Incidence and consumption of endangered fishes by channel catfish (*Ictalurus punctatus*) in the San Juan River

Scope of Work

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Background

The channel catfish (*Ictalurus punctatus*) is a highly invasive fish species that has been repeatedly identified as having negative impacts on native fishes (Fuller et al. 1999; Tyus and Saunders 2000). In the Colorado River basin the introduction of channel catfish is thought to threaten native fishes through predation, competition, and as a choking hazard (Tyus and Nikirk 1990; Ryden and Smith 2002; Franssen et al. 2014). Assessing the potential predation impacts on native species by nonnatives requires information on the diet, gut evacuation rates, and daily ration of the predator (Johnson et al. 2008). However, a fish species predation capability will vary spatially and temporally based upon variable demographic rates, prey availability, and abiotic conditions, thus quantifying a predator's ability to diminish native fishes needs to incorporate multiple spatial and temporal scales. Finally, it is necessary to understand prey population size to evaluate if mortality induced by the predator can result in a notable impact on its population. Once the potential predatory impacts on native species are identified for a predator, management strategies can be developed to produce more successful conservation efforts. Previous channel catfish diet work in the San Juan River found no evidence of predation of any endangered fish but argued that their work does not negate the possibility of predation, especially since all samples were only collected during early morning and afternoon hours (Patton 2015). Given the uncertainty and potentially variable importance of channel catfish predatory impacts throughout the San Juan River, this proposal has the overarching goal of identifying the mortality of endangered fish species in the San Juan River basin attributed to consumption by channel catfish.

Objectives

1) Determine the daily ration and gut evacuation rates of channel catfish in two reaches of the San Juan River to understand the potential for predatory impacts on native fishes.
2) Determine the incidence of endangered species in the diet of channel catfish throughout the San Juan River at multiple temporal scales (diel and seasonal).
3) Obtain estimates for maximum predatory impacts channel catfish can impose on native fishes.

Methods and sampling design

Objective 1: Determine the daily ration and gut evacuation rates of channel catfish in two reaches of the San Juan River to understand the potential for predatory impacts on native fishes.

Surveys at two reaches (an upstream reach – Hogback to Shiprock and a downstream reach – Bluff to Mexican Hat) of the San Juan River will be conducted with raft electrofishing at bimonthly intervals from March through November. Daily ration (Eggers 1979; Boisclair and Leggett 1988) of channel catfish will be measured in each reach during all sampling events. Samples will be collected at 3-hour intervals within a reach to measure how gut volumes fluctuate throughout a day and seasonally (Table 1). The reach lengths will be optimized (using previous studies data to understand variation in channel catfish densities) to allow us to catch enough fish over time to conduct a robust analysis of changes in ration size, but short enough to minimize travel time through the reach. In the event that we are not able to capture enough fish for computing reliable estimates of daily ration, we will follow Boisclair and Leggett (1988), who recommend the Eggers model that allows for variable catch rates in each time period. Sample reaches will also be chosen to minimize hazards of night-time electrofishing. Additionally, rafts will be equipped with flood lights to facilitate night-time capture of fishes. To reduce stress to native fishes only channel catfish will be targeted and netted, and electrofishing will be stopped if endangered species remain in the electric field.

Gut evacuation rates will be measured with field and laboratory experiments. During field gut evacuation experiments, 50 adult channel catfish will be removed from each study reach during the time of day when stomachs are at peak fullness (computed from daily ration sampling) and placed in portable pools. Stomachs from 10 fish will be removed every 3-4 hours over a 24 hour time period. Stomachs will be weighed and related to the total body mass of the individual to obtain gut fullness and evacuation rates following procedures by Persson (1979) and Grove and Crawford (1980). Laboratory experiments will be conducted to reduce advanced gut evacuation associated with stress in the field (Boisclair and Leggett 1988). After acclimation in the laboratory, channel catfish will be fed a measured amount of food representative of field diets and procedures will then follow those conducted in the field. Laboratory methods will follow those of field gut evacuation experiments. Hatchery raised channel catfish will be used for laboratory trials, with the assumption that gut evacuation rates do not vary from wild San Juan River channel catfish. Water temperatures will be continually monitored during all field and laboratory studies.

Data collected from these experiments will be used to parameterize the following equations, thus allowing us to calculate daily ration:

Gut fullness is calculated as:

$$F_t = G_t/W_t x100$$

Where F_t = gut fullness; G_t = weight of stomach contents; and W_t = weight of fish.

Evacuation rate (hours) is calculated as:

$$R = (\ln F_{t+1} – \ln F_t)/T$$

Where R = evacuation rate; F_t = gut fullness at t; F_{t+1}= gut fullness at t+1; and T = time between interval.

Daily ration (% body weight) is calculated as:

$$D = F_t * R * 24 + (S_{24}-S_0)$$

D = daily ration; F_t = mean gut fullness of all fish collected; R = maximum evacuation rate; and $S_{24}-S_0$ = final minus initial median gut fullness values.

