TO: **ISAC AND UNL**

FROM: **EDO**

SUBJECT: FALL SCIENCE MEETING DISCUSSION SESSION OUTLINE: MOVMEENT OF PALLID STURGEON WITHIN THE PLATTE RIVER SYSTEM

DATE: AUGUST 28, 2025

At the September Fall Science Meeting, the EDO anticipates a 1 1/2-hr block allocated to discussing technical points relevant to the analysis of factors associated with Pallid Sturgeon movement within the Platte River system.

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.

Movement of Pallid Sturgeon within the Platte River System

Research Objective – PRRIP needs information on the suite of conditions under which pallids are more likely to move up into Segment 2 of the Platte and depart Segment 2 of the Platte. Development of this analysis requires integrations of contextual knowledge about lower Platte River hydrology, morphology (hydraulics), and PS behavior patterns.

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

- **Response Variables**
  - Review methods used to classify series of detections into state changes to/from Segment 1 of the Platte, Segment 2 of the Platte, and the Elkhorn. Which receivers, where located, series of detections required to assign transitions and directionality, and decision rules in place for assignments.
  - How are gaps in detections dealt with in terms of assigning directionality and timing of movement? How large are gaps in detections within the dataset? When are data eliminated or not used and why?
  - Thoughts on how to account for discrepancies in sampling effort and detection probability across states?
- **Explanatory Variables**
  - Current thoughts on spatially and temporally appropriate explanatory variables based upon formal hypotheses to address Program questions, patterns and dynamics of the Platte system, and pallid movement/behavior patterns?
  - How might we translate gradually changing conditions sampled by fish as they move through time and space in a linear system into explanatory variables?

- What are the appropriate time periods and spatial extents over which to explain pallid sturgeon movement? Can you use patterns in detection histories to inform this choice?
- If these segments are different geomorphologically, hydrologically, and with regard to continuity of detection data, how do we appropriately select explanatory variables that are useful in predicting state transitions (which variables are important) but also provide good variable estimates (what levels of each variable facilitate or impede pallid movement) to connect to Program water management? For example, do you expect the same set of variables to be important for a transition from Segment 1 to Segment 2 and from Segment 1 to the Elkhorn? Do you expect the level of those variables (temperature ranges under which pallids move, for example) to be the same across segments?

- **Analytical Framework**
  - Briefly summarize input dataset (integration of discussion above). How much data do you have to inform movement upstream of the Elkhorn, into the Elkhorn, and downstream of the Elkhorn? How many fish contribute to that dataset and how are they distributed through time and over river conditions? Consider plots of raw data relevant to posed hypotheses to provide insights for tailoring your variables, analysis framework and model selection.
  - Potential for integration of 2009-2011 (Hamel, Spurgeon, Pegg, et al. data) to incorporate a broader range of flows.
  - Discussion of analysis framework – benefits and limitations:
    - Consider a state transition model for the decision at the Elkhorn alone.
    - Can we adapt a state transition model developed to answer immigration/emigration question at the Missouri confluence to this decision point? Better to just have one model?
    - Any advances in utilization of a Bayesian framework? Are there sticking points we could help you address?
    - Are there other analytical frameworks that could be used? How might they allow us to integrate characteristics from both the “from” and the “to” locations to better explain transitions?
  - Hypothesis based suites of variables and process for model selection – thoughts on candidate models?

ISAC Focus areas for discussion and advice

- **Explanatory Variables –** Thoughts on appropriate spatial and temporal scales of explanatory variables to link up with pallid detections.
- **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.

MOVEMENT OF PALLID STURGEON WITHIN THE PLATTE RIVER SYSTEM

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The EDO has edited the content of UNL's 2023 Data Analysis Plan to reflect only those items specific to addressing factors associated with Movement of Pallid Sturgeon within the Platte River System.

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

Study Objective 1:

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:

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,

The purpose of this document is to outline data needs for each of the above-listed objectives 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.

Objective 1

Objective 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.

Question 2. What river conditions (water temperature, river discharge, turbidity), spatial arrangement of reaches, season, and fish characteristics (reproductive, non-reproductive, stocking origin) are related to movement by Pallid Sturgeon and subsequent connectivity within and among lower Platte River reaches and tributaries?

Experimental Units: Individual Pallid Sturgeon.

Response Variables: There will be a hierarchical structure used to assess movements within the Platte River basin that will capitalize on integrating multiple data sources including extensive and intensive tracking as well as the passive receiver network similar to Moore et al. (2021). The Platte River basin will be subdivided into reaches that will include 1) the Platte River above the Loup River confluence, 2) the Loup River, 3) the Platte River between the Loup River confluence and the Elkhorn River confluence, 3) the Elkhorn River, and 4) the Platte River below the Elkhorn River confluence. Each reach contains multiple passive receivers which will be used to infer presence of a Pallid Sturgeon within a reach. Passive receiver arrays provide sub-daily scale detection data and can assess potential movements between reaches if such movements occur within days. Response variables will include Pallid Sturgeon detections, the direction and magnitude of movement of individual Pallid Sturgeon (determined from previous detection locations), and maximum upstream river kilometer occupied. The initial focus will be to assess movement probabilities among reaches (Inter-reach connectivity). Movement information from intensive (daily), extensive (monthly), and passive (acoustic receivers) tracking will be used. Given constraints that daily encounters may not occur as a result of non-perfect detection or limited movement among reaches, scaling of time periods may be necessary (e.g., use of weekly or monthly movements in place of daily). Such scaling of the response variable will automatically necessitate a change in the temporal scale of predictor variables used to assess correlation with inter-reach connectivity. Additional response variables will include the number of detections between successive river reaches as well as the number of detections at individual receivers within the Platte River basin.

