**COLORADO RIVER RECOVERY PROGRAM** Project No.: 161b
**FY-2011-2013 SCOPE OF WORK for:**

Population abundance and dynamics of introduced northern pike, Yampa River, Colorado

Lead Agency: Colorado State University
Submitted by: Kevin R. Bestgen, John Hawkins, Koreen Zelasko, and Gary White
Larval Fish Laboratory
Department of Fish, Wildlife, and Conservation Biology
Colorado State University, Fort Collins, Colorado 80523
Phone: (970 491-1848)
Email: kbestgen@colostate.edu

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Category:
_ Ongoing project
_ Ongoing-revised project
X Requested new project
_ Unsolicited proposal

Expected Funding Source:
X Annual funds
_ O&M funds
_ Capital funds
_ Other (explain)

I. Title of Proposal: Population abundance and dynamics of introduced northern pike, Yampa River, Colorado

II. Relationship to RIPRAP: General Recovery Program Support Action Plan:
*See RIPRAP at* http://www.coloradoriverrecovery.org/documents-publications/foundational-documents/recovery-action-plan.html*]*

III. REDUCE NEGATIVE IMPACTS OF NONNATIVE FISHES AND SPORTFISH MANAGEMENT ACTIVITIES (NONNATIVE AND SPORTFISH MANAGEMENT)

- III.A.2.c. Evaluate the effectiveness (e.g., nonnative and native fish response) and develop and implement an integrated, viable active control program.
- III.A.2.c.3. Level II synthesis: assimilate Level 1 syntheses into a basinwide and population scale analyses of effectiveness of nonnative fish management. .

III. Study Background/Rationale:

Introduction and establishment of non-native fish in western rivers of the USA is a major threat to conservation of native fish assemblages (Minckley and Deacon 1968; Stanford and Ward 1986; Moyle et al. 1986; Carlson and Muth 1989; Minckley and Deacon 1991; Olden et al. 2006). In the upper Colorado River Basin, non-native fish invasions began over 100 years ago, with introduction of channel catfish *Ictalurus punctatus*, common carp *Cyprinus carpio*, and salmonids for sport fishery purposes. In the 1970's, small-bodied species such as red shiner were expanding rapidly (Vanicek et al.1970; Holden and Stalnaker 1975a and 1975b), and potential negative effects of that species and other small-bodied fishes have been documented (Haines and Tyus 1990; Dunsmoor 1993; Ruppert et al. 1993; Muth and Snyder 1995; Bestgen et al. 2006a). More recently, piscivores such as smallmouth bass *Micropterus dolomieu* and northern pike *Esox lucius* have established and are common in the Yampa River, occasionally common in the upper and middle Green River basins, and present in the upper Colorado River (Wick et al. 1985; Anderson 2002, 2005; Bestgen et al. 2006b; Burdick 2008).

The predatory threat of large-bodied piscivorous taxa such as northern pike and smallmouth bass is substantial. For example, based on results of a bioenergetics model, Johnson et al. (2008) ranked smallmouth bass and northern pike as the first and second-most problematic invasive species because of their high abundance, habitat use that overlaps with most native fishes, and capability to consume a wide variety of life stages of native fishes in the Colorado River Basin. Expanded populations of piscivores such as northern pike are a major impediment to conservation actions aimed at recovery efforts for the four endangered fishes in the Upper Colorado River Basin: Colorado pikeminnow *Ptychocheilus lucius*, razorback sucker *Xyrauchen texanus*, humpback chub *Gila cypha*, and bonytail *Gila elegans* (U.S. Fish and Wildlife Service 2002a, b, c, d). Northern pike are especially problematic because they are capable of consuming nearly all life stages of native fishes, including adult Colorado pikeminnow (J. Hawkins, pers. obs.). Evidence that northern pike may yet be a potent predatory problem in the Yampa River is that abundance of Colorado pikeminnow continued to decline from the 2000-2003 period and stabilized at a relatively low level from 2006-2008 (Bestgen et al. 2010) in spite of pikeminnow abundance increases in the four other major population areas in the Green River Basin.

