivalent resistance of their electrodes and make recommendations needed for individual boats to conform to the "standard" boat.

4. Develop model specific to conductivity range encountered by electrofishing fleet in rivers of the Upper Basin to guide selection of spherical anode diameter and electroshocker control settings.

5. Identify current properties of electroshocker output at various control setting when exposed to resistors simulating changing water conductivity.

VIII. **FY-2006 Work (first year of two-year project)**

Deliverables/Due Dates:

1. Specifications for fleet's "Standard Boat" (September 2006).

2. Model for Upper Basin water conductivity range recommending anode diameter and electroshocker control settings (September 2006).

3 Begin evaluation of conformity of individual boats in electrofishing fleet to "Standard Boat" (September 2006)

Budget
Labor: 180 hours @ $25/hour = $4,500
Travel: $500

TOTAL FY 2006 = Up to $5,000

FY-2007 Work (second year of two-year project)

Deliverables/Due Dates:

1. Evaluation of electroshockers under variable resistors (December 2006)

2. Presentation to Upper Basin Researchers Meeting (January 2006).

3. Complete evaluation of conformity of individual boats in electrofishing fleet to "Standard Boat" (April 2007).

4. Prepare report of findings (July 2007).

Budget
Labor: 180 hours @ $25/hour = $4,500
Travel: $500

TOTAL FY 2007 = Up to $5,000

IX. Budget summary
2006 up to $5,000
2007 up to $5,000
Total up to $10,000

X. Reviewers:

Lori Martin, Colorado Division of Wildlife
Larry Kolz, National Conservation Training Center

XI. References

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Bonar, S. A., and W. A. Hubert. 2002. Standard sampling of inland fish: benefits, challenges, and a call for action. Fisheries 27(3):10-16.

Burkhardt, R. W., and S. Gutreuter. 1995. Improving electrofishing catch consistency by standardizing power. North American Journal of Fisheries Management 15:375-381.

Chick, J. H., S. Coyne, and J. C. Trexler. 1999. Effectiveness of airboat electrofishing for sampling fishes in shallow, vegetated habitats. North American Journal of Fisheries Management 19::957-967.

Kolz, A. L. 1989. A power transfer theory for electrofishing. U.S. Fish and Wildlife Service Technical Report 22:1-11.

Kolz, A. L. 1993. In-water electrical measurement for evaluating electrofishing systems. U.S. Fish and Wildlife Service Biological Report 11.

Miranda. L. E. 2005. Refining boat electrofishing equipment to improve consistency and reduce harm to fish. North American Journal of Fisheries Management 25:605-618.

Miranda, L. E. and C. R. Dolan. 2003. Test of a power transfer model for standardized electrofishing. Transactions of the American Fisheries Society 132:1179-1185.

Miranda, L. E., and A. B. Spencer. 2005. Understanding the output of a Smith-Root GPP electrofisher. North American Journal of Fisheries Management 25:848-852.

Snyder, D. E. 1995. Impacts of electrofishing on fish. Fisheries 20(1):26-39.

Table 1. Summary of aluminum-hull boats in Colorado River Recovery Program electrofishing fleet, May 2006.

Station	Boat mfg.	Name/description	Length	Shocker
CDOW Gr.Jct.	Clark	Martin, flat bottom	18’	GPP-5.0
	Clark	Elmblad, flat bottom	18’	GPP-5.0
	Clark	Chaser, flat bottom	17’	GPP-5.0
CSU - LFL	Clark	Disco-Valante, semi-V	16’	GPP-5.0
	Clark	Deja vu, semi-V	16’	VVP-15
	Clark	Sea Monkey, semi-V	17’	GPP-5.0
UDWR Moab	Waterman	jon-boat, flat-bottom	16’	GPP-5.0
	Waterman	jon-boat, flat-bottom	16’	GPP-5.0
UDWR Vernal	?	?		GPP-5.0
	?	?		GPP-5.0
USFWS Gr.Jct.	Clark	semi-V	17’	GPP-5.0
	?	War Wagon I	16’	VVP-15(B)
	?	War Wagon II	16’	VVP-15(B)
USFWS Vernal	Lowe	Roughneck, ?	17’	GPP-5.0
	Lowe	Roughneck, ?	17’	GPP-5.0
	Monark	?	16’	GPP-5.0
	Monark	?	16’	GPP-5.0

APPENDIX D

COLORADO RIVER RECOVERY PROGRAM
FY 2006 ANNUAL PROJECT REPORT
PROJECT NO.: 147
STANDARDIZATION OF RECOVERY PROGRAM ELECTROFISHING FLEET

COLORADO RIVER RECOVERY PROGRAM RECOVERY PROGRAM
FY 2006 ANNUAL PROJECT REPORT PROJECT NUMBER: 147

I. Project Title: ***Standardization of Recovery Program Electrofishing Fleet***

II. Principal Investigator(s):

Patrick J. Martinez
Colo. Div. Wildlife
711 Independent Ave.
Grand Jct., CO 81505
pat.martinez@state.co.us
Phone 970-255-6141
FAX 970-255-6111

Larry Kolz
447 Whitetail Lane
Grand Jct., CO 81503
lkolz@bresnan.net
Phone 970-255-8338

III. Project Summary:

The Upper Colorado River Recovery Program consists of six separate field stations located in Colorado and Utah conducting electrofishing in riverine critical habitat for endangered fishes and in adjacent river reaches. Each of these stations has two to four aluminum-hull elctrofishing boats that operate on one or more rivers each year to capture endangered, native or nonnative fishes. Kolz (1989) developed a model of the transfer of power from water to fish which compensated for the power needed to deliver constant electric power to fish in waters with differing conductivities.

Standardization of electrofishing in waters having differing conductivities is now viewed as essential when monitoring temporal and spatial differences in fish assemblages (Miranda and Dolan 2003). The benefits of standardization for fisheries programs include minimizing variation in catchability, maximizing catch and reducing injury to fish (Bonar and Hubert 2002, Miranda 2005). Standardizing the electrofishing fleet within the Recovery Program would promote and facilitate comparison of catch data among rivers and reaches, and may maximize the catch of target native or nonnative fishes, thus benefiting stock assessments or removal of target fishes.

The purpose of this project is to provide a standardization protocol for the aluminum-hulled boats in the Recovery Program's electrofishing fleet, to evaluate individual boats in the fleet to determine if they conform to standardized critieria, and to make recommendations that would bring individual boats into conformance with standards set for the electrofishing fleet. The electrical resistance of the standard boat hull in combination with dual spherical anodes has been calculated. The significant parameter from this study is the 2.1 ohms of electrical resistance calculated for the boat hull. This is the first parameter that will be measured for the other boats in the Recovery Program's fleet to ensure that all the boats have equally effective hulls. Implementation of this standardization protocol and evaluation of the electrofishing fleet is scheduled for completion in 2007.

IV. Study Schedule:

FY-06 -Establish electrical resistance for "standard boat" using two spherical anodes.
-Develop guidelines to implement standard criteria for electofishing fleet.

FY-07 -Evaluate output characteristics of the Smith-Root and Coffelt pulse generators.
-Determine conformance of individual boats in fleet to standardized criteria.

V. Relationship to RIPRAP:

General Recovery Program Support Action Plan

V.A. Measure and document population parameters to determine status and biological response to recovery actions.
V.A. 2. Evaluate population estimates.
V.C. Develop and enhance scientific techniques required to complete recovery actions.
V.D. Establish sampling procedures to minimize adverse impacts to endangered fishes.
V.D.2. Implement scientific sampling protocols to minimize mortality for all endangered fish.

VI. Accomplishment of FY 2006 Tasks and Deliverables, Discussion of Initial Findings and Shortcomings:

1. Establish “standard” electrofishing boat. *As noted above, the standard electrical resistance to which all aluminum-hulled boats in the electrofishing fleet will be compared has been developed.*

2. Recommend electrode deployment that can be accommodated by all boats in the fleet. *Key measurements pertaining to electrode deployment were obtained for boats from the six field stations to assess their capacity to conform to standard guidelines.*

3. Evaluate electrofishing fleet for the equivalent resistance of their electrodes and make recommendations needed for individual boats to conform to the “standard” boat. *Evaluation of individual boats will commence in 2007. The implementation of standardized electrofishing techniques will require field personnel to be attentive to significant electrofishing parameters. An outline of these parameters has been prepared and will be refined as information from the generator/electroshocker output evaluation becomes available.*

4. Develop model specific to conductivity range encountered by electrofishing fleet in rivers of the Upper Basin to guide selection of spherical anode diameter and electroshocker control settings. *Voltage and current measurements were taken with the standard boat using paired combinations of spherical anodes having diameters of 8, 9, 10, 11, and 12 inches. The total resistance variations for the electrode arrays for each combination of the five sphere sizes in water conductivities of 100 to 1000 µS/cm have been calculated. It is not necessary, at this time, to select a standard for the size for the anode spheres, but it will be recommended that field operators experiment with the 8, 9 and 10-inch spheres to compare their effectiveness with the 11-inch anodes currently in use.*

5. Identify current properties of electroshocker output at various control setting when exposed to resistors simulating changing water conductivity. *In November, 2006, we will initiate an evaluation of the output characteristics of the Smith-Root and Coffelt pulse generators. These measurements will be made by operating the pulsators into fixed resistive loads. The goal is to develop a power chart that defines the limiting parameters of peak voltage, current, and power for the GPP-5.0 and VVP-15 electroshockers.*

VII. Recommendations:
-Complete evaluation of electroshocker outputs and incorporate findings in standard electrofishing protocol.
-Perform electrical resistance evaluation of as many individual electrofishing boats as feasible prior to completion of 2007 sampling season, preferably under local water conditions in which individual boats typically operate.

VIII. Project Status: *On track and ongoing.*

IX. FY 2006 Budget Status

A. Funds Provided: *$10,000 from National Fish and Wildlife Association*.
B. Funds Expended: *$1,425, plus approximately $600 from RIP funds for stainless steel spheres and electrical resistors and about $400 from CDOW for electrical meters and probes.*
C. Difference: *$8,575. Work is ongoing and evaluation of individual boat is expected to consume the majority of the budget.*
D. Percent of the FY 2006 work completed, and projected costs to complete: *25%*
E. Recovery Program funds spent for publication charges: *None.*

X. Status of Data Submission (Where applicable): N/A.

XI. Signed: Patrick J. Martinez November 6, 2006
Principal Investigator Date

References:

Bonar, S. A., and W. A. Hubert. 2002. Standard sampling of inland fish: benefits, challenges, and a call for action. Fisheries 27(3):10-16.

Kolz, A. L. 1989. A power transfer theory for electrofishing. U.S. Fish and Wildlife Service Technical Report 22:1-11.

Miranda. L. E. 2005. Refining boat electrofishing equipment to improve consistency and reduce harm to fish. North American Journal of Fisheries Management 25:605-618.

Miranda, L. E. and C. R. Dolan. 2003. Test of a power transfer model for standardized electrofishing. Transactions of the American Fisheries Society 132:1179-1185.

APPENDIX E

SPECIFIC AND AMBIENT CONDUCTANCE IN RIVERS OF THE UPPER COLORADO RIVER BASIN OBTAINED FROM 22 USGS STREAM GAGES IN SIX RIVERS FROM 1997-2005

Table E-1. Specific and ambient conductivity for the Yampa River at Steamboat Springs, Colorado (Routt County, Hydrologic Unit Code 14050001, USGS 09239500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 6,695 feet asl.