EDO: According to Chris Pullano's MS thesis, detection probabilities at North Bend (Segment 2) are lower than at Louisville (Segment 1). If overall ability to detect fish is lower upstream of the Elkhorn due to higher variability and frequency of low water conditions, how does this impact modeled transition probabilities and the conditions under which these transitions are concluded to occur?

There are fewer fish and larger gaps in detections over time in the reach upstream of the Elkhorn (Segment 2) than downstream of the Elkhorn (Segment 1).

There are probably not enough fish moving into the Loup (18) or central Platte (2) for a strong test of factors important for a state transition from Segment 2 of the Platte to the Loup or the central Platte.

__Predictor Variables:__ Potential predictor variables include reproductive status of individual Pallid Sturgeon, origin (i.e., hatchery-origin versus wild-origin), day-of-year, and the suite of variables characterizing the flow regime, temperature regime, and turbidity of the Platte River reach or tributary where movement was detected. The source of temperature and discharge data will be the USGS gaging stations located throughout the lower Platte River and the lower extents of major tributaries. Specific gages will include 06793000 (Loup River near Genoa, NE), 06800500 (Elkhorn River near Waterloo, NE), 06794700 (Platte River near Schuyler, NE), 06796000 (Platte River near North Bend, NE), 06796500 (Platte River near Leshara, NE), 06801000 (Platte River near Ashland, NE), and 06805500 (Platte River near Louisville, NE). Few tributaries enter the Platte River between these gaging stations and the information gleaned at each gage will be appropriate for assessing the hydrologic conditions and temperature of that river reach. Reproductive season will be delineated based on water temperature where spawning season will include the period in late winter and early spring when water temperatures are between 14 and 24 C. If water temperature is not available from USGS gages, we will use the temperature data from individual receivers within each river reach.

EDO: If these segments are different geomorphologically, hydrologically, and with regard to continuity of detection data, how do we appropriately select explanatory variables that are useful in predicting state transitions (which variables are important) but also provide good variable estimates (what levels of each variable facilitate or impede pallid movement) to connect to Program water management?

Hypotheses:

Hypotheses associated with inter-reach connectivity

1) River Conditions
    a) River discharge
        i) Transition probabilities from downriver to upriver reaches will be greater during or immediately following periods of elevated discharges. (Testable hypothesis #1)
    b) Water temperature
        i) Transition probabilities from downriver to upriver reaches will be greater during periods when water temperature is within spawning range. (Testable hypothesis #2)
2) Spatial arrangement of reaches
    a) Distance between reaches

i) Transition probabilities between the Platte River below the Elkhorn River and the Elkhorn River will be greater than transition probabilities between the Platte River below the Elkhorn River and reaches above the confluence with the Ekhorn River. (Testable hypothesis #3)

3) Fish Characteristics
   a) Reproductive state
      i) Transition probabilities among reaches will be greater for reproductively-ready Pallid Sturgeon compared to non-reproductively ready Pallid Sturgeon. (Testable hypothesis #4)

Hypotheses associated with space use and residency

1) Fish Characteristics
   a) Reproductive state
      i) Pallid Sturgeon will exhibit three unique movement patterns including a migratory pattern, a sedentary pattern, and a roaming pattern that will be dependent on reproductive status and/or season. (Testable hypotheses #1)

Potential Analyses: A multistate movement model may be used to quantify the probability of movement among river reaches (Inter-reach connectivity). Multistate models will be constructed using Program MARK or the RMark package in Program R. We also may use a mix of analytical approaches that include Generalized Linear Models, Generalized Linear Mixed Models, and Generalized Additive Models to test for differences in movement related to the suite of predictor variables. For instance, a generalized linear mixed model may be used to assess differences in total documented distance moved (or additional response variables such as transition from downstream to upstream reaches) where individual Pallid Sturgeon would be considered a random effect and sex and reproductive status would be considered fixed effects. Further analyses may include multi-distance spatial clustering where we will evaluate aggregation and dispersion relative to time and environmental variables in a similar fashion as Holmquist et al. (2019). Kernel distance sampling may be used to evaluate space use between sexes and reproductive classes. Space use assessments may be expanded depending on data availability from outside the Platte River basin. Network analysis may be used to assess connectivity among river reaches where the number of times individuals are detected at different receiver locations or river reaches could be used to evaluate movement propensity within the river network. Any inference to origin will be dependent on the number of wild fish tagged in the Platte River system. See Figure 1 for a decision tool to help support decisions regarding statistical approaches to analyze movement data obtained through telemetry studies.

