TO: ISAC AND UNL

FROM: EDO

SUBJECT: FALL SCIENCE MEETING DISCUSSION SESSION OUTLINE: PALLID STURGEON HABITAT IN THE LOWER PLATTE RIVER

DATE: SEPTEMBER 3, 2025

At the September Fall Science Meeting, the EDO anticipates a 1 1/2-hr block allocated to discussing technical points relevant to the analyses describing Pallid Sturgeon habitat.

WHY: Critical moment for discussion/brainstorming prior to jumping off into detailed data analyses. This project is so large and complex it has been difficult to focus discussions toward one research question at a time and address critical analysis assumptions, methods, etc. This is our attempt to focus those discussions at the September workshop.

HOW: We are going to frame up (to the best of our ability) key points and uncertainties around each of the major analyses including thoughts on specific input from various parties that would be helpful.

Pallid Sturgeon Habitat in the Lower Platte River

Research Objective – PRRIP needs information on the suite of conditions used by Pallid Sturgeon while occupying the lower Platte River. Identifying Pallid Sturgeon habitat based upon quantitative metrics is the first step toward quantifying availability and connectivity under different flow regimes. Development of this analysis requires an understanding of the appropriate scale for defining Pallid Sturgeon habitat, something which requires the integration of contextual knowledge about lower Platte River hydrology and geomorphology (hydraulics) as the forces shaping Pallid Sturgeon habitat as well as patterns in Pallid Sturgeon behavior.

UNL Overview presentation (30-40 minutes of content - anticipate extended discussion)

- **Defining Appropriate Scale**
  - Provide further clarification on choice of scale for assessing pallid habitat?
  - What is pallid habitat and what is a patch as you have defined them? Are they the same thing?
- **Experimental Design and Sampling Regime**
  - Describe the sampling regime for collecting ADCP data. For which fish? At similar discharge as when fish present? How is your ADCP mapping data distributed over the range of discharges experienced during your study period?
  - Captures and active tracking locations also provide a source for environmental variables at pallid use locations. Briefly summarize the sampling regime for collecting these data? How are the data distributed over discharge, Segment 1 vs. Segment 2, and cohort? How do you plan on using this additional information?
  - Can you use data from other sand bed tributaries like the Yellowstone (through collaboration with folks like Carrie Elliott) to help draw conclusions?
  - How will you control for different sampling regimes and levels of effort across methods?

    - How do your data collection methods and detection limits impact your assessment of pallid habitat? Are we gathering information on where pallids sit or where pallids are able to move through the system, or both?
- **Response Variables**
    - Describe how use vs. available locations are defined and assigned across mapped areas.
    - How many use and available locations are within each 200m mapped area?
- **Explanatory Variables**
    - What plans are there to broaden habitat selection analyses beyond selection for depth and velocity (Froude number, run/riffle/pool)?
    - How might you derive additional habitat metrics at use and available locations? Would they be point based or area based (over what area)?
- **Analytical Framework**
    - Briefly summarize input dataset (integration of discussion above). How much data do you have to inform selection analyses? How many fish contribute to that dataset and how are they distributed through time, space, conditions? Consider plots of raw data relevant to posed hypotheses to provide insights for tailoring your variables, analysis framework and model selection.
    - Discussion of analysis framework – benefits and limitations:
        - How might you evaluate if your selectivity index is significantly different from 0?
        - Rationale for choice for a GLM analysis framework
        - Are there other analytical frameworks that could be used? How might they allow us to integrate a broader dataset while still allowing us to get good estimates of characteristics pallids select in each river segment?
    - Hypothesis based suites of variables and process for model selection – thoughts on candidate models?

ISAC Focus areas for discussion and advice

- **Appropriate Scale for Habitat Analysis –** What is the appropriate scale (length and width of river channel) for characterizing pallid habitat from a geomorphic perspective? For example, bedforms in the lower Platte are predominantly transverse bars. Should the appropriate length and width of a habitat patch be on the same scale as a sandbar?
- **Response and Explanatory Variables –**
    - Thoughts on the sampling regimes used to collect pallid sturgeon locations for this analysis and ways to appropriately address non-random and potentially non-independent sampling in analyses.
    - Thoughts on appropriate ways to assign use and available locations. Physical river scientists, are locations within the 200m mapped area independent? How might we test for this? If not, what analytical tools are available to deal with this?
- **Analytical Framework –** Discussion of benefits and limitations of various analysis frameworks given the data and progress to date.

- **Candidate Models –** Thoughts on how to best develop suites of candidate models given data and model analysis framework choice(s).

The remainder of this PDF is comprised of a compendium of information previously provided to the ISAC. All UNL references specific to the analysis of Pallid Sturgeon immigration and emigration at the Platte-Missouri Confluence have been combined along with prior ISAC and EDO comments and feedback. Consider it an easy reference guide for reviewing past information relevant to this session of the September ISAC workshop.

PALLID STURGEON
HABITAT IN THE LOWER PLATTE RIVER

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The EDO has edited the content of UNL's 2023 Data Analysis Plan to reflect only those items specific to identifying Pallid Sturgeon Habitat in the lower Platte River.

Data Management and Assessment Plan (8/25/2023)

Study Objective 2:

The Pallid Sturgeon Biology in the Platte River and its Tributaries project is intended to provide information pertaining to known knowledge gaps about environmental correlates of Pallid Sturgeon use, of the lower Platte River and its tributaries. The specific objective is to:

2. Identify Pallid Sturgeon spawning habitat in the lower Platte River and its tributaries,

The purpose of this document is to outline data needs for the above-listed objective as well as provide an outline of considered statistical and non-statistical approaches to assess the obtained data*. Statistical analyses may change as more data are acquired and assumptions of different statistical tests are evaluated.

<u>*NOTE:</u> The information contained herein is not intended to be a compendium of all possible analyses or questions that may be addressed. Rather this document provides a guide for how the analyses are currently, and will be in the future, handled. A guiding reference for analyzing telemetry data is provided by Whoriskey et al. (2019) and references therein.

Data Sources and Analyses:

<u>Pallid Sturgeon Encounter Data Sources:</u> Data used to summarize and analyze movement (i.e., into, out of, and within the Platte River system) and potential spawning habitat use of Pallid Sturgeon in the Platte River system will come from two primary sources of acoustic telemetry: 1) a passive receiver array within the lower Platte River basin and 2) active (extensive and intensive) tracking within the lower Platte River and its largest two tributaries including the Loup River and Elkhorn River. The two primary sources of detecting Pallid Sturgeon will be used in isolation or combined depending on the question being addressed and the spatial and temporal resolution of predictor variables accessible. Common data types gathered for all tracking activities include date an individual was detected, time of day detected, and georeferenced location (GPS coordinates for active tracking or receiver location if detected on passive array).

Passive tracking (acoustic receiver network)

The passive receiver array within the lower Platte River basin currently includes 30+ InnovaSea VR2Tx receivers including locations within the Loup River and Elkhorn River. Date, time, and water temperature information are all recorded when a Pallid Sturgeon implanted with a transmitter is detected. Water temperature is also continuously recorded by each receiver at 15-minute intervals.

Active tracking

Extensive tracking occurs monthly from March to November and covers the entire lower Platte River from the confluence of the Loup River to the Missouri River including the lower Elkhorn River (Arlington, NE to confluence), and lower Loup River (Columbus, NE to confluence). Extensive tracking efforts are typically completed within one week of initiation.

Intensive tracking includes daily—to the extent possible—relocations of reproductively ready Pallid Sturgeon during the spawning season (when water temperatures are between 15 C and 24 C). Reproductively ready Pallid Sturgeon are identified either through *in situ* collections (trot lining by UNL crews) within the lower Platte River or through detection within the passive receiver array (the last known reproductive assessment by Missouri River Pallid Sturgeon Assessment crews are used to determine reproductive status). Attempts to locate and follow reproductively ready Pallid Sturgeon generally occur daily during the spawning season to assess behaviors that will hopefully lead to identification of spawning sites if spawning occurs.

Habitat use for relocated, reproductively ready Pallid Sturgeon has been and will continue to be assessed at multiple spatial scales. Micro-scale habitat variables used to describe habitat at the location of capture include water velocity (Hach water velocity meter), water depth (depth stick or sonar), water temperature (YSI meter), and turbidity (YSI meter). Mesoscale habitat variables used to describe the area surrounding the location of capture include primary-channel, secondary-channel, or braided. Sandbar complexes were also categorized as dry, partial, overflowing, or braided. Macroscale habitat measures will include the river reach where detection occurred (see Question 2 below). These data are consistent with previous habitat measures from the Platte River (Peters and Parham 2008; Hammen et al. 2018; Hamel and Pegg 2019; HDR 2009). We will use the nearest USGS hydrologic stream gage to assess river discharge where reproductively ready Pallid Sturgeon were located. Additional, date-specific habitat measures are collected from other sources (e.g., USGS, NWS, USFWS, USCOE, etc.) and will be used to explore correlates of fish movement patterns using the analysis framework in Figure 1.

EDO: Jenna's AFS presentation summarizes the number of fish for which ADCP habitat mapping data are available, 59 maps for 39 unique fish.
11 females, 12 males, 16 unknown
21 maps in segment 1
38 maps in segment 2
33 adults, 6 sub-adults (what is a sub-adult?)
11 Reproductive, 28 non-reproductive
What is the sampling regime for this dataset? Which fish are mapped, which are not, and why? What is the distribution across years, seasons, river conditions?

Are environmental variables also collected for other actively tracked fish, for which ADCP data are not available?
Are environmental variables collected at capture locations?
How do you plan to integrate these data?
How will you control for different levels of effort across methods, time, and space?

Objective 2

Objective 2. Identify Pallid Sturgeon spawning habitat in the lower Platte River and its tributaries.

Question 1. What physical and chemical variables at relocation points are associated with reproductively-ready Pallid Sturgeon use in the lower Platte River basin including tributaries?

Experimental Units: Individual reproductively ready male and female Pallid Sturgeon.

Response Variables: Repeated presence points from reproductively ready female and male Pallid Sturgeon obtained from intensive and extensive tracking efforts.

Predictor Variables: Predictor variables will include individual-level covariates including sex and age (if known) as well as reach-specific assessments of the full range of discharge, temperature, turbidity, depth and velocity at an approximately 1Km river reach scale. Characterization of depth and velocity will follow closely those methods used in the Missouri River from Acoustic Doppler Current Profiler (ADCP) and side-scan technology (Elliot et al. 2020). The synthesis of ADCP data will enable estimation of meso-habitat availability within the river reach as well as channel complexity that can be used to assess use and availability of habitats. A measure of distance to nearest sandbar complex will also be assessed. The development of a 2-D hydraulic model (pending completion by EDO) may enhance the type and breadth of predictor variables available for analyses including providing estimates of sheer stress near relocation points as well as an assessment of the dynamic nature of areas where Pallid Sturgeon reside and move (e.g., potential avoidance of areas that exhibit greater sheer stress during hydropeaking).

EDO: Elliot et al. 2020 does not give details on methods for translating transect-based ADCP data into use and available "points or patches". How were metrics for use and available derived? Braaten et al. 2015 (Elliott second author) - Migrations and swimming capabilities of endangered pallid sturgeon to guide passage designs in the fragmented Yellowstone River – does a better job of describing methods for quantifying metrics at use location (+ 5m buffer) along a transect vs availability for the transect as a whole. It does not rely on kriging to fill in the blanks. Would this be a better alternative? Pros? Cons?

Further explanation of choice of scale for mapping habitat, how habitat is to be defined (habitat, habitat patch, matrix, etc.) and detail on methods for assigning use vs. available locations would be helpful.

NOTE on 2D model: The model cannot be used to provide estimates of characteristics at fish relocation points as it is a one-time snapshot of a very dynamic system. That is, the model is not intended to be used to assess characteristics at individual use locations that are outside of when the LiDAR data were collected. However, once pallid habitat characteristics are identified (through field measurements at use locations and selection analysis) it can be used to model about how much (not where) habitat there might be under varying flow conditions (as you state below).

Hypothesis: Pallid Sturgeon in the Platte River will use deeper depths and moderate velocities than what is available when spawning is present. (Testable hypothesis #1).

Potential Analyses: Generalized linear models and generalized linear mixed models—with logit links—may be used to evaluate habitat use of reproductively ready Pallid Sturgeon in the lower Platte River. Presence points as well as the summary of availability from the ADCP data (and potential 2-D hydrologic model) will be used to infer habitat selection. Further, a full suite of selectivity indices exists to assess habitat selection. For instance, Ivlev's Selectivity Coefficient has been used to assess Pallid Sturgeon habitat selection in the Missouri River mainstem (Elliot et al. 2020) and may be used to assess Pallid Sturgeon habitat selection in reaches of the Platte River. Additional analyses may include regression tree methods (e.g., random forests or boosted regression tree) to evaluate habitat suitability within the lower Platte River provided the results of the 2-D hydrologic model. Such an approach may allow assessment of the contiguousness of habitat patches within the Platte River under varying flow conditions.

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Table 1. Sources of data for potential variables describing river conditions derived for use in analyses for Question 1 and Question 2 assessing correlates with Pallid Sturgeon movement into, out of, and within the Platte River. This list is not exhaustive and some sources may be added or removed depending on data availability.

Variable Type	Variable	Unit of measure	Minimum Scale	Source	Description
Response	Pallid Sturgeon entering/exiting Platte River	Count	Daily	Passive Receiver	Daily counts from the passive receiver at the confluence of the Platte River with the Missouri River. Additional detections from the USGS receiver will be added when data becomes available.
Response	Pallid Sturgeon location within/among Platte River basin reaches	Detection (Yes/No)	Daily	Passive Receiver/Active Tracking	The river reach a Pallid Sturgeon is detected in will be documented and used to assess transition probabilities among river reaches
Predictor	Water temperature	°C	15 minutes	USGS Gages	Water temperature will be obtained from the USGS gage located in Louisville, NE on the Platte River.
Predictor	Water temperature	°C	15 minutes	VR2Tx (Receivers)	Water temperatures will be obtained when receivers are recovered. Continuity of data dependent on recovering receivers (USGS receivers will be primary source).
Predictor	River Discharge	m^3/s	15 minutes	USGS Gages	River discharge will be obtained from the USGS gage located in Louisville, NE on the Platte River.
Predictor	Turbidity	NFU or NTU	15 minutes	USGS Gages	Turbidity will be obtained from the USGS gage located in Louisville, NE on the Platte River.

Table 2. Parameters generated from flow data using the Index of Hydrologic Alteration (IHA; Richter et al. 1996). Table modified from The Nature Conservancy (2009). Similar parameters can be developed for water temperature.

IHA Parameter Group	**Hydrologic Parameters**	**Ecosystem Influence**
Magnitude of monthly water conditions (12 parameters)	Mean or median flow for each month	• Habitat availability for aquatic organisms • Soil moisture for plants • Availability of water for terrestrial animals • Influences water temperature, oxygen levels, photosynthesis in water column
Magnitude and duration of annual extreme water conditions (12 parameters)	Annual minimum, 1-day mean Annual minimum, 3-day mean Annual minimum, 7-day mean Annual minimum, 30-day mean Annual minimum, 90-day mean Annual maximum, 1-day mean Annual maximum, 3-day mean Annual maximum, 7-day mean Annual maximum, 30-day mean Annual maximum, 90-day mean Number of zero-flow days Base flow index: 7-day minimum flow/mean flow for year	• Balance of competitive, ruderal, and stress-tolerant organisms • Creation of sites for plant colonization • Structuring aquatic ecosystems by abiotic vs. Biotic factors • Structuring of river channel morphology and physical habitat conditions • Duration of stressful conditions such as low oxygen in aquatic environments • Duration of high flows for aeration of spawning beds in channel sediments
Timing of annual extreme water conditions (2 parameters)	Julian date of each annual 1-day maximum Julian date of each 1-day minimum	• Compatibility with life cycles of organisms • Predictability/avoidability of stress for organisms • Access to special habitats during reproduction to avoid predation • Spawning cues for fish • Evolution of life-history strategies
Frequency and duration of high and low pulses (4 parameters)	Number of low pulses within each water year Mean or median duration of low pulses (days) Number of high pulses within each water year Mean or median duration of high pulses (days)	• Availability of floodplain habitat for aquatic organisms • Nutrient and organic matter exchange between river and floodplain • Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)

IHA Parameter Group	Hydrologic Parameters	Ecosystem Influence
Rate and frequency of water condition changes (3 parameters)	Rise rates: Mean or median of all positive differences between consecutive daily values Fall rates: Mean or median of all negative differences between consecutive daily values Number of hydrologic reversals	• Drought stress • Entrapment of organisms on islands, floodplains (rising levels) • Desiccation stress on low0mobility organisms

The EDO has edited the content of Jenna Ruoss' 2024 PhD Proposal and June 2025 Progress Update to reflect only those items specific to identifying Pallid Sturgeon Habitat in the lower Platte River (Chapters 4 and 5 of her proposal)

CHAPTER 4. QUANTIFICATION OF DISTINCT HABITAT PATCHES IN THE LOWER PLATTE RIVER

Methods

Study Area

I will use an acoustic doppler current profiler (ADCP) to map the South Bend to Louisville, Nebraska area (walking bridge to Highway 50 bridge; Figure 9) to compare habitat types generated by ADCP to those generated from previous methods described by HDR (2009). An ADCP is a hydroacoustic tool based on principles of Doppler shifts, meaning it uses sound to measure water velocity and depth (Simpson 2001). The ADCP (River Surveyor S5/M9; SonTek, San Diego, California) will be mounted to an airboat at a fixed transducer depth of ~3 cm (Figure 10). Each transect will be mapped using a zigzag pattern at low idle speeds of approximately 1-1.5 m/s perpendicular to flow. Each transect will be approximately less than 5 m apart for accurate interpolation (Gaeuman and Jacobson 2005; Wyman et al. 2017).

Delineating Habitat Patches

The ADCP collects data in one-second intervals at each location. These data points contain mean column water velocity (m/s) and depth (m) per each interval. The locational points and the associated velocity and depth will be plotted and interpolated using the Geostatistical Analyst extension toolbox in ArcGIS Pro 3.0.0. The Geostatistical Analyst extension toolbox has an ordinary kriging tool which can be used to interpolate the depths and velocities for spaces not measured by the ADCP. Ordinary kriging is expressed using the formula (Esri Inc. 2022):

$$Z(s) = \mu(s) + \varepsilon(s)$$

Where Z(s) is the variable of interest (i.e., estimated depth or velocity) and calculated by the deterministic trend μ(s) and random, autocorrelated errors ε(s).

Depth and velocity maps will be generated individually using the kriging tool and will be transformed from vector to raster format (example Figure 11; Jacobson and Laustrup 2000; Elliot et al. 2004; Jacobson et al. 2009). Then, the depth and velocity maps will be combined to form composite maps of depth-velocity (Bowen et al. 2003) for the delineation of patch types (Neely et al. 2010).

My first approach for delineating habitat patches will be to pre-determine types. Patch types will be classified as flat, riffle, run, and plunge based on depth and velocity (see Table 5 for criteria; HDR 2009). A stepwise discriminant function analysis will be used to determine if the pre-determined patch types are distinct based on water depth and velocity (Hitchman et al. 2018). I will then be able to compare the results of my study to those found in HDR (2009) and characterize the variability (e.g., size and distribution) of habitat types from 2008-2009 to present-day.