Table 1: Time matrix of daily ration sampling and field gut evacuation trials. Sampling will occur at two study reaches in the San Juan River and be conducted bimonthly from March to November.

TIME	DAY 1	DAY 2	DAY 3	DAY 4
9A		Daily Ration		Gut Evacuation
12P		Daily Ration		Gut Evacuation
3P	Daily Ration			Gut Evacuation
6P	Daily Ration			Gut Evacuation
9P			Daily Ration	Gut Evacuation
12A			Daily Ration	Gut Evacuation
3A		Daily Ration		Gut Evacuation
6A		Daily Ration		Gut Evacuation

Objective 2: Determine the incidence of endangered species in the diet of channel catfish throughout the San Juan River basin at multiple temporal scales (diel and seasonal).

Diet samples will be collected every other month from March through November from large (>300mm) channel catfish, which should encompass the time periods when water temperatures are within the feeding range for ictalurids and for individuals that have the highest diet proportions containing fish (Brooks et al.

2000; Bourret et al. 2008; Tim Patton, unpublished data). Each sampling event will include 4 days of collecting channel catfish stomachs in the two intensively sampled reaches. Stomach contents will be collected in 3-hour blocks over 24 hour time periods to identify the diet of channel catfish during different diel periods. In addition to the two intensively sampled reaches, we will conduct comprehensive diet surveys throughout the river from Hogback Diversion to Bluff, UT. These surveys will occur prior to runoff (May), after runoff (July) and in the autumn (September). The time of day that fish collections will be made in extensive sampling surveys will be based on results from daily ration experiments. Assuming there is diel variation in consumption rates, which has been previously documented with channel catfish (Weisberg and Janicki 1990), we will only sample fish during time periods when channel catfish consumption is the highest. This will allow for higher probabilities of stomachs containing prey items that will be used for diet analysis, identify spatial variation in the diets, and allow for easier identification of prey items. All stomach contents will be identified, measured and weighed. If stomach contents are heavily digested, methods using pharyngeal teeth will be used to identify razorback suckers (unique tooth count of 67-74) and Colorado pikeminnow (ratio of the total length of the arch to the post-tooth section of the arch of 1.8-2.1) following Patton (2015). Sizes of partially digested prey items will be estimated by the lengths of remaining body parts. For example, if we find a neurocranium, we might use reference specimens to establish the length-weight relationships between interorbital width and total mass. After diet analysis is complete and daily ration and gut evacuation is computed, the total potential (maximum number of fish consumed) and actual (number of fish consumed during the study) mortality by channel catfish on native fishes can be calculated. Using the equations in *Objective 1*, the amount of endangered fish consumed by channel catfish can be calculated. As an example, we used mock data in Table 2 to illustrate how we will estimate daily consumption rates. By fitting an equation to the change in daily consumption rates over time (Figure 1) we can extrapolate those rates to estimate the consumption of endangered fish over the entire year. The mock data plotted in Figure 1 yield a total yearly consumption of endangered fish of 60.1 g/catfish. Using this value, the total consumption of endangered fish by channel catfish can be extrapolated with population size and age structure data in the San Juan River (Table 3). We will work with the SJRBRIP scientists that are obtaining population estimates for endangered species and catfish to parameterize these models.

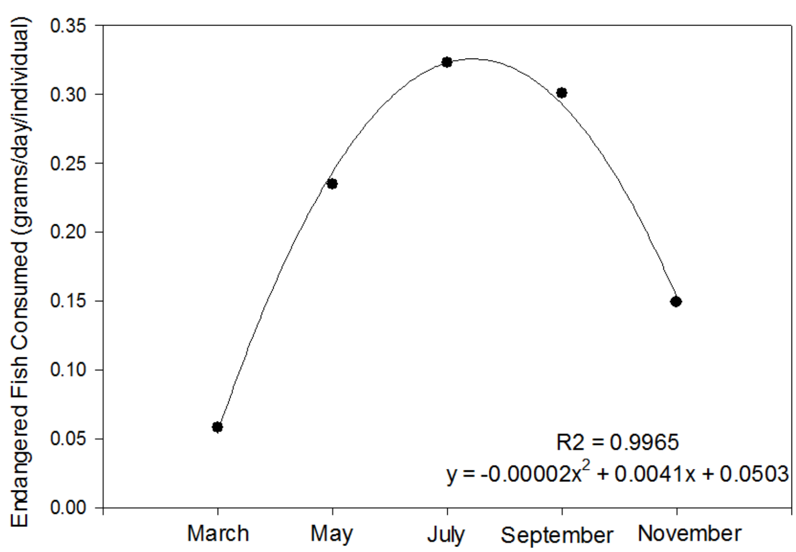

Figure 1: The relationship between sampling event and endangered fish consumption by channel catfish derived from mock data in Table 2.