In response to the predatory threat posed by non-native northern pike, the Upper Colorado River Recovery Implementation Program initiated efforts to control such species via mechanical removal in affected stream reaches; some of this activity has been ongoing in the middle Green River, Utah, for some time. Interim goals for removal actions have also been established for the Yampa River and include reduction of northern pike and increasing the composition the small-bodied fish community to 10-30% native fishes. The current density is 21 pike/mile (Craig to Hayden) and 7.9 pike/mile in critical habitat. The interim target for critical habitat is 3 NP/mile (or current pikeminnow density [1.9 pikeminnow/mile in 2008], whichever is lower). To date, substantial information has been collected on distribution, population abundance, size structure, and movements of northern pike concurrent with removal actions throughout the Upper Green River Basin. Removal efforts implemented vary in intensity and effectiveness across stream reaches where pike exist, but only a few areas are thought to approach levels of removal needed to enhance survival prospects for native fishes (Badame et al. 2008; Burdick 2008; Hawkins et al. 2009). Further, limited understanding of population level effects of removal actions inhibits the ability of managers to understand effectiveness of removal programs and formulate a comprehensive control strategy that will effectively reduce populations of northern pike and enhance prospects for recovery of native fish populations.

Research to better understand abundance and population dynamics of smallmouth bass in the Upper Colorado River Basin is presently underway and we plan to model the northern pike analysis after that successful smallmouth bass model to the extent possible. Our basic approach will be to conduct comprehensive abundance estimates at appropriate temporal and spatial scales, which when coupled with immigration data, should allow for a more comprehensive understanding of abundance dynamics of pike populations in the Yampa River. This understanding will allow managers to assess the role of the buffer removal area in the vicinity of Hayden, Colorado, on pike populations in downstream critical habitat and will also aid assessment of immigration from sources upstream of there, and explore more effective means to achieve recovery of native fishes. Influence of important environmental factors on northern pike abundance dynamics, such as stream flow levels and subsequent reproductive effort, will allow simultaneous assessment of trajectories of pike populations under different levels of removal effort.

IV. Study Goals, Objectives, End Product:

A. Goal: Our goal is to develop comprehensive age- or size-structured abundance estimates and immigration rates to understand factors that affect northern pike population dynamics in the Yampa River.

B. Objectives: 1) Assess effectiveness of the Recovery Program's removal efforts to date; and, 2) Predict the Recovery Program's ability to achieve removal targets.

C. End Products: See item VIII.

V. Study area: Yampa River, Colorado; middle and upper Green River sampling and tag recapture data may also be useful to determine emigration-immigration dynamics in the Yampa River.

VI. Study Methods/Approach:

We propose to use the comprehensive non-native fish removal database with records through 2010 to develop abundance estimates and investigate aspects of the population dynamics of northern pike in the Yampa River, Colorado. Our goal is to develop comprehensive age- or size-structured abundance models to understand factors that affect northern pike population dynamics in the Yampa River.

Aspects of northern pike abundance have been investigated in the Yampa River in various efforts (e.g., Finney and Haines 2008; Martin et al. 2010) but never in a comprehensive fashion. Similar to the smallmouth bass data collection and analysis, a more comprehensive look at pike data would likely give the Program and participants a clearer understanding of the status of northern pike in the Yampa River and would further inform removal efforts designed to control their distribution and abundance.

*Database organization*.—The first element of any data synthesis would be to organize the database. Even though the data are already in a single place for the most part, sorting out important records and recapture data with all its nuances is an important first step and will familiarize investigators with the quantity and quality of the available data.