My second approach for delineating habitat patches will be to calculate Froude numbers (Fr) based on depth and velocity:

$$Fr = \frac{V}{\sqrt{gD}}$$

in which *V* is current velocity, *D* is depth, and *g* is a gravitational constant. Froude numbers will be calculated using the *Raster Calculator* tool in ArcGIS Pro and a map of Froude numbers in the study area will be generated using the depth and velocity raster maps (example Figure 12). Yu (1996) established Froude values for the Platte River, in which pools had Fr < 0.2, run had Fr 0.2-0.4, and riffle had Fr > 0.4. I will use these previously derived values to assess patch availability. I will then be able to compare the habitat patches derived from using Froude values to those derived by HDR (2009) to determine if there are differences in estimating habitat using these two types of methods to discern patches.

Patch availability will be considered as mean patch size and patch density (Bowen et al. 2003). Mean patch size will be calculated as the total area of the patches within the study area divided by the number of patches. Patch density will be calculated as the number of patches of each type divided by study are length (Bowen et al. 2003). In addition, I will map the study area at minimum once per season to understand how patch availability varies on a temporal scale. Further, I will map the study area at different levels of discharge (e.g., high > 169 cms [6000 cfs], intermediate 84-142 cms [3,000-5,000 cfs], and low < 84 cms [3,000 cfs]; HDR 2009) to understand how patch availability changes under varying flow conditions. Finally, I will map a river reach of approximately the same size as the HDR (2009) study area in the upper segment to understand the dynamics of patch availability above and below the Elkhorn River tributary of the Platte River.

June 2025 Update

Chapter 4. Quantification of Distinct Habitat Patches in the Lower Platte River

The stage change study area near South Bend, Nebraska has been mapped at what is considered a high threshold and intermediate threshold. Analyses are underway.

EDO: So, you will quantify run, riffle, and pool patch availability as mean patch size and density within the study reach rather than total area of each patch type within the study area? Or is that my misinterpretation of what is written? I see these as very different metrics. Availability is typically thought of as how much. Though availability is the product of size and distribution, each is a unique ecological metric.

Do you think pallid sturgeon need large contiguous patches, or can lots of smaller patches separated by a permeable matrix serve as habitat? Why, and under what circumstances? The answer to this question will help you hypothesize what you think is pallid habitat? Is pallid habitat only the pools, or do pallids need some combination of pools, runs and riffles to satisfy life history/biological requirements?

Were you able to map the same two reaches (one above Elkhorn (where?), one below Elkhorn) every season (once per year, or once in spring, once in summer, and once in fall)? Over what distribution of discharge were you able to map?

CHAPTER 5. HABITAT PATCH SELECTION BY PALLID STURGEON IN THE LOWER PLATTE RIVER

Methods

Fish Sampling

See Chapter 2 Methods – Fish Sampling.

Active Tracking

Active tracking will include extensive tracking to locate all fish and intensive tracking to follow reproductively-ready adults during the spawning season. Both tracking events will use an InnovaSea VR100-300 mobile tracking receiver with an omnidirectional VHTx-69k transponding hydrophone to locate fish. Extensive tracking will be conducted monthly from April – November as river conditions (flow, weather, ice, etc.) allow. The search process will be a systematic sweep sample where the field crew(s) search for fish in the Platte River between Columbus to Plattsmouth and radiate into the tributaries. Special attention will be given to reproductively ready females, which are females in reproductive stage IV (e.g., black egg female) per U.S. Geological Survey Columbia Environmental Research Center Guidelines, to attempt to delineate spawning habitat. A female sturgeon considered reproductive ready will be intensively tracked for the duration of the spawning season and/or until spawning behavior and confirmation of spawning occurs. Intensive tracking consists of attempting to relocate the fish daily during the potential spawning season.

Pallid Sturgeon Habitat Selection

I will use the ADCP to create depth-velocity composite maps for detection locations and potential spawning locations to understand Pallid Sturgeon habitat selection and use (methods for ADCP described in Chapter 3). The scale at which Pallid Sturgeon select habitat has not been established (Johnson et al. 2006). Therefore, available habitat patches will be assessed within 100 m upstream and 100 m downstream of the detection location based on the observations that repeat detections of Pallid Sturgeon throughout the day were within approximately 100 m of the original detection location (e.g.,

Figure 13; Bonnot et al. 2011). I will use a discrete choice model to determine the probability of habitat patch use and selection by Pallid Sturgeon.

I will use generalized linear mixed discrete choice modeling with a binomial family and a logit link to determine Pallid Sturgeon habitat selection based upon habitat type and patch size using the *lme4* package in Program R (Bates et al. 2015; R Core Team 2022). Other possible predictor variables that may be incorporated will include season and reproductive status. Discrete choice models estimate the probability that an individual will choose a location as a function of habitat characteristics of that location and other available locations at that given time (Cooper and Millspaugh 2009; Bonnot et al. 2011; Moore et al. 2022). The habitat area considered as “selected” will be determined within a buffered area surrounding the detection location based on acoustic telemetry accuracy performance (Johnston 2000; Johnson et al. 2006; Pullano and Ruoss, unpublished data; see Figures 11-12 for example of buffered detection). If there are multiple types of habitat patches within the buffer, then the dominant type (i.e., percent composition) will be considered “selected (=1).” Otherwise, habitat patches where the sturgeon was not detected within the 200-m reach will be considered unselected (=0). Habitat patches derived from Chapter 4 will be used for this investigation as the choice set (i.e., pool, riffle, run based on Froude values). A random intercept to account for repeated observations will be incorporated (Jenkins et. al 2019). I will add the continuous variable of patch size to the attribute set of each patch. The area of each patch (m^2) will be calculated within the 200-m reach.

I will develop *a priori* models representing hypotheses on habitat type and patch size that may influence Pallid Sturgeon habitat selection (Table 6). A forward selection process will be used to build the models (Zurr et al. 2007). The first candidate model will be a null model. Then the habitat type and patch size will be used independently to assess habitat selection. Finally, the additive effects of habitat type and patch size will be used. The assumption of the discrete choice model is that the patch the Pallid

Sturgeon chooses is a function of these variables known as the utility. The utility provided by the patch *i* to individual *j* (U_{ij}) *is* represented:

$$U_{ij} = \beta' X_{ij} + e_{ij} = b_1 x_{1j} + b_2 x_{2j} + b_3 x_{3j} + \ldots$$

where X_{ij} is a vector of length *m* of the variables of resource *i* which will be the category of habitat patches found within the 200-m reach presumably perceived by the individual *j (*Cooper and Millspaugh 1999). Then *β* is a vector length *m* of reputable parameters that determine each attribute's contribution to utility. The error term is then denoted by e_{ij}. I will not include substrate as previous investigations have documented that the Platte River is primarily composed of sand (Peters et al. 1989).

The relative probability (*P*) that an individual Pallid Sturgeon (*i*) will choose a specific habitat (*A*) instead of the other available habitat points (*j*) due to the utility (*U*) the habitat provides is expressed by (Cooper and Millspaugh 1999):

$$P_j(A) = \frac{\exp\,(U_{Aj})}{\sum_{Ai} \exp\,(U_{ij})}$$

I will use Akaike's Information Criterion corrected for small samples sizes (AICc) for determining the support of the candidate models (Burnham and Anderson 2002). I will also assess model weights to determine the best fit model for Pallid Sturgeon habitat selection (Burnham and Anderson 2002). Then, I will use a k-fold cross validation to estimate the accuracy of the top-ranked models to assess the predictive ability of the habitat selection models (Boyce et al. 2002). A k-fold cross validation entails removing 20% of the original dataset (testing data) and using the remaining as a training set. Then, the model is refit using the training set to see if values generated for resource selection correlate with the testing data (Boyce et al. 2002).

June 2025 Update

Chapter 5. Habitat Patch Selection by Pallid Sturgeon in the Lower Platte River

We have mapped over 50 Pallid Sturgeon detection locations from 2023-2025. Habitat maps are being derived from the acoustic doppler current profiler data and habitat selection indices are currently being built.

EDO: The focus here is on reproductively ready fish, but intensive active tracking and ADCP mapping occurred for other fish as well. Please describe your sampling regime, how were fish chosen for active tracking and collection of environmental variables and ADCP mapping?

All results depend on what you define as a patch. If repeat detections of PS throughout the day were generally within approximately 100m of the original location, is this area not also considered as used rather than available but not selected? Is this +/-100m area actually the used habitat patch based upon pallid detections, rather than a single estimated point location based upon when your receiver signal strength maxes out after following the fish over time.
Are you using the repeat detections within the +/- 100m as used locations as well? If so, are they independent?
Are you picking random non-detection points within the +/- 100m area as your random sample of available but non-selected points? Are those independent?

You have a use location via telemetery with a 7.5 m detection buffer = used habitat. It is likely that your estimated use location plus buffer will contain more than one patch type. Are PS use locations heterogenous most of the time, and if so, what does that tell you? Does assigning them to one category miss the point? Can a habitat patch in the lower Platte River be heterogeneous?

Question for ISAC physical scientists: What is the appropriate scale (length and width of river channel) for characterizing pallid habitat from a geomorphic perspective? For example, bedforms in the lower Platte are predominantly transverse bars. Should the appropriate length and width of a habitat patch be on the same scale as a sandbar?

Habitat in this analysis is solely defined by Froude number (velocity and depth), as Froude number decides whether it is a run, riffle, or pool (assignment of patch type is by Froude number).
No temperature, structure, substrate, etc?
So, instead of testing a suite of variables to see what pallids select in an effort to characterize pallid habitat more generally, you are asking what velocity to depth ratio is selected.
What happens if results from analyses about what factors are important for pallid immigration, occupancy, emigration, and movement show that temperature is a key factor associated with LPR use? Any plans for incorporating temperature data into this analysis?
Are there any other environmental variables for which you have data that could be incorporated here to answer the more general question of "what is pallid habitat on the lower Platte River".

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Table 5. Criteria for pre-determined habitat patches adapted from HDR (2009).

Habitat Type	Depth (m)	Velocity (m/s)
Flat	< 0.46	< 0.61
Riffle	< 0.46	> 0.61
Run	> 0.46	> 0.15
Plunge	*	*

*Plunge – visually identified based on a localized and quick change in topography that occurs along the margins of sand bars

Table 6. Candidate models for the discrete choice model, where U_{ij} is the random effect of the individual.

Candidate Model	Hypothesis	Model Structure
Selection ~ 1	Neither habitat type or patch size influences habitat selection.	$B_0 + B_1 + U_{ij}$
Selection ~ habitat_type	The type of habitat significantly positively influences the probability of selection.	$B_0 + B_1(\text{Habitat}) + U_{ij}$
Selection ~ patch_size	The size of the habitat patch positively influences the probability of selection.	$B_0 + B_1(\text{Patch}) + U_{ij}$
Selection ~ habitat_type + patch_size	Habitat type and patch size positively influences the probability of selection.	$B_0 + B_1(\text{Habitat}) + B_2(\text{Patch}) + U_{ij}$

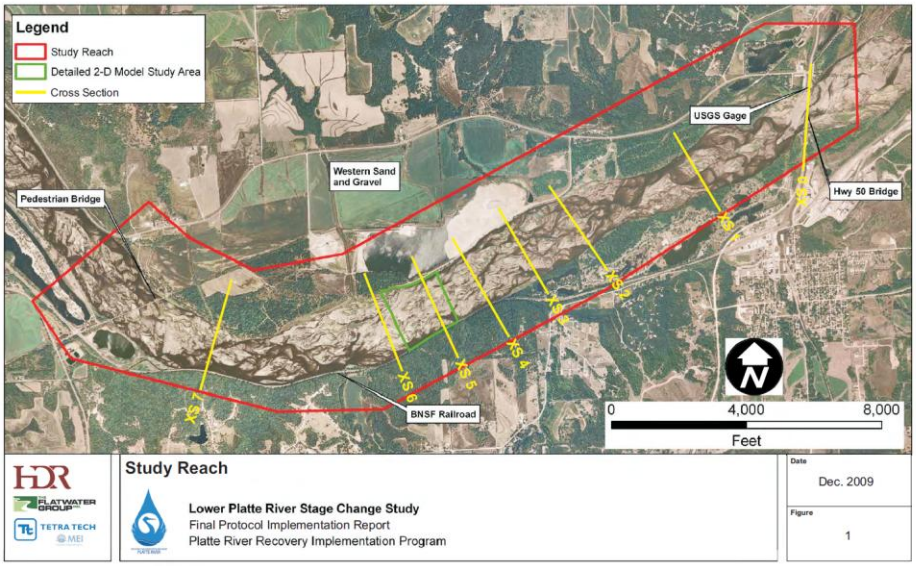

Figure 9. Study site for the stage change study which will be used to new derive habitat patches in the lower Platte River using the ADCP (Source: HDR 2009).

Figure 10. The ADCP mounted to side of the airboat. Transducer is approximately 3 cm below the rig to measure depth and velocity.

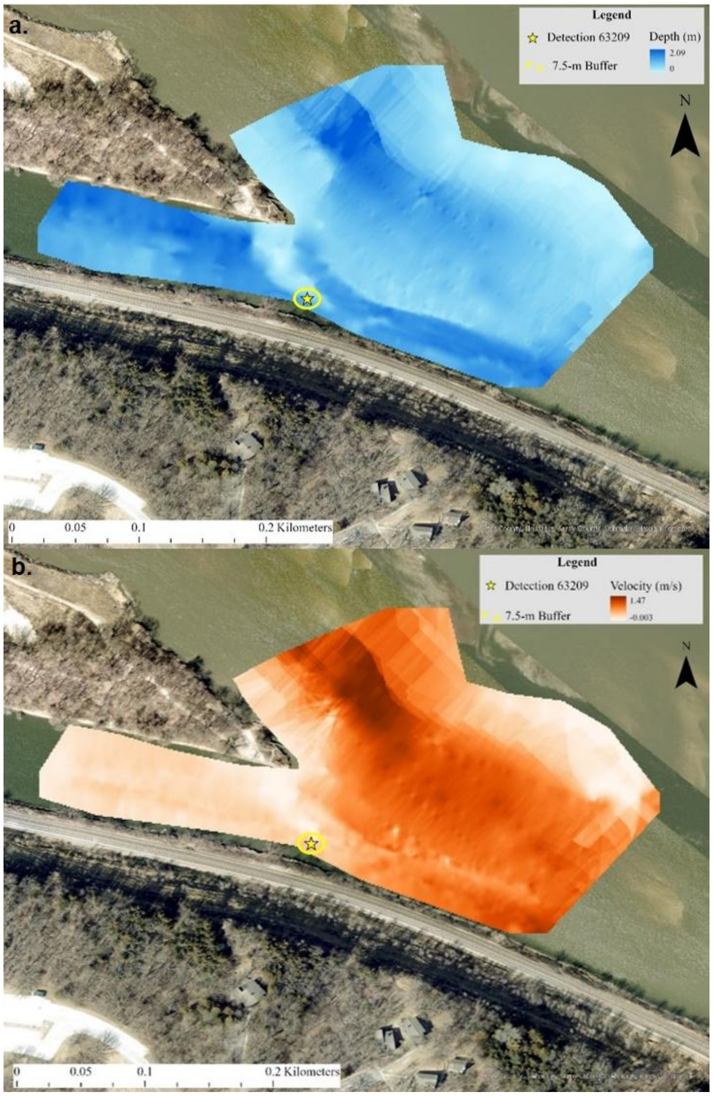

Figure 11. Examples of (a) depth and (b) velocity maps of the Salt Creek mouth in the Platte River created using data from the ADCP.

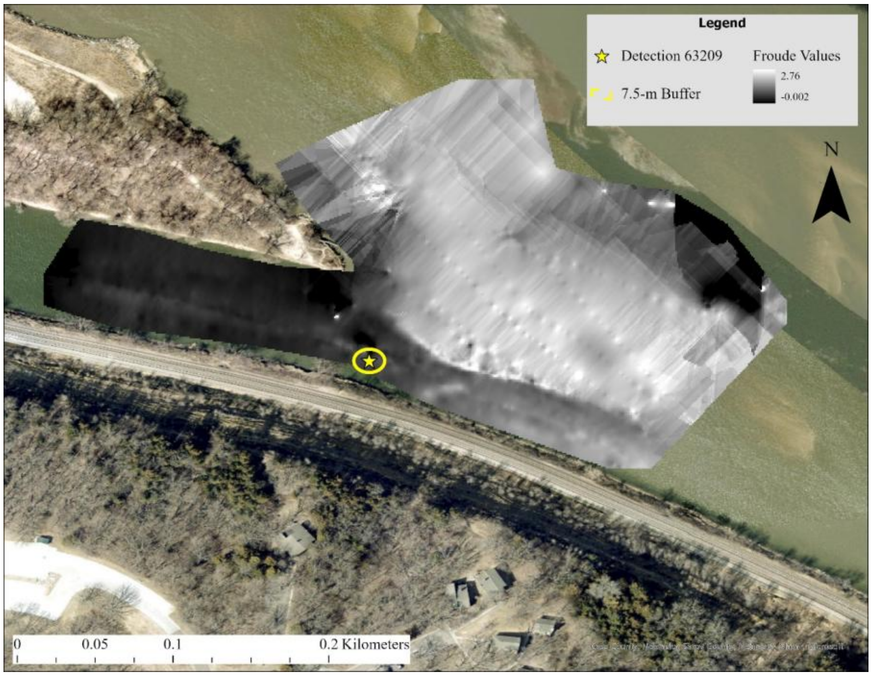

Figure 12. An example of a Froude value map derived from the depth and velocity raster maps (Figure 11) generated in ArcGIS Pro.

Figure 13. Active detection locations and timestamps of A69-9001-54336 (reproductive ready female) on May 10, 2023 in which detections were recorded within approximately 100 m throughout the day.