Yampa River at Steamboat Springs, CO**: Specific Conductance**, water, unfiltered, microsimens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	316		345	245	110	83	113	263	276	209	210	240
1998	262	273	244	232	115	59	169	285	247	255	290	
1999	309		306		139	67	169	295		316	325	
2000	296	312	314	235	59	73	152	259	259		276	293
2001		345	323	240	54	110	226	300	324	318	294	277
2002		339		278	67	124	199	211	256	251		
2003	277	309	305		123	98		260	286	305		318
2004			311		86	66	186	222		197		
2005	288					75		255	275			
Mean of monthly specific conductivity	291.3	315.6	306.9	246.0	94.1	83.9	173.4	261.1	274.7	264.4	279.0	282.0

Yampa River at Steamboat Springs, CO: **Ambient Conductance**, water, unfiltered, microsimens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	193	214		162	74	58	86	226	243	162	134	146
1998	161	167	157	162	81	41	152	258	201	186	182	
1999	190		196		98	47	153	262		209	209	
2000	182	208	202	154	43	61	140	210	194		176	179
2001		212	224	170	37	99	208	276	263	261	206	171
2002		209		197	46	113	186	184	211	168		
2003	170	189	200		86	74		248	243	241		199
2004			202		63	51	172	194		137		
2005	176					58		215	222			
Mean of monthly ambient conductivity	178.7	199.8	196.8	169.0	66.0	66.9	156.7	230.3	225.3	194.9	181.4	173.8

Table E-2. Specific and ambient conductivity for the Yampa River below Craig, Colorado (Moffat County, Hydrologic Unit Code 14050001, USGS 09247600), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 6,100 feet asl.

Yampa River below Craig, CO: **Specific Conductance**, water, unfiltered, microsimens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			637.50	729.00	370.00	133.00		298.00	337.00			493.00
1998	521.00	622.00	476.00	591.50	147.00	150.00	222.00	358.67	380.33	438.00	400.00	
1999		600.00	871.00		188.50	94.00	199.00	337.50		412.33	466.00	
2000	506.00	675.00	793.50	329.00	176.00	139.67	299.00	333.00	435.00	215.00	550.00	400.00
2001			616.00	657.00	118.38	158.00	357.00	433.00	438.00	442.33		500.00
2002			680.00	574.00	106.00	255.00	411.00	435.89	424.00	352.00	365.00	
2003		402.00	585.00	465.50	146.00			341.00	446.00	396.00		407.00
2004			587.00		85.00	144.00	203.50	362.00		217.00		
2005	293.00					134.00		273.50	386.00			
Mean of monthly specific conductivity	440.00	574.75	655.75	557.67	167.11	150.96	281.92	352.51	406.62	353.24	445.25	450.00

Yampa River below Craig, CO: **Ambient Conductance**, water, unfiltered, microsimens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			415.64	490.60	273.29	105.91		280.81	277.55			300.50
1998	317.57	381.39	297.85	409.25	111.63	118.04	204.28	337.76	339.96	345.02	249.68	
1999		365.72	563.40		139.09	71.52	179.88	321.52		310.36	309.90	
2000	309.03	419.66	528.22	246.88	131.81	115.63	289.39	316.00	362.55	172.92	347.41	243.81
2001			392.58	445.66	87.07	138.09	337.74	382.97	373.09	334.13		305.97
2002			419.44	411.56	84.08	257.54	400.95	398.61	338.99	232.70	228.28	
2003		245.52	360.84	334.09	106.35			330.37	426.14	340.67		248.08
2004			370.04		65.32	126.36	194.63	342.81		149.84		
2005	178.95					107.56		255.69	304.96			
Mean of monthly ambient conductivity	268.52	353.07	418.50	389.67	124.83	130.08	267.81	329.62	346.18	269.38	283.82	274.59

Table E-3. Specific and ambient conductivity for the Yampa River near Maybell, Colorado (Moffat County, Hydrologic Unit Code 14050002, USGS 09251000), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 5,900 feet asl.

Yampa River near Maybell, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	770	753	705	916	336	173	250	353	484	391		
1998	712	900	805	701	265	170	354	546	605	621	587	
1999	827		862		361	139	294	440		604	648	
2000	776	940	857	338	189	236	447		590	481	686	609
2001	619		786	317	124	256	434	473		562		659
2002		617	753	268	170	291	868	1029	1000	467	536	598
2003		614	783	710	345	118	351	587		519	513	
2004		597	636	284	136	170	316	445	435	272	316	
2005		515	615	236	120	112	282	360	519			
Mean of monthly specific conductivity	740.8	705.1	755.8	471.3	227.3	185.0	399.6	529.1	605.5	489.6	547.7	622.0
Yampa River near Maybell, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	469	459	481	691	262	141	242	320	433	288		
1998	434	552	512	499	202	137	335	523	587	453	368	
1999	504		581		259	88	269	413		451	433	
2000	473	595	565	251	147	210	443		526	385	420	371
2001	377		496	243	98	233	436	428		439		403
2002		376	469	206	131	272	824	979	812	333	362	364
2003		375	524	498	251	93	349	536		408	335	
2004		364	431	201	100	149	296	380	389	200	208	
2005		314	420	172	93	94	263	323	446			
Mean of monthly ambient conductivity	451.4	433.6	497.7	345.1	171.4	157.4	384.1	487.8	532.2	369.6	354.3	379.3

Table E-4. Specific and ambient conductivity for the Yampa River near Deerlodge Park, Colorado (Moffat County, Hydrologic Unit Code 14050002, USGS 09260050), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 5,600 feet asl.

Yampa River at Deerlodge Park, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			643.00	674.00	231.00	193.00		422.50			635.00	684.00
1998	626.00	853.00	794.50	685.50	261.67	209.67	285.00		644.00	635.00	573.00	
1999		684.00	685.50		233.33	164.00		407.58		623.67	662.00	
2000	849.00	850.00	845.00	549.50		123.53	445.00	754.67	646.00	459.00		594.00
2001			691.00	418.00	157.50	229.56	474.00	700.00	727.00	657.67		
2002				640.00	244.00	233.00	862.00	984.78	879.50	586.00	619.00	
2003			618.00	350.00	193.00		440.00	683.50	639.00	596.00		619.00
2004			617.00	316.00	131.00		346.33	523.00		380.00		
2005	495.00					193.00		405.00	639.00			
Mean of monthly specific conductivity	656.67	795.67	699.14	519.00	207.36	192.25	475.39	610.13	695.75	562.48	622.25	632.33

Yampa River at Deerlodge Park, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997			453.78	462.65	171.64	162.78		387.25			390.13	416.09
1998	384.60	518.90	521.43	499.84	201.48	168.63	266.44		596.14	479.35	364.09	
1999		424.42	450.93		179.66	133.92		394.20		467.80	449.05	
2000	517.49	572.03	581.18	392.82		105.32	444.12	752.06	562.38	382.55		362.06
2001			425.38	328.29	126.46	201.61	427.62	704.17	614.37	474.67		
2002				466.21	206.20	214.83	896.38	987.38	695.54	402.25	391.77	
2003			378.18	266.84	142.55		451.47	656.31	578.76	464.39		377.30
2004			395.17	245.25	101.47		330.26	517.85		255.56		
2005	302.62					153.69		401.01	532.57			
Mean of monthly ambient conductivity	401.57	505.11	458.01	380.27	161.35	162.97	469.38	600.03	596.63	418.08	398.76	385.15

Table E-5. Specific and ambient conductivity for the White River near Meeker, Colorado (Rio Blanco County, Hydrologic Unit Code 14050005, USGS 09304500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 6,300 feet asl.

White River near Meeker, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		437	457	461	245	222	361	400	361	375		330
1998		530		360		234	347	423	479		492	
1999	508	489	480	450	238	231	383		371	473		500
2000		496	547	404	224	460		599	496		556	550
2001	537	476		515	230	479			583	555		489
2002		483	526	347	403	577	700			549		520
2003	512		503	413	222		402		588	491		531
2004	521	563	433	385	272	465		573		498		
2005									510			
Mean of monthly specific conductivity	519.5	496.3	491.0	416.9	262.0	381.1	438.6	498.8	484.0	490.2	524.0	486.7

White River near Meeker, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		268	311	283	169	160	308	327	262	285		201
1998		336		258		178	271	373	402		320	
1999	317	302	331	291	172	161	328		276	329		308
2000		322	381	306	158	394		513	366		362	335
2001	327	317		350	183	391			445	474		299
2002		316	336	266	292	455	647			404		331
2003	314		336	296	162		353		467	387		324
2004	318	378	314	263	190	388		514		366		
2005									388			
Mean of monthly ambient conductivity	319.0	319.9	334.8	289.1	189.4	303.9	381.4	431.8	372.3	374.2	341.0	299.7

Table E-6. Specific and ambient conductivity for the White River below Taylor Draw Reservoir (Kenney Reservoir), above Rangely, Colorado (Rio Blanco County, Hydrologic Unit Code 14050007, USGS 09306305), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 5,260 feet asl.

White River below Taylor Draw Res. Above Rangely, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997				732.00		339.00		339.00	623.00			
1998	693.00				473.00	510.00	675.00	686.00			725.00	
1999				797.00		332.00		704.00	711.00		725.00	
2000				812.00	421.00		710.00	813.00			714.00	
2001			825.00			339.00	671.00	734.00				
2002			695.00		555.00	806.00	930.00		966.00			
2003		757.00			434.00		552.00	645.00		644.00		
2004			697.00		404.00		637.00				623.00	
2005		696.00		669.00		417.00			699.00			
Mean of monthly specific conductivity	693.00	726.50	739.00	752.50	457.40	457.17	695.83	653.50	749.75	644.00	696.75	-
White River below Taylor Draw Res. Above Rangely, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997				543.89		275.36		298.06	576.70			
1998	424.92				365.64	390.36	672.33	640.06			516.74	
1999				577.70		273.44		649.10	643.97		482.14	
2000				575.32	350.53		674.37	755.56			450.11	
2001			536.82			274.27	621.13	695.79				
2002			436.40		451.70	767.07	909.96		878.41			
2003		469.71			331.53		518.11	621.18		505.78		
2004			431.63		326.21		592.00				436.20	
2005		447.53		486.37		332.73			608.52			
Mean of monthly ambient conductivity	424.92	458.62	468.28	545.82	365.12	385.54	664.65	609.96	676.90	505.78	471.30	-

Table E-7. Specific and ambient conductivity for the Colorado River below Glenwood Springs, Colorado (Garfield County, Hydrologic Unit Code 14010005, USGS 09085100), 1997-1999. Ambient conductivity calculated using available water temperature records. Gage at 5,701 feet asl.

Colorado River below Glenwood Springs, CO, **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	760.0	757.0		620.0	302.5		467.0		700.0	605.0	760.0	
1998	668.0	700.0		612.0	299.0	251.0	330.0	670.0		616.0	732.0	
1999	716.0	787.0		737.0	392.0	317.5		560.0				
Mean of monthly specific conductivity	714.7	748.0		656.3	331.2	284.3	398.5	615.0	700.0	610.5	746.0	

Ambient Conductance, Water, Unfiltered, microsimens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	486.8	489.7		425.6	220.8		390.8		563.0	472.3	491.6	
1998	419.4	457.3		424.3	222.2	192.1	265.4	583.3		448.7	492.6	
1999	447.8	490.3		495.0	288.4	238.5		460.3				
Mean of monthly ambient conductivity	451.3	479.1		448.3	243.8	215.3	328.1	521.8	563.0	460.5	492.1	

Table E-8. Specific and ambient conductivity for the Colorado River near Cameo, Colorado (Mesa County, Hydrologic Unit Code 14010005, USGS 09095500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,814 feet asl.

Colorado River near Cameo, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	1020	1090	848	574	351	257	597	567	806	776	935	898
1998	902	965	991	804	469	426	489	817	990	917	980	
1999			1280	1070		336	664		874	793	1100	
2000	1080		1080	732	292	286	863	862	864	935	1040	1270
2001		1254	1260	1040	446	603	938	839	898	1010		1230
2002			1340	816	790	920		1100	1210	1230		1360
2003		1350	1330	1080	383	398	834	875		836		1140
2004		1220	1020	991	405	642	915	994			940	1190
2005	1210	1200		602	300	397	526		895			
Mean of monthly specific conductivity	1053.0	1179.8	1143.6	856.6	429.5	473.9	728.3	864.9	933.9	928.1	999.0	1181.3

Colorado River near Cameo, CO: **Ambient Conductance**, water, unfiltered, microseimens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	646	709	603	435	264	208	535	489	727	55	641	564
1998	565	629	662	594	349	339	419	739	898	710	677	
1999			879	819		262	610		746	609	717	
2000	715		743	556	230	222	786	773	737	684	660	805
2001		841	902	841	345	527	865	744	710	743		750
2002			893	631	655	825		1037	1043	896		852
2003		900	940	820	298	321	778	813		646		727
2004		819	803	788	305	566	862	891			639	725
2005	770	766		446	233	308	462		731			
Mean of monthly ambient conductivity	674.0	777.3	803.1	658.9	334.9	397.6	664.6	783.7	798.9	620.4	666.8	737.2

Table E-9. Specific and ambient conductivity for the Colorado River near Colorado-Utah State Line, Colorado (Mesa County, Hydrologic Unit Code 14010005, USGS 09163500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,325 feet asl.