*Parameter estimation models and assumptions.*—The second element is the development of revised annual abundance estimates over time. This would give the Program valuable information about trends over time and fluctuations in size and age structure, and, minimally, allow us to incorporate size-dependent effects on capture probabilities. Two general classes of models can be used to estimate abundance of animal populations in the wild and are differentiated based on assumptions about population demographics. The first class of models is closed population estimators. Closed population estimators have four main assumptions. The first is that the population is geographically and demographically closed so that N, the true population size, is constant during the short-term annual sampling event. Geographic closure assumes that there is no immigration to or emigration from the population of interest. Demographic closure assumes no births or deaths within the sampling period. A second assumption that is often difficult to meet is that all individuals in the population have the same probability of being captured during each sampling occasion. Differences in capture probability among individuals are well-known in fish populations and can stem from physical, behavioral, or environmental variation. Size-related differences often result in varying susceptibility to sampling gear. A group of individuals that occupies a habitat type different than that used by most individuals in the population may also cause unequal probabilities of capture. Other behavioral differences may also cause differences in capture probability among individuals. Capture probabilities may also vary among occasions because of changes in environmental conditions such as stream flow. A third assumption of closed abundance estimators is that previously marked animals can be reliably distinguished from unmarked animals. A final assumption is that closed population that tagged fish are representative of the population to which inferences are being made and that the fate of individuals is independent of each other.

The second class of models is open population estimators. Open population models are useful to estimate population abundance as well as the joint probability of survival/immigration, and births or recruitment/emigration (Lebreton et al. 1992). This general model class is termed the Jolly-Seber (J-S) model (Jolly 1965, Seber 1965). Similar to closed population models, J-S population estimation models assume that tagged fish are representative of the population to which inferences are being made and that the fate of individuals is independent of each other. An assumption not common with closed abundance estimators is that fish in an identifiable class or group (e.g., adults) have the same survival and capture probabilities for each time interval. A consequence of this component in J-S population models is that all releases should be made within a short time period so that rates among individuals are the same. The J-S models do not generally require assumptions of no immigration, emigration, recruitment, or mortality. However, geographic closure is still important when population size is the parameter of interest. Although open models can estimate more and different parameters and have less restrictive underlying assumptions, abundance estimates generated from such models are often less precise than those for closed population models. Another disadvantage of abundance estimates calculated from open population models is that they are all based on model $M_t$, a model that allows for time varying probabilities of capture. Although time variation is likely among sampling occasions, J-S models assume no heterogeneity or behavioral response among individuals in the estimated population. Thus, abundance estimates calculated from open population models do not allow as thorough an evaluation of assumptions as do closed population models.

The robust design for capture-recapture studies attempts to capitalize on the strengths of closed and open population models by combining the use of each in an overall sampling and estimation program (Pollock 1982, 1990). The robust design employs sampling at two scales. Sampling occasions completed at closely spaced intervals (e.g. weeks) are used to estimate population size using closed population models. That level of sampling completed in two or more consecutive years allows for estimation of population probabilities of capture, recruitment, and annual survival rates. The robust design approach was employed by Osmundson and Burnham (1998) and Bestgen et al. (2005; 2007; 2010) to estimate abundance and survival rate of Colorado pikeminnow in the Colorado River and the Green River, respectively. This approach offers advantages of both closed and open population estimation methods if certain assumptions are met. A particular advantage is that the robust design allows evaluation of heterogeneity effects within individuals among capture occasions. Size-dependent effects were very important for capture probabilities of bass and had a subsequently large influence on abundance estimates (A. Breton, unpublished data) and likely will be important for pike as well. We will assess if such an approach is feasible for analysis of the northern pike data.

Because we know exploitation rates and abundance in the same hypothetical year and can estimate abundance the following year, we should also be able to estimate immigration rates of pike into various study reaches. This is so because in several reaches, especially in critical habitat, little or no in situ recruitment is thought to occur but instead occurs mainly as downstream immigration from upstream source populations where spawning habitat is more abundant. This is an important departure from the smallmouth bass scenario, where reproduction and recruitment are essentially occurring in the same reaches where large populations of adults occur.