EDO: If these segments are different geomorphologically, hydrologically, and with regard to detection probability, how do we appropriately model conditions associated with movement across them?

Can we see the dataset to assess for each segment:
Fish numbers?
Gaps in detections?

Direction of movement? Not sure if have contiguous detections up in these reaches to assess direction of movement?
Timing of movement?

An alternative might be a separate analysis of conditions when fish are present vs probable absent by segment (if enough fish).

Data Preparation, Storage, and Sharing:

Standardized telemetry data analyses developed by Flavio and Baktoft (2021) named “Actel” will be followed as a general data pipeline to facilitate initial, basic data analyses from listening arrays in the Platte River and tributaries (Figure 2). Preliminary QA/QC will be used to identify possible data anomalies including the presence of undocumented tag numbers or tags from other studies and species.

EDO: What standardized decision rules (series of detection histories) are used in Actel to determine when detections are contiguous and when gaps are too large to assume contiguity of movement. How are gaps in detections handled in Actel? How does Actel assign direction of movement in these cases? How are these decision rules reflected in analyses?

Telemetry data for assessment of movement through the passive receiver array will be formatted into four tables that will include the tag data, the receiver locations and release sites, the receivers deployed at each site, and a detection file. These tables can then be used to create summaries of:

a. Residence times, and
b. Movement events.

Data from active tracking will be stored as a .csv file with all identifying information for each fish including tag ID, initial tagging date, agency that originally tagged the individual, the last known reproductive status of the fish, and the last known location of the fish. All data will be stored using a OneDrive account and backups will be created on an external hard drive.

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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	ºC	15 minutes	USGS Gages	Water temperature will be obtained from the USGS gage located in Louisville, NE on the Platte River.
Predictor	Water temperature	ºC	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

Figure 1. Potential analytical approaches based on goals and data constraints for assessing acoustic telemetry data. Diagram from Whoriskey at al. (2019)

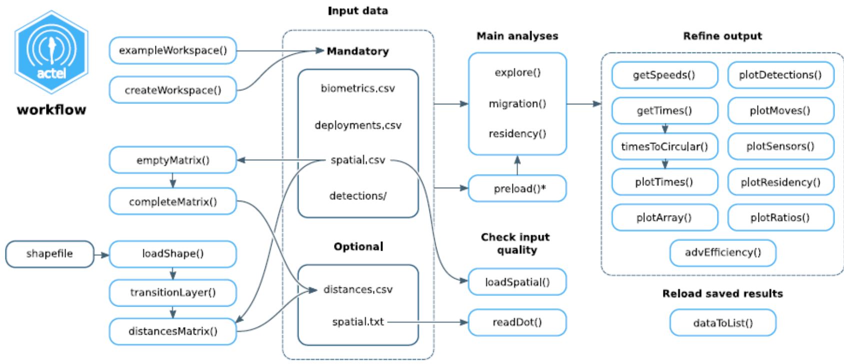

Figure 2. The actel workflow with associated packages as described in Flávio and Baktoft (2021). The approach to processing and analyzing telemetry data from passive receivers as well as active tracking for Pallid Sturgeon in the Platte River basin will follow a similar process. Figure from Flávio and Baktoft (2021).

The EDO has edited the content of UNL's 2024 Annual Report and 2025 Progress Update to reflect only those items specific to addressing factors associated with Movement of Pallid Sturgeon within the Platte River System.

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

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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. Some of the effort related to particular objectives have shifted during the life of the project. However, this report will focus on preliminary analyses for **Objective 1** related to immigration, emigration, and movement within the lower Platte River per EDO instructions. Additional information is provided regarding proposed approaches for creating continuous-time multistate models to assess probability of movement among the different reaches of the lower Platte River and tributaries. We also provide, as a supplement to this report (see Supplement 1, Chapter 2, Pullano thesis), an in-depth analysis of detection efficiency of the passive acoustic receiver array using experimental approaches conducted seasonally and through summarizations of detections of individual Pallid Sturgeon throughout the network using the *actel* package (Flávio and Baktoft 2021) in Program R (R Core Team 2022). Further, we provide, as a supplement to this report (see Supplement 1, Chapter 3, Pullano thesis), estimates of space use, residency, and movement of sub-adult and adult Pallid Sturgeon in the lower Platte River.

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:

Acoustic receiver detection efficiency

- See supplement (Supplement 1, Chapter 2, Pullano thesis) to this report for full assessment of acoustic receiver detection efficiency.

Pallid Sturgeon space use in Platte River

- See supplement (Supplement 1, Chapter 3, Pullano thesis) to this report for full assessment of Pallid Sturgeon space use in the Platte River.

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.

Statistical Analyses

- Preliminary analyses confirmed the analytical models outlined in the data management plan will converge. Incorporation of additional data for both the fish movements and environmental variables will occur as additional data are attained. We will continue to build, refine, and seek improved avenues to analyze the data.
- Continue building GLM models with more robust data as we acquire such from partner agencies. Included in these analyses will be additional measures of environmental variability as outlined in the data management plan (e.g., discharge and water temperature). Other variables (e.g., turbidity) will be assessed as data become available.