Colorado River near Colorado-Utah State Line, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	887		724	468	375	301	544	837	1000	819	882	832
1998	858	859	915	795	436	480	625	1070	1200	1010	1100	1160
1999	1160	1120	1170	967	619	473	697	861	895	762	1100	
2000	1085	1140	947	917	409	517	1060	1060	1147	1190	1240	1230
2001	1280	1250	1220	1050	751	662	1100	1190	1130	1230		1280
2002		1170	1170	847	943		1320	1400	1600	1510		1470
2003		1470	1240	1260	485	537	1060		1050	1210		1300
2004			1034	1030	677	880	1170	1260			1230	1330
2005		1150		472	445	437	699	1170	1100			
Mean of monthly specific conductivity	1054.0	1165.6	1052.5	867.3	571.1	535.9	919.4	1106.0	1140.3	1104.4	1110.4	1228.9

Colorado River near Colorado-Utah State Line, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	584		503	346	290	242	473	776	924	616	618	522
1998	550	556	631	592	349	393	576	1018	1106	779	755	716
1999	755	743	844	729	500	392	644	768	759	597	749	
2000	689	790	671	702	336	446	1017	979	1031	907	812	765
2001	796	799	871	820	616	539	1122	1146	1009	932		796
2002		757	811	668	766	1294	1359	1393	1109	957		999
2003		912	964	379	448	1031	858		881	828		918
2004			594	853	579	885	1072	1146			833	812
2005		742		332	352	348	639	1116	926			
Mean of monthly ambient conductivity	674.8	757.0	736.1	602.3	470.7	618.9	862.2	1042.8	968.1	802.3	753.4	789.7

Table E-10. Specific and ambient conductivity for the Gunnison River below Gunnison Tunnel, Colorado (Montrose County, Hydrologic Unit Code 14020005, USGS 09128000), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 6,526 feet asl.

Gunnison River below Gunnison Tunnel, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	187	187	197	206	160	151	165	174	170	170	173	179
1998	182	181	181	224	172	149	181	182	181	193	193	207
1999	197		229	201	214	186	192	197		185	193	186
2000	198	204	214	205	173	173	191	192	192			206
2001	201		213	225		196		199		191	205	
2002			209	219	212	206	215	212	220			
2003			236	233	218	177	200	207	220	213	233	232
2004	235		236		223	184		206	210		227	
2005		220		233	223	193	200		205			
Mean of monthly specific conductivity	200.0	198.0	214.4	218.3	199.4	179.4	192.0	196.1	199.7	190.4	204.0	202.0

Gunnison River below Gunnison Tunnel: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	121	119	128	135	114	111	126	135	134	126	124	119
1998	115	116	117	151	121	108	137	139	139	145	136	142
1999	129		155	134	151	137	145	150		140	143	129
2000	128	129	143	139	124	129	143	147	150			138
2001	127		138	152		152		151		144	146	
2002			135	147	154	156	166	166	176			
2003			154	155	153	133	151	160	174	169	168	154
2004	148		153		156	138		156	163		164	
2005		140		155	157	147	155		160			
Mean of monthly ambient conductivity	128.0	126.0	140.4	146.0	141.3	134.6	146.1	150.5	156.6	144.8	146.8	136.4

Table E-11. Specific and ambient conductivity for the Gunnison River at Delta, Colorado (Delta County, Hydrologic Unit Code 14020005, USGS 0944250), 1997-2004. Ambient conductivity calculated using available water temperature records. Gage at 4,910 feet asl.

Gunnison River at Delta, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	479.00		386.00		580.00	211.00	1310.00		949.00	880.00	597.00	
1998	597.00	571.00	646.00	462.00	314.50	510.00	757.00	840.00		886.00	820.00	
1999		607.00	628.00	682.00	397.00	521.00	692.00		627.00		569.00	563.00
2000		674.00	556.61	391.00	357.00	553.00	655.00			840.00	795.00	
2001	650.00	689.00		481.50	312.45	643.00	722.50	800.00	788.00	904.00	771.50	
2002		610.00	569.30	574.00		834.00	570.00	794.50	1010.00	1010.00	982.00	
2003				606.00	380.00	710.00		715.00		872.00		906.00
2004	763.00		719.00	734.00	339.00	783.00		830.00				
Mean of monthly specific conductivity	622.25	630.20	584.15	561.50	382.85	595.63	784.42	795.90	843.50	898.67	755.75	734.50
Gunnison River at Delta, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	316.03		247.22		418.34	162.30	1151.78		801.98	692.50	415.52	
1998	377.84	370.08	439.94	326.05	229.10	421.70	678.88	740.01		679.50	556.22	
1999		399.69	444.96	485.61	299.39	449.98	655.97		515.72		397.95	396.54
2000		445.57	374.62	283.70	287.12	451.86	544.83			682.30	531.84	
2001	397.77	456.39		354.24	312.45	549.88	619.09	695.07	650.29	705.78	553.16	
2002		375.51	400.21	438.26		722.46	506.14	712.51	879.27	780.76	650.47	
2003				437.09	294.33	608.38		629.89		698.55		574.55
2004	502.41		544.91	521.09	245.97	724.80		759.24				
Mean of monthly ambient conductivity	398.51	409.45	408.64	406.58	298.10	511.42	692.78	707.34	711.81	706.57	517.53	485.54

Table E-12. Specific and ambient conductivity for the Gunnison River near Grand Junction, Colorado (Mesa County, Hydrologic Unit Code 14020005, USGS 09152500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,628 feet asl.

Gunnison River near Grand Junction, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	572.00	540	386	383	330	412	496	880	888	652	638	585
1998	535	612	645	613	334.5	493.5	841	1040	1040	948	1010	
1999	896		852	741.5		599.7143	914		721.3333	484	831	
2000	888		747.3333	439	477	633.6	873	866		995	1110	904
2001		870.1538	958	540	479	949	1040	1400		1020		965
2002			810	925	1090	915		1130	1250	1200		1260
2003		1180	1050	642	488	724	883	981		1200		1300
2004		1170	688	734	526	1090	974	1070			1180	1060
2005	860	685	484	383	322.6667	559.3333	1005.333		1110			
Mean of monthly specific conductivity	750.20	842.86	735.59	600.06	505.90	708.46	878.29	1052.43	1001.87	928.43	953.80	1012.33
Gunnison River near Grand Junction, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	366.35	347.22	269.73	279.82	253.84	334.65	422.91	915.55	782.30	499.05	455.34	378.40
1998	342.48	395.08	428.94	452.77	255.02	397.30	760.21	932.68	923.49	722.75	704.37	
1999	593.51		602.47	550.95		535.70	847.75		611.40	383.90	594.65	
2000	595.24		510.63	335.35	375.37	542.10	786.02	811.22		757.08	739.64	574.41
2001		577.70	657.60	426.63	368.82	887.21	947.57	1192.52		728.45		605.93
2002			584.23	751.35	997.07	870.80		1023.48	1025.44	900.49		823.13
2003		826.19	803.69	521.47	380.24	626.55	837.03	915.31		925.80		819.52
2004		812.72	521.42	527.32	397.07	993.13	949.25	971.05			851.10	646.10
2005	568.53	477.71	373.41	290.27	252.25	476.76	930.00		923.30			
Mean of monthly ambient conductivity	493.22	572.77	528.01	459.55	409.96	629.36	810.09	965.97	853.18	702.50	669.02	641.25

Table E-13. Specific and ambient conductivity for the Dolores River near Slick Rock, Colorado (San Miguel County, Hydrologic Unit Code 14030002, USGS 09168730), 1997-2003. Ambient conductivity calculated using available water temperature records. Gage at 5,400 feet asl.

Dolores River near Slick Rock, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997					350.00	305.00	317.67	325.00				
1998		784.00		636.00	297.50		280.00					
1999					478.00	353.00		642.00				
2000			734.00	653.50	440.50		287.00	775.00			440.00	387.00
2001		413.00	660.00	628.00		650.00						
2002		450.00		450.00	526.00	792.00						
2003			475.00	518.00	651.00							
Mean of monthly specific conductivity	-	549.00	623.00	577.10	457.17	525.00	294.89	580.67	-	-	440.00	387.00

Dolores River near Slick Rock, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997					245.06	228.87	289.63	303.24				
1998		522.41		440.91	213.52		271.81					
1999					353.76	301.28		618.29				
2000			515.96	483.16	355.68		278.60	767.36			297.87	249.34
2001		276.29	485.56	515.18		556.97						
2002		299.85		336.35	501.59	815.88						
2003			378.26	397.27	602.62							
Mean of monthly ambient conductivity	-	366.19	459.93	434.58	378.70	475.75	280.01	562.97	-	-	297.87	249.34

Table E-14. Specific and ambient conductivity for the Dolores River at Bedrock, Colorado (Montrose County, Hydrologic Unit Code 14030002, USGS 09169500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,940 feet asl.

Dolores River at Bedrock, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		1390		566	348	321	482	645	525	825	858	
1998	932		1010	396	304		533	794	395	855		1040
1999			1140		546	401		992		555		806
2000			1010	1451	342	661	645	594			686	805
2001		791	1010	657		1000	637	755		708	858	
2002		983		1060	1710	1068		545	1790		1340	1320
2003		1280		737	998	1980	1090	2490		1520		1180
2004	1320		637	662	930	622	655	513		770		972
2005		954	893	347		399	585	531				
Mean of monthly specific conductivity	1126.0	1079.6	950.0	734.5	739.7	806.5	661.0	873.2	903.3	872.2	935.5	1020.5

Dolores River at Bedrock, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		904		392	253	249	473	618	507	677	539	
1998	568		673	275	233		408	794	376	822		790
1999			700		406	298		845		531		573
2000			616	1002	275	513	577	530			483	577
2001		503	651	489		795	613	674		562	552	
2002		605		803	1474	948		534	1574		828	805
2003		791		541	904	1769	991	2393		1282		718
2004	803		459	523	795	536	616	438		571		592
2005		583	599	261		335	551	486				
Mean of monthly ambient conductivity	685.5	677.2	616.3	535.8	620.0	680.4	604.1	812.4	819.0	740.8	600.5	675.8

Table E-15. Specific and ambient conductivity for the Green River near Greendale, Utah (Daggett County, Hydrologic Unit Code 14040106, USGS 09234500), 1997-2000. Ambient conductivity calculated using available water temperature records. Gage at 5,594 feet asl.

Green R. near Greendale, UT: **Specific Conductance**, water, wnfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	475.04		448.65	453.11	457.06	504.64		502.47		494.74	443.69	
1998	426.91	411.56		384.28	391.27		393.80	416.83		466.90	434.10	
1999	432.45	422.26	224.32		425.59	443.17	476.24	503.60		477.46		449.92
2000	430.70		422.26	434.99	441.42		482.56	460.67				
Mean of monthly specific conductivity	441.28	416.91	365.08	424.13	428.83	473.90	450.87	470.89	-	479.70	438.89	449.92
Green R. near Greendale, UT: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	720.00		680	680	640	640		650		640	640	
1998	660	630		600	570		530	550		610	620	
1999	630	640	340		620	600	610	620		630		630
2000	640		640	640	600		600	620				
Mean of monthly ambient conductivity	662.50	635.00	553.33	640.00	607.50	620.00	580.00	610.00	-	626.67	630.00	630.00

Table E-16. Specific and ambient conductivity for the Green River above Gates of Ladore, Colorado (Moffat County, Hydrologic Unit Code 14040106, USGS 404417108524900), 1999-2002. Ambient conductivity calculated using available water temperature records. Gage at 5,360 feet asl.