Table 2: Calculations of gut fullness (F_t), evacuation rate (R), difference between final and initial gut fullness values (S_{24}-S_0), daily ration (D), average weight of channel catfish, daily consumption by channel catfish, diet composition of endangered fish, and endangered fish consumed during bimonthly sampling events derived mock data.

Sampling Event	Temp (^oC)	F_t	R	S_{24-S0}	D	Weight (g)	Consumption (g/d)	Diet Composition of Endangered Fish (%)	Endangered Fish Consumed (g/d/individual)
March	14	0.00155	0.22	0.00087	0.9054	380	3.44	1.7	0.0584
May	17	0.00255	0.42	0.001	2.6704	400	10.681	2.2	0.2349
July	23	0.0038	0.58	0.0015	5.4396	440	23.934	1.35	0.3231
September	22	0.00335	0.51	0.0012	4.2204	460	19.413	1.55	0.3009
November	15	0.0022	0.33	0.00089	1.8314	480	8.790	1.7	0.1494

Table 3: Individual consumption of endangered fish across a range of possible adult channel catfish (> 300 mm) population sizes in the San Juan River between PNM Diversion and Mexican Hat. Total consumption of endangered fish by channel catfish is based on mock data presented above and the total number of individual endangered fish consumed is based on the assumption that average weight of prey is 10 grams (approximately 100 mm). Note: these numbers are just an illustration of the expected results.

Individual Consumption (g/yr)	Population Size	Total Consumption (g/yr)	Total Individuals Consumed
60.1	10,000	601,000	60,100
	15,000	901,500	90,150
	20,000	1,202,000	120,200
	25,000	1,502,500	150,250
	30,000	1,803,000	180,300
	35,000	2,103,500	210,350
	40,000	2,404,000	240,400
	45,000	2,704,500	270,450
	50,000	3,005,000	300,500

Objective 3: Obtain estimates for maximum predatory impacts channel catfish can impose on native fishes.

Growth rates, diet composition, water temperature and activity will be used to develop a bioenergetics model for channel catfish in the San Juan River using Fish Bioenergetics 4.0. Growth rates of channel catfish will be measured using spines or otoliths from male and female channel catfish collected throughout the San Juan River following procedures of Buckmeier et al. (2002). An age-length relationship will be used to calculate yearly growth rates of channel catfish in different reaches of the river. Temperature and activity will be assessed using archival radio tags that are implanted in a fish and continuously record temperature and movement every minute for a 400+ day period (see Hedden et al. 2016 for example with flathead catfish). We propose to tag 10 fish in the lower reach (Bluff to Mexican Hat) and 10 fish in the upper reach (Hogback to Shiprock) in March and recover the implanted transmitters the following year. Internal body temperature for fish will be used to parameterize bioenergetics models and activity sensors will be used to evaluate the temperatures at which the fish are active. Bioenergetics models will be constrained to those times when catfish are active. Combined, these data will allow us to obtain estimates of maximum predatory impacts channel catfish can impose on native fishes (e.g., Hedden et al. 2016).

Literature

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Budget

Period: January 1, 2018 to December 31,2019

Task Description	Year 1	Year 2
Task		
Salaries		
Research assistant (9 month)	$ 32,308	$ 33,923
Undergraduate field technician (9 month)	$ 16,000	$ 16,800
Fringe benefits		
Research assistant (30%)	$ 9,692	$ 10,177
Field technician (1%)	$ 160	$ 168
Travel		
Per diem (3 - 15 day trips and 2 - 10 day trips per year x $20/day per person)	$ 2,600	$ 2,600
Lodging (3 nights per trip x 5 trips x $100/night)	$ 1,500	$ 1,500
Mileage (2000 miles per trip; 0.50/mile x 10,000 miles)	$ 5,000	$ 5,000
Supplies		
Sampling (whirl paks, waders, holding tanks)	$ 4,500	$ 4,500
Laptop computer	$ 2,000	$ -
Archival radio tags ($500 each x 20)	$ 10,000	
Total direct costs	**$ 83,760**	**$ 74,668**
F&A (17.5% CESU)	**$ 14,658**	**$ 13,067**
Incl KSU 17.5%	**$ 98,418**	**$ 87,735**

Budget Justification

We are requesting a minimum of two years funding because flow conditions can be highly variable among years and multiple years will allow for a more robust analysis with larger sample size. A full-time research assistant will be paid for 9 months and will oversee the data collection, laboratory work, analysis and report writing. Undergraduate field technician will assist is all aspects of data collection and laboratory work. Travel will cover costs of 5 trips from Manhattan, KS to the San Juan River each year. There will be 2 10-day trips and 3 15-day trips. Lodging will cover 3 hotel rooms per trip; personnel will be camping the rest of the trips. Supplies will cover whirlpaks, formalin, waders and a holding tank (for gut evacuation experiments). A laptop computer is requested for data entry, storage and running bioenergetics models. Overhead rate (F&A) is 17.5% per the cooperative ecosystem studies unit (CESU) agreement with Kansas State University.