*Environmental effects on recruitment and immigration*.—A third element of the northern pike data synthesis is to understand size of recruitment year-classes and immigration in relation to hydrologic conditions or spawning habitat availability and how those factors relate to the Program's ability to deplete pike and achieve removal goals. We are also trying to understand these effects on smallmouth bass (e.g., effects of flows and temps on spawning success and recruitment) but it is slightly different because we do not have data to estimate those relationships directly. This is because we do not study pike extensively where they reproduce (an exception is the CDOW effort upstream). Understanding recruitment relationships with hydrology and water temperature could be accomplished by estimating abundance of age-1 pike in a reach by year (from estimates), and relating those to environmental conditions in the prior year. An added element that may be useful to consider is to sample some age-0 pike in places where they are abundant and conduct otolith increment analysis to better understand timing of spawning in relation to flow levels and water temperatures. Understanding timing of reproduction would allow for a better understanding of factors that may negatively influence pike reproduction and abundance.

A fourth element that would be useful to understanding pike impacts on Yampa River fishes but was not funded for study is to employ existing bioenergetics models using real or hypothetical abundance levels and various population size structures. One outcome of pike removal has been shifts in size structure of pike in reaches over years. Brett Johnson and others (2008, North American Journal of Fisheries Management) formulated a bioenergetics model for Yampa River predators, including northern pike. Inputs of different pike densities (abundance) and size structures into that model would allow evaluation of existing and potential predation demand. This would allow a more informed understanding of a variety of removal scenarios and potentially predict when or how much recovery of native fish populations might be achieved with additional removals. Such an approach may be useful in the future should funding become available.

Koreen Zelasko and Gary White are available to conduct most investigation elements and would be responsible for most of the data organization, estimation, and report preparation. It will also be invaluable to have researchers who collected much of the relevant data close at hand (e.g., John Hawkins) to assist with this project.

VII. Task Description and Schedule

**Task 1: Assess effectiveness of the Recovery Program's removal efforts to date**

We will use the Recovery Program database to develop age- or size structured abundance estimates and immigration rates to evaluate past exploitation and future exploitation strategies on the northern pike population in the Yampa River. Equation fitting, survival estimation, and model selection using existing data will be implemented with SAS and program MARK (White and Burnham 1999). A relatively simple population dynamics modeling approach may be implemented if data are available to describe effects of various environmental correlates on pike reproduction and year-class strength. For example, data may show that high (or low) flow years promote reproduction and dispersal of large numbers of young pike downstream. Relating flow levels to pike populations when they were produced (using age-specific abundance estimates) and optimizing when and where removal efforts occur may assist the program with developing the best pike control strategy.

**Task II.** Assess if Recovery Program efforts have had a significant population level impact on northern pike.

We will attempt to determine what population level effects have been caused by human exploitation (electrofishing) and what effects may be from other factors such as the relative role of immigration from upstream sources. We will explore potential impacts of removals on size structure, population numbers, biomass, and other parameters. An important part of this portion of the study will be identifying information gaps critical to obtaining a better understanding of the pike abundance dynamics in the Yampa River. We will also attempt to describe the relative effects of environmental conditions on effectiveness of removal efforts. As described above, it may be possible to attribute various population level changes to environmental conditions (e.g., high flow events, changes in temperature, turbidity). It will also be possible to understand variation in sampling effort and effects of environmental factors on such (e.g., streamflow, turbidity, water temperature levels), which will lead to optimizing conditions for sampling and removal rates.

We understand that managers cannot manipulate flow and temperature regimes in the mostly unregulated Yampa River. However, analyses may be useful to understand potential effects of long-term changes to flows and water temperatures. Most scenarios that we envision could involve reductions in flows and increases in water temperature, similar to that observed in the recent drought period, the energetic consequences of which were described for the major non-native predator fishes, including smallmouth bass, in the Yampa River (Johnson et al. 2008). Similar to drought conditions, stream flows could be reduced by long-term global climate change or diversion of Yampa River flows to off-channel reservoirs, as has been proposed for oil shale development in western Colorado. An understanding of abundance dynamics would be useful to explore scenarios and determine the duration and conditions under which mechanical removal would need to proceed under expectations for long-term changes in Yampa River (or other system) flows.