Green River above Gates of Lodore, CO: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999					615	633						
2000				679	645	624	640					
2001					642							
2002				702	667	708						
Mean of monthly Specific conductivity				690.5	642.3	655.0	640.0					

Green River above Gates of Lodore, CO: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1999					462	476						
2000				479	486	487	533					
2001					488							
2002				496	504	581						
Mean of monthly ambient conductivity				487.5	485.0	514.7	533.0					

Table E-17. Specific and ambient conductivity for the Green River near Jensen, Utah (Unitah County, Hydrologic Unit Code 14060001, USGS 09261000), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,758 feet asl.

Green R. near Jensen, UT: **Specific Conductance**, water, unfiltered, microsemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	730.00		710	700				550		590	650	
1998				560	333.6	344.5	320			620		
1999			656		411.3	392.5	540	620				
2000			677.5	510.5	312	285	564.5	650	640			
2001			720	690	345	357	590	710				
2002				548	274.2	340.5	677	715	994	685		
2003			688	432	360		597	708				
2004											550	
2005			680	350.3	325.1	250	450	654				
Mean of monthly Specific conductivity	730.00	-	688.58	541.55	337.32	328.25	534.07	658.14	817.00	631.67	600.00	-

Green R. near Jensen, UT: **Ambient Conductance**, water, unfiltered, microsimens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	472.19		473.10	541.12				488.38		442.74	446.18	
1998				399.93	249.11	287.55	307.57			460.67		
1999			463.42		310.14	320.50	519.03	578.48				
2000			469.68	380.06	260.04	235.66	514.33	468.82	546.23			
2001			507.79	513.70	280.23	312.77	550.49	675.71				
2002				407.44	213.97	265.71	565.36	687.69	905.66	582.33		
2003			536.08	287.29	1720.74		5937.37	715.04				
2004											527.60	
2005			457.62	235.76	251.20	202.62	402.76	634.86				
Mean of monthly Ambient conductivity	472.19	-	484.61	395.04	469.35	270.80	1256.70	607.00	725.95	495.25	486.89	-

Table E-18. Specific and ambient conductivity for the White River near Watson, Utah (Uintah County, Hydrologic Unit Code 14050007, USGS 09306500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,947 feet asl.

White River near Watson, UT: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997											700	
1998				940			490			750		
1999			850					700		750		
2000							700	840		700	730	
2001	790			850	368		720	760	780	800	690	786
2002	720	715		595	550		945	968	994	867	703	
2003	780		734	720	380	309	574	765	771	661		680
2004		726	725	513		454		685		700	600	
2005			730	626	330		460	672				
Mean of monthly Specific conductivity	763.3	720.5	759.8	707.3	407.0	381.5	648.2	770.0	848.3	746.9	684.6	733.0

White River near Watson,UT: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997											457	
1998				661			448			580		
1999			657					680		557		
2000							700	776		592	445	
2001	482			427	302		692	723	693	669	508	508
2002	439	437		485	448		1047	854	883	676	457	
2003	475		473	555	311	257	567	747	700	568		416
2004		442	523	385		389		609		552	400	
2005			492	478	275		451	621				
Mean of monthly Ambient conductivity	465.3	439.5	536.3	498.5	334.0	323.0	650.8	715.7	758.7	599.1	453.4	462.0

Table E-19. Specific and ambient conductivity for the Green River at Green River, Utah (Emery County, Hydrologic Unit Code 14060008, USGS 09315000), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,040 feet asl.

Green River at Green River, UT: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		800.00	740	600	385	372.5	520	700	720			
1998								660	760	780	750	730
1999			740	720	540		567.5	750	780	780	800	770
2000			780	550	435	500	740	760	800	800	820	
2001	860	870	820	590	350	570	760				890	
2002			910		530	510	800		980			
2003			940		540		500	800			810	
2004		850		630	335	400	586	837	795	646	832.5	841
2005	890	888	837.5	842	470	420	690		790			
Mean of monthly specific conductivity	875.00	852.00	823.93	655.33	448.13	462.08	645.44	751.17	803.57	751.50	817.08	780.33

Green River at Green River, UT: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
	Monthly mean in uS/cm											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		497.38	513.01	473.10	311.84	342.43	496.85	659.63	614.51			
1998								640.68	648.65	757.17	640.12	564.31
1999			507.96	465.72	401.23		443.06	591.37	749.71	757.17	689.59	566.48
2000			514.63	335.24	295.66	398.17	650.62	716.16	792.12	768.94	720.96	
2001	651.77	562.75	499.82	366.82	265.26	462.99	661.63				847.01	
2002			866.05		386.08	367.85	682.79		941.95			
2003			940.00		470.10		357.08	637.07			786.29	
2004		850.00		432.45	223.22	328.14	480.72	728.66	754.11	620.92	720.45	685.83
2005	641.29	553.18	531.11	553.34	340.68	306.55	554.94		667.61			
Mean of monthly ambient conductivity	646.53	615.83	624.65	437.78	336.76	367.69	540.96	662.26	738.38	726.05	734.07	605.54

Table E-20. Specific and ambient conductivity for the Colorado River near Cisco, Utah (Grand County, Hydrologic Unit Code 14030005, USGS 09180500), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,040 feet asl.

Colorado River near Cisco, UT **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		930	670	500	365	343	705	850	940			
1998								1090		1130	1120	1190
1999			960	930	455	420	860	950	880		920	1050
2000			1040	590	560	750	1020	1090	1070	1190	1300	
2001	1280	1260	1200	680	520	850	1190				1270	
2002	1270	1200	1110		1120	1160	1390	1660				
2003			1490	840	420		890	1200			1400	
2004			700		510	790		1300	1260		1200	1280
2005			940	430	390		730	1130				
Mean of monthly specific conductivity	1275.0	1130.0	1013.8	661.7	542.5	718.8	969.3	1158.8	1037.5	1160.0	1201.7	1173.3

Colorado River near Cisco, UT **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997		626	478	379	294	286	644	801	787			
1998								1058		856	754	740
1999			742	719	381	369	810	904	751		651	693
2000			788	465	473	679	971	1027	931	996	800	
2001	780	815	909	515	427	801	1144				846	
2002	790	739	825		946	1093	1363	1460				
2003			1064	649	358		839	1131			933	
2004			520		427	708		1225	1119		857	812
2005			645	323	320		688	1044				
Mean of monthly ambient conductivity	785.0	726.7	746.4	508.3	453.3	656.0	922.7	1081.3	897.0	926.0	806.8	748.3

Table E-21. Specific and ambient conductivity for the Dolores River near Cisco, Utah (Grand County, Hydrologic Unit Code 14030004, USGS 09180000), 1997-2005. Ambient conductivity calculated using available water temperature records. Gage at 4,165 feet asl.

Dolores River near Cisco, UT: **Specific Conductance**, water, unfiltered, microsiemens per centimeter at 25 C												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000									1410	1110	1090	
2001	2140	1540	1170	460		430	620	1120			1220	1300
2002			1290	1350	1550	2180		4010				
2003			2380	660		450	960	1880				
2004			790	800		410	900	1260			1180	1400
2005			1410	4220	350	360		1090				
Mean of monthly specific conductivity	2140	1540	1408	1498	950	766	826.7	1872	1410	1110	1163.3	1350

Dolores River near Cisco, UT: **Ambient Conductance**, water, unfiltered, microsiemens per centimeter												
Year	Monthly mean in uS/cm											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000									1227.5	892.7	691.2	
2001	1304.4	996.1	869.3	362.7		367.0	539.8	1024.5			888.7	792.4
2002			885.5	1075.1	1432.0	2054.3		3741.5				
2003			1716.6	520.4		384.1	904.6	1843.1				
2004			622.9	624.6		386.4	900.0	1130.0			834.4	887.8
2005			987.2	3135.5	262.6	319.7		1027.1				
Mean of monthly ambient conductivity	1304.4	996.1	1016.3	1143.7	847.3	702.3	781.5	1753.2	1227.5	892.7	804.8	840.1

APPENDIX F

COLORADO RIVER RECOVERY PROGRAM
FY 2006 ANNUAL PROJECT REPORT
PROJECT NO.: C-18/19
CHEMICALLY FINGERPRINTING NONNATIVE FISHES IN RESERVOIRS

COLORADO RIVER RECOVERY PROGRAM
FY 2006 ANNUAL PROJECT REPORT

RECOVERY PROGRAM
PROJECT NUMBER: C-18/19

I. Project Title: Chemically Fingerprinting Nonnative Fishes in Reservoirs

II. Principal Investigator(s):

Patrick J. Martinez
Colorado Division of Wildlife
711 Independent Ave.
Grand Junction, CO 81505
Phone: 970-255-6143
FAX: 970-255-6111
pat.martinez@state.co.us

Brett M. Johnson
Dept. of Fish, Wildlife and Conservation Biology
Colorado State University
Fort Collins, CO 80523
970-491-5002
970-491-5091
brett@warnercnr.colostate.edu

III. Project Summary:

This project addresses movement of nonnative fishes (including northern pike, smallmouth bass, largemouth bass, black crappie, and walleye) into river reaches of critical habitat from reservoirs. These species are believed to pose a significant predatory threat to endangered and other native fishes (Tyus and Saunders 1996; Martinez et al. 2001; Johnson et al. 2005). However, it is uncertain to what extent the presence of nonnative species in critical habitat is the result of escapement or illicit transfers from reservoirs. This study will provide the means to assess the proportion of nonnative fishes in these rivers that originate from reservoirs and thereby guide management efforts to reduce this influx of nonnative fishes. Funding for the study arrived late in the fiscal year and thus, processing of available samples was delayed. However, we are still on track to complete the study in FY09.

IV. Study Schedule: FY06-FY09

V. Relationship to RIPRAP:

General Recovery Program Support Action Plan:
III. Reduce negative impacts of nonnative fishes and sport fish management activities.
III.A.2. Identify and implement viable control measures.

Colorado River Action Plan: Main stem
III. Reduce negative impacts of nonnative fishes and sport fish management activities.
III.A.4.a. Evaluate sources of nonnative fishes and make recommendations.

VI. Accomplishment of FY 2006 Tasks and Deliverables, Discussion of Initial Findings and Shortcomings:

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Tasks proposed for FY06 were accomplished to the degree possible, given the delay in funding for the study.

Task 1. Field Collections

Brett Johnson prepared the Animal Care and Use Committee protocol for the project, and the protocol was approved by the CSU Office of Regulatory Compliance (protocol no. 06-220A-01).

Pat Martinez and his field technicians led field collection efforts within Colorado. Preliminary reservoir sampling was conducted during June-September 2006. Pat Martinez also coordinated the sampling program with the respective states and crews operating in the target reservoirs and river reaches. A total of 1,129 fish were collected by the end of September, 2006 (Table 1). The greatest numbers of species and samples were obtained from the Colorado and Yampa rivers. The specimens collected to date will provide a base from which to subsample to achieve acceptable limits of statistical certainty in classification of fish origins, and provide insights into additional sampling required in FY07. We also received 370 samples of six other nonnative fish species (Table 2) that may also be subsampled for analysis should information on their provenance become a management concern.

Table 1. Number of nonnative fish of primary species collected for microchemical analysis of otoliths through September, 2006. Species codes are: BCR = black crappie, LMB = largemouth bass, NPK = northern pike, SMB = smallmouth bass, WAE = walleye.

Water body	BCR	LMB	NPK	SMB	WAE	Sum
Colorado River	1	259	0	205	1	466
Rifle Gap Reservoir	0	0	24	22	6	52
Rifle Gap Spillway	0	0	0	0	3	3
McPhee Reservoir	0	0	0	11	0	11
Duchesne River	0	0	0	16	0	16
Green River	6	0	3	54	11	74
Gunnison River	0	3	0	48	0	51
Yampa River	102	0	141	169	1	413
Elkhead Reservoir	16	11	0	16	0	43
Sum	125	273	168	541	22	1,129

Table 2. Number of "incidental" nonnative fishes collected for microchemical analysis of otoliths through September, 2006. These specimens may be analyzed later. Species codes are: SNF = sunfish, BBH = black bullhead, GSD = gizzard shad, BGL = bluegill, CCF = channel catfish, YPE = yellow perch.

