FORAGE FISH ABUNDANCE AND THE INFLUCENCE OF RIVER FLOW – MANAGEMENT IMPLICATIONS FOR THE ENDANGERED LEAST TERN

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ABSTRACT

Forage fish abundance was sampled at several sites on the central Platte River, Nebraska periodically from 1999-2008 by implementing the Platte River Recovery Implementation Program's forage fish monitoring protocol. Fish abundance is being measured by the Program to relate to river discharge and interior least tern (*Sterna antillarum*) productivity. Fish were caught in open channel habitats using seines, counted, and identified to species. The abundance of the predominant six forage species was log-transformed and modeled against river discharge at the time and location of sampling. A generalized additive model was used to explore the complexity of the relationship between discharge and fish abundance. A mixed-effects model was used to explore the fixed effect of discharge and the random effects of sampling site and date on fish abundance. Model results show discharge has a statistically significant main effect on fish abundance, but the variance structure of the model suggest an unreliable result and the need to enhance sampling locations, the range of discharges sampled, and collection of data related to other parameters such as channel width and water temperature.

INTRODUCTION

The Platte River Recovery Implementation Program (Program) initiated on January 1, 2007 to address issues related to the loss of habitat in the Platte River in central Nebraska by managing certain land and water resources following the principles of adaptive management to provide benefits for four "target species": the endangered whooping crane (*Grus americana*), interior least tern (*Sterna antillarum*), and pallid sturgeon (*Scaphirhynchus albus)*; and the threatened piping plover (*Charadrius melodus*). Central to the Program is its Adaptive Management Plan, which provides a systematic process to test priority hypotheses and apply the information learned to improve management on the ground (AMP, 2006).

Figure 1. Interior least tern (*Credit: Jim Jenniges*)

Figure 2. Sand shiner (*Credit: Cornell University*)

Interior least terns utilize open river sandbars and gravel pit spoil piles ("sandpits") for nesting on the central Platte River annually from May through August (Held, 2007). During the nesting season on the Platte, least terns forage for small fish generally less than 8 centimeters in length in sand pits and open river channel (Wilson et al., 1993; NRC, 2005). The decline in productivity of least terns on the central Platte is often attributed to several factors including the loss of river sandbar habitat, flow alteration, and sandbar encroachment (NRC, 2005). As such, several priority hypotheses in the AMP focus on the productivity of interior least terns on the central Platte and its relationship to habitat availability, river flow, and other factors (AMP, 2006).

One of the central priority hypotheses, T2, states: "Tern productivity is related to the number of prey fish (<3 inches) and fish numbers limit tern production below 800 cfs from May-September." This hypothesis relates to concerns over the relationship between declining tern productivity on the central Platte and the availability of forage fish in the river due to low summer flows. A sub-hypothesis of T2 postulates a non-linear relationship between the number of fish (fish abundance) and river discharge (Figure 3).

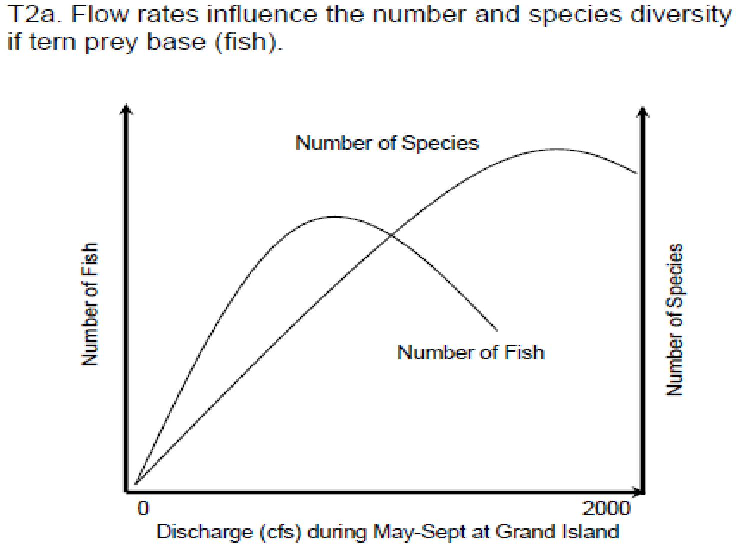

Figure 3: X-Y graph for forage fish abundance/river discharge hypothesis (AMP, 2006).