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Between the Currents: Pallid Sturgeon Habitat in a Missouri River Tributary
Jenna Ruoss, Christopher Pullano, Jonathan Spurgeon, Mark Pegg, and Kirk Steffensen
Platte River
Recovery Implementation Program
SCHOOL OF NATURAL RESOURCES
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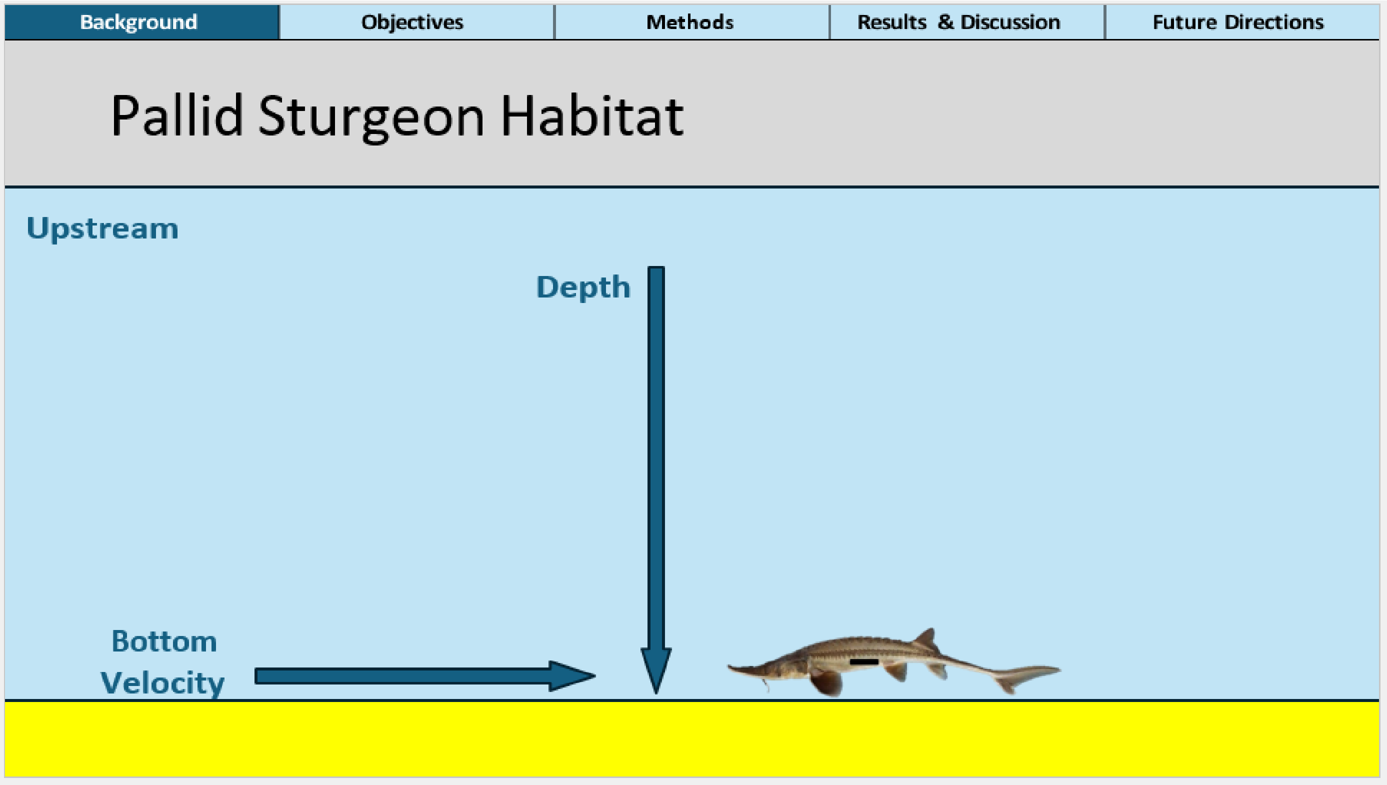
Background | Objectives | Methods | Results & Discussion | Future Directions

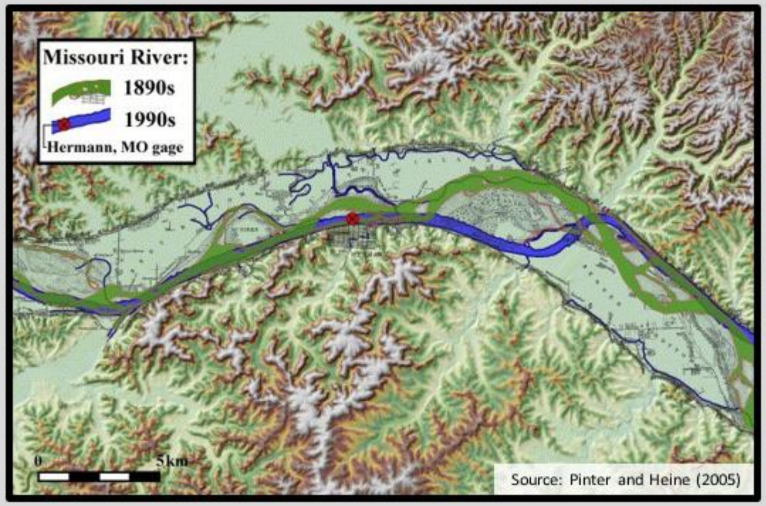
Pallid Sturgeon Life History and Distribution



Background
Objectives
Methods
Results & Discussion
Future Directions
Pallid Sturgeon Habitat
Upstream
Depth
Bottom
Velocity

Background | Objectives | Methods | Results & Discussion | Future Directions

The Mainstem Missouri River



The Role of Tributaries – The Lower Platte River


Source: Jeff Barnes

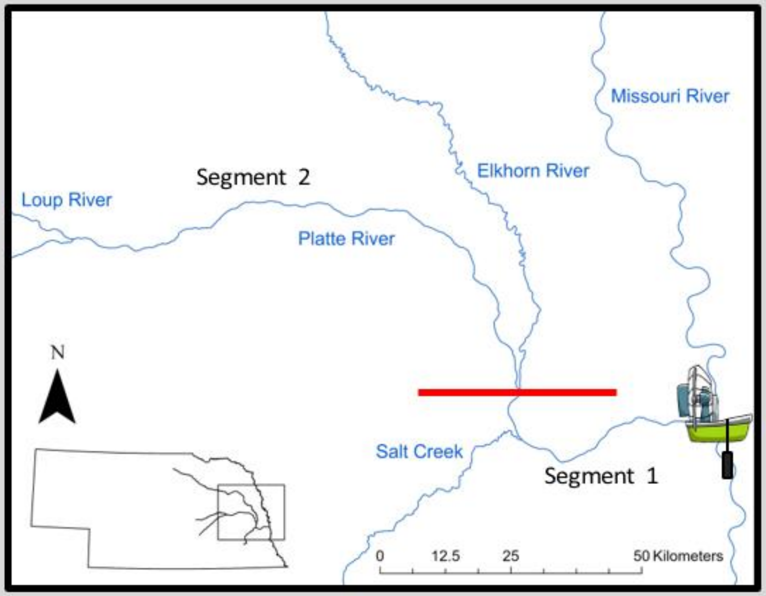
What is the selectivity of habitats by Pallid Sturgeon?

1. Assess habitat selection of Pallid Sturgeon throughout the Platte River.
2. Examine if habitat selection varies across river reaches and among Pallid Sturgeon demographics.

Pallid Sturgeon Sampling

Background | Objectives | Methods | Results & Discussion | Future Directions

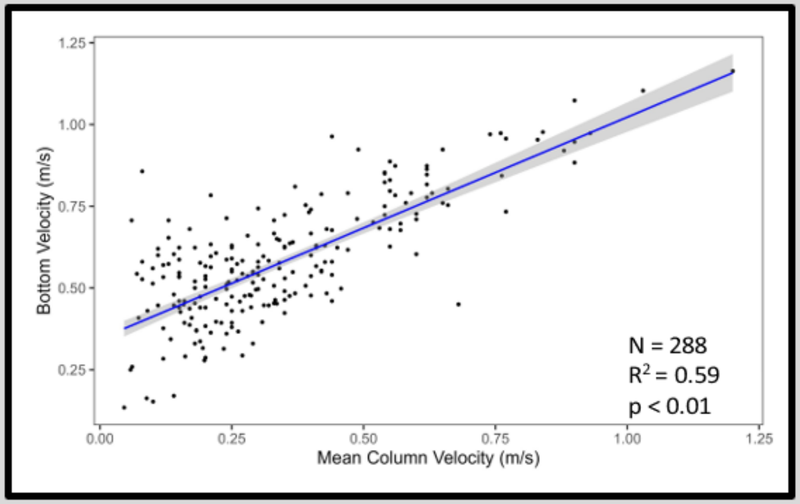
Active Tracking



Habitat Mapping

Latitude, Longitude, Depth, Mean Column Velocity

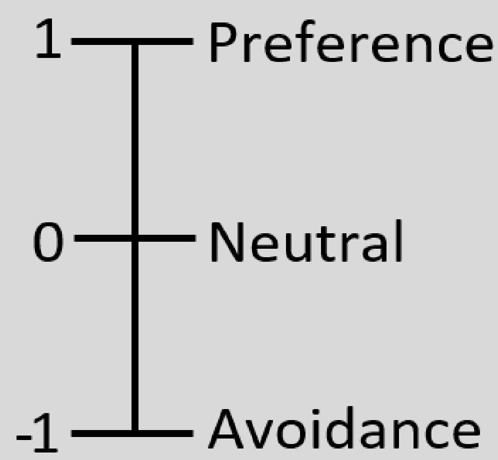
Estimating Bottom Velocity



BBBBBBBBBBBB VVVVVVBBVVVVBBVV = 0.88 x MMVVMMMM CCBBVVCCBBMM VVVVVVBBVVVVBBVV − 0.16

Ivlev's Electivity Index

$$EE = \frac{(CC - MM)}{(CC + MM)}$$

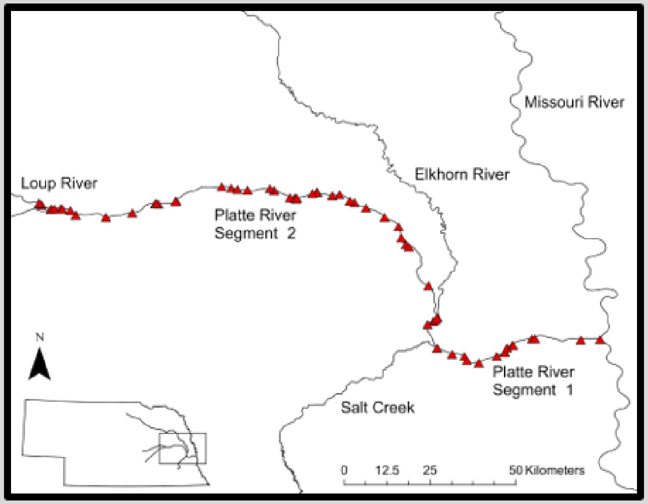


EE= selectivity coefficient for resource unit

CC = sampled proportion of used habitat units

MM = sampled proportion of available habitat units

Mapped Pallid Sturgeon 2023-2025



59 maps for 39 unique Pallid Sturgeon

Segment Maps

Segment 2 = 38

Segment 1 = 21

Demographics

Sex

♀ = 11, ♂ = 12, ? = 16

Life Stage

Adult = 33 (FL ≥ 750 mm), Sub-Adult = 6 (FL < 750mm)

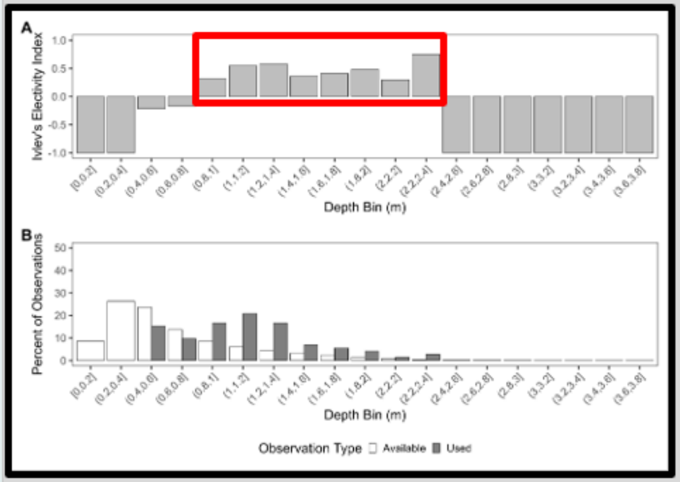
Reproductive Condition

Reproductive = 11, Non-Repro. = 28

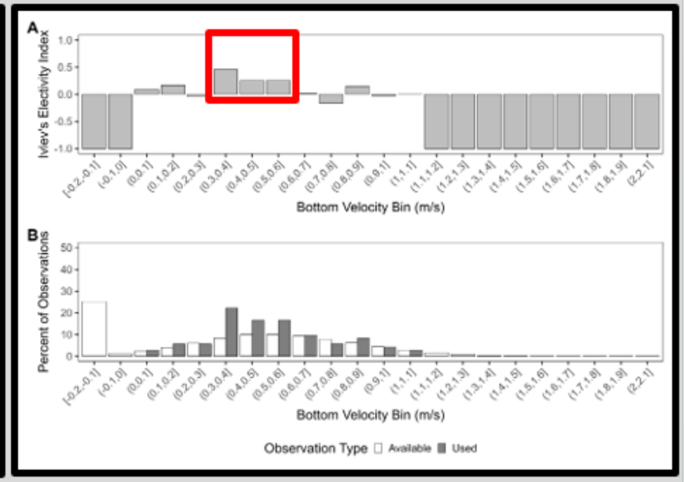
Background | Objectives | Methods | Results & Discussion | Future Directions

1. Assess habitat selection of Pallid Sturgeon throughout the Platte River.

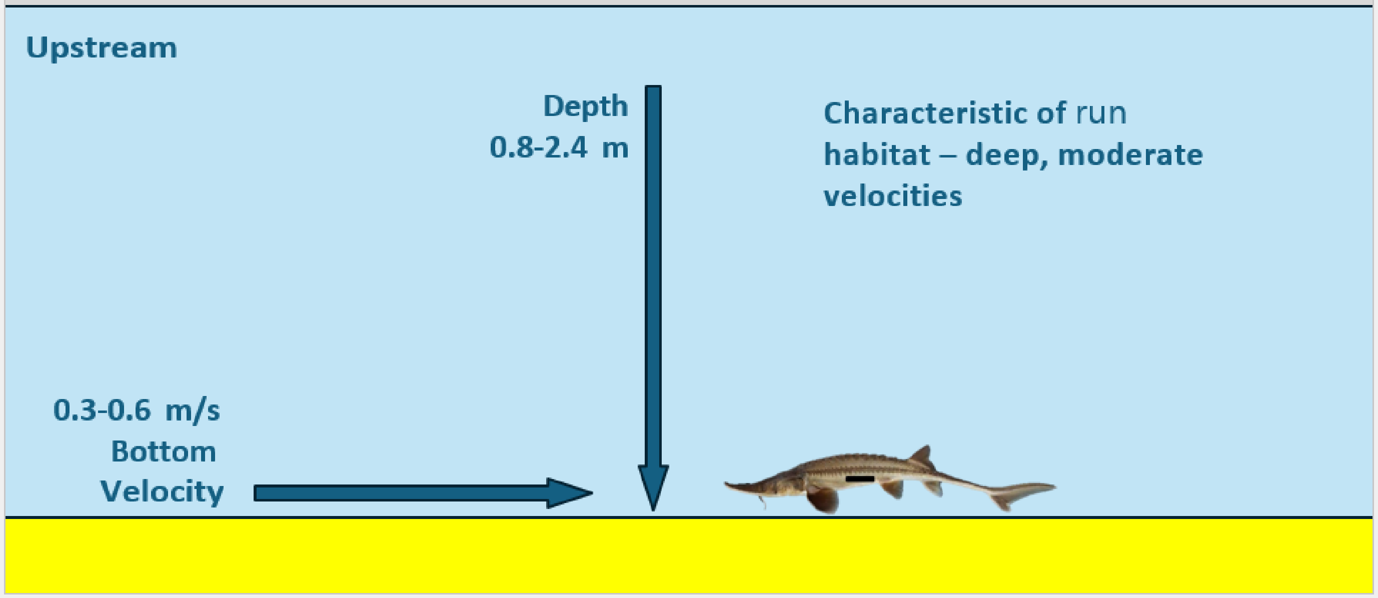
Depth – Positively selected 0.8-2.4 m



Velocity – Positively selected 0.3-0.6 m/s

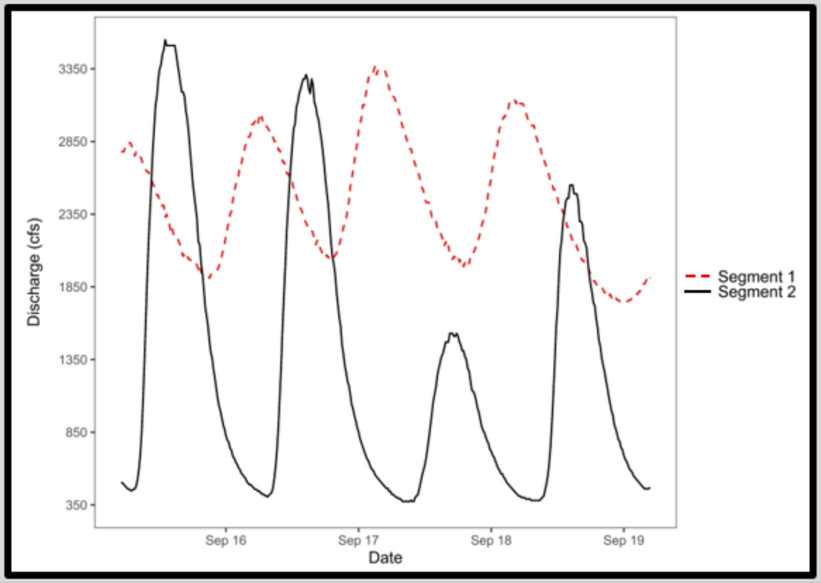


1. Assess habitat selection of Pallid Sturgeon throughout the Platte River.



Background	Objectives	Methods	Results & Discussion	Future Directions

2. Examine if habitat selection varies across river reaches and among Pallid Sturgeon demographics.

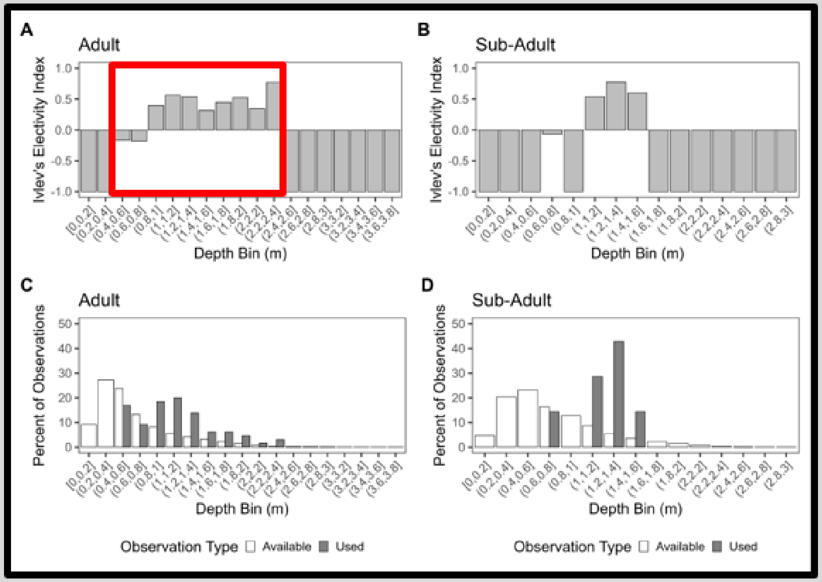


Wilcoxon Rank Sum Test
W = 770, $p < 0.05$

Higher preference for deeper water in Segment 2

Potential extra stress in Segment 2 attributed to the effects of hydropeaking

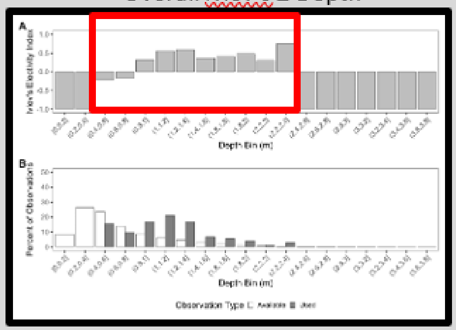
2. Examine if habitat selection varies across river reaches and among Pallid Sturgeon demographics.