Water body	SNF	BBH	GSD	BGL	CCF	YPE	Sum
Colorado River	0	0	0	21	0	0	21
Rifle Gap Reservoir	0	0	0	0	0	0	0
Rifle Gap Spillway	0	0	0	0	0	5	5
McPhee Reservoir	0	0	0	0	0	0	0
Duchesne River	0	0	0	0	0	0	0
Green River	17	0	0	1	20	0	38
Gunnison River	214	7	4	3	0	0	228
Yampa River	0	0	0	78	0	0	78
Elkhead Reservoir	0	0	0	0	0	0	0
Sum	231	7	4	103	20	5	370

Task 2. Microchemical Analysis of Otoliths

Brett Johnson conducted a nation-wide search and recruited an outstanding graduate research associate for the project. The student, Phillip Brinkley, worked in Dr. Keith Gido's laboratory at Kansas State University. Phil will be primarily responsible for performing analyses on otolith samples and interpreting the data. He will also be assisting with future field collections, beginning in spring 2007.

VII. **Recommendations**:

Continue the project as outlined in the Scope of Work. Pat Martinez and field technicians should lead field collection efforts in cooperation with the graduate research associate. Full scale reservoir and river sampling should be conducted during May through August 2007, with emphasis on waters sampled with less intensity in FY06. Pat Martinez should continue to coordinate sample acquisition with the respective states and crews operating in the target reservoirs and river reaches.

Task 2. Microchemical Analysis of Otoliths.

The graduate student should begin work in early January, 2007. The graduate student should spend several days working in Pat Martinez's lab to become familiar with otolith extraction, mounting, and sectioning techniques, before the spring 2007 semester begins.

VIII. **Project Status:**

This project will continue through FY 2007 and beyond and it should be considered on track and ongoing. There have been no significant changes in project direction, probability of success, or alignment with RIPRAP objectives and deadlines.

IX. **FY 2006 Budget Status**

A. Funds Provided: $20,557.00
B. Funds Expended: $ 8,386.65
C. Difference: $12,170.35
Funds were not fully expended because we received our first increment of funding late in FY06, and because we could not hire a graduate research associate until funding for FY07 was confirmed. These unused funds will be expended during FY07.
D. Percent of the FY 2006 work completed, and projected costs to complete: 40% completed, $12,170.35 will be required to accomplish all objectives of the FY06 work plan.
E. Recovery Program funds spent for publication charges: $0

X. Status of Data Submission (Where applicable): N/A

XI. Signed:

Patrick J. Martinez	11/09/06
Principal Investigator	Date
Brett M. Johnson	11/09/06
Principal Investigator	Date

XII. References:

Johnson, B. M., G. Whitledge, M. Sullivan, and D. Gibson-Reinemer. 2005. Stable isotopes and statistics. Progress report, Colorado Division of Wildlife, Grand Junction, Colorado, 22 pages.

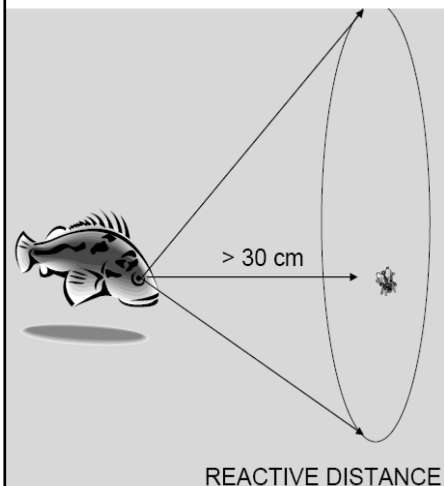
Martinez, P. J., B. M. Johnson, and J. D. Hobgood. 2001. Stable isotope signatures of native and nonnative fishes in Upper Colorado River backwaters and ponds. The Southwestern Naturalist 46: 311-322.

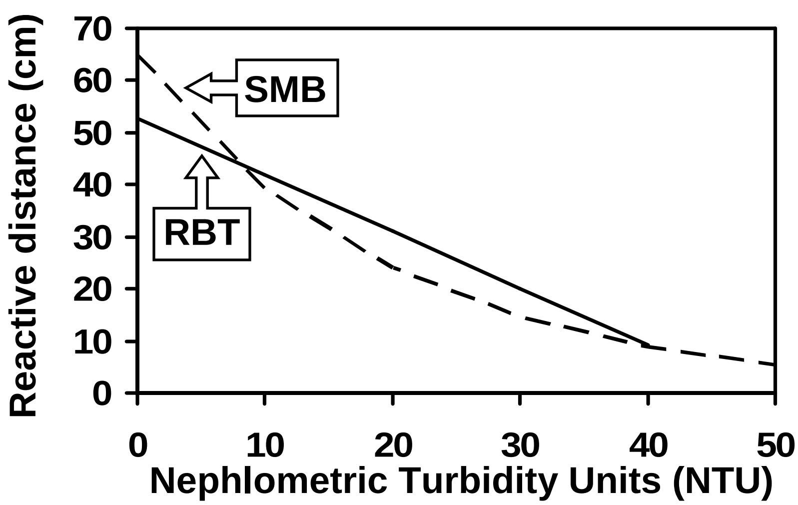
Tyus, H. M., and J. F. Saunders, III. 1996. Nonnative fishes in natural ecosystems and a strategic plan for control of nonnatives in the Upper Colorado River basin. Recovery Implementation Program DRAFT REPORT. Cooperative Agreement No. 14-48-006-95-923. U.S. Fish and Wildlife Service, Denver, Colorado.

APPENDIX G

POWERPOINT PRESENTATION: THE USE OF WATER TEMPERATURE, DISCHARGE & TURBIDITY TO APPROXIMATE THE DURATION OF OPTIMAL CONDITIONS FOR SMALLMOUTH BASS ANGLING IN THE YAMPA RIVER

The Use of Water Temperature, Discharge & Turbidity to Approximate the Duration of Optimal Conditions for Smallmouth Bass Angling in the Yampa River





RBT: decline in foraging strikes & feeding behavior at higher turbidity, also prey within visual field often ignored

SMB: increased turbidity reduced reaction to prey, but not foraging success upon reacting to prey

Suspended sediment transport:

- YAR above LSR near Maybell, 1998-2002
- $Q_S = 0.0000581\ Q^{2.13}$, where Q_S = sediment discharge in tons per day; Q = water discharge in cfs
- **Elliot, J. G. & S. P. Anders. 2005. Summary of sediment data from the YAR & Upper GRR Basins, CO & UT, 1993-2003.**

Suspended sediment concentration (SSC):

- $Q_S = Q_W * SSC * 0.0027$, where Q_S = sediment discharge in tons per day; Q_W = water discharge in cfs; SSC = suspended sediment concentration in mg/l
- **Dinehart, R. L. ????. Sediment transport at gaging stations near Mt. St. Helens, WA, 1980-1990. Data collection & analysis. USGS.** http://vulcan.wr.usgs.gov/Projects/Sediment_Trans/PP1573/PDF/pg1-30.pdf

Convert SSC to NTU (Nephlometric Turbidity Units):

- $SCC_{mg/l} = 3.399\ NTU – 5.603$
- **Barrett, J. C., et al. 1992. Turbidity-induced changes in reactive distance of rainbow trout. TAFS 121:437-443.**

Rainbow trout reactive distance vs. turbidity (NTU):

- $RD_{cm} = -1.09\ NTU + 52.81$, where RD = reactive distance in cm
- **Barrett, J. C., et al. 1992. Turbidity-induced changes in reactive distance of rainbow trout. TAFS 121:437-443.**

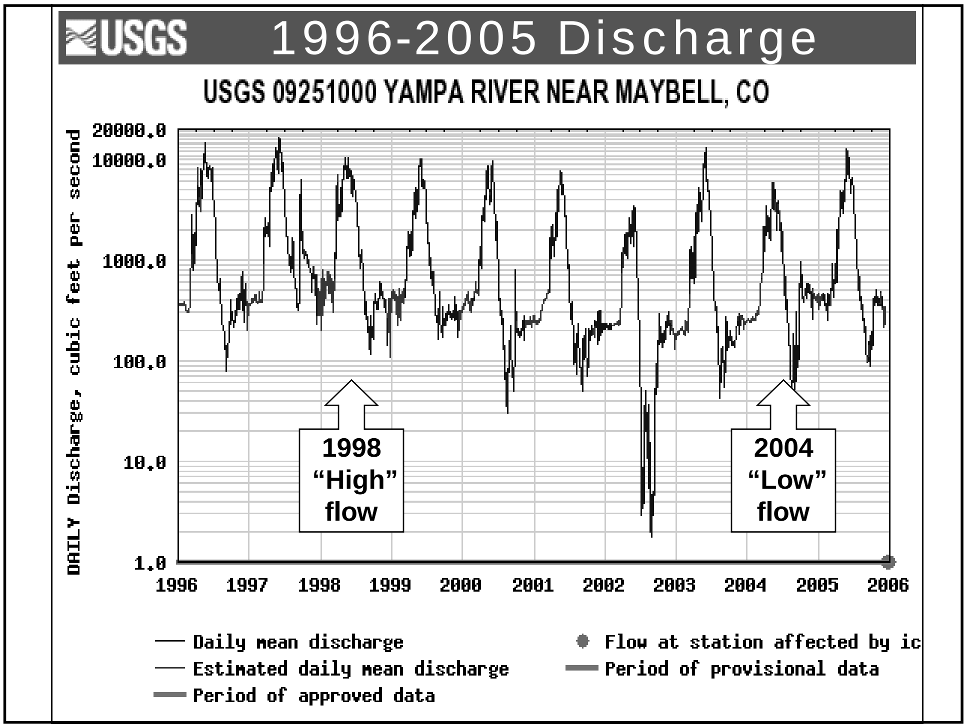
Smallmouth bass RD vs. NTU:

- $RD_{cm} = 65.0 * 2.718^{(-0.05\ NTU)}$
- **Sweka, J. A. & K. J. Hartman. 2003. Reduction of reactive distance & foraging success in smallmouth bass exposed to elevated turbidity levels. Environ. Bio. of Fishes 121:437-443.**

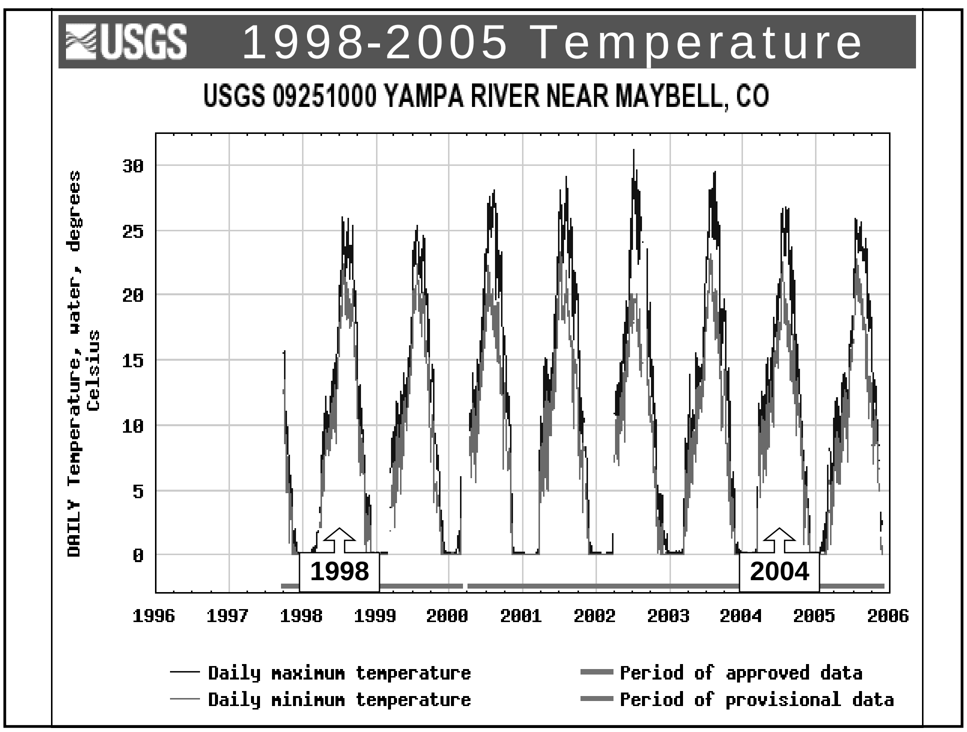
Turbidity (NTU)	Condition or ecological significance
0	Perfectly clear water
<5	Clear water
5	Turbidity just noticeable
10	Trout switch from passive to active feeding @ RD~ 40 cm (16 in.) - requires more energy & may reduce growth
12	Abrupt decline in RBT CPUE & angling effort (used as surrogate for SMB)
15	Turbidity pronounced
20	Periphyton productivity & invertebrate density severely reduced if turbidity persistent
25	Muddy

http://www.deq.state.or.us/WQ/WQRules/Rulemaking/Div041DraftTechBasisRevTurbidity.pdf