The objective of this analysis was to utilizing existing central Platte forage fish monitoring data to estimate the impacts on forage fish abundance due to river discharge and other factors and begin to build empirical evidence to test the forage fish-related tern hypotheses in the AMP. The results of the analysis could be useful in further estimating the relationship between prey abundance and tern productivity and how those two parameters can factor into Program management actions.

METHODS

Sampling Area

The sampling area encompassed the roughly 90 miles of the central Platte River where Program activities are focused, consisting of an area 3.5 miles on either side of the Platte River centerline beginning at the junction of U.S. Highway 283 and Interstate 80 near Lexington, Nebraska and extending eastward to Chapman, Nebraska. Forage fish sampling occurred during a portion of the summer least tern nesting season between July 1 to August 31 in 1999, 2003, 2005, 2007, and 2008. Four forage fish sampling sites were established in 1999 based on their relationship to areas managed as least tern nesting habitat. A fifth sampling location near Alda, Nebraska was added in 2003 (Jenniges and Peyton, 2007). Sampling locations included: Lexington (1.6 km downstream of the US Highway 283 river bridge); Overton (2.3 km upstream of the Overton river bridge); Cottonwood Ranch (8 km upstream of the US Highway 183 river bridge); Elm Creek (1 km downstream of the US Highway 183 river bridge); and Alda (2.4 km downstream of the Alda river bridge). Sampling was conducted by staff from the Nebraska Public Power

District, Central Nebraska Public Power and Irrigation District, Central Platte Natural Resources District, and the Program Executive Director's Office.

Sampling Design and Techniques

Forage fish data was collected in 1999-2008 through implementation of the Program monitoring protocol, *Monitoring Riverine Prey Base for Least Terns: Fish Species Composition, Spatial Distribution, and Habitat Utilization in the Central Platte River* (AMP, 2006). Each study area included a 200 m reach of river with habitat classifications of open channel, open channel and side channel bank, open channel snag, backwater, isolated backwater, slough, pond, and side channel (AMP, 2006). For the purposes of this analysis, only data collected from the open channel habitat classification at each sampling location was considered. In all years, roughly 80% of all fish collected were in the open channel. Previous investigations of tern foraging behavior, as well as observation of tern foraging on the central Platte, generally indicate a preference for open water foraging on rivers (Wilson et al., 1993; Tibbs and Galat, 1998).

Only open channel data collected for six species of forage fish (Table 1) were included in the analysis since those six species comprised between 75%-90% of all fish sampled every year. In addition, least terns are generally considered to be opportunistic feeders that focus on a certain size range of fish as opposed to species-specific forage selection (USFWS, 2006).

Common Name	Scientific Name
Red shiner	*Cyprinella lutrensis*
Sand shiner	*Notropis stramineus*
Bigmouth shiner	*Notropis dorsalis*
Brassy minnow	*Hybognathus hankinsoni*
Mosquitofish	*Gambusia affinis*
Plains killifish	*Fundulus zebrinus*

Table 1. Predominant identifiable forage fish species sampled on the central Platte River, 1999-2008.

The forage fish monitoring protocol defines open channel as the flowing portion of the active channel area greater than 23 m (AMP, 2006). From 1999-2008, all open channel areas at each site were sampled using 1/8-inch mesh seines to enclose an area 7.5 m by 15 m and capture available forage fish of the appropriate size (AMP, 2006). In 1999-2005, a total of ten randomly placed seining replicates were completed in open channel at the Cottonwood Ranch, Elm Creek, and Alda sites; only five seining replicates were conducted at the Lexington and Overton sites because of insufficient channel area. Beginning in 2007, seine hauls were taken at each of six transects at all sites. All captured fish were identified to species and counted.

Data Analysis

All statistical analyses were conducted using the software package R, Version 2.8.0 (R Core Development Team, 2008). Forage fish abundance was reported as the number of total individuals of the six primary fish species by site, date, and seine haul (n=180). The abundance data was log-transformed to ensure a more normal distribution for analysis. Discharge in cubic feet per second (cfs) was reported as the mean daily flow on the day of sampling and was collected from the U.S. Geological Survey streamflow Web site (USGS, 2008). Attempts to include water temperature and channel width data in the analysis were abandoned because of incomplete data collected and reported for these parameters.