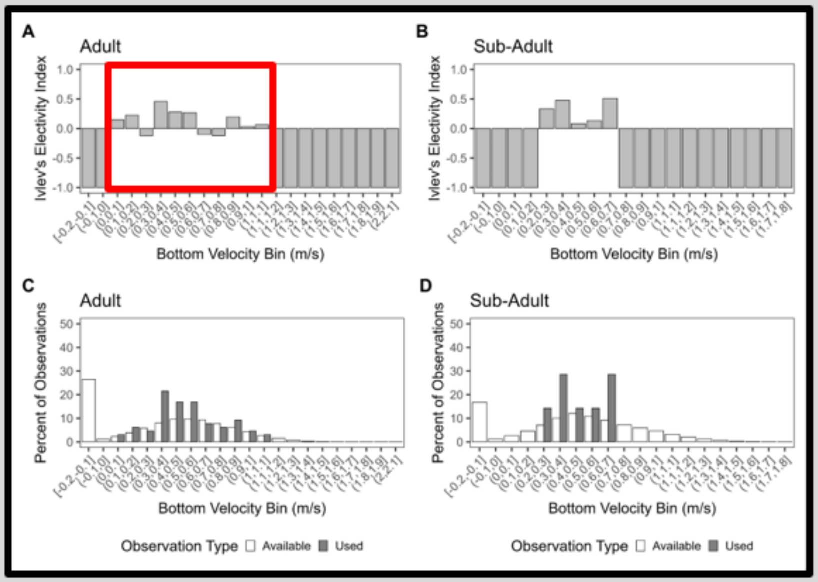
Wilcoxon Rank Sum Test
W = 192, p = 0.51

Adult = 33, Sub-Adult = 6

Overall Ivlev's *E* Depth



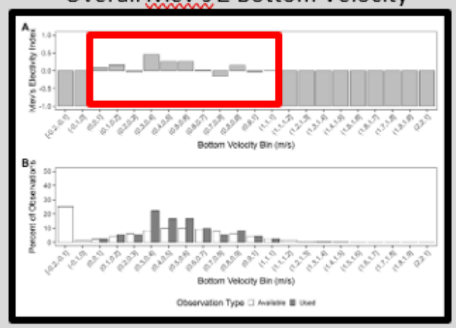
2. Examine if habitat selection varies across river reaches and among Pallid Sturgeon demographics.



Wilcoxon Rank Sum Test
W = 241, p = 0.80

Adult = 33, Sub-Adult = 6

Overall Ivlev's *E* Bottom Velocity



What is the selectivity of habitats by Pallid Sturgeon?

1. Assess habitat selection of Pallid Sturgeon throughout the Platte River.
   a) Positively selected depths ranging from 0.8-2.4 m.
   b) Positively selected bottom velocities ranging from 0.3-0.6 m/s.
2. Examine if habitat selection varies across river reaches and among Pallid Sturgeon demographics.
   a) Higher preference for deeper water in Segment 2.
   b) No significant difference among sex, life stage, or reproductive condition.
   c) Generally, the overall habitat Ivlev's Electivity Indices may be used as a proxy across demographics of Pallid Sturgeon in the Platte River.

Background | Objectives | Methods | **Results & Discussion** | Future Directions

Previous Studies

Platte River

Depths 0.33 – 1.52 m
Bottom Velocities < 0.7 m/s

Yellowstone River

Depths 0.6 – 14.5 m
Bottom Velocity 0.65 m/s

Lower Missouri River

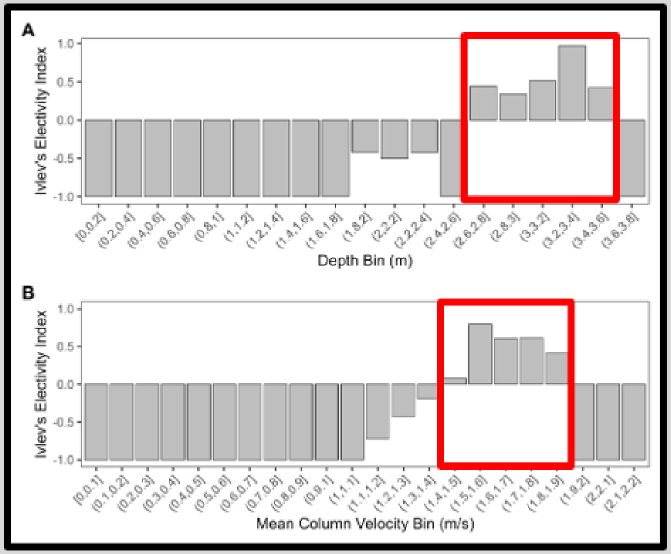
*Mean Depth 6.6 m
*Mean Column Velocity 1.4 m/s
*Presumed spawning
Deep, slow areas - wing dikes

Snook 2001, Swigle 2009

Bramblett and White 2001

* Elliot et al. 2020, Jacobson et al. 2009

Platte River Spawning Female 2024



Lower Missouri
River

*Mean Depth 6.6 m
*Mean Column Velocity 1.4 m/s
*Presumed spawning
Deep, slow areas - wing dikes

*Elliot et al. 2020, Jacobson et al. 2009

Highlights and Future Research

- Pallid Sturgeon positively selected habitats associated with *run* characteristics
- Pallid Sturgeon in Segment 2 preferentially selected deeper habitats compared to Segment 1
- Future studies could explore depth and velocity combinations instead of as individual components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• Professors: Dr. Kevin Pope, Dr. Rene Martin
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• Crew Lead: C. Jordan
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• Technicians: C. Dollen, M. Pugh, N. Manzi, S. Garcia, C. Grant, G. VanEngen, T. MacDonald, J. Reichel
• Undergraduate Students: C. Engel, E. Humphrey, C. Vacha, J. Dagen
• U.S. Geological Survey, Missouri Department of Conservation, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service
Platte River
Recovery Implementation Program
SCHOOL OF NATURAL RESOURCES
NEBRASKA
GAME PARKS


Thank you!
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The EDO has edited the content of UNL's 2024 Annual Report and 2025 Progress Update to reflect only those items specific to identifying Pallid Sturgeon Habitat in the lower Platte River.

Pallid Sturgeon Biology in the Platte River and its Tributaries

Annual Progress Report
(Year 3: 2024)
+
JUNE 2025 Platte River Pallid Sturgeon Project Overview and Progress Update

Prepared by: Jenna Ruoss, Christopher Pullano, and Mark Pegg University of Nebraska-Lincoln

Project Lead: Mark Pegg
School of Natural Resources
Lincoln, Nebraska 68583
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Note: the 2024 Annual Report is focused on data summarization pertaining to movement patterns within as well as immigration into and emigration from the Platte River per guidance from the EDO.

Definition of Acronyms and Terms

Acronyms

AIC_c	Akaike's Information Criteria - corrected for small sample sizes
CI	95% Confidence Interval
CMS	Cubic Meters Per Second
COE	United States Corps of Engineers
EDO	Executive Director's Office
GLM	Generalized Linear Model
MDC	Missouri Department of Conservation
NGPC	Nebraska Game and Parks Commission
PRRIP	Platte River Recovery and Implementation Program
UNL	University of Nebraska-Lincoln
USGS	United States Geological Survey

Terms

Non-Reproductive	Individual in Reproductive Stage I, II, or III per USGS–-Columbia Environmental Research Center Guidelines (https://www.cerc.usgs.gov/pubs/v_clips/reproduction.pdf).
Reproductive	Individual in Reproductive Stage IV (e.g., black egg female) per USGS–-Columbia Environmental Research Center Guidelines (https://www.cerc.usgs.gov/pubs/v_clips/reproduction.pdf).
InnovaSea	Tag and receiver manufacturer.

Executive Summary

The goal of this project is to fill gaps in understanding regarding the movement ecology and reproduction ecology of Pallid Sturgeon *Scaphirhynchus albus* in the lower Platte River basin. Specific interests include quantifying extent of use by Pallid Sturgeon of the lower Platte River and its tributaries, what environmental or biotic variables facilitate Pallid Sturgeon movement into, out of, and within the lower Platte River, and assessing Pallid Sturgeon habitat use in the lower Platte River. Original objectives of this project were to: 1) identify the timing and extent of Pallid Sturgeon movement into and within the lower Platte River and its tributaries, 2) identify Pallid Sturgeon spawning habitat in the lower Platte River and its tributaries, 3) verify successful spawning by Pallid Sturgeon in the lower Platte River and its tributaries, and 4) provide Pallid Sturgeon genetic samples for further population and hybridization assessment.

Spawning—defined as release of eggs—by a single female Pallid Sturgeon was observed in Spring 2024 in the Loup River (Objectives 2 & 3).

Acoustic telemetry including passive and active tracking has been used to evaluate movement of Pallid Sturgeon from 2022 to 2024. A passive array of acoustic receivers (N = 35 total, 27 in 2024) throughout the lower Platte River, the Elkhorn River, and the Loup River monitors movements of Pallid Sturgeon as they pass each receiver location generally from late-February through mid-November. Active tracking, where crews cover the entirety of the study area, was used to supplement the passive array and locate fish monthly from March through October. The active tracking data were used for this report to document instances when immigration or emigration occurred but were missed by the passive receiver array. Pallid Sturgeon detected in passive and active tracking came from a combination of individuals captured in the lower Platte River as part of this project and individuals implanted with transmitters by concurrent work in the Missouri River. Pallid Sturgeon were captured in the lower Platte River using trotlines baited with nightcrawlers *Lumbricus terrestris* following the Range-wide Pallid Sturgeon Handling Protocols and Procedures (U.S. Fish and Wildlife Service 2019). Trotlines were deployed throughout the lower 160 km reach of the lower Platte River.

A total of 70 Pallid Sturgeon have been captured using trotlines by UNL since March 2022. Spring 2024 sampling resulted in 17 Pallid Sturgeon captured with 11 being large enough to be implanted with acoustic tags (One tagged individual was later determined to be a hybrid based on genetic results from Dr. Heist). To date, 147 unique Pallid Sturgeon have been either tagged by UNL or documented moving into the lower Platte River system from Missouri River tagging efforts since March 2022.

JUNE UPDATE: We have encountered 164 uniquely tagged Pallid Sturgeon in the Platte River system thus far. Encounters have occurred throughout the study area (Figure 2). These detections typically account for about 30% of the total number of Pallid Sturgeon with transmitters implanted for the entire Lower Missouri River system each year.

- Twenty (20) Pallid Sturgeon encountered are suspected to be wild (i.e., no known genetic relation to hatchery produced individuals) with another 12 of unknown origin.
- Most Pallid Sturgeon (77%) are of hatchery origin.
- Hatchery produced Pallid Sturgeon stocked at locations throughout the lower Missouri River Basin have been detected in the Platte River system (Appendix A). Pallid Sturgeon use in the Platte River is not necessarily a phenomenon of solely local fish stockings.
- Multiple year-classes of hatchery produced Pallid Sturgeon are using the Platte River.

Key findings include:

Pallid Sturgeon Reproduction

- There appears to be multiple movement patterns in the Platte River presumably for reproduction. Both one-step and two-step migration strategies were observed (See Supplement 1, Chapter 3 to this report for full description).

- Stage IV reproductive female Pallid Sturgeon (i.e., black egg females) have been documented in the lower Platte River and tributaries. Evidence of spawning, based on departure time and no eggs present upon recapture did occur in 2024 by a single female Pallid Sturgeon. Another female, gravid Pallid Sturgeon that displayed possible spawning movement behavior (e.g., quick upstream-downstream movements) was recaptured downstream in the lower Missouri River and confirmed to have spawned somewhere between Louisville, Nebraska (most upstream detection/presumed apex of migration) and the recapture site.

JUNE UPDATE: The Pallid Sturgeon in the Platte River potentially contribute to natural reproduction. Sample sizes are low, but there is some evidence to suggest there have at least been attempts to spawn in the Platte River system.

- We have documented behavior consistent with spawning activities as seen on the Missouri River.
- We have documented females void of eggs following the spawning window that remained entirely in the Platte River system during the spawning season.
- Verification of successful spawning and contribution to the recovery of the species remain to be evaluated.

Adjustments to field protocols and statistical analyses are planned for 2025 and include:

Field Protocols

- No Pallid Sturgeon sampling (i.e., trotlines) will be conducted in 2025 per the project timeline.

EDO: There were no captures in the fall of 2024 either since Chris Pullano was trying to graduate. Last capture season was spring of 2024.

- The emphasis will be on maintaining the current configuration of the passive acoustic receiver array.
- Monthly river sweeps will continue. This effort also includes additional sweeps to locate Pallid Sturgeon during the pre-spawn and spawning timeframe (i.e., late March – through May).

EDO: One of the tradeoffs upon dropping trawling from the protocol was to increase sweeps to fill detection gaps apparent in 2022 dataset for movement analyses.

INTRODUCTION

Pallid Sturgeon *Scaphirhynchus albus* (Forbes and Richardson 1905) is a federally endangered fish first listed in 1990 (USFWS 1990). Pallid Sturgeon occupy the Missouri and Mississippi rivers and other major tributaries such as the Platte, Yellowstone, and Kansas rivers (Bailey and Cross 1954; Kallemeyn 1983). Rivers that historically were occupied by Pallid Sturgeon were characterized as large, swift, turbid, braided, and free flowing (Bailey and Cross 1954; Dryer and Sandvol 1993; Peters and Parham 2008). Habitat alterations such as channelization and impoundments have been suggested as major contributors to the decline of Pallid Sturgeon as contemporary conditions no longer align with the life-history needs of the species (Kallemeyn 1983; Dryer and Sandvol 1993). Of particular concern is the near or complete loss of spawning and recruitment habitat for the species.

Recovery efforts for Pallid Sturgeon in the Missouri River basin have largely focused on the mainstem and typically included obtaining information on population dynamics (e.g., population estimates, movement, survival, etc.), habitat modification (e.g., creating interception and rearing zones), and propagation (e.g., stocking hatchery reared individuals). However, there are substantial gaps in knowledge regarding Pallid Sturgeon use of tributaries to the mainstem Missouri River including how and when Pallid Sturgeon use these tributaries, what initiates their use (e.g., environmental cues), and whether successful spawning occurs. These knowledge gaps are the impetus for this project. Pallid Sturgeon has been documented using tributaries across its distribution in the upper and lower Missouri River basins (Bramblett and White 2001; Hamel et al. 2016). Seasonal presence and spawning by Pallid Sturgeon within tributaries is thought to coincide with hydrologic and temperature regimes (Hamel et al. 2016). Of particular interest is 1) further understanding of movement patterns and potential causes of movement into and throughout tributaries, and 2) the prevalence of spawning and recruitment of Pallid Sturgeon within tributaries.

Efforts reported here were part of a project initiated in July 2021 as part of the Platte River Recovery Implementation Program's (PRRIP) ESA compliance contributions related to the federally endangered Pallid Sturgeon in the lower portion of the Platte River, Nebraska. This 5-year study was intended to provide information pertaining to known knowledge gaps about environmental correlates of Pallid Sturgeon use, spawning habitat, and reproduction and recruitment in the lower Platte River and its tributaries. The original project objectives were to:

1. Identify relations among environmental conditions (i.e., river discharge and temperature) with the timing and extent of Pallid Sturgeon movement into and within the lower Platte River and its tributaries.

2. Identify Pallid Sturgeon spawning habitat in the lower Platte River and its tributaries.

3. Verify successful spawning by Pallid Sturgeon in the Platte River and/or its tributaries.
    Per ISAC and EDO guidance, larval sampling was dropped from sampling protocol in 2024. As such, documentation of these objectives is largely observational from capture and telemetry data.

4. Provide Pallid Sturgeon genetic samples for further population and hybridization assessment (in collaboration with Southern Illinois University's parallel project).
    Per ISAC and EDO guidance, larval sampling was dropped from sampling protocol in 2024. As such, samples provided by this project for genetic analysis are largely limited to tissue samples obtained upon capture of adults and juveniles as well as any eggs collected from egg mats placed opportunistically downstream of potential spawning behavior.

JUNE 2025 UPDATE: Some adjustments to those objectives have occurred over the course of the study as benefits to effort for return became clearer. Specific, mutually agreed changes were as follows:

- Objective 3 was effectively dropped for 2024-2025 sampling. Time allocation for this objective was concurrent with increased demand for active telemetry during spawning. Egg and larval sampling in 2022-2023 resulted in no egg or larval Pallid Sturgeon being captured. Given the time demands and no successful captures, diverting effort originally directed toward this objective was shifted to add a second active telemetry crew during the spawning season. This was implemented to increase detection locations. However, egg mats were used to attempt to collect eggs or larvae in the drift just downstream of suspected spawning locations if Pallid Sturgeon behavior warranted such during the ensuing years.

JUNE UPDATE: Direction of Research and Expectations

Studying Pallid Sturgeon populations, coupled with monitoring their recovery, has been ongoing in the Missouri River since their listing as an endangered species in 1990. Almost all of that effort has focused on understanding population dynamics, habitat use, and propagation in the mainstem Missouri River or Yellowstone River as part of the recovery plan. A growing body of literature suggests tributaries to large rivers, like the Missouri River, play a more substantial role in conservation and management of native riverine species than perhaps historically thought given the anthropogenic footprint on large rivers. However, little information exists about the role tributaries to the Missouri River, especially the Platte River, may play in Pallid Sturgeon biology under contemporary conditions.

The information gap that exists for the Platte River and its contribution to Pallid Sturgeon biology likely stems from several interconnected factors such as jurisdictional boundaries that create coordination challenges. Further, limited historical data preclude a clear understanding of how the Platte River contributes to Pallid Sturgeon use and overall contribution to the lower Missouri River population. Additionally, the practical realities required of field sampling in the Platte River is also likely a factor in the paucity of data. Unlike other regional rivers of comparable size, the Platte River presents unique physical characteristics that make conventional gear and methods used for fish sampling and data collection extremely challenging to implement. Although far from perfect, we have been able to overcome some of these challenges to show that Pallid Sturgeon are using the Platte River.

We see the outcomes of this study as valuable contributions to the global understanding of Pallid Sturgeon biology. To that end, we will provide further insight into environmental cues, movement patterns, and spawning behaviors in a lesser-studied system. These results can potentially inform decisions on river management in both the Platte River and Missouri River.

We have newfound insight into the disproportionate presence of Pallid Sturgeon using the Platte River. We find it interesting that about 1/3 of all fish with transmitters in the lower 1,300 km of the Missouri River system find their way to the Platte River annually. Those fish compose a substantial cross-section of ages, stocking locations if hatchery produced, and wild individuals. We can only speculate on the reasons at this time, but there appears to be some attraction to this system.

JUNE UPDATE: Answer Program questions

The Adaptive Management Plan includes broad hypotheses as part of the Conceptual Ecological Models and Hypotheses section with further research objectives outlined in the Monitoring and

Research section of that plan. We identify below where this project may be able to provide supporting information to address those hypotheses and the research objectives that fall under their umbrella.

Broad Hypotheses:

PS-1: Current habitat in the lower Platte River is/is not suitable for adult and juvenile Pallid Sturgeon.

> Both active and passive tracking provides evidence of Pallid Sturgeon use across an array of ages to date. Further analyses on residence times, use distribution areas, etc. (see Pullano thesis, annual report) also provide insight on the extent of usage by individuals and compositely.
>
> Much of the work being conducted by the current graduate student will provide greater understanding of habitat use, selection (within reasonable distance of an individuals location), and habitat availability. The extent and level of detail for those analyses are contingent upon mapping habitat where the fish was or was not at individual detection sites to extrapolate up to larger spatial scales across the river. Mapping specific fish locations is completed, as is some site specific information on broader habitat availability (sensu Stage Change Study and our own mapping), but extrapolation to the Platte River is pending availability of habitat modeling data from outside resources.

PS-2: Water related activities above the Loup River do/do not impact Pallid Sturgeon habitat.

> Tying specific water management related activities above the Loup River will be difficult at present unless the activity can be measured at Pallid Sturgeon locations. We have documented Pallid Sturgeon upstream of the Loup River, but sample size is very small (n < 5 total detections). Tying those detections to a single, specific management action is not currently likely. There are fish detections near the Loup River-Platte River confluence that may be more immediately responsive to any detectable change if or when such occurs. Realistically, analyses will likely be more related to connections for detectable differences (e.g., hydropeaking) and overall water availability in the system. Unsurprisingly, when there is more water in the lower Platte River system we see more activity.

PS-3: Non-Program actions (e.g., harvest, stocking, Missouri River conditions) determine the occurrence of Pallid Sturgeon the lower Platte River

> Efforts from Objective 1 of this study should provide at least some insight on non-program activities. Specifically, actions like stocking have increased the number of Pallid Sturgeon in the entire lower Missouri River system as part of the recovery plan. Fewer than 100 Pallid Sturgeon have been stocked directly into the Platte River (n = 84 in 1998; n = 15 in 1999) yet numerous year-classes of hatchery fish are present (Table A.1; Figures A.1 – A.2). Comparisons of Pallid Sturgeon to Shovelnose Sturgeon capture ratios from trotline sampling can be comparatively evaluated between the Missouri River and Platte River under current management conditions (historic data are sparse) to gauge disparity in contribution of wild/hatchery fish. Further, the telemetry data denoting movement into and out of the Platte River will provide information into how Missouri River conditions may impact use.

JUNE UPDATE: Objective 2. Identify Pallid Sturgeon spawning habitat in the lower Platte River and its tributaries.

Question 1. What physical and chemical variables at relocation points are associated with reproductively-ready Pallid Sturgeon use in the lower Platte River basin including tributaries?

We have assessed spawning habitat selection, based on behavioral detections, for the female we confirmed had spawned (A69-1604-30379 hereafter 30379) during 2024. Throughout the duration of the project, 30379 was the only instance in which spawning behavior was observed and the acoustic doppler current profiler (ADCP) was available. Active tracking occurred while 30379 was moving swiftly up- and downstream along the riprap at Louisville, Nebraska. The ADCP was mounted from the airboat using a winch with a fixed transducer depth of 3 cm. Transects were mapped in a zigzag pattern perpendicular to flow at low idle speeds of < 3 m/s. Transects were approximately 1 to 20 m apart as conditions allowed, following methods similar to Elliot et al. (2020). The ADCP records depth, mean column velocity, latitude, and longitude every 1-second. Maps of depth and average water column velocity using the ADCP data were developed in ArcGIS Pro for visual representation of spawning habitat (Figure 13). The Geostatistical Analyst extension toolbox has an ordinary kriging tool to interpolate the depths and velocities for spaces not measured by the ADCP.

Interpolated depths and velocities at each fish location was classified as *used habitat* and were extracted from ArcGIS Pro using the *Extract Values to Points* tool. Raw depth and velocity data recorded from the entire reach were classified as *available habitat*. The degree of habitat selection was explored using Ivlev's index of electivity (Strauss 1979). Ivlev's index of electivity has been conventionally used for comparing diets of fishes and other aquatic organisms (Strauss 1979), but has more recently been used to understand habitat selection (Lee and Suen 2014; Elliot et al. 2020). Ivlev's electivity coefficient is expressed as:

$$E_i = \frac{o_i - \pi_i}{o_i + \pi_i}$$

where E_i is the electivity coefficient for resource unit *i* (from -1 to +1), o_i is the sampled proportion of used habitat units; and π_i is the sampled proportion of available habitat units. Positive values indicate selection, values near zero suggest habitat is used in similar proportion to its availability, and negative values indicate avoidance. To complement the electivity index, proportions of used and available depths and velocities were graphed to visualize patterns of habitat selection.

Results indicated that 30379 positively selected deeper habitats ranging from 3.2 to 3.4 m, with an Ivlev coefficient of 0.97, thus reflecting disproportionately greater use relative to availability (Figure 14). Furthermore, 30379 also positively selected for relatively swift mean column velocities ranging from 1.5 to 1.6 m/s, indicated by an Ivlev coefficient of 0.53 (Figure 15). The results indicating that 30379 selected for deeper, faster waters while exhibiting spawning behavior complements observations by Fuller et al. (2008) and DeLonay et al. (2012) concerning spawning by Pallid Sturgeon.

JUNE UPDATE Objective 3. Verify successful spawning by Pallid Sturgeon in the Platte River and/or its tributaries.

Question 1. Is there evidence of spawning defined as the release of gametes in the Platte River or its tributaries?

Collection of Pallid Sturgeon eggs or larvae were unsuccessful using the originally proposed sampling regime in 2022-2023. The sampling required substantial time commitment for what had been no return on sturgeon egg/larvae collection. Therefore, modification of the objective prior to the 2024 field season dropped the ichthyoplankton net sampling to capitalize on gaining more information from active tracking. Egg mats were strategically placed downstream of suspected spawning locations observed during active tracking per conversations with USGS personnel in the Upper Missouri River Basin in 2023-2024 (no spawning behavior explicitly observed in 2025). No sturgeon eggs were collected using this method.

There is evidence of spawning (i.e., release of gametes) by Pallid Sturgeon despite no physical capture of eggs or larval in the Platte River system. Fish A69-1604-22188 was confirmed to have spawned near the Loup River confluence with the Platte River in Spring 2024 (see below for full description of spawning activity). Indicators of spawning included loss of mass and no eggs present upon surgical examination.

Question 2. Do reproductively ready Pallid Sturgeon exhibit similar spawning behaviors as those found in the Missouri River mainstem and the Yellowstone River?

We have documented instances of adult Pallid Sturgeon exhibiting spawning behaviors. Excerpts from past annual reports and spring 2025 observations summarize spawning behaviors seen in the Platte River system to date. Figures provided for the 2022 detections are visualizations of potential spawning behavior as examples to observations for all years.

2022

A NGPC tagged (A69-1602-58917) mature female Pallid Sturgeon exhibited a repeated pattern of upstream and downstream movement within the same general area on May 8, 2022 (Figure 16). The female was first detected in the Elkhorn River, approximately 50 meters from the mouth. After the initial detection, it did not appear in that area for approximately five minutes but was relocated after drifting approximately 100 meters downstream from the Elkhorn River mouth into the Platte River. This female then repeatedly moved away from and toward the second location about every 5 to 10 minutes. This behavior is consistent with female spawning behavior observed in the Missouri River and suggested potential spawning.

The second instance of suspected spawning behavior occurred approximately 8 km upstream from the confluence of the Platte River with the Missouri River. A male Pallid Sturgeon (A69-1602-62101) captured by our crews on March 29, 2022 was determined to be reproductively mature and made small (< 1 km) upstream and downstream movements until its last known detection at that location on May 11, 2022 (Figure 17). This behavior is also consistent with male spawning behavior.

2023

PLS22-018 (A69-1604-30383) was tagged by NGPC in September, 2022 in the Missouri River and entered the Platte River in the fall. She moved upstream in the Platte River in the spring, with her apex being downstream of Rogers, Nebraska (Figure 18). She began rapid downstream movement around May 6, and crews recaptured her near Venice, Nebraska on May 9. Our recapture indicated she had not spawned (i.e., no loss in mass, black eggs present) and left the Platte River on or about May 15. She then proceeded upstream in the Missouri River to the Ponca, NE area. The USFWS recaptured her on her movement downstream June 7, 2023 and confirmed she was void of eggs.

UNL23-793 (A69-9001-54336) was initially captured and implanted with a transmitter by UNL crews on April 9, 2023 at about river kilometer (RKM) 112 near North Bend, NE (Figure 19). She was actively detected downstream of the Schuyler bridge near RKM 138 on April 17, 2023 and passed by our passive station at RKM 140 on April 18. The female was actively detected near RKM 153 on April 24, 2023 and again at RKM 154 on April 25, 2023. By May 8, 2023 she had stopped at RKM 157, but was detected by the passive receiver at the Loup Power Canal (RKM 160). Active tracking on the same day indicated she moved about 3 km into the Loup River. She continued upstream in the Loup River, moving past our passive listening station in the Loup at RKM 5 on May 12, 2023. Her apex movement, determined via active tracking, occurred at RKM 6.5 on May 12. Downstream movement in the Loup River was initiated on May 13, 2023 when she returned to the confluence with the Loup and Platte rivers. However, May 14, 2023 she was actively detected downstream of the Columbus bridge – 5-6 km upstream of the Loup and Platte river confluence in the Platte River. She was subsequently recaptured on May 25, 2023 in the Loup River at RKM 2 for reproductive reassessment. She was 75g lighter than her initial capture weight and eggs appeared to still be in viable condition. She was detected passively on July 3, 2023 near the confluence of the Elkhorn River (Platte RKM 51.5). The NGPC Missouri River Program office successfully recaptured her in the Missouri River on July 13, 2023 where they confirmed she was void of eggs.

2024

Nebraska Game and Parks Commission tagged A69-1604-22188 on September 20, 2023 near the mouth of the Platte River and reported the sturgeon as a black egg female Pallid Sturgeon. She was then detected at the Louisville passive receiver gate on October 23, 2023 (Figure 20). Most receivers were retrieved for the winter shortly thereafter through late February, 2024, but the fish was detected at the passive receiver near Fremont on March 17, 2024. She was detected on the Loup power canal return on April 28-29 and May 1-2, 2024 and then the Loup River (RKM 3) receiver on May 13, 2024 (presumably going into the Loup River and redetected on May 19, 2024 moving downstream. Crews actively detected this female between the Loup River and Platte River confluence and Loup power canal return on May 20, 2024 and initiated recapture and reproductive assessment efforts. The ovary was completely empty with transparent folds and no sign of going atretic, thus spawning was determined to have occurred.

Missouri Department of Conservation captured A69-1604-30379 on March 20, 2024 for evaluation and reported the sturgeon as a black egg female deemed high priority. On April 28, 2024 she entered the Platte River (Figure 21). She was actively detected near Louisville, NE (~RKM 24) on May 1, 2024 along the shoreline containing riprap to protect railroad infrastructure. The female exhibited short distance up and downstream movement along the riprap throughout the day. On May 2, 2024 she was found in the same general area. Relocation attempts failed thereafter, but she was detected at the Platte River confluence passive receiver gate on May 9, 2024 moving downstream into the Missouri River. Field crews from USGS recaptured her downstream from the Platte River near Missouri River RKM 910 on May 30, 2024. That assessment determined a complete spawn had occurred.

2025

There were priority (suspected to be spawning capable) adults in the Platte River system during the 2025 spawning window, but no specific behavior typical of spawning was observed. Specifically, three males remained in or near the Loup River confluence for the duration of the spawning window. A priority female was also in the lower portion of the Platte River prior to optimal spawning temperatures (Figure 22). She eventually moved to the confluence of the Platte River with the Missouri River where she was believed to have spawned in the Missouri River. This female subsequently moved back into the Platte River where we re-captured her to verify she was spent (i.e., eggs absent verified by visual inspection of gonads).

Deviations from Plan and Future Adjustments

2024 Adjustments

We deployed an additional receiver ~0.5 km upstream of the Platte-Missouri River confluence in 2024 to assist with directional movements in that area (Figure 1). In addition, we deployed an extra receiver upstream of the Elkhorn River confluence to reinforce the gated array in this area (Figure 1).

2025 Proposed Adjustments

We are working closely with faculty in the UNL Statistics department to aid in model development. As such, we will continue to explore appropriate techniques to evaluate the data we are collecting. Further, we intend to refine the multistate, mark-recapture model to estimate movement probabilities in/out of the Platte River, in/out the Elkhorn River, upstream of the Elkhorn River, and Loup River (if possible). Transition (movement) information is already in hand within the Platte River for the 2022-2024 sampling seasons. We also plan on using a multinomial logit link instead of a sin link as well as including covariates such as sex, reproductive status, etc. However, computing power is currently a limiting factor in refining and developing models at this time. We are working on improved access to the UNL Holland Computer Center (https://hcc.unl.edu/) that will alleviate some of these issues. In addition, developing a complete model for movements of fish tagged in the lower Missouri River basin is predicated on having access to the full Lower Missouri River Pallid Sturgeon telemetry catalog so that numbers, tagging locations, etc. are known for all potential individuals in the system. These data will allow us to build accurate capture histories for fish that could potentially engage the Platte River in some way. Discussions with USGS to acquire those data are ongoing.

Unresolved data issues

Data availability for environmental variables discussed below are not currently available or are pending future data sharing from other organizations. These unresolved issues will likely impact inference and resolution of some analyses pending their future availability. A brief synopsis of the current situation with each source of data follows to explain potential shortfalls in useable information.

Missouri River data – Access to Pallid Sturgeon telemetry data from the Missouri River, currently managed by USGS, is currently limited to only those receiver stations at the mouth of the Platte River. This has limited our capacity to determine emigration out of the Platte River effectively if or when a Pallid Sturgeon makes such a move but goes undetected by that subset of receivers. This situation has forced an assumption that downstream movement to the mouth of the Platte River is effectively an emigration event. Additional detection information from the Missouri River receiver network would provide additional support and confirmation of the emigration event if individuals are detected elsewhere, thus improving certainty of specific behaviors. Similarly, water temperature data are not publicly available at the Platte River-Missouri River confluence. However, the telemetry receivers managed there by USGS should be recording temperature. Water temperature measured by the USGS Louisville gage in the Platte River is correlated to water temperatures measured by the UNL receiver located < 5km from the gage (Figure 15). Therefore, acquiring these data from the USGS telemetry receivers in the Missouri River near the mouth of the Platte River would provide an opportunity to specifically investigate the thermal regime differences between the two river systems and provide broader, system-wide data compatibility.

Water quality parameters - A suite of water quality parameters are currently being measured by a single gage station in the Platte River (Louisville). That gage measures temperature, turbidity, conductivity, dissolved oxygen, and nitrate/nitrite in addition to discharge and water elevation. Other gages in the study area have measured these parameters in the past but do not currently align with the 2022-2025 field sampling scheduled for this project. Therefore, inferences made related to these parameters and Pallid Sturgeon movements in the Platte River and its tributaries will likely be coarse at best.

Data Preparation, Storage, and Sharing

The completed data set from all fieldwork will include (including metadata):

- All capture effort and species caught (2022-2024),
- Egg/larval fish sampling effort and catch (2022-2023),
- Egg mat sample effort and catch (2023-2024),
- Receiver deployment (all years),
- Passive receiver detections (all years; all species),
- Active detections and tracking effort (all years; all species),
- Merged or compatible to merge USGS detection dataset.
- Habitat measurement data from ADCP

EDO: In addition to raw data files, the EDO will need all data analysis input datasets that include the suite of:

Environmental variables at active tracking locations
Environmental variables associated with use and available locations – input dataset for habitat selection analysis.

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Table 1. Number of individual Pallid Sturgeon detected actively or passively throughout the lower Platte River system. The Platte River segments are distinguished by the Elkhorn River confluence at river kilometer (rkm) 52 (Platte Segment 1 ≤ rkm 52; Platte Segment 2 > rkm 52).

River	Year	Transmitters
Platte Segment 1	2022	54
	2023	71
	2024	88
Platte Segment 2	2022	9
	2023	19
	2024	29
Elkhorn	2022	10
	2023	15
	2024	18
Loup	2022	0
	2023	2
	2024	10
Central Platte	2022	0
	2023	0
	2024	2

JUNE UPDATE:

Table 5. The number of unique transmitters in each river segment per year. Platte Segment 1 refers to the Platte River downstream of the Elkhorn River confluence whereas Platte Segment 2 is the Platte River upstream of the Elkhorn River.

River	Year	Transmitters
Platte Segment 1	2022	54
	2023	71
	2024	88
	2025	47
Platte Segment 2	2022	9
	2023	26
	2024	36
	2025	23
Elkhorn	2022	10
	2023	15
	2024	18
	2025	4
Loup	2022	0
	2023	2
	2024	10
	2025	6
Central Platte	2022	0
	2023	0
	2024	2
	2025	0

*Note, number of unique transmitters in Platte Segment 2 different from previous reports for 2023 and 2024 due to updated data/detections from the river right North Elkhorn Receiver getting misclassified as downstream of the Elkhorn River instead of upstream.

Table 2. All tagged Pallid Sturgeon recorded by UNL personnel within the lower Platte River or its tributaries from 2022 to 2024. Implant date indicates when an individual Pallid Sturgeon was surgically implanted. Origin indicates whether an individual is hatchery or wild. Reproductive status indicates whether an individual was reproductive or non-reproductive at the time of the last status check (i.e., when implanted). Sex was determined during implantation.

Acoustic ID	Implantation Date	Hatchery Origin	Reproductive Status	Sex
A69-1604-30384	2022-09-29	Hatchery	Non-Reproductive	Female
A69-1604-30381	2022-09-14	Hatchery	Non-Reproductive	Female
A69-1604-22191	2023-09-18	Hatchery	Non-Reproductive	Female
A69-1602-59359	2019-09-03	Hatchery	Non-Reproductive	Female
A69-1602-59365	2019-09-04	Hatchery	Non-Reproductive	Female
A69-1604-30389	2023-03-21	Probable Wild	Reproductive	Male
A69-1602-59354	2019-10-09	Probable Wild	Non-Reproductive	Female
A69-1602-19520	2019-10-24	Hatchery	Non-Reproductive	Female
A69-1602-19523	2019-10-25	Probable Wild	Reproductive	Female
A69-1602-58909	2020-06-12	Probable Wild	Non-Reproductive	Female
A69-1602-58917	2020-06-11	Probable Wild	Non-Reproductive	Female
A69-1602-59046	2020-09-21	Hatchery	Non-Reproductive	Female
A69-1602-59352	2020-10-08	Hatchery	Non-Reproductive	Male
A69-1602-59024	2020-10-14	Hatchery	Non-Reproductive	Female
A69-1602-59972	2020-10-22	Hatchery	Non-Reproductive	Unknown
A69-1602-59977	2020-10-14	Unknown	Non-Reproductive	Female
A69-1602-59988	2020-11-11	Hatchery	Non-Reproductive	Unknown
A69-1602-59578	2020-03-25	Hatchery	Non-Reproductive	Unknown
A69-1602-59582	2021-03-08	Hatchery	Non-Reproductive	Unknown
A69-1602-55342	2021-03-10	Hatchery	Non-Reproductive	Unknown
A69-1602-55362	2021-03-17	Unknown	Non-Reproductive	Unknown
A69-1602-55344	2021-03-25	Hatchery	Non-Reproductive	Male
A69-1602-55340	2021-03-25	Hatchery	Non-Reproductive	Male
A69-1602-55335	2021-03-25	Hatchery	Non-Reproductive	Female
A69-1602-55337	2021-03-25	Hatchery	Non-Reproductive	Male
A69-1602-59042	2022-04-09	Hatchery	Non-Reproductive	Female
A69-1602-59980	2021-03-25	Hatchery	Non-Reproductive	Unknown
A69-1602-49638	2021-04-13	Hatchery	Reproductive	Male
A69-1602-55347	2021-04-13	Hatchery	Non-Reproductive	Female
A69-1602-55355	2021-04-15	Hatchery	Non-Reproductive	Female
A69-1602-19542	2021-04-16	Unknown	Reproductive	Male
A69-1602-55356	2021-03-30	Hatchery	Non-Reproductive	Female
A69-1602-49643	2021-06-05	Hatchery	Reproductive	Male
A69-1602-54451	2021-06-19	Hatchery	Non-Reproductive	Male