> EDO: Turbidity and the difference in temp/turbidity/stage between the Missouri and the Platte are variables of PRRIP interest for investigation.
> - Turbidity data are available at Leshara and Louisville in the Platte River from Mar-Oct throughout the study, but turbidity data are not available from nearby USGS gages on the Missouri for the study period.
> - Passive receivers (UNL and USGS) in the Platte and the Missouri record water temperature data that can be utilized for this study.
> - Water temperature data are available at Overton, Leshara, and Louisville in the Platte River from Mar-Oct throughout the study, but only available until June 25, 2022 at Omaha and Nebraska City from USGS gages in the Missouri. Temperature data are available at USGS gage at Rulo, NE, but this is too far away and with multiple tributaries entering prior.

- Explore the use of continuous-time, multistate models to model movement through the lower Platte River and its tributaries. The turn to continuous-time multistate models is desired to prevent the loss of data when individuals make more than a single transition among river segments within a single day.
- Explore alternative distributions during model building to include those capable of handling count data and potentially models with hierarchical structure. Zero-inflated models have been performed to model immigration and emigration to and from the Platte River.

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.

Focus of this report

The information contained in this report solely reflects preliminary analyses and analyses plans of data collected through 2024 for portions of Objective 1. Specifically, we provide:

1) Insights into movements strictly pertaining to immigration and emigration events at the Platte River-Missouri River confluence,

2) An initial analysis and suggested refinements to the analysis plan for assessing the probability of movement among reaches of the lower Platte River (i.e., multi-state models and continuous-time multi-state models),

3) An assessment of receiver efficiency as part of an overall perspective of Objective 1 in terms of movement (Supplement 1, Pullano thesis), and

4) An analysis of movement and space use of sub-adult and adult Pallid Sturgeon as an appendix to this report (Supplement 1, Pullano thesis).

Objective 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.

This objective identifies 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. A supplement to this report has been provided with a description of movement patterns observed (e.g., one-step and two-step migration strategies; Supplement 1, Pullano thesis) that also includes details regarding acoustic receiver detection efficiency. Further, the supplement provides estimates of space use and activity patterns of sub-adult and adult Pallid Sturgeon.

Question 1. What river conditions (e.g., water temperature, river discharge, turbidity), season, and fish characteristics (reproductive, non-reproductive, stocking origin) are related to movement by Pallid Sturgeon into (immigration) and out of (emigration) the Platte River basin?

Question 2. What river conditions (water temperature, river discharge, turbidity), spatial arrangement of reaches, season, and fish characteristics (reproductive, non-reproductive, stocking origin) are related to movement by Pallid Sturgeon and subsequent connectivity within and among lower Platte River reaches and tributaries?

Study Area

The lower Platte River is a 160-km reach, starting at the confluence of the Loup River and the Platte River near Columbus, Nebraska. The Elkhorn River and Salt Creek are major tributaries of the lower Platte River before it flows into the Missouri River near Plattsmouth, Nebraska. The focal locations for collecting Pallid Sturgeon and habitat data include the lower Platte River from the Loup River confluence to the Platte River terminus with the Missouri River, the Elkhorn River, the Loup River, and Salt Creek (Figure 1).

JUNE UPDATE: Also includes portions of the Loup River (~20km), Elkhorn River (~50 km), and Salt Creek (~5 km) where access allowed receiver deployment and/or active tracking (Figure 1). Note that there have been no detections in Salt Creek over the life of the study. Therefore, analyses of movement in and out of tributaries to the Platte River will largely focus on the Elkhorn and Loup rivers.

Methods

The following information outlines data sources and preliminary analyses used to investigate movements between the Missouri River and Platte River, movement between reaches of the Platte River, and space use of Pallid Sturgeon in the Platte River (Supplement 1, Pullano thesis). These analyses and results may change as additional data are collected. As such, all results should be viewed as preliminary.

Pallid Sturgeon Detections

- Pallid Sturgeon were caught via trotline sets in early spring (2022, 2023, and 2024) and fall (2022 and 2023) in the lower Platte River (UNL crew) and Missouri River (USGS, NGPC, MDC, USFWS, COE crews). Pallid Sturgeon of appropriate size (fork length and weight) were surgically implanted with acoustic tags (InnovaSea V13 or V16) following approved guidelines (U.S. Fish and Wildlife Service 2019).
- Passive acoustic receivers were deployed and maintained in the lower Platte River (maintained by UNL crew) and Missouri River (maintained by USGS crew) to create a system-wide array. The passive receiver array is used to detect upstream or downstream movement patterns. The date and time as well as the unique identification number were recorded each time a Pallid Sturgeon passed a receiver. Acoustic receivers also recorded water temperature every 15 minutes. The passive detection data were from two sources. These two sources were used to provide detection data for individual Pallid Sturgeon movement between the lower Platte River and Missouri River.