Given the predicted non-linear relationship between discharge and forage fish abundance in priority hypothesis T2a, a generalized additive model (GAM) was used to develop a smoothed term for discharge (s[Discharge]) and a fixed effect of the interaction of sampling site and date of sampling (Site*Date) in order the explore the complexity of the relationship between discharge and fish abundance. The model for that GAM analysis is represented by the formula:

*Log.Abundance~s(Discharge)+Site*Date*

A mixed-effects model was then used to estimate the fixed effect of discharge and the random effects of sampling site and sampling date on fish abundance. The model for the mixed effects analysis is represented by the formula:

Log.Abundance~Discharge, random=~1|Site/Date

RESULTS

Summary of the GAM shows the smoothed discharge term is not significant (p=0.877) on 0.95 estimated degrees of freedom. A plot of the smoothed discharge term against the actual discharge values (Figure 4) reveals a smoothed line with a very slight slope and large confidence intervals. Only 33.3% of the deviance in fish abundance is explained by this GAM. An ANOVA comparison between this GAM and one without the smoothed discharge term did not show a significant increase in deviance (p=1).

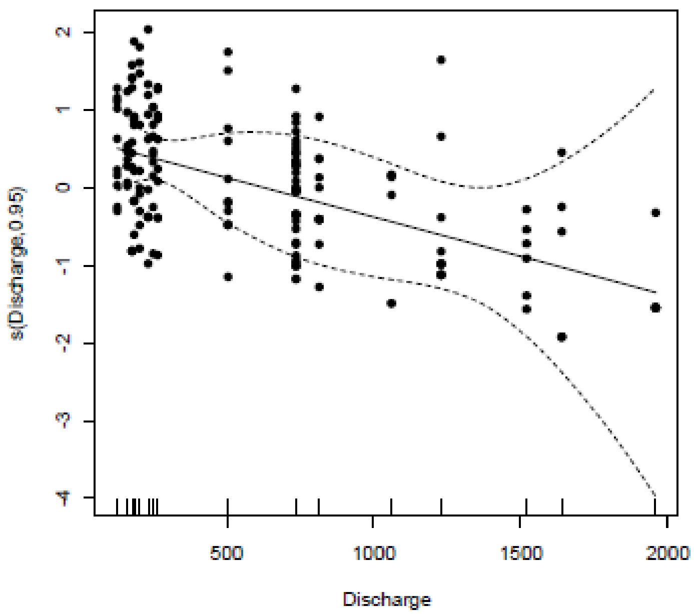

Figure 4: Plot of the smoothed fit of discharge against actual discharge values.

Since the expected degrees of freedom in the GAM analysis did not easily reflect that discharge should be modeled as a second, third, or higher-order polynomial, the main effect of discharge on fish abundance was modeled as a first-order polynomial in the mixed-effects model. A summary of the mixed-effects model analysis shows discharge (value=-0.000623) is a significant (p=0.0007) main effect on fish abundance – as discharge increases, fish abundance decreases. Model-checking analysis shows the residuals are generally normally distributed by both sampling site and date. A variance components analysis of the mixed-effects model shows that

76% of the overall variance in the model is explained by residuals as opposed the fixed effect of discharge or the random effects of sampling site and sampling date.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Despite several years of data collection and the availability of a rather large sample size (n=180), the statistical analyses performed with the data did not reveal a large influence of discharge on forage fish abundance. The mixed effects model showed a significant effect of discharge on abundance, but the variance structure of that model suggests an unreliable result. With 76% of the overall variance of that model explained by the residuals, there is clearly a very large amount of variability between seine hauls and fish caught were likely overabundant at one sampling site versus another, within the portions of the sampled open channel habitat, or according to sampling date. Although the GAM analysis did not suggest discharge should be modeled as a second- or third-order polynomial, the relationship is still most likely non-linear in nature as reflected by priority hypothesis T2a (Figure 3) and given a basic understanding of the ecology of forage fish in the Platte River – at zero discharge there are no fish and then increasing discharge supports an increasing number of fish up to a certain point before the river becomes too fast and deep to support fish in their expected habitats and making them unavailable as forage.