Acoustic ID	Implantation Date	Hatchery Origin	Reproductive Status	Sex
A69-1602-49254	2021-10-20	Hatchery	Non-Reproductive	Unknown
A69-1602-49253	2021-10-20	Hatchery	Non-Reproductive	Unknown
A69-1602-63212	2022-03-17	Unknown	Non-Reproductive	Male
A69-1602-63223	2022-03-29	Hatchery	Non-Reproductive	Female
A69-1602-63086	2022-04-07	Unknown	Non-Reproductive	Female
A69-1602-54445	2022-04-07	Unknown	Non-Reproductive	Female
A69-1602-63209	2022-09-14	Hatchery	Non-Reproductive	Unknown
A69-1604-30380	2022-09-14	Hatchery	Non-Reproductive	Female
A69-1604-30383	2022-09-14	Hatchery	Reproductive	Female
A69-1604-30391	2022-09-14	Hatchery	Non-Reproductive	Female
A69-1602-49647	2023-03-15	Hatchery	Reproductive	Male
A69-1604-30387	2023-03-23	Unknown	Non-Reproductive	Unknown
A69-1604-22492	2023-04-25	Unknown	Reproductive	Male
A69-1604-22499	2023-04-27	Hatchery	Non-Reproductive	Female
A69-1604-22502	2023-04-18	Hatchery	Non-Reproductive	Female
A69-1602-63083	2023-07-11	Unknown	Non-Reproductive	Female
A69-1604-24613	2023-07-11	Unknown	Non-Reproductive	Female
A69-1604-24615	2023-07-11	Hatchery	Non-Reproductive	Male
A69-1602-63085	2023-07-11	Probable Wild	Non-Reproductive	Female
A69-1604-20601	2023-08-29	Unknown	Non-Reproductive	Female
A69-1604-20593	2023-09-11	Unknown	Non-Reproductive	Female
A69-1604-20596	2023-09-11	Hatchery	Non-Reproductive	Unknown
A69-1604-20595	2023-09-12	Hatchery	Non-Reproductive	Unknown
A69-1604-20594	2023-09-12	Hatchery	Non-Reproductive	Female
A69-1604-22192	2023-09-18	Hatchery	Non-Reproductive	Unknown
A69-1604-22194	2023-09-21	Hatchery	Non-Reproductive	Male
A69-1604-65040	2023-09-21	Unknown	Non-Reproductive	Female
A69-1604-22188	2023-09-20	Hatchery	Reproductive	Female
A69-1604-22190	2023-09-20	Unknown	Non-Reproductive	Male
A69-1602-62089	2022-03-17	Hatchery	Non-Reproductive	Unknown
A69-9001-58904	2022-03-17	Hatchery	Non-Reproductive	Unknown
A69-9001-58905	2022-03-17	Hatchery	Non-Reproductive	Unknown
A69-9001-58907	2022-03-19	Hatchery	Non-Reproductive	Unknown
A69-1602-62100	2022-03-25	Hatchery	Non-Reproductive	Unknown
A69-1602-62101	2022-03-29	Wild	Reproductive	Male
A69-9001-58908	2022-04-10	Hatchery	Reproductive	Male
A69-1602-62092	2022-04-16	Hatchery	Non-Reproductive	Unknown
A69-1602-62091	2022-04-16	Hatchery	Non-Reproductive	Unknown
A69-9001-58906	2022-04-16	Hatchery	Reproductive	Male

Acoustic ID	Implantation Date	Hatchery Origin	Reproductive Status	Sex
A69-1602-62090	2022-10-25	Hatchery	Non-Reproductive	Unknown
A69-1602-62094	2022-10-27	Hatchery	Non-Reproductive	Unknown
A69-1602-62095	2022-10-27	Hatchery	Non-Reproductive	Unknown
A69-1602-62099	2022-11-01	Hatchery	Non-Reproductive	Unknown
A69-1602-62097	2022-11-01	Hatchery	Non-Reproductive	Unknown
A69-1602-62088	2023-03-21	Hatchery	Non-Reproductive	Unknown
A69-1602-62098	2023-03-22	Hatchery	Reproductive	Male
A69-1602-62096	2023-03-22	Hatchery	Non-Reproductive	Unknown
A69-9001-54335	2023-03-24	Hatchery	Reproductive	Male
A69-9001-54336	2023-04-09	Hatchery	Reproductive	Female
A69-9001-54334	2023-04-11	Hatchery	Reproductive	Male
A69-1604-13377	2023-04-11	Hatchery	Non-Reproductive	Unknown
A69-9001-54330	2023-04-18	Hatchery	Reproductive	Male
A69-9001-54337	2023-04-18	Hatchery	Reproductive	Female
A69-1602-62093	2023-10-11	Hatchery	Non-Reproductive	Unknown
A69-1604-13378	2023-10-17	Hatchery	Non-Reproductive	Unknown
A69-9001-54329	2023-10-18	Hatchery	Non-Reproductive	Unknown
A69-9001-54333	2023-10-19	Hatchery	Non-Reproductive	Unknown
A69-1602-63070	2022-11-01	Probable Wild	Reproductive	Male
A69-1602-55338	2021-03-25	Hatchery	Non-Reproductive	Male
A69-1602-54437	2021-06-18	Probable Wild	Non-Reproductive	Male
A69-1602-63220	2022-09-14	Probable Wild	Reproductive	Male
A69-1602-49250	2021-10-20	Hatchery	Non-Reproductive	Female
A69-1602-63206	2021-10-21	Hatchery	Non-Reproductive	Female
A69-1602-55353	2021-03-18	Hatchery	Non-Reproductive	Male
A69-9001-54327	2024-03-13	Probable Wild	Non-Reproductive	Unknown
A69-1602-62087	2024-03-21	Hatchery	Non-Reproductive	Unknown
A69-1604-34819	2024-04-14	Hatchery	Non-Reproductive	Unknown
A69-1604-22505	2023-07-12	Probable Wild	Reproductive	Male
A69-1604-65039	2023-09-21	Hatchery	Non-Reproductive	Male
A69-1604-30379	2022-10-26	Probable Wild	Reproductive	Female
A69-9001-54331	2023-10-19	Hatchery	Non-Reproductive	Unknown
A69-1602-63082	2023-07-11	Probable wild	Non-Reproductive	Female
A69-1604-20592	2023-09-07	Hatchery	Non-Reproductive	Unknown
A69-1604-20598	2023-08-09	Hatchery	Non-Reproductive	Female
A69-1604-22498	2023-04-27	Probable Wild	Non-Reproductive	Male
A69-1604-24609	2023-07-11	Probable Wild	Non-Reproductive	Female
A69-1604-62358	2024-03-06	Hatchery	Reproductive	Female
A69-9001-54328	2024-04-19	Hatchery	Non-Reproductive	Unknown

Acoustic ID	Implantation Date	Hatchery Origin	Reproductive Status	Sex
A69-9001-54338	2024-04-24	Hatchery	Non-Reproductive	Male
A69-9001-54332	2024-03-29	Hatchery	Non-Reproductive	Unknown
A69-1604-13379	2024-03-16	Hatchery	Non-Reproductive	Unknown
A69-1602-55351	2021-03-11	Hatchery	Non-Reproductive	Unknown
A69-9001-54325	2024-03-28	Hatchery	Non-Reproductive	Unknown
A69-1604-13380	2024-03-14	Hatchery	Non-Reproductive	Unknown
A69-1604-20599	2023-08-29	Hatchery	Non-Reproductive	Male
A69-1602-49246	2022-11-01	Hatchery	Reproductive	Male
A69-1602-63077	2023-04-04	Hatchery	Non-Reproductive	Female
A69-1604-22193	2023-09-20	Hatchery	Non-Reproductive	Unknown
A69-1604-30386	2022-09-29	Hatchery	Non-Reproductive	Female
A69-1604-60653	2024-05-02	Hatchery	Non-Reproductive	Unknown
A69-1604-62351	2024-03-14	Hatchery	Non-Reproductive	Unknown
A69-1604-62679	2024-04-02	Hatchery	Non-Reproductive	Female
A69-1602-63093	2023-06-01	Probable Wild	Non-Reproductive	Male
A69-1604-24614	2023-07-11	Probable Wild	Non-Reproductive	Male
A69-1604-65038	2024-05-15	Hatchery	Non-Reproductive	Female
A69-9001-43956	2024-09-04	Hatchery	Non-Reproductive	Unknown
A69-1604-60258	2024-09-10	Hatchery	Non-Reproductive	Unknown
A69-1604-34818	2024-04-18	Hatchery	Non-Reproductive	Unknown
A69-1604-20597	2023-09-12	Hatchery	Non-Reproductive	Female
A69-1604-62349	2024-03-07	Hatchery	Non-Reproductive	Unknown
A69-1604-62350	2024-03-12	Hatchery	Non-Reproductive	Unknown
A69-1604-62357	2024-09-04	Hatchery	Non-Reproductive	Female
A69-1604-64456	2024-10-02	Hatchery	Non-Reproductive	Female
A69-1604-65066	2024-04-03	Hatchery	Non-Reproductive	Male
A69-1604-65068	2024-04-03	Hatchery	Non-Reproductive	Unknown
A69-9001-43948	2024-09-12	Hatchery	Non-Reproductive	Unknown
A69-9001-43953	2024-10-10	Hatchery	Non-Reproductive	Female
A69-9001-45370	2024-09-24	Probable Wild	Non-Reproductive	Female
A69-1602-55329	2021-03-09	Probable Wild	Non-Reproductive	Male
A69-1604-22189	2023-09-18	Unknown	Non-Reproductive	Female
A69-1602-49249	2022-10-26	Probable Wild	Reproductive	Male
A69-9001-54326	2024-03-30	Hatchery	Non-Reproductive	Unknown
A69-1604-22487	2023-07-11	Probable Wild	Non-Reproductive	Female

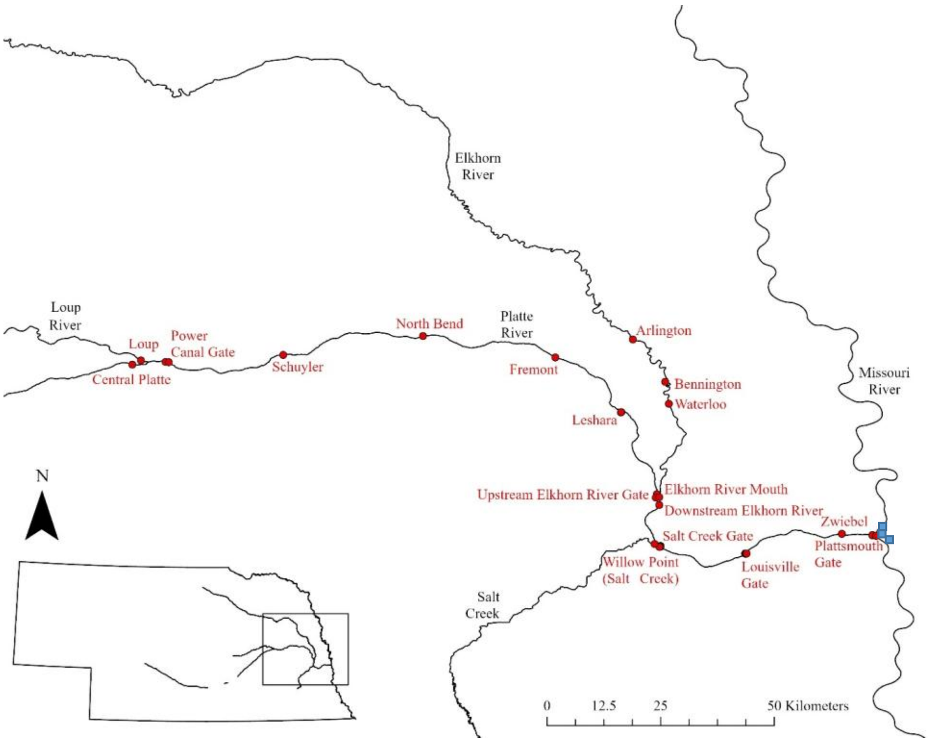

Figure 1. Map of study area with InnovaSea VR2Tx receivers (red circles) deployed in clustered arrays for passive tracking. General locations of receivers operated by USGS in the Missouri River and Platte River (blue boxes) are included for reference.

JUNE UPDATE:

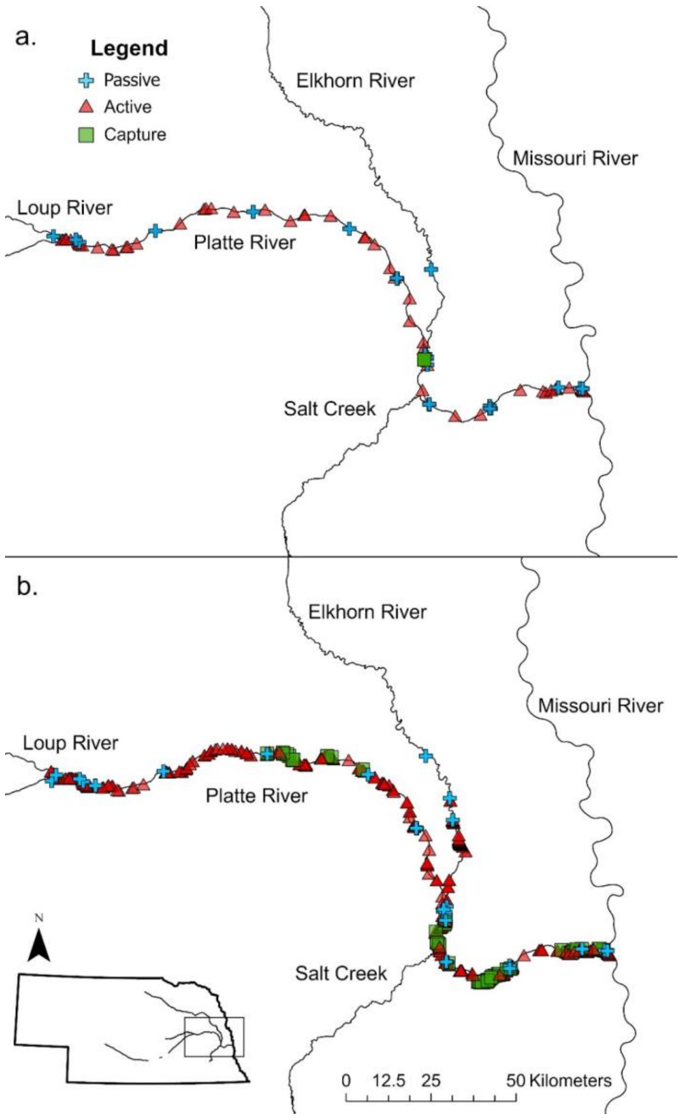

Figure 2. Passive detections by receivers, active detections during river sweeps, and captures of Pallid Sturgeon for 2025 (a). Trotlining did not occur during 2025, thus the only capture depicted is the recapture of a high priority female for reproductive reassessment. Passive detections, active detections, and captures of Pallid Sturgeon encompassing 2022 through May 31, 2025 (b).

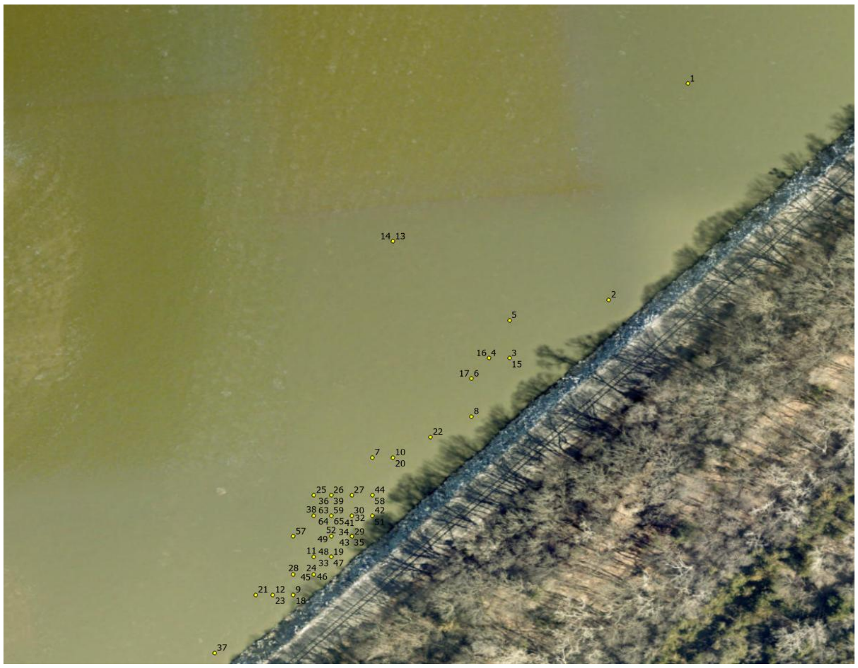

Figure 2. Active detections from Louisville, Nebraska after encountering a gravid female seemingly exhibiting spawning movement (e.g., quick upstream-downstream movement).

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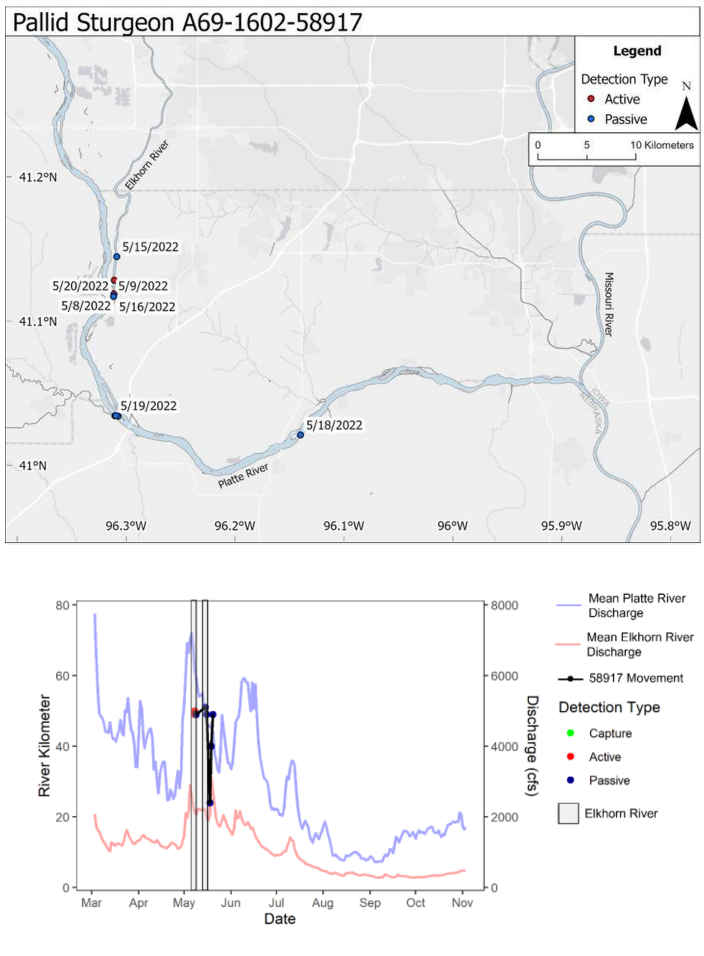

Figure 16. Capture location and relocations of Pallid Sturgeon A69-1602-58917 in the lower Platte River during 2022 (top). Green dot indicates location and date of capture, red dots indicate locations made during active tracking, and blue dots indicate detections at passive receivers. The bottom graph shows linear movement of the fish through time. The grey box indicates the general period of time the fish was located within the Elkhorn River. Discharge (cubic feet per second; cfs) is provided for both the Platte River and Elkhorn River over the period of record.