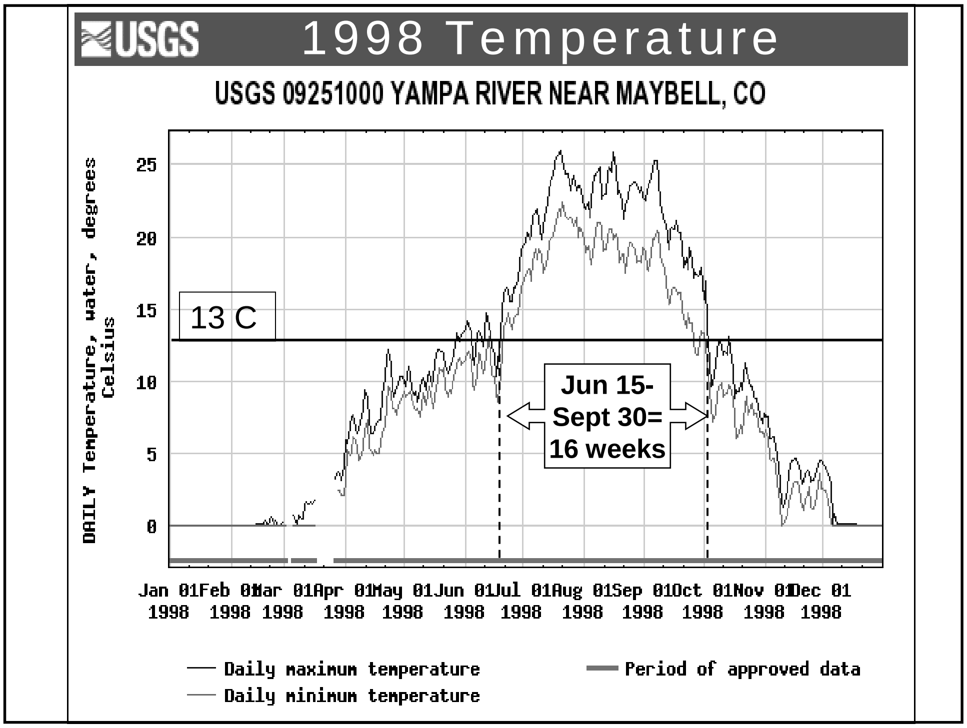
Yampa River discharge (cfs)	Sediment transport (tons/day)	SSC (mg/l)	NTU	Reaction distance in cm (inches)	
				RBT	SMB
10,000	19,239	712	211	0	0
5,000	4,395	326	98	0	0.5 (0.2)
1,000	143	53	17	37 (14)	28 (11)
700	**67**	**35**	**12**	**40 (16)**	**36 (14)**
500	33	24	9	43 (17)	41 (16)
100	1	4	3	50 (20)	56 (22)

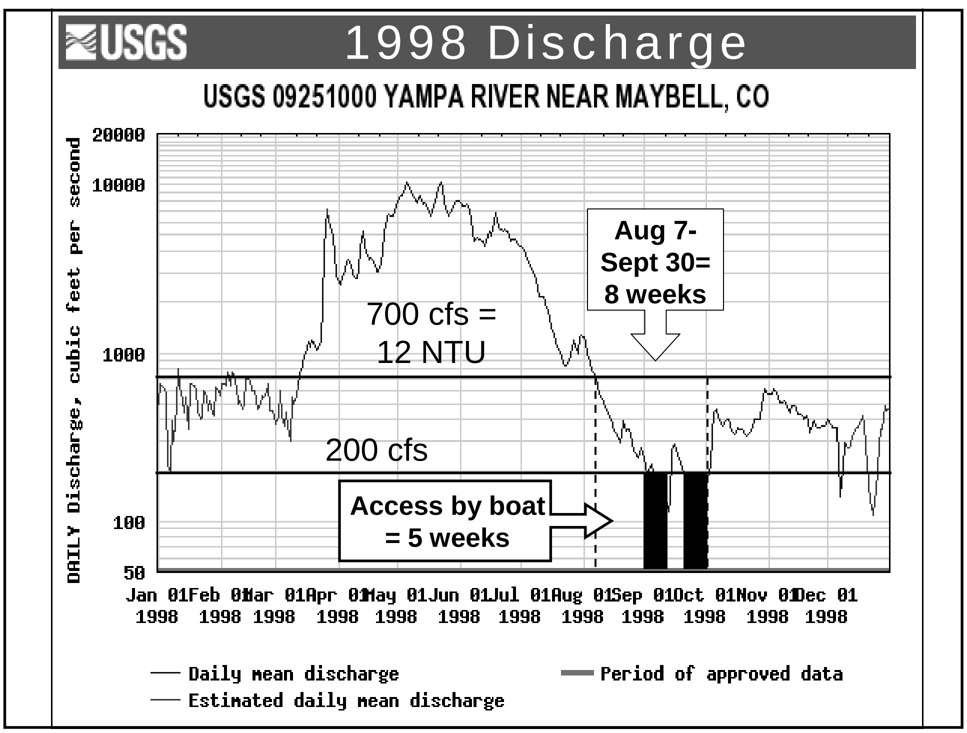


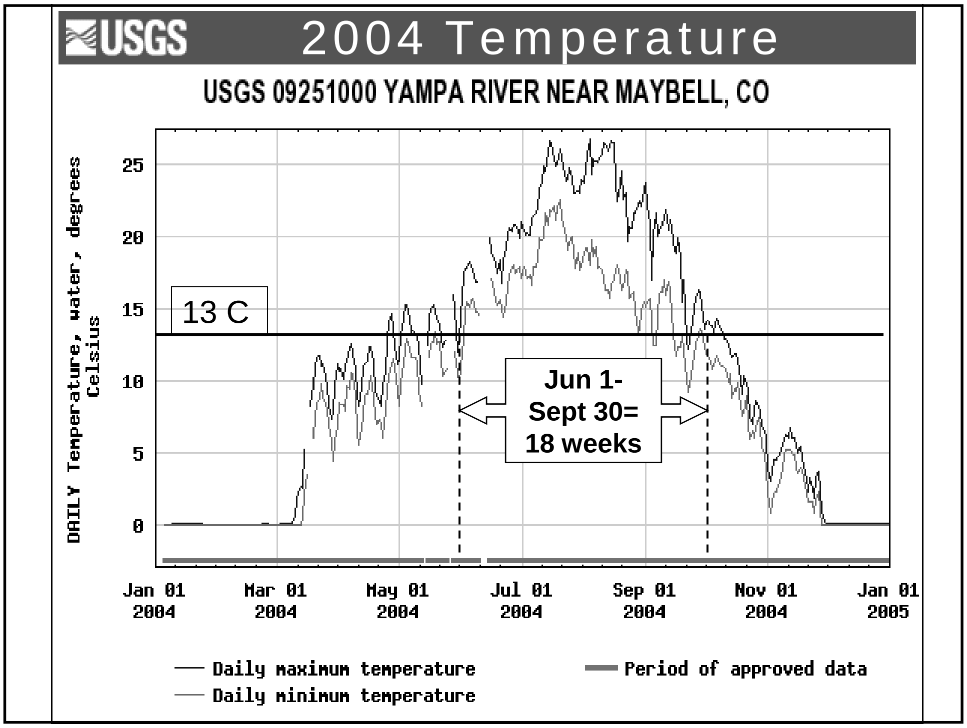
USGS
1996-2005 Discharge
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO
DAILY Discharge, cubic feet per second
20000.0
10000.0
1000.0
100.0
10.0
1.0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
1998 "High" flow
2004 "Low" flow
Daily mean discharge
Estimated daily mean discharge
Period of approved data
Flow at station affected by ic
Period of provisional data

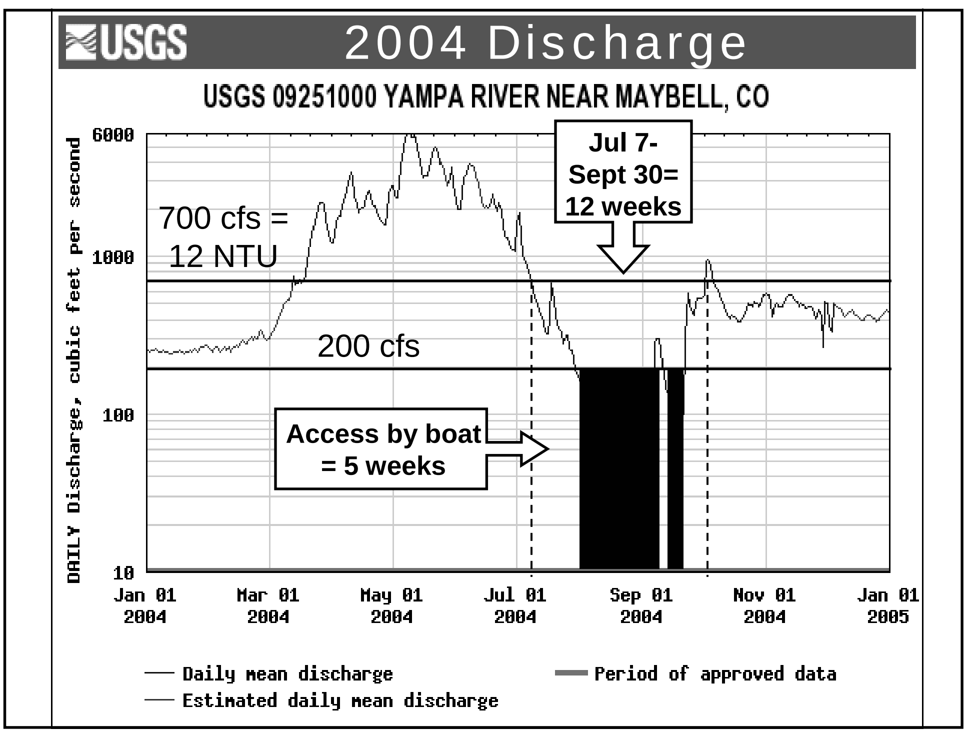


USGS
1998-2005 Temperature
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO
DAILY Temperature, water, degrees Celsius
30
25
20
15
10
5
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
1998
2004
Daily maximum temperature
Daily minimum temperature
Period of approved data
Period of provisional data


USGS
1998 Temperature
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO
DAILY Temperature, water, degrees Celsius
25
20
15
10
5
0
13 C
Jun 15-
Sept 30=
16 weeks
Jan 01 Feb 01 Mar 01 Apr 01 May 01 Jun 01 Jul 01 Aug 01 Sep 01 Oct 01 Nov 01 Dec 01
1998 1998 1998 1998 1998 1998 1998 1998 1998 1998 1998 1998
Daily maximum temperature
Daily minimum temperature
Period of approved data


USGS
1998 Discharge
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO
DAILY Discharge, cubic feet per second
20000
10000
1000
100
50
Aug 7-
Sept 30=
8 weeks
700 cfs =
12 NTU
200 cfs
Access by boat
= 5 weeks
Jan 01 Feb 01 Mar 01 Apr 01 May 01 Jun 01 Jul 01 Aug 01 Sep 01 Oct 01 Nov 01 Dec 01
1998 1998 1998 1998 1998 1998 1998 1998 1998 1998 1998 1998
Daily mean discharge
Estimated daily mean discharge
Period of approved data


USGS
2004 Temperature
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO
DAILY Temperature, water, degrees Celsius
25
20
15
10
5
0
13 C
Jun 1-
Sept 30=
18 weeks
Jan 01 2004
Mar 01 2004
May 01 2004
Jul 01 2004
Sep 01 2004
Nov 01 2004
Jan 01 2005
Daily maximum temperature
Daily minimum temperature
Period of approved data


USGS
2004 Discharge
USGS 09251000 YAMPA RIVER NEAR MAYBELL, CO
DAILY Discharge, cubic feet per second
6000
1000
100
10
700 cfs =
12 NTU
200 cfs
Jul 7-
Sept 30=
12 weeks
Access by boat
= 5 weeks
Jan 01 2004
Mar 01 2004
May 01 2004
Jul 01 2004
Sep 01 2004
Nov 01 2004
Jan 01 2005
Daily mean discharge
Estimated daily mean discharge
Period of approved data

Yampa River smallmouth bass sport fishery

- restricted to 8-12 optimum weeks in Jul, Aug & Sep
- <200 cfs limits boat access for anglers to only 5 weeks
- further restricted by base flow storm induced turbidity
- shore access limited due to road conditions (storms)
- SMB fishability 6-10 weeks due to turbidity & access
- private land restricts public access in some reaches
- angler use characterized as low, fish “unpressured”
- unpredictable access & turbidity limits organized derby
- angling unable to control SMB due to local conditions

APPENDIX H

TEMPERATURE AND DISSOLVED OXYGEN PROFILES AND CRUSTACEAN ZOOPLANKTON DATA FROM HIGHLINE LAKE, 2005 AND 2006

Table H-1. Temperature (°C) and dissolved oxygen (mg/L) profiles, and Secchi depth (m) at three stations an Highline Reservoir on 15 May. 1 June, and 28 July 2006. Values in parenthesis denote maximum water depth at station.