As designed, the current forage fish monitoring protocol is aimed simply at measuring fish abundance and available forage fish species. However, this does not easily translate into data useful for assessing priority hypotheses such as T2a and ultimately the relationship between forage fish abundance, discharge, and least tern productivity. A basic evaluation of the data shows a narrow range of fish abundance by site (Figure 5) and discharge by site (Figure 6), thus limiting the ability of the data to reveal significant relationships.

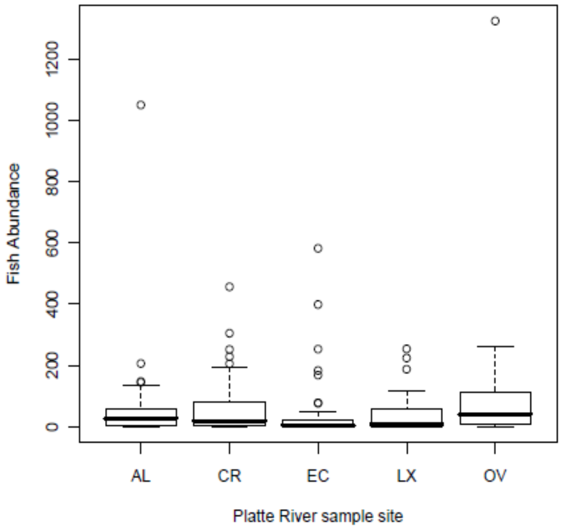

Figure 5. Fish abundance by sample site.

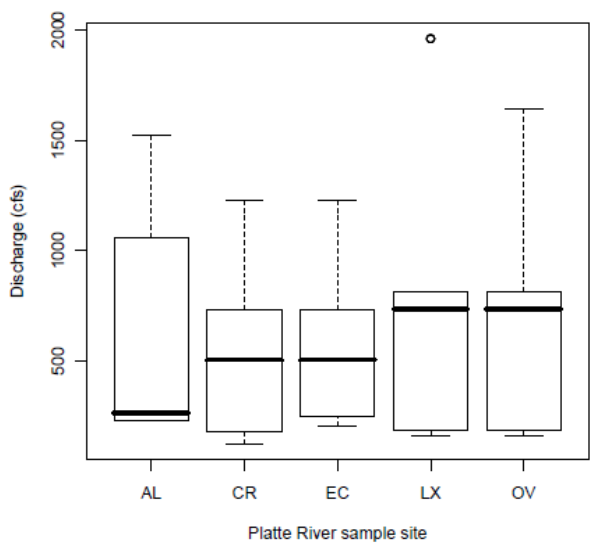

Figure 6. Discharge by sample site.

This is indicative of both spatial and temporal pseudoreplication as confounding factors in the quality of data collected under this monitoring protocol. The five sampling sites have now been sampled in generally the same way over the course of several years. This may be leading to localized conditions at each site influencing the amount and type of forage fish caught, as well as how those fish are responding to river flow conditions. Similarly, sampling occurs at roughly the same time each year providing only limited discharge response data.

In terms of sampling locations, a more systematic approach should be developed that links forage fish sampling locations with Program anchor points across the sampling area as well as tern foraging locations identified through the ongoing interior least tern and piping plover foraging habits study being conducted by the USGS. Consideration should also be given to sampling forage fish at a range of discharges during the May-September time period to provide a larger data set of fish abundance at different river discharges and to capture a broader fish response to discharge related to both fish recruitment and availability as tern forage.

While hypothesis T2a focuses on the relationship between discharge and fish abundance, other parameters such as channel width and water temperature are significant to terns, fish, and overall evaluation of Program management actions. The current forage fish monitoring protocol calls for these and other physical attributes of the fish sampling locations to be measured (AMP, 2006). However, these data are not always collected and reported completely. Future implementation of this monitoring protocol should include proper collection and reporting of these additional parameters to assist with future analysis of data and provide a more rigorous exploration of the relationship of these parameters to forage fish abundance and ultimately least tern productivity.

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