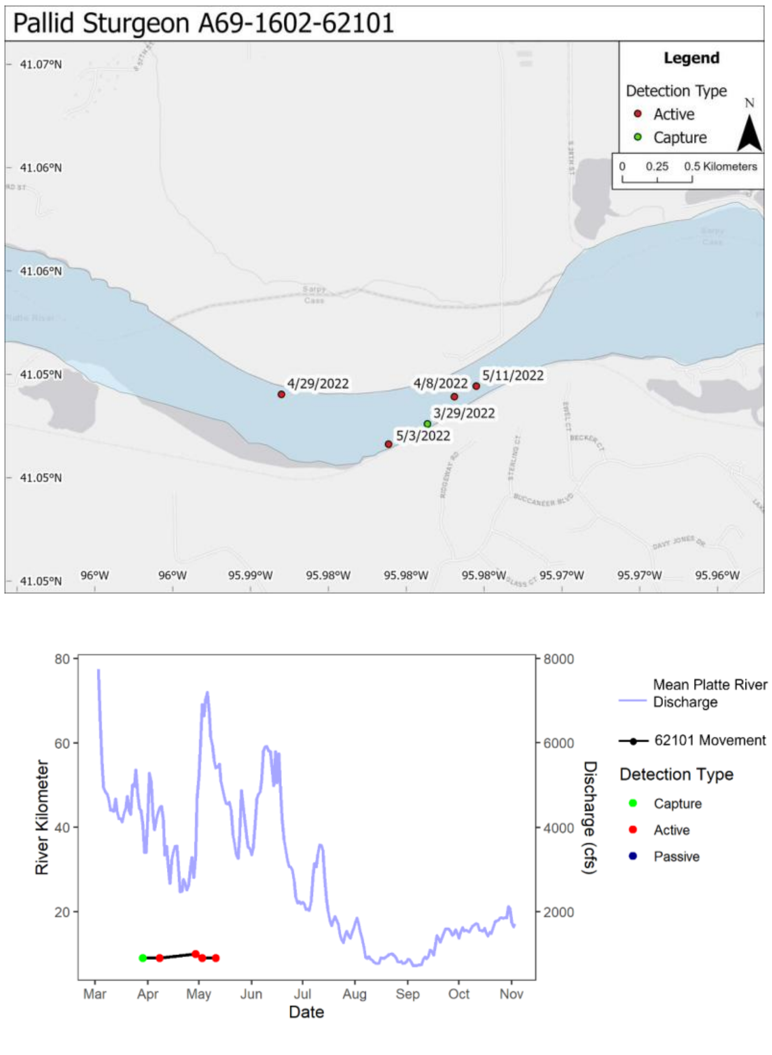

Figure 17. Capture location and relocations of Pallid Sturgeon A69-1602-62101 in the lower Platte River during 2022 (top). Green dot indicates location and date of capture, red dots indicate locations made during active tracking, and blue dots indicate detections at passive receivers. The bottom graph shows linear movement of the fish through time. Discharge (cubic feet per second; cfs) is provided for the Platte River over the period of record.

A69-1604-30383

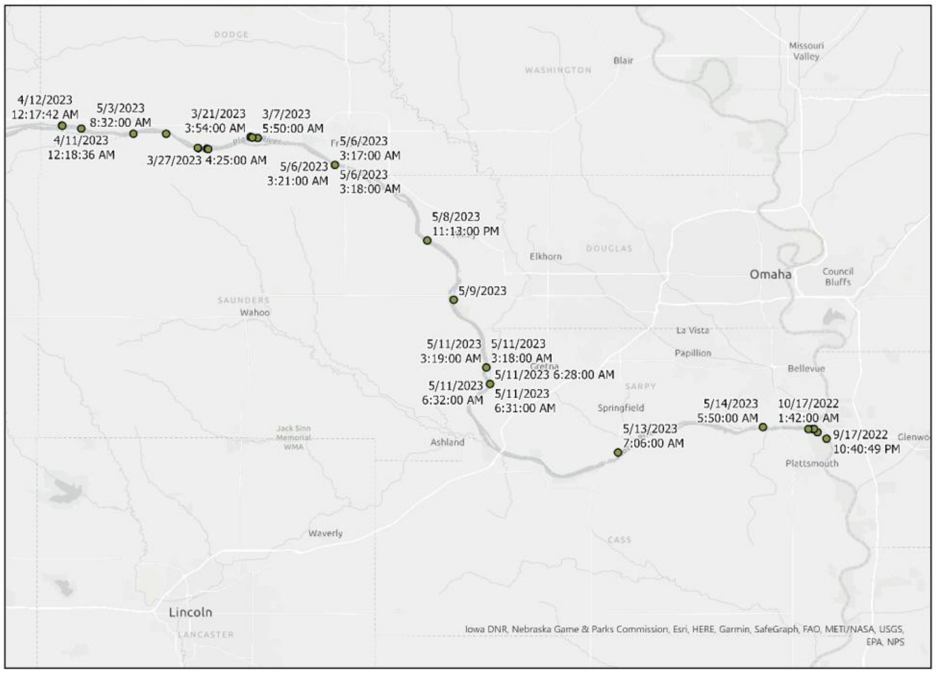

Figure 18. Relocations of A69-1604-30383 through Fall 2022 to Spring 2023.

A69-9001-54336

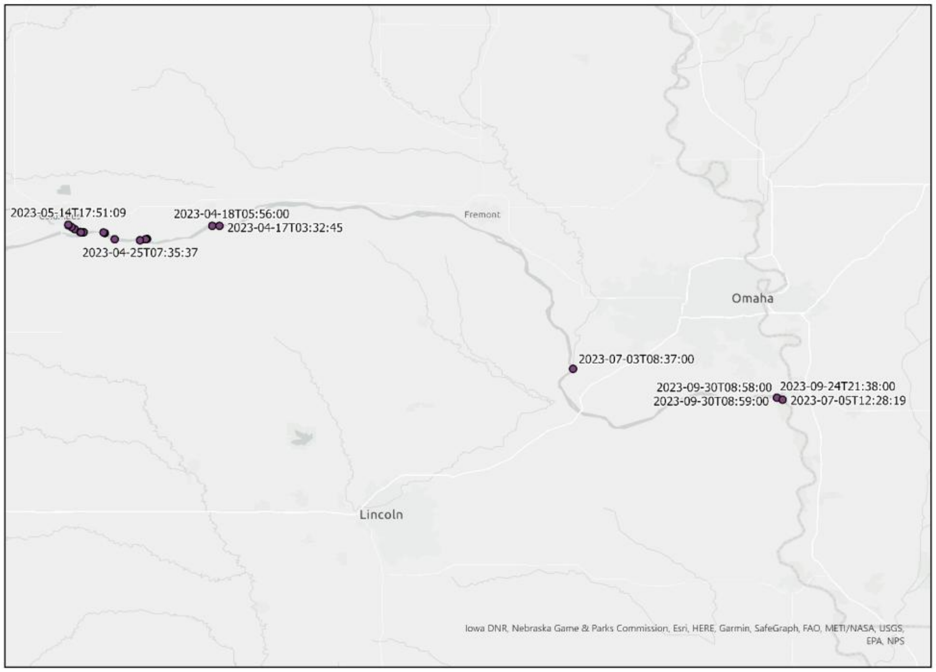

Figure 19. Relocations of A69-9001-54336 throughout the spring of 2023.

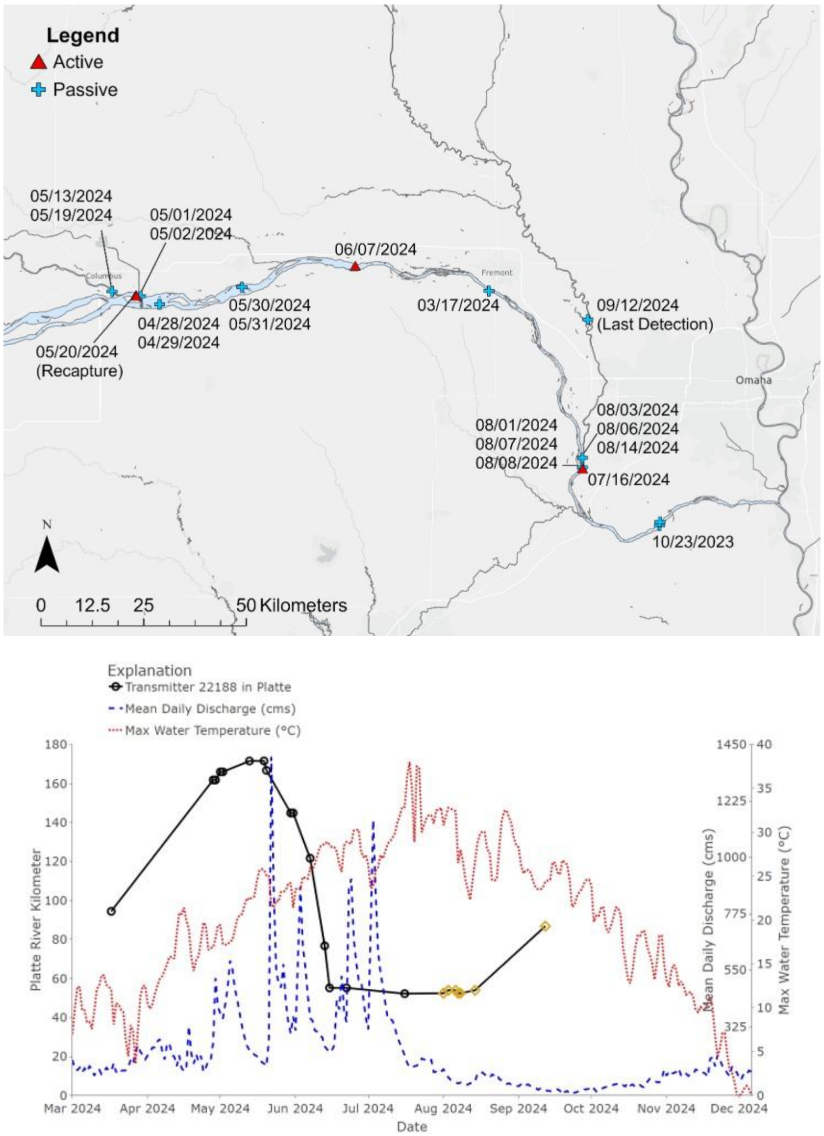

Figure 20. Relocations of Pallid Sturgeon A69-1604-22188 in the lower Platte River during 2024 (top). The bottom graph shows linear movement of the fish through time. Discharge (cubic meters per second; cms) and maximum water temperature are provided for the Platte River over the period of record.

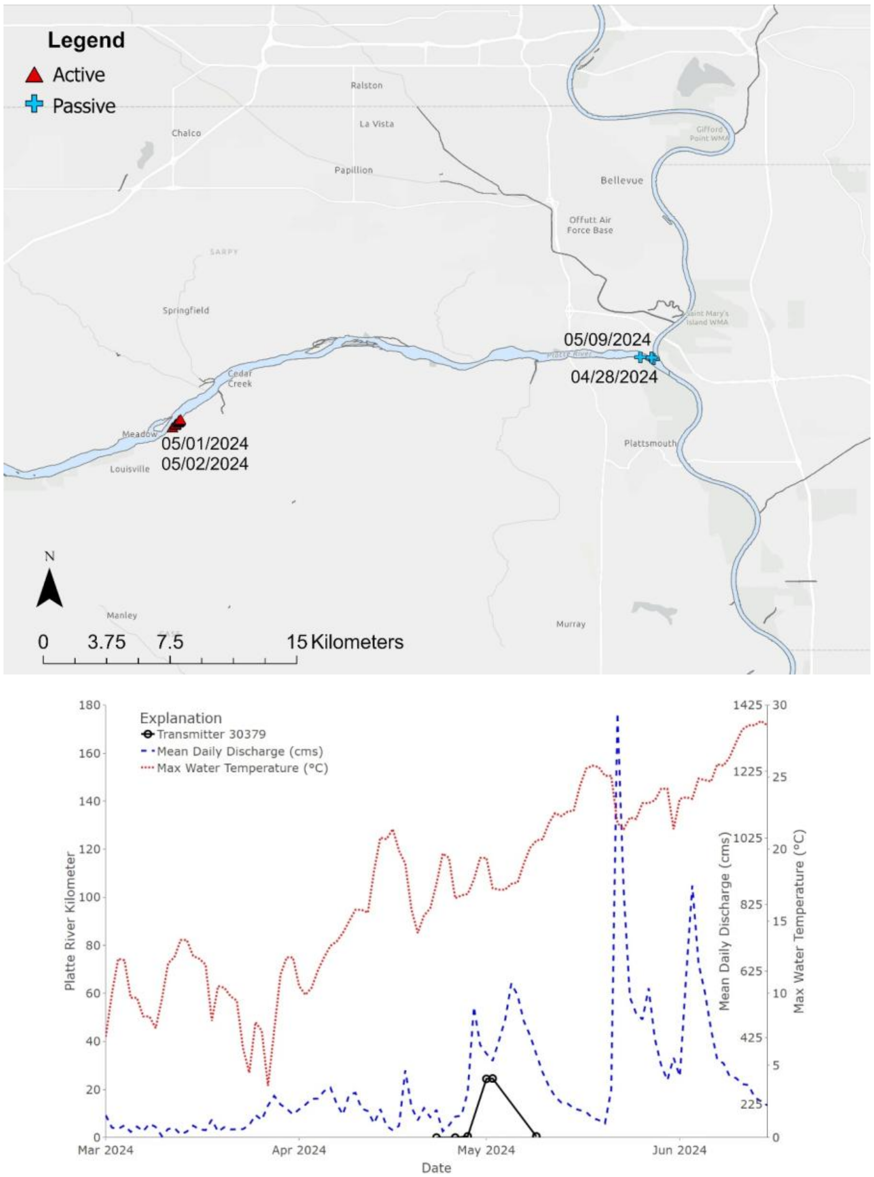

Figure 21. Relocations of Pallid Sturgeon A69-1604-30379 in the lower Platte River during 2024 (top). The bottom graph shows linear movement of the fish through time. Discharge (cubic meters per second; cms) and maximum water temperature are provided for the Platte River over the period of record.

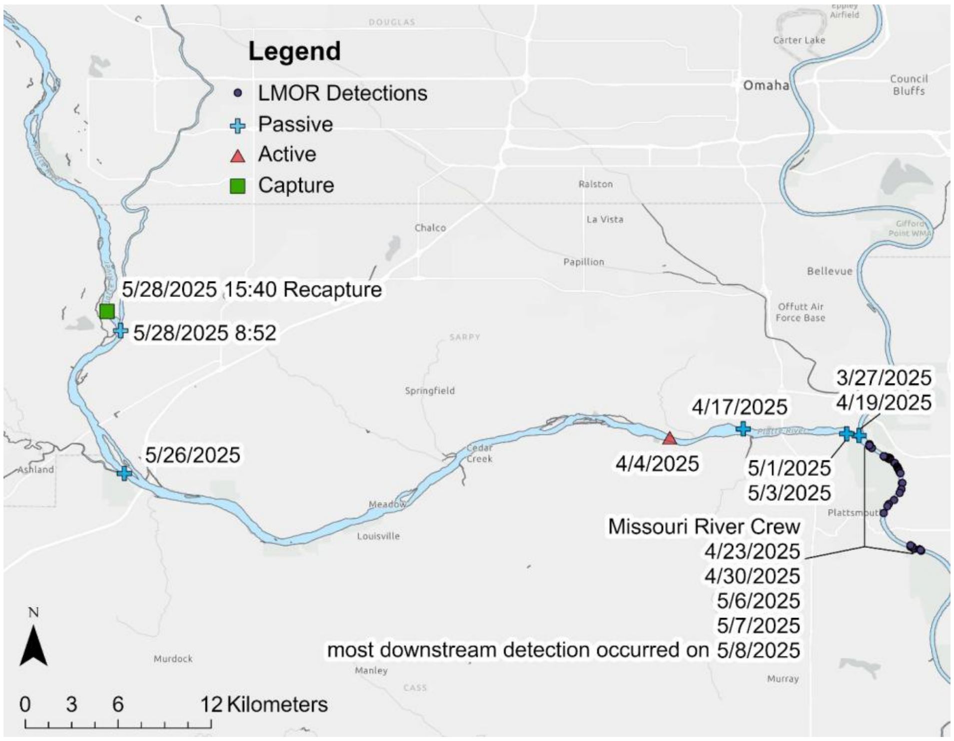

Figure 22. Detections for high priority female A69-1602-63085 throughout the lower Platte and Missouri rivers through the time of recapture on May 28, 2025.

JUNE UPDATE:

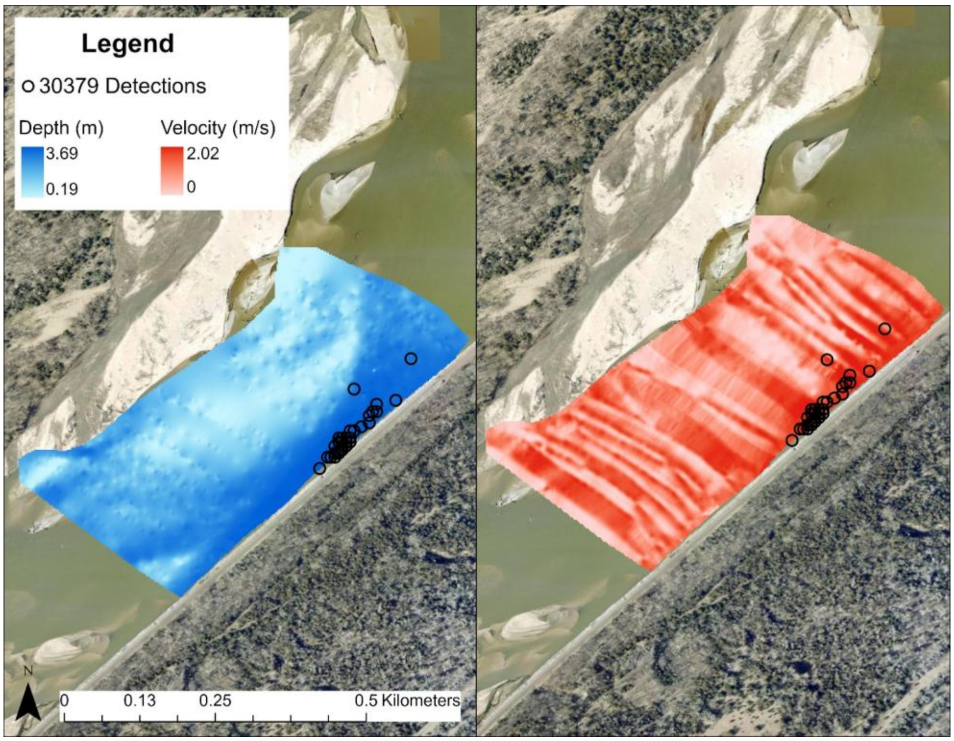

Figure 13. Depth (left) and velocity (right) maps interpolated using data generated by the ADCP on May 1, 2024. Active detections for A69-1604-30379 (30379; circles) included on each map.

JUNE UPDATE:

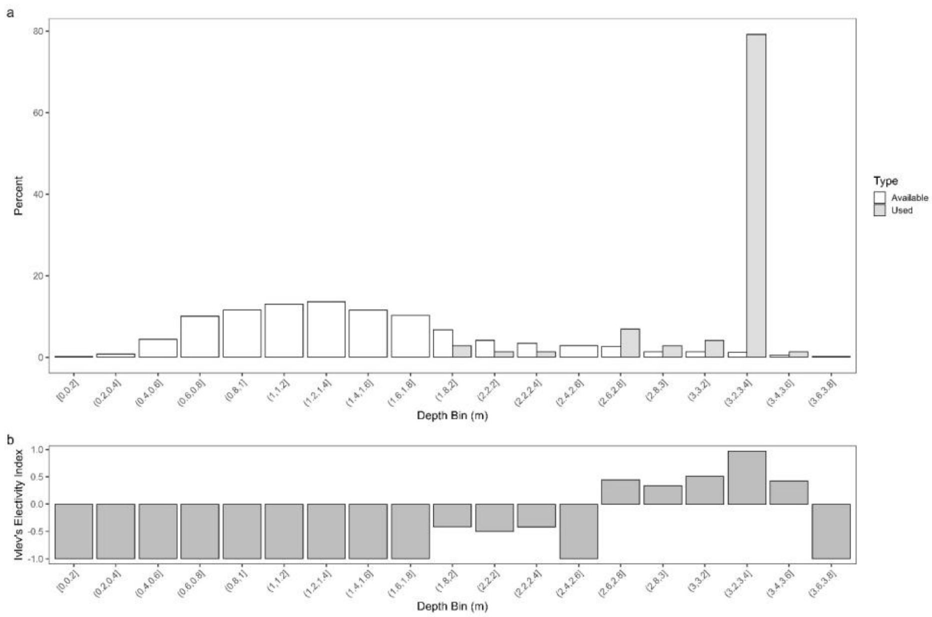

Figure 14. Percent available versus used of depths (a) and Ivlev's Electivity Index showing degree of depth selection by female Pallid Sturgeon 30379 (b).