    - The UNL-led project has deployed 35 receivers in the lower Platte River basin (Figure 1). Note that some receivers have remained at-large (e.g., buried in sand too deep to recover, moved to unknown locations during high discharge events, vandalized, etc.) for an extended period. We continually attempt recovery of those receivers, but the current array configuration consists of 27 receivers that are routinely maintained and monitored. Receivers are strategically positioned to optimize detections where one or more receivers are used to form a "gate" that is intended to detect fish moving through specific locations (see Supplement 1, Pullano thesis, Figure 2.3). For example, two of those receivers are located about 1 km upstream from the Missouri River within the Platte River to assist with directional movements associated with the Platte-Missouri confluence interface.
    - The USGS maintains one receiver in the Platte River at the confluence and three receivers in the Missouri River around the Platte-Missouri confluence area, with two immediately upstream and one downstream of the confluence.

- UNL crews conducted monthly river-wide surveys to actively detect Pallid Sturgeon between receiver locations. The combination of passive detections and active detections were used for assessment of movement.
- Individual detection histories for Pallid Sturgeon result from a combination of active detections from the lower Platte River and its tributaries (e.g., monthly river sweeps) and

passive (e.g., acoustic receiver array) and USGS receivers in the Missouri River located just upstream and downstream of the confluence with the Platte River. These detection histories comprise input data for use in movement models concerning immigration, emigration, and movement within the Platte River system.

Statistical Analysis

Pallid Sturgeon movement within the Platte River

- Discrete-time multistate models were developed to assess movement among reaches of the lower Platte River and tributaries. Multistate models were developed in Program MARK using a daily time-step. Three geographic states of interest were used given the propensity of Pallid Sturgeon movements observed in the field. The geographic states were river reaches and included the lower Platte River upstream of the Elkhorn River confluence, the lower Platte River downstream of the Elkhorn River confluence, and tributaries of the lower Platte River (e.g., Loup and Elkhorn rivers). The model was an intercept only model; that is covariates were not included in the model and parameters were held constant among periods. Further, we used the default sin link function to estimate all parameters because it allows a range of flexibility in estimating parameters. Additional link functions that may be better suited for the multi-state analyses are being explored. Other link functions like the multinomial logit link function to estimate the transition parameters among states have some promise as they allow for some flexibility in recapture or re-sight occasions.
    - Discrete-time multistate models are generalized versions of Cormack-Jolly-Seber models. Therefore, the assumptions of the model are similar. The assumptions include 1) every individually marked organism present in state *r* at sampling period *i* has the same probability of being recaptured; 2) every marked individual in state *r* following the sampling period *i* has the same probability of surviving until period $i + 1$ and moving into state *s* by period $i = 1$; 3) marks are neither lost nor overlooked and were recorded correctly; 4) sampling periods occur over small temporal scales and recaptured organisms are immediately released; 5) all emigration from the sampling area is permanent; 6) the fate of each organism with respect to capture and survival probability is independent from another organisms. The multistate model parameters will be estimated using individual mark-recapture data (i.e., detection history for each tagged fish).
- Continuous-time multistate models are also being explored to make better use of the transition data collected. Continuous-time multistate models can be viewed as a special case of a continuous-time hidden Markov model (Rushing 2023). These models assume any number of animals are captured, marked, and then monitored in continuous time (e.g., passive acoustic array that is constantly monitoring). Continuous-time models have nearly identical assumptions as discrete-time models. The use of traditional (discrete time) multistate models necessitates binning transitions among geographic states into discrete intervals. If an individual makes multiple transitions each day, those must be

removed and the last transition used. Continuous-time multistate models alleviate the need to bin transitions (Rushing 2023). As such, less data loss from binning may occur and transitions within a day can be incorporated into model structures.

Acoustic receiver detection efficiency

- See Supplement 1 (Chapter 2, Pullano thesis) to this report for full assessment of acoustic receiver detection efficiency.

Pallid Sturgeon space use in Platte River

- See Supplement 1 (Chapter 3, Pullano thesis) to this report for full assessment of Pallid Sturgeon space use in the Platte River.

<u>General Results</u>

- Crews from UNL captured 70 Pallid Sturgeon (genetic samples were taken for all fish) of which 41 were implanted with acoustic tags during 2022-2024.
- Pallid Sturgeon were detected throughout the lower Platte River system as well as in the Central Platte River upstream of the Central Platte-Loup River confluence (Table 1).
- A total of 147 unique Pallid Sturgeon transmitters have been detected either passively or actively in the lower Platte River or its tributaries by UNL from 2022 to 2024 (Table 2). The 147 Pallid Sturgeon observed in the lower Platte River or its tributaries accounts for 31% of all telemetry tagged Pallid Sturgeon in the Lower Missouri River as of fall 2024.
  - The UNL passive receiver array has a total of 45,525 Pallid Sturgeon detections for 2022-2024. A total of 137 individual Pallid Sturgeon have been identified throughout the lower Platte River via the passive receiver array.
  - Active telemetry (i.e., monthly river sweeps) has detected a total of 104 unique Pallid Sturgeon with a total of 232 active detection events 2022-2024.
  - There were 94 Pallid Sturgeon detected both actively and passively during 2022-2024.
  - Only 10 unique Pallid Sturgeon were detected solely through active tracking.

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.

- Pallid Sturgeon were detected throughout the lower Platte River and the Elkhorn River from 2022 through 2024. Ten Pallid Sturgeon were detected in the Loup River in 2024. Furthermore, two Pallid Sturgeon were documented in the Central Platte River in 2024 (Table 1).