Water depth (m)	Highline 15 May 2006					
	P1 (7.8m)		P2 (11.2m)		P3 (4.5m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	17.5	7.7	18.9	7.0	19.0	6.5
1	16.8	7.6	17.7	7.4	18.2	6.8
2	16.6	7.6	16.9	7.6	17.8	7.0
3	16.4	7.5	16.7	7.5	17.6	7.0
4	16.2	7.5	16.5	7.4	17.0	7.1
5	15.1	6.9	15.9	7.2		
6	14.6	6.4	15.2	6.7		
7	14.3	6.1	14.6	6.4		
8			14.3	6.0		
9			14.1	5.4		
10			13.9	5.8		
Secchi (m)	0.60		0.68		0.74	

Water depth (m)	Highline 1 June 2006					
	P1 (12m)		P2 (11.0m)		P3 (5.5m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	17.8	7.9	17.9	7.7	17.9	7.6
1	17.5	7.7	17.8	7.7	17.9	7.7
2	17.3	7.8	17.1	7.8	17.5	7.6
3	15.9	7.0	16.0	7.3	16.7	7.0
4	15.5	7.1	15.8	6.9	16.2	6.6
5	15.3	7.0	15.5	7.2	16.1	5.9
6	15.1	6.7	14.9	7.1		
7	14.8	6.7	14.8	7.1		
8	14.3	5.8	14.3	7.0		
9	13.8	5.0	14.1	5.5		
10	13.6	3.9	13.5	3.8		
11	13.6	3.9	13.2	3.2		
Secchi (m)	1.30		1.05		0.80	

Water Depth (m)	Highline 28 July 2006					
	P1 (10.7m)		P2 (10.0m)		P3 (5.8m)	
	°C	mg/l	°C	mg/l	°C	mg/l
0	24.9	6.7	25.2	6.6	24.5	6.6
1	24.8	6.7	24.9	6.5	24.8	6.6
2	24.7	6.7	24.8	6.7	24.6	6.0
3	24.6	6.6	24.5	6.6	24.3	5.6
4	24.4	5.9	22.7	3.8	23.8	4.6
5	22.9	3.8	21.7	3.7	23.0	3.2
6	20.0	1.4	19.0	0.9		
7	18.8	0.7	19.1	0.8		
8	18.3	0.5	17.5	0.2		
9	16.9	0.2	16.7	0.3		
10	16.3	0.2	17.6	0.1		
Secchi (m)	0.77		0.59		0.65	

Table H-2. Crustacean zooplankton, excluding nauplii, densities (number per liter) estimated from duplicate samples collected at three stations in Highline Reservoir, 16 June 2005 and 15 May 2006.

Zooplankton Species	Station #1 (0-10m)			Station #2 (0-10m)			Station #3 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Highline - 16 June 2005 - Mean *Daphnia* density = 10.7/L										
Bosmina longirostris	0.4		0.4	0.1	1.6	0.9	1.3	2.3	1.8	1.0
Ceriodaphnia megalops	0.0		0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0
Unidentified/ Unknown *Daphnia* spp.	0.5		0.5	0.6	1.3	1.0	1.6	4.0	2.8	1.4
Diacyclops b. thomasi	8.7		8.7	11.5	8.4	9.9	14.5	18.2	16.4	11.7
Daphnia mendotae	5.1		5.1	8.0	7.9	8.0	8.4	18.8	13.6	8.9
Leptodiaptomus nudus	2.0		2.0	1.6	3.0	2.3	2.5	2.3	2.4	2.2
Diaphanosoma spp.	0.1		0.1	0.4	0.0	0.2	0.4	1.1	0.7	0.3
Mean total no./L	16.9			22.3			37.8			25.7

Zooplankton Species	Station #1 (0-10m)			Station #2 (0-10m)			Station #3 (0-10m)			Mean no./L
	a	b	mean	a	b	mean	a	b	mean	
Highline - 15 May 2006 - Mean *Daphnia* density = 19.9/L										
Bosmina longirostris	12.9	8.0	10.5	11.7	8.4	10.1	73.4	102.8	88.1	36.2
Ceriodaphnia megalops	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Unidentified/ Unknown *Daphnia* spp.	1.3	0.0	0.6	0.3	0.6	0.4	4.9	3.3	4.1	1.7
Diacyclops b. thomasi	41.7	28.3	35.0	41.9	26.8	34.3	129.1	67.5	98.3	55.9
Daphnia mendotae	7.1	3.7	5.4	5.6	14.0	9.8	34.9	43.2	39.0	18.1
Leptodiaptomus nudus	0.0	0.0	0.0	0.3	0.6	0.4	0.6	0.0	0.3	0.3
Mean total no./L	51.7			55.1			229.8			112.2

Table H-3. **Length frequency of crustacean zooplankton (measured to the nearest 0.01mm) collected in Highline Reservoir on May 15, 2006. Bl = *Bosmina longirostris*, Cdm = *Ceriodaphnia megalops,* Dbt = *Diacyclops bicuspidatus thomasi*, D. spp. = Diaphanosoma spp., Dgm = *Daphnia galeata mendotae, and* Ln = *Leptodiaptomus nudus*.**

Length Class in mm	**Highline- 15 May 2006**					
	Bl	Cdm	Daphnia spp.	Dbt	Dgm	Ln
0.2	1					
0.3	25					
0.4	50	1	1	9	2	
0.5	16		5	27	7	
0.6			4	43	17	
0.7			1	33	20	
0.8				15	23	
0.9			4	17	28	
1			2	6	10	
1.1				1	6	
1.2			2	1	9	1
1.3					5	
1.4					1	
1.5					1	
2.2			1			
Totals	92	1	20	152	129	1
Mean length	0.4	0.4	0.8	0.7	0.8	1.2

Length class in mm	**Highline- 16 June 2005**						
	Bl	Cdm	Daphnia spp.	Dbt	Dgm	Dm	Ln
0.3	2				1		
0.4	8	1	4	6	2		2
0.5			7	24	14		2
0.6			5	14	20	1	1
0.7			9	33	20	1	4
0.8			2	15	12	1	1
0.9			3	13	12	2	1
1			2	3	16	1	1
1.1			1	2	8	1	
1.2			3	2	14	1	3
1.3			1	1	3	1	3
1.4					1		1
1.5							5
1.6					1		
2					1		
Totals	10	1	37	113	125	9	24
Mean Length	0.4	0.4	0.7	0.7	0.8	0.9	1.0

APPENDIX I

ISOTOPIC, ELEMENTAL & BIOENERGETICS STUDIES: APPLICATION OF ISOTOPIC AND ELEMENTAL TECHNIQUES TO IDENTIFY PROVENANCE OF FISHES AND TO FACILITATE BIOENERGETICS PROJECTIONS OF FOOD-WEB IMPACTS OF PISCIVORES IN RESERVOIRS

ANNUAL REPORT

PREPARED BY:

DR. BRETT M. JOHNSON

FISHERIES ECOLOGY LABORATORY
DEPARTMENT OF FISHERY AND WILDLIFE BIOLOGY
COLORADO STATE UNIVERSITY, FORT COLLINS, CO 80523-1474
VOICE (970) 491-5002 FAX (970) 491-5091

Prepared for:

Patrick J. Martinez
Aquatic Research Biologist
Colorado Division of Wildlife

ISOTOPIC, ELEMENTAL & BIOENERGETICS STUDIES: APPLICATION OF ISOTOPIC AND ELEMENTAL TECHNIQUES TO IDENTIFY PROVENANCE OF FISHES AND TO FACILITATE BIOENERGETICS PROJECTIONS OF FOOD-WEB IMPACTS OF PISCIVORES IN RESERVOIRS.

Period of Performance: 07/01/05 - 06/30/06

Prepared by:

Dr. Brett M. Johnson

Fisheries Ecology Laboratory
Department of Fishery and Wildlife Biology
Colorado State University, Fort Collins, CO 80523-1474
voice (970) 491-5002 fax (970) 491-5091

TABLE OF CONTENTS

INTRODUCTION

An understanding of trophic dynamics is fundamental to effective fishery management. Knowledge of food web interactions is also essential for evaluating the importance of competitive and predatory relationships among native and nonnative fishes. This report summarizes continuing research aimed at developing, refining and applying new methodologies for the study of trophic dynamics in rivers in Colorado.

DIET OF NONNATIVE FISHES IN THE YAMPA AND COLORADO RIVERS

Current estimates of diet of smallmouth bass, northern pike and channel catfish in the Yampa River and Colorado River (Figure 1) were provided in the draft manuscript entitled “Smallmouth bass are the primary predatory threat to the native fish assemblage of the Yampa River, Colorado” by Johnson et al. (abstract below). A total of 904 stomach samples from nonnative fishes sampled from the Colorado River are in our database. These include: 2 black bullhead, 14 black crappie, 42 bluegill, 140 channel catfish, 174 largemouth bass, 327 smallmouth bass, and 205 sunfish. A little more than 300 samples have been processed and the remainder should be prioritized for processing in the upcoming year.