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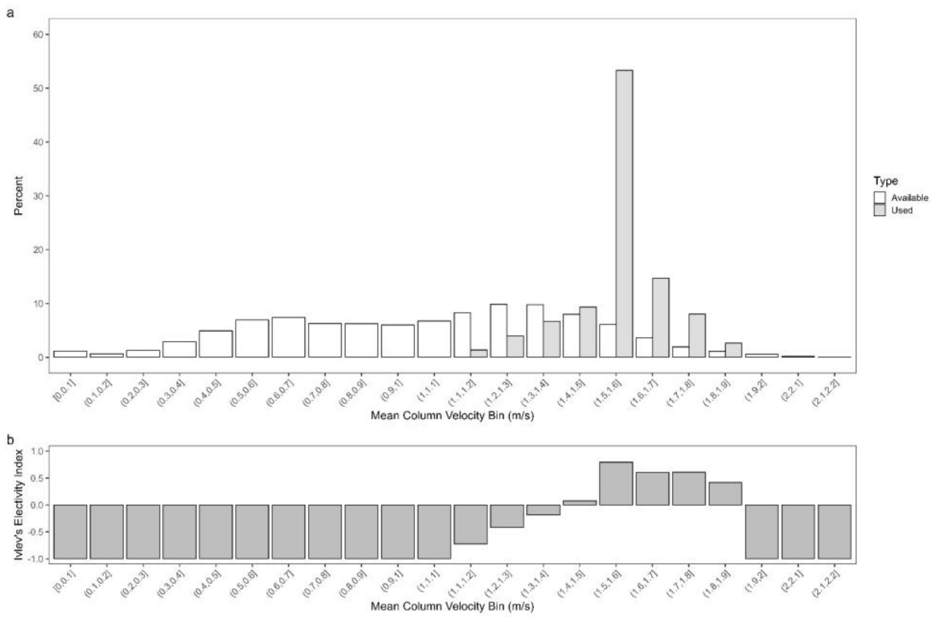

Figure 15. Percent available versus used of mean column velocity (a) and Ivlev's Electivity Index showing degree of mean column velocity selection (b) by female Pallid Sturgeon 30379.

UNL Concerns and Requests

The primary concern we have regarding analysis is largely centered on environmental conditions and measurements within the basin that are largely beyond our control. This situation will potentially limit inferences for some of the overall program hypotheses and questions. For example, water conditions have generally been on the median or lesser side of flows for the duration of the project. It is unclear how Pallid Sturgeon will respond to greater annual flow cycles when they occur beyond what has previously been reported in the literature.

Outstanding data limitations, issues, and needs

Continuity of environmental data measured by external sources. Hydrologic gages and water quality data are disjointed and can limit inference tied to specific behaviors. Turbidity is a prime example wherein there are substantial data gaps over the course of the study (see below for more information). Continuously monitored turbidity data are not available from USGS as originally anticipated. That is, there are numerous breaks in the data string that can overlap with when Pallid Sturgeon are moving into, out of, or within the Platte River system. These breaks range from 1-2 hours to multiple days (Figure 23). We will attempt to align turbidity observations with specific Pallid Sturgeon movement as best possible, but may be limited to daily mean or median values rather than using specific time an individual was detected. Further, the spatial coverage of gages that measure turbidity is coarse at best. This will likely limit inferences to localized turbidity conditions, especially at suspected transition points like the Platte River-Missouri River confluence.

Largely related to low sample size of unique individuals observed, spawning locations, timing, etc. will likely not be explicitly identified. We do anticipate showing habitat selection for individuals exhibiting such behavior. However, the lack of egg or larvae captures precludes location identification. This is not entirely unexpected given their federal status, but does inhibit inferences beyond generalities to some extent.

ISAC assistance

We would appreciate ISAC input on additional analyses and/or approaches that may be warranted. Many of the analytical outputs so far are typical of fish telemetry and mark-recapture projects. Analyses have not deviated greatly from those "analytical norms" for the field, but we are open to other analyses should a need arise.

We are consulting with statisticians at UNL presently (Dr. Clint Leach, USGS Cooperative Fish and Wildlife Research Unit and Dr. Sanjay Shaudhuri, Statistics), but further input is welcomed from the ISAC regarding utility of multi-state models, direction/guidance on potential contacts to assist with model development, etc.

ISAC Comments and Suggestions

Pallid Sturgeon

PRRIP is interested in determining how Program water management actions might affect pallid sturgeon in the LPR. The challenge is to find reliable predictive relationships which link flow metrics to biological responses.

Questions

1. For UNL - **Objective 1.** Has it been possible to quantify habitat patches in the LPR (Chapter 4 of Ruoss thesis), and assess selection of these patches (Chapter 5 of Ruoss thesis)? If so, what do these results indicate about the depth-velocity preferences of reproductively ready pallid sturgeon? Are the sample sizes large enough to draw general conclusions? [from Dave]
2. Will the LPR results be compared with Missouri River datasets to assess transferability or divergence of findings (from Michal)?
    a. Are there Missouri River movement/spawning findings that do not apply in the Platte and vice versa and why?
    b. Can we identify which cues are "universal" for pallid sturgeon vs. system-specific?
    c. Are Platte-using fish a distinct behavioral subset?
3. For UNL - **Objectives 2 and 3.** Full credit to the UNL team for successfully tracking fish and detecting suspected spawning events; that's a very tough job. Given that you have only one suspected spawning event with ADCP data (for female 30379 in 2024), it does not appear feasible with the data collected during this project to develop flow and depth correlates of spawning behaviour for the Platte River. Do you agree with that assessment? Could you use past observations of Platte River spawning to expand the available data set, or are these observations also lacking ADCP data? Could you simply examine what flows occurred in years with and without potential spawning events, as Robb Jacobson did earlier (figure below)? [From Dave]
    a. Background (from progress report sections on objectives 2 and 3):
    b. 2024. Female 30379 showed spawning behavior on May 1-2 2024 near Louisville and selected deeper, faster water relative to what was available (only suspected spawning event with ADCP data). She moved into the Missouri River on May 9. USGS recaptured her at Missouri River RKM 910 on May 30 and confirmed spawning. That recapture location is 316 km upstream of the Platte-Missouri confluence. Is it possible that female 30379 actually spawned in the Missouri?
    c. 2024. Female 22188 was detected near Louisville (Oct 2023), Fremont (March 2024), and the Loup River (April-May 2024), and recaptured by UNL in May 20 near the Loup-Platte confluence where spawning was confirmed.
    d. 2023. Female 30383 entered the Platte in the fall of 2022, moved upstream in the spring of 2023, and left the Platte in May of 2023, having not yet spawned. Recapture by

Commented [1]: Dave, I had the exact same question and you phrased it better than I could! ...and I think it feeds pretty well into your Question 5 below, which I'd also wanted to ask. The difficulty in this work seems to me to be an issue of a) small population of fish, and b) a narrow window of flow variability that make it tough to draw meaningful conclusions about physical habitat utilization.

Commented [MH2]: Mark Pegg email from 9/2/2025: The potential spawning site was based solely on behavior.   The ISAC comments are a bit confused it seems with a metric to Imperial conversion issue on location of the recapture in the Missouri River. Specifically, RKM 910 is in kilometers NOT miles which puts the recapture nearer [and downstream of] the confluence with the Platte (Platte Confluence = RKM 957) than their comment indicated. That capture is consistent with rapid downstream movement following spawning as has been seen in other females. Still not a smoking gun on exact spawning site, but the behavior in the Platte and the rapid downstream displacement is consistent with others observed in the Missouri River.

USFWS on June 7 2023 in the Missouri River near Ponka NE confirmed that she had spawned.

e. 2023. Female 54336 was tracked in the Platte River near North Bend and Schuyler, spent time in the Loup River during May 2023, but had not spawned. Recapture by NGPC on July 13 2023 in the Missouri River confirmed spawning.

f. 2022. Female 58917 (near Elkhorn confluence) and male 62101 (8 km upstream from Platte-Missouri confluence) exhibited spawning behaviour in 2022, but there were no ADCP data available.

g. Robb Jacobson's simple analysis (PPT here). Notes to this slide say:"Upstream is above St. Joseph [RM 449, 145 miles downstream of Platte-Missouri confluence]. Yellow indicates existence of a substantive spring pulse; blue are intentional experimental spring pulses; gray is no data. Distribution of spawning related to March and May pulses. Although low n, the spawning events are statistically independent of flow pulses. Dominant cue appears to be water temperature, which is controlled mostly by weather, not flow."

Eco Flows and Pallid Sturgeon Spawning

Intentional spring pulses

Substantial spring pulse

No data

	Upstream		Downstream		Platte	
Year	**March**	**May**	**March**	**May**	**March**	**May**
2005			**84k**	**120k**		
2006		**10k**		**60k**		
2007	**28k**	**[2]**	**60k**	**284k**		
2008	**7k**	**[2]**	**120k**	**140k [3]**		
2009		**7k [1]**	**120k**	**234k [1]**		
2010	**55k**	**[2]**	**210k**	**285k [1]**		
2011	**44k**	**163k [2]**		**208k**		**45k [3]**
2012		**19k [2]**	**81k [1]**	**61k**	**[2]**	**16k**
2013		**70k [4]**	**143k**	**105k**		**[1]**
2014		**40k [1]**	**43k**	**79k**		**28k [2]**

[x] = # spawning events

USGS

Spawning events are independent of flow pulses; dominant cue is water temperature threshold

4. For UNL/EDO: It seems to me that the PRRIP could put a lot of money, time, and effort into tracking PS and gathering data on habitat use in the Platte River, and this might not approach the level of work that's been done on the Missouri River to understand these same phenomena. To what extent can the PRRIP leverage physical habitat utilization information from the Missouri River to understand how PS use the Platte River? Since it's the same species of fish, I'd figure that habitat requirements would be similar between the two systems [From Alan]
5. For UNL: how are you accounting for effort in your analyses of the tracking data? For example, if you are spending more time doing active tracking in one section of the river, how will the models reflect that? [From Jennifer]
6. For UNL: in Document 9 (Pallid Sturgeon Annual Report), the Executive Summary lists four objectives, but only the first one (timing and extent of PS movement into/within Platte River) is the focus of the report. How much, if at all, have Objectives 2-4 changed? And when considering objective 1, from a fish ecology perspective, are "movement" and "use" equivalent? I feel like the question the PRRIP is after, and I might be wrong, is one of *use*. That is, can we detect patterns in the physical characteristics of places that PS are hanging out? Will movement/emigration/immigration data answer this question? [From Alan]
7. For UNL: in Document 11 (Revised Chapter 2), Figures 2.9/2.10, I'd really encourage trying a different elevation model interpolation technique instead of kriging. Specifically, can you use the ADCP data to generate a TIN (triangulated irregular network), then edit that TIN, then produce your DEM? I think it will remove a lot of the 'pitting' artifacts that you're seeing from point based transect data. [From Alan]
8. For UNL: There are references to turbidity as a physical habitat metric that might matter to PS (e.g., Line 221 of Document 2a) , but I'm not seeing it receive the level of attention that say, depth/velocity and temperature are getting. I'm aware that those latter physical variables are much easier to measure than at-a-point turbidity, but I was wondering what the current state of including turbidity as a correlate with PS use is? [From Alan]
9. Are there other factors such as energetic costs, turbidity, or prey availability that might be factored into habitat suitability?
10. Given that projected increases in high-temperature/low-flow events are a key risk factor for Platte habitat use, can UNL model pallid sturgeon response probabilities under combined high temperature + low flow scenarios?
    a. Are there stable refuge areas (deep pools, shaded reaches, groundwater inflows) that mitigate extreme temps?
11. How much of the apparent absence of spawning or residence in shallow braided channels is due to telemetry detection limits?
    a. Are there methods that could improve detection in shallow habitats?
12. Is it possible to quantify detection probability by habitat type to correct for bias in habitat selection models?
13. Are there plans to analyse depth and velocity combinations, not just single metrics?
14. Is reproduction and spawning the primary or main aspect of PS ecology that we are considering? How critical is survival? Which aspect of their life stage most influences population growth?

Commented [3]: Survival from reproduction to age-1 is thought to most strongly limit population growth. Survival after age-1 is pretty high. Reproduction and spawning is the main aspect of PS ecology under consideration.

15. If a PS spawns and eggs are fertilized in LPR, what will be the destination of these larval fish? Will they float to a place where they are likely to be successful?
16. It doesn't seem that there are many reproductively active fish in the lower Missouri River – low effective population size. Are there too many places to spawn and not enough fish? Will a female disperse eggs without a male around to fertilize them?

Commented [4]: I think most pallid sturgeon biologists would say that survival to age-1 is a more limiting factor to the population than spawning habitat. PS spawn every year across a wide range of locations in the LMR. There are more and more hatchery fish in the LMR that have reached adulthood and are spawning in the LMR, so the numbers of fish may not be the most limiting factor. Median # of estimated wild / unknown adult PS in the LMR is 688 (95% BCI range is 463 to 971). Median # of estimated hatchery-origin adult PS in the LMR is 1829 (95% BCI range is 1305 to 2488). These data are from the 2024 MRRP AM Compliance Report Appendix, saved in the Pallid Sturgeon Google Drive folder.

Commented [5]: Most active telemetry studies in the LMR have focused on females, and confirmed spawning by recapture and confirmation that eggs have been released (see Elliott et al., 2020, saved in Pallid Sturgeon folder on Google Drive). However, there has been less effort in tracking males, so I don't think it's known whether female PS in the LMR do or don't disperse eggs in the absence of males. In the lower Yellowstone River, the historical spawning site at Fairview had lots of males, and females would join them. With the creation of the bypass around Intake Dam, fewer males and females are remaining in the lower Yellowstone River and more are migrating higher up the YS and Powder Rivers.

From: Jennifer Hoeting, PRRIP ISAC
August 19, 2025

I originally created this document to summarize my questions and suggestions in preparation for the July 2, 2025 meeting with EDO. The page numbers reference the document "Platte River Pallid Sturgeon Project Overview and Progress Update; June, 2025." I'm providing this document to UNL in August 2025 as some of the statistical suggestions may be useful to Jenna and others. I do not need any written response to my questions or suggestions.

Overall, nice job giving a succinct summary of the considerable analysis work that you have done.

Suggestions:

- Fig 14 & 15: Has anyone used a statistical test with the Ivlev's Electivity Index to determine if any of these results suggest a significant difference from 0? I think it might be easier to skip the index and test the bins in the (a) plots to see if they are different (or something along these lines). If no one has ever done a statistical test with these types of data, this could lead to an interesting paper. You might want to work with one of your local statisticians to think about the appropriate analyses.

Other general comments

- Color schemes for plots: About 1 in 12 males are red/green color blind, so avoid using that scheme for plots (e.g., Fig 3, 4). R has lots of good color schemes to improve plots and avoid issues with colorblindness and similar issues.
- I assume in your final papers and dissertation that you'll provide the summary statistics for the variables you are considering in your modeling (e.g., summary statistics for the predictors used to create Tables 3 and 4). The summary statistics would be useful for the EDO, ISAC and others.

Remaining EDO Questions and Comments

Defining appropriate scale:

- Further discussion of choice of scale for mapping and defining habitat is warranted
    - What is the appropriate scale (length and width of river channel) for characterizing pallid habitat from a geomorphic perspective? For example, bedforms in the lower Platte are predominantly transverse bars. Should the appropriate length and width of a habitat patch be on the same scale as a sandbar?
    - Is pallid habitat only the pools, or do pallids need some combination of pools, runs and riffles to satisfy life history/biological requirements?
        - What is habitat and what is a patch as you have defined it? Are they the same thing?

Experimental design and sampling regime:

- Were you able to map the same two reaches (one above Elkhorn (where?), one below Elkhorn) every season (once per year, or once in spring, once in summer, and once in fall)? Over what distribution of discharge were you able to map?
- Alternatives for translating ADCP data along transects into map of depth, velocity, Froude number.
    - Kriging vs TIN
    - Braaten et al. 2015 - Migrations and swimming capabilities of endangered pallid sturgeon to guide passage designs in the fragmented Yellowstone River – methods for quantifying metrics at use location (+ 5m buffer) along a transect vs availability for the transect as a whole.

- What is the sampling regime for the ADCP mapped dataset? Which fish are mapped, which are not, and why? What is the distribution across years, seasons, river conditions? Were maps created at a similar discharge as when the fish was present?
- Will you be using other sources of data to evaluate pallid habitat beyond those fish for which ADCP data are available?
    - Are environmental variables also collected for other actively tracked fish? How many? How are they distributed through time, space, and cohort?
    - Are environmental variables collected at capture locations?
    - What is your plan for using these additional sources of environmental data?
- How will you control for different sampling regimes and levels of effort within and across methods?

Response variables:

- Further clarification on how use vs. available locations are defined and assigned across the ADCP mapped area would be helpful.
    - How were the multiple detections within 100 m upstream and downstream within the same day dealt with? Are they independent? Would the entire area then be considered as “used” or was each detection location considered an independent use location?
    - Are “available” locations a random and independent sample?

Explanatory Variables:

- Habitat in the selection analysis proposed in Ch 5 is solely defined by Froude number (velocity and depth), as Froude number decides whether it is a run, riffle, or pool. Are there any plans for incorporating additional explanatory variables into the habitat analysis to answer the more general question of "what is pallid habitat on the lower Platte River".
- How might you derive additional habitat metrics at use and available locations? Would they be point based, area based (over what area)?
- How common is it for pallid use locations (plus detection buffer) to contain more than one patch type (run, riffle, pool)? If common, how might you accommodate for this heterogeneity.
- The 2D hydrodynamic model is not intended to be used to assess characteristics at individual use locations that are outside of when the LiDAR data were collected. However, once pallid habitat characteristics are identified (through field measurements at use locations and selection analysis) it can be used to model about how much (not where) habitat there might be under varying flow conditions (as you state below).

Analysis:

- How might you evaluate if your selectivity index is significantly different from 0?
- Beyond a selectivity index what discrete choice selection analyses are you thinking about? Can you provide an update on this effort?
- PRRIP needs information on what pallid sturgeon select in Segment 1 of the LPR and what they select in Segment 2 of the LPR over a range of hydrologic conditions. That is, we need to know what factors are important and an estimate of each metric that increases the probability of use in each river segment. How might you design analyses so results reflect pallid selection rather than simply describing differences in availability between Segment 1 and 2?
    - Have you considered an analysis by segment or normalizing your ADCP data for flow if you compare across segments?
- How might you hypothesize selection of conditions by reproductively ready adults to differ from that of non-reproductive adults or juveniles? Can you design an analysis to test your prediction?
- Do you expect adults to use different segments of the river differently from juveniles? How might you test this. If so, how might you need to tailor your habitat selection analysis to account for these differences?

Interpretation of results

- Areas of clear signal, high confidence
    - What other signals, besides statistical significance might lend support to selection and differences that are biologically important?
    - Are the observed differences something PRRIP can impact?
    - Further work to be done - next steps
- Areas of weak signal, low confidence and uncertainties remaining
    - Warrant further investigation or not?