EDO: How do you deal with multiple, repeated detections and state transitions by a single fish? Is there a temporal component for defining independence of events? Do certain individual fish contribute heavily to your dataset? Is there a need to include a Fish ID variable?

EDO: Is there a way to visually demonstrate how spring/spawning, summer, and fall contribute to the distribution of discharge, CV, temp, turbidity in Figures 4-7 (like you did in Fig 8 for June update, for example)? Might that help identify specific periods within which you might look to see which variables matter?

Question 2 Movement within and through the Platte System Results:. What river conditions (water temperature, river discharge, turbidity), spatial arrangement of reaches, season, and fish characteristics (reproductive, non-reproductive, stocking origin) are related to movement by Pallid Sturgeon and subsequent connectivity within and among lower Platte River reaches and tributaries?

Multistate Model

Transitions between different river reaches were evident throughout the lower Platte River system (Table 13). Transition probabilities ranged from 0.006 [CI 0.004-0.009] to 0.28 [CI 0.26-0.31]. The transition probability was highest for the reach downstream of the Elkhorn River confluence to tributaries, which included the Elkhorn and Loup rivers. The lowest transition probability was for Pallid Sturgeon moving from upstream of the Elkhorn River confluence to downstream of the Elkhorn River confluence (Figure 14). The probability of survival was relatively consistent across river reaches, ranging from 0.98 [CI 0.97-0.99] to 0.99 [CI 0.99-0.99]. The probability of detection among reaches ranged from 0.008 [CI 0.005-0.011] to 0.85 [CI 0.82-0.88]. The probability of detection was lowest in the reach upstream of the Elkhorn River confluence and highest in the reach downstream of the Elkhorn River confluence (Figure 14).

JUNE UPDATE:

We intend to use a multistate model to assess movement among the larger spatial scales we have defined in the Platte River because we have known encounter histories for all fish located. A drawback to these models is they are data hungry so it may be difficult to incorporate covariates into a converging model. We are exploring options to alleviate some of the issues (e.g., Bayesian approach), but recognize there are limits to what those options can do as well. Therefore, analyses along the same approach to Question 1 above may also be used to supplement how environmental conditions influence movement. The below summarizes the most recent transition probabilities from the working multi-state model.

There have been fewer unique transmitters detected in 2025 across all river segments compared to previous years (Table 5). Despite the lower number of unique Pallid Sturgeon transmitters, transitions still occurred throughout the Platte River system (Table 6). The three-state multi-state model on a daily time-step was updated to include detection histories from the project inception to May 30, 2025. The three states were: (A) upstream of the Elkhorn River confluence, (B) downstream of the Elkhorn River confluence, and (C) tributaries which included the Elkhorn, Loup, and central Platte rivers (Table 7). The highest probability of transition was from downstream of the Elkhorn River confluence (Platte Segment 1) to the tributaries at 0.20 (Figure 12).

Discussion

Question 2 Movement within and through the Platte System

The multistate mark-recapture model produced transition probabilities for Pallid Sturgeon among all three geographic states (Figure 9). Our results correspond with the study by Hamel et al. (2014), in which Pallid Sturgeon were captured throughout the entirety of the lower Platte River. We also demonstrated that Pallid Sturgeon may be more apt to transition to tributaries, primarily the Elkhorn River, rather than the upper segment of the Platte River upstream of the Elkhorn River confluence. In addition, the probability of detection was also highest in the Platte River downstream of the Elkhorn River, which also complements the study by Hamel et al. (2014), in which Pallid Sturgeon abundances were highest in this reach of river. Pallid Sturgeon occurrence has been tied to the flow regime, in which higher discharges result in higher occurrences (Hamel et al. 2016). Further, discharge or its correlates may be especially important in influencing Pallid Sturgeon movement into different reaches of the lower Platte System. For example, Spurgeon et al. (2016) highlighted that reaches within the lower Platte River may be categorized as different flow units (e.g., intermediate vs high). Those flow units may influence dispersal throughout the lower Platte River. Future models will continue to incorporate relevant measures of discharge and other abiotic factors (e.g., water temperature) to assist with determining the probability of transitioning to different river reaches.

EDO: These results are what you would expect in a linear system where numbers further into the system are necessarily smaller (can never be larger than) than numbers at the beginning of the system. The trick will be to isolate the dispersion/distance effects from the environmental effects.

Is the highest transition probability from downstream of Elkhorn (Segment 1 of Platte) to tributaries driven by the larger number of fish that originate in Segment 1 (typical linear system with more fish at the beginning). NOTE: Tables of raw data on numbers of unique transmitters in each segment and numbers of transitions do not agree with modeled transition probabilities. They suggest fish are more likely to go to Segment 2 than the Elkhorn). The interesting question here is under what conditions they enter the Elkhorn and under what conditions they enter Segment 2 of the Platte – so this choice modeled on its own is informative.

Is it informative to include Loup and central Platte data with Elkhorn data, or is it more confusing?

Lowest transition probability was Segment 2 to Segment 1. Is this result likely to be informative in terms of environmental variables, or dominated by a combination of the following:

a) fewer fish using Segment 2
b) dependent upon lower number of detections in Segment 2 plus subsequent detection in Segment 1
c) rapid exit of the system making it more difficult to detect downstream movement.

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.

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. 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). 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.

EDO: Figure 15 relationship between Louisville gage and UNL receiver – data points generally below the 1:1 line such that UNL receiver temps appear to be consistently lower than USGS gage temps at Louisville. Is this relationship consistent across multiple gage/receiver locations? Is the scale of the difference important? Should you decide on a single data source? Which is more informative given where in the water column each of these gather data? Which UNL receivers are buoyed at the top of the water and which are fixed lower in the water column?

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 capture
Environmental variables at active tracking locations
Environmental variables associated with passive detections
Environmental variables associated with each state transition (immigration/emigration/state transition)

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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

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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

Table 13. Raw number of transitions among the Missouri River (MOR), lower Platte River downstream of the Elkhorn River confluence (LPR), the Elkhorn River (ELK), the lower Platte River upstream of the Elkhorn River confluence (UPR), and the Loup River (LOU). Raw transitions do not take into account a single Pallid Sturgeon moving back and forth between river reaches multiple times). First column is considered "from" and top row is considered "to" the respective state.

	MOR	LPR	ELK	UPR	LOU
MOR	2138	208	0	0	0
LPR	186	941	36	55	0
ELK	2	31	124	4	0
UPR	2	49	7	185	14
LOU	0	1	0	13	14

EDO: How will the raw dataset be processed into final number of independent transitions for analysis?
These tables and the number of unique transmitters in each segment (Tables 1 and 5 above) both show more fish and more transitions from LPR (Segment 1) to UPR (Segment 2) than from LPR (Segement 1) to Elkhorn. This contradicts the transition probability results from your state transition model (Figures 14 and 12 below) that say it is more likely that fish go from Segment 1 to tribs (with most of trib data coming from fish in the Elkhorn)..How do you explain this?

JUNE UPDATE:

Table 6. Raw number of transitions among the Missouri River (MOR), lower Platte River downstream of the Elkhorn River confluence (LPR), the Elkhorn River (ELK), the lower Platte River upstream of the Elkhorn River confluence (UPR), the Loup River (LOU), and the Central Platte River (CPR) from March 17, 2022 to May 30, 2025. Raw transitions are on a daily time-step based on the Pallid Sturgeon's last known detection per day, therefore transitions do not take into account a single Pallid Sturgeon moving back and forth between river segments multiple times within a day. First column is considered "from" and top row is considered "to" the respective state.

	MOR	LPR	ELK	UPR	LOU	CPR
MOR	2138	211	0	0	0	0
LPR	186	1112	40	77	0	0
ELK	2	34	129	4	0	0
UPR	2	65	8	312	18	1
LOU	0	1	0	16	16	1
CPR	0	0	0	0	2	1

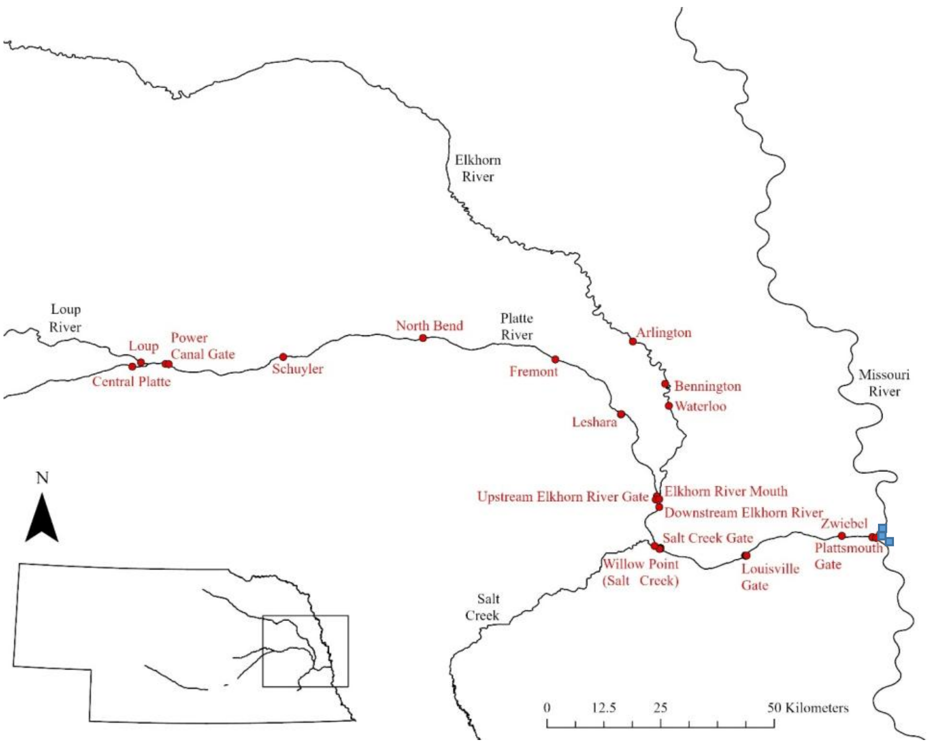

Figure 1. Map of study area with InnovaSea VR2Tx receivers (red circles) deployed in clustered arrays for passive tracking. General locations of receivers operated by USGS in the Missouri River and Platte River (blue boxes) are included for reference.

JUNE UPDATE:

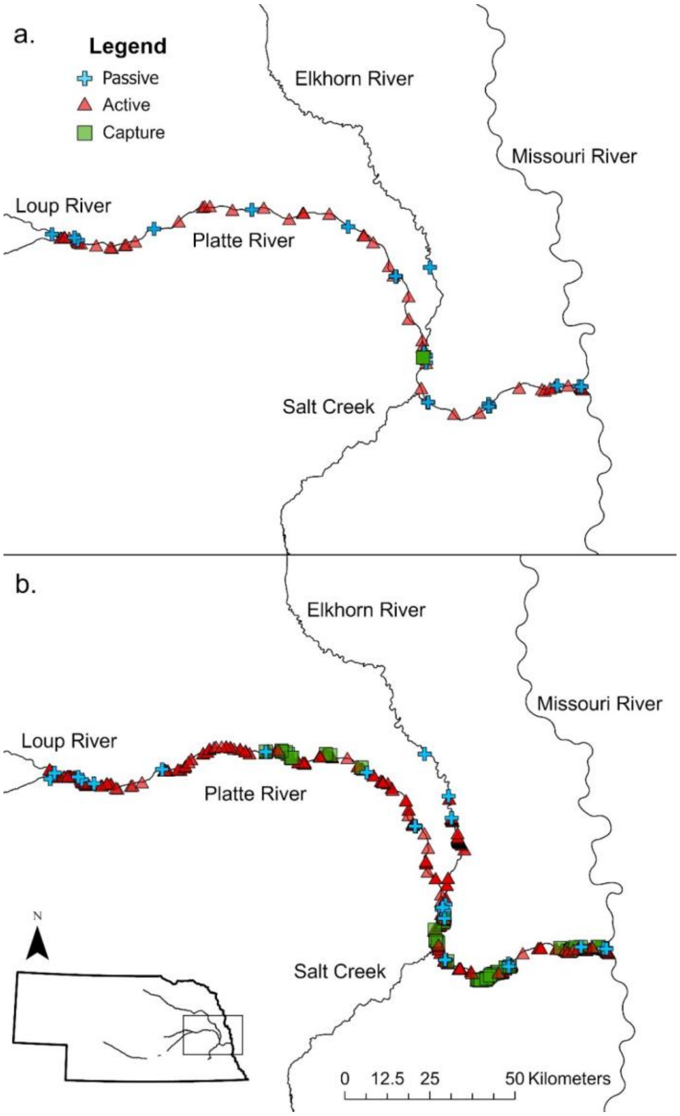

Figure 2. Passive detections by receivers, active detections during river sweeps, and captures of Pallid Sturgeon for 2025 (a). Trotlining did not occur during 2025, thus the only capture depicted is the recapture of a high priority female for reproductive reassessment. Passive detections, active detections,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

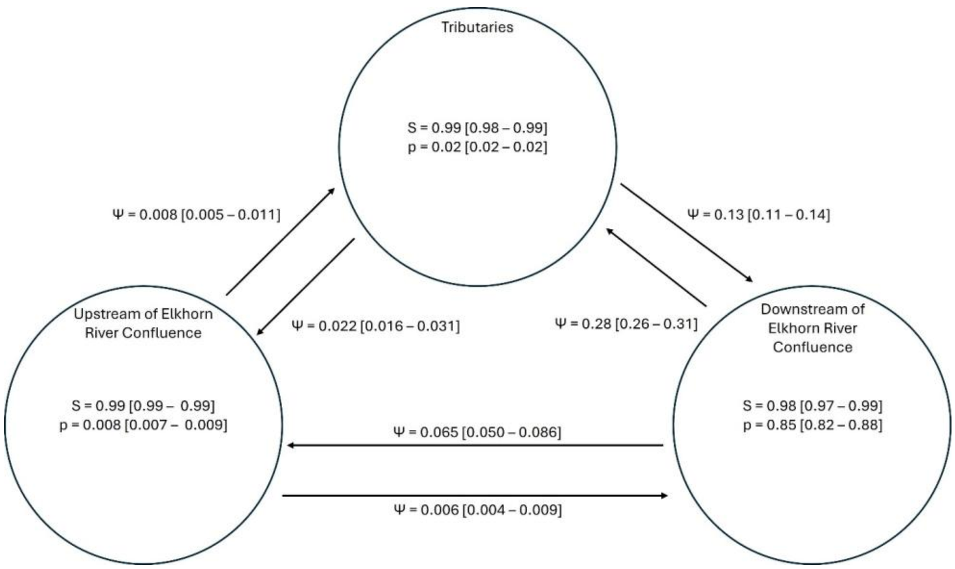

Figure 14. Multistate model depicting the probabilities of survival (S), detection (p), and transition (ψ) with 95% confidence intervals for three states within the Platte River system. Upstream of the