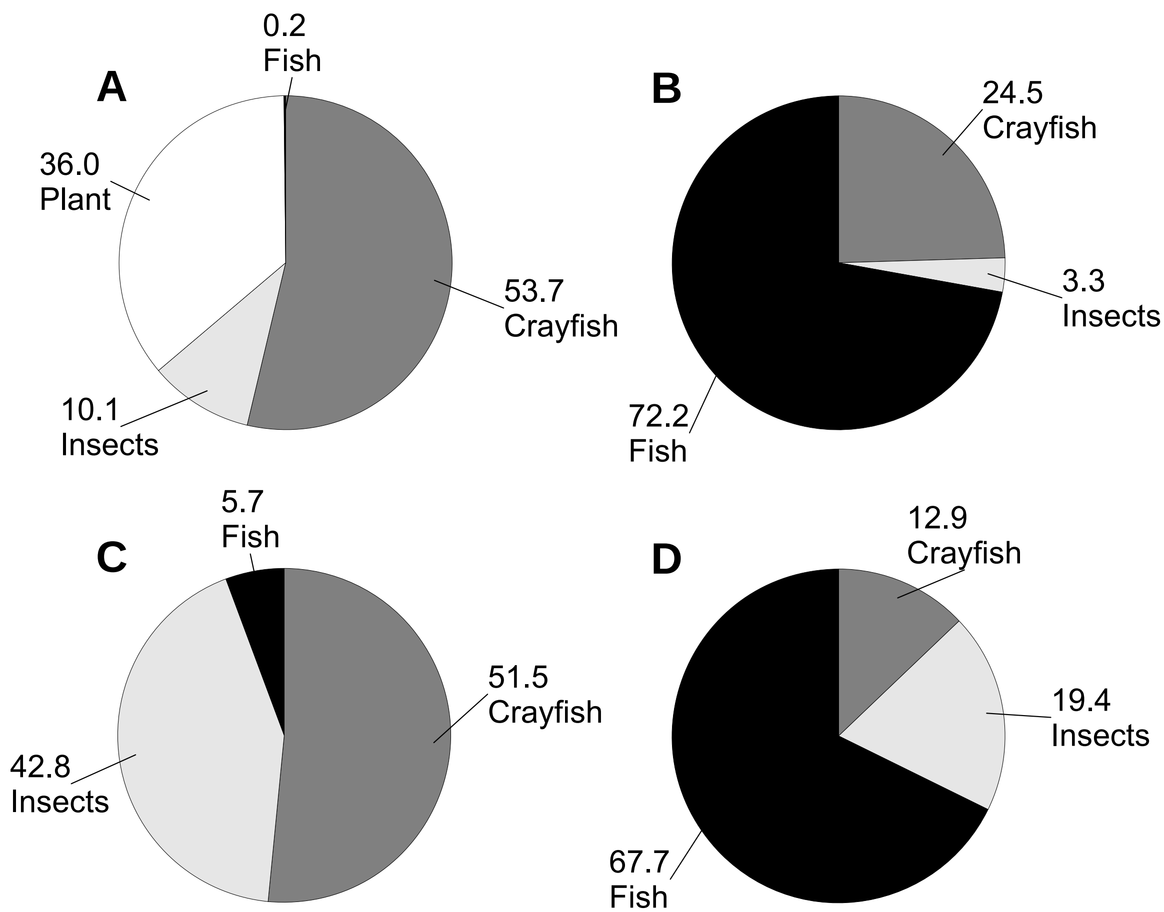


Figure J-1. Relative diet composition of a) channel catfish, b) northern pike, and c) smallmouth bass sampled from the Yampa River during summer, 2003-2005, and d) smallmouth bass sampled from the Colorado River during summer, 2004 (From Johnson et al. in prep).

Centrarchids in the Yampa and Colorado rivers

Current estimates of consumptive demand of smallmouth bass in the Yampa River were provided in the draft manuscript entitled "Smallmouth bass are the primary predatory threat to the native fish assemblage of the Yampa River, Colorado" by Johnson et al. (abstract below). Bioenergetics simulations of centrarchid consumption in the Colorado River await the completion of a large number of diet samples.

ISOTOPIC AND ELEMENTAL ANALYSES

More emphasis was focused on otolith preparation, our diet analysis work and manuscript preparation this year, necessitating the postponement (with sponsor approval) of some of the intended laboratory work on this aspect of the study. Interpretations of existing analyses are presented below.

There is an apparent mismatch between what the stomach data and stable isotope data are indicating about channel catfish diet in the Yampa River. As reported last year (Johnson et al. 2005), stable isotope analysis showed a relatively high trophic position of channel catfish, based on the nitrogen isotope signature ($\delta^{15}N$ = 11.2, n = 13 fish). This signature is consistent with a high proportion of fish in the diet, and is similar to the signature found for northern pike ($\delta^{15}N$ = 11.6) which are known to be highly piscivorous. However, we found very few fish in catfish stomach samples and that finding is consistent with other studies (Tyus and Nikirk 1990; Brooks et al. 2000). Currently available data limit our ability to resolve the discrepancy. Although we have a fairly robust sample of catfish stomachs, they were taken on just a few dates (06/01/04, 06/29/05, 06/30/05, 07/05/05, and 07/06/05) and the isotopic signatures of channel catfish reported by Johnson et al. (2005) were determined from a sample of 11 fish (348-618 mm TL) sampled from the Yampa River on October 22, 2003. Further, isotopic data for aquatic insects (e.g., ephemeropterans, plecopterans and tricopterans) in the Yampa River are scant but these organisms appear to be important in the diet of channel catfish. Diet and isotope samples from catfish captured over a wider range of dates and more isotopic data for aquatic insects would help us interpret the apparent inconsistency between channel catfish diet and stable isotope signatures.

Thirty additional samples of channel catfish (Figure 3) were obtained from CDOW during late June and early July 2005; a subset of these samples should be processed to determine if their isotopic signatures are consistent with findings from 2003. Tissue samples should also be collected from a wide range of fish sizes and from aquatic insects during early spring to late fall to facilitate inter-annual and intra-annual comparisons of isotopic signatures.

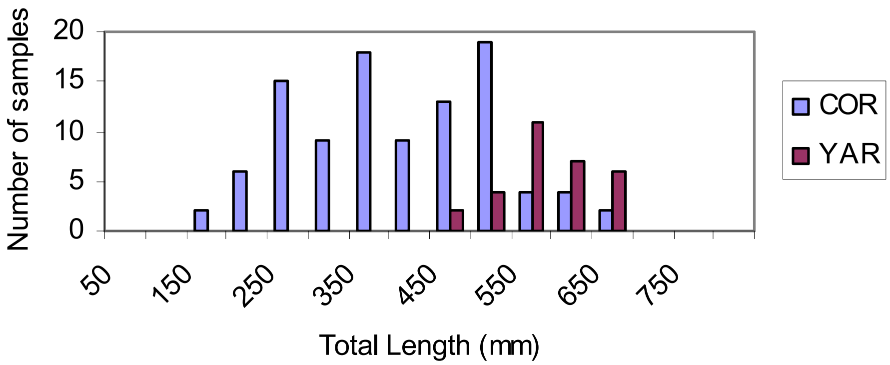


Figure 2. Size distribution of channel catfish sampled for stable isotope analysis from the Colorado (COR) and Yampa (YAR) rivers since June 2005.

COLLABORATION ON MANUSCRIPTS

This year three manuscripts (abstracted below) were carried to various stages of completion. One paper (Whitledge et al. 2006) has been published by the Canadian Journal of Fisheries and Aquatic Sciences. Whitledge et al. (In Press) has been accepted by the Transactions of the American Fisheries Society, and Johnson et al. (In Prep) is currently being reviewed by coauthors.

1. Whitledge, G. W., B. M. Johnson, and P. J. Martinez. 2006. Stable hydrogen isotopic composition of fishes reflects that of their environment. Canadian Journal of Fisheries and Aquatic Sciences 63:1746-1751.

ABSTRACT

Otolith microchemistry and isotopic analyses have emerged as effective techniques for providing insights into fish environmental history that are difficult to obtain by other means. Stable hydrogen isotope ratio ($^2H/^1H$ or D/H, expressed as δD) is a possible environmental marker that has not been employed in fish provenance research, although it has been applied as a natural tracer of terrestrial organism migrations. We illustrate the potential of δD to serve as a new natural marker of fish environmental history by demonstrating that significant linear relationships ($r^2 \geq 0.97$) exist between fish otolith and muscle δD and δD of waters fish inhabit. Differences between mean water δD and both muscle and otolith δD were not significantly correlated with fish total length and were not significantly different among species, indicating that water-fish δD relationships are consistent across fish sizes and species. High r^2 values for regressions of otolith and muscle δD on water δD for fishes inhabiting locations with diverse thermal regimes suggest that relationships between water and fish δD are not strongly affected by water temperature. Demonstration that fish δD clearly reflects water δD provides a foundation for future research to reconstruct fish movement among locations with distinct δD signatures.

2. Whitledge, G. W., B. M. Johnson, P. J. Martinez and A. M. Martinez. 2006. Provenance of nonnative centrarchids in the upper Colorado River revealed by stable isotope and microchemical analyses of otoliths. Transactions of the American Fisheries Society (In Press).

ABSTRACT

Nonnative fishes represent a significant impediment to recovery of imperiled fishes, including those endemic to the Colorado River in the southwestern U.S. Efforts to control non-indigenous fish abundance in the upper Colorado River basin have been unsuccessful, due in part to lack of knowledge regarding nonnative fish recruitment sources. We determined provenance (floodplain pond vs. riverine habitats) of nonnative centrarchid fishes (largemouth bass Micropterus salmoides, green sunfish Lepomis cyanellus, bluegill L. macrochirus, and black crappie Pomoxis nigromaculatus) in the upper Colorado River using stable hydrogen isotopic composition (δ^2H) and Sr:Ca ratios in fish otoliths as natural markers of environmental history. δ^2H analysis revealed that 59% of centrarchids exhibited otolith core signatures expected for riverine-origin fish, while 22% emigrated from floodplain ponds and 19% were of uncertain origin. Sr:Ca data were consistent with δ^2H assays and indicated that relatively few fish immigrated to the river from high-salinity habitats. Black crappie was the only species that originated primarily from floodplain ponds. Efforts to control abundance of most fishes included in this study should be concentrated in riverine habitats given the hydrologic conditions present during our study. However, the proportion of pond-origin fish increased with fish age, which coupled with historical river discharge data suggested that floodplain pond contributions to riverine populations of nonnative fishes may fluctuate with inter-annual variations in flow regime and river-pond connectivity. Our results are the first to demonstrate the utility of δ^2H as a natural marker of fish provenance that will likely provide valuable insights for management of fishes in other environments.

3. Johnson, B. M., P. J. Martinez, J. A. Hawkins, and K. T. Bestgen. In Preparation. Smallmouth bass are the primary predatory threat to the native fish assemblage of the Yampa River, Colorado. For: North American Journal of Fisheries Management.

ABSTRACT

Because of its relatively natural hydrograph the Yampa River, Colorado is considered the “crown jewel” of native fish habitat in the upper basin of the Colorado River, and it has been the stronghold of a relatively intact native fish assemblage. Nonnative fishes are thought to pose the greatest threat to native fishes in this system. Removal programs for nonnative northern pike and channel catfish have been implemented to foster native fish populations, highlighting managers’ perception of the threat posed by each. Recent expansion of nonnative smallmouth bass in the Yampa River and a concurrent precipitous

decline in native fishes prompted this assessment of the relative impact of all three nonnative predators on the native fish assemblage. We used field estimates of abundance, growth, and diet composition of each piscivore to quantify the biomass of prey consumed using bioenergetics models. Despite few fish in their diet, the total consumption of fish by smallmouth bass (15.2 kg•km-1•year-1, 95% CL: 13.3 – 17.1 kg•km-1•year-1) was similar to that consumed by northern pike (13.7 kg•km-1•year-1, 95% CL: 11.4 – 16.0 kg•km-1•year-1), and was about 60 times higher than the biomass consumed by channel catfish (0.22 kg•km-1•year-1, 95% CL: 0.05 – 0.40 kg•km-1•year-1). Data on smallmouth bass diet in the upper Colorado River, where small-bodied prey fish were plentiful, suggested that potential piscivory by smallmouth bass could be as high as ten times more than that by the northern pike and channel catfish populations, or about 168.5 kg•km-1•year-1 (95% CL: 147.0 – 189.9 kg•km-1•year-1). This level of piscivory is similar to the estimated biomass and annual production of small-bodied fishes (<150 mm TL) present in the river. Thus, smallmouth bass currently present the greatest predatory threat to the native fish assemblage of the Yampa River.

RECOMMENDATIONS

1. Additional diet and isotope samples from channel catfish captured from the Yampa River over a wider range of dates would help us interpret the apparent inconsistency between channel catfish diet and stable isotope signatures. Tissue samples should be collected from a wide range of catfish sizes during early spring to late fall to facilitate inter-annual and intra-annual comparisons of isotopic signatures.

2. Given the importance of ephemeropterans, plecopterans and tricopterans in the diet of both channel catfish and smallmouth bass in the Yampa River, additional samples of these insects should be gathered for isotopic analysis, during spring, summer and fall.

3. We should continue to work on manuscripts deriving from this research and submit them to scientific journals.

LITERATURE CITED

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Johnson, B. M., P. J. Martinez, J. A. Hawkins, and K. R. Bestgen. In Preparation. Smallmouth bass are the primary predatory threat to the native fish assemblage of the Yampa River, Colorado. For: North American Journal of Fisheries Management.

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