**Task 3**: Determine means to predict the Recovery Program's ability to achieve removal targets.

Based on a better understanding of population and immigration levels, we should be able to determine an exploitation strategy, perhaps one that is life stage specific that results in achieving population removal goals. For example, is it more effective to increase reductions in source areas with high abundance of large adults or is a riverwide removal effort the most effective for achieving target levels of reductions? Incorporation of movement/immigration data will have important uses. For example, it may also be useful to simulate effects of movements of pike from upstream sources relative to removal rates. Depending on levels of tag recaptures, we may also be able to estimate specific levels of more recent, chronic levels of escapement from particular sources, and impacts to removal efforts in the Yampa River.

**Task 4**: Final report

VIII. FY-2011-2012-2013 Work

- Deliverables/Due Dates

A draft report, in Recovery Program format, will be available for review according to the schedule provided. The report is expected to contain available information on northern pike control, particularly that revealed by data analyses.

Schedule

**Task 1. Data organization and abundance estimates.** We cannot start this project until September 2011 due to other commitments. Data organization will be completed in December 2011. Abundance estimates will be conducted from January 2012 to November 2012.
**Task 2**. **Understand population dynamics effects**. Nov. 2012- March 2013.
**Task 3. Evaluate efficacy of Program removal targets.** March 2013-June 2013.
**Task 4. Final report.** 30 September 2013, final 31 December 2013.

IX. Budget Summary –Fringe benefits are 25% of the total amount of salaries. LFL overhead rate is 17.5% and is charged to all items. Fringe on salary and overhead are figured into costs.

**FY 2011**

Tasks 1-3, data organization, data analysis, annual report preparation

| Item | | | | Cost |
|---|---|---|---|---|
| Labor | Units | Cost/unit | | |
| Principal investigator (d) | 25 | 490 | | $12,250 |
| Biologist (d) | 132 | 330 | | $43,560 |
| Technician (d) | 5 | 145 | | $725 |
| | | | subtotal | $58,515 |
| Travel | | | | |
| Meeting | 2 | 600 | | $1,200 |
| | | | subtotal | $1,200 |
| Computer, software | 1 | 2,265 | subtotal | $2,265 |
| | | | Total | $60,000 |

Total tasks 1-3 $60,000

**FY 2012**

Tasks 1-3, data organization, data analysis, annual and draft final report preparation

| Item | | | | Cost |
|---|---|---|---|---|
| Labor | Units | Cost/unit | | |
| Principal investigator (d) | 25 | 490 | | $12,250 |
| Biologist (d) | 140 | 330 | | $46,200 |
| Technician (d) | 2.4 | 145 | | $350 |
| | | | subtotal | $58,800 |
| Travel | | | | |
| Meeting | 2 | 600 | | $1,200 |
| | | | subtotal | $1,200 |
| | | | Total | $60,000 |

| | |
|---|---|
| Total tasks 1-3 | $60,000 |

**FY 2013**

Task 4, final report preparation

| Item<br>Labor | Units | Cost/unit | | Cost |
|---|---|---|---|---|
| Principal investigator (d) | 5 | 490 | | $2,450 |
| Biologist (d) | 22 | 330 | | $7,260 |
| Technician (d) | 2 | 145 | | $290 |
| | | | subtotal | $10,000 |
| | | | Total | $10,000 |

| | |
|---|---|
| Total task 4 | $10,000 |

| | |
|---|---|
| FY 2011: | $60,000 |
| FY 2012: | $60,000 |
| FY 2013: | $10,000 |
| Total | $130,000 |

X. Reviewers:

XI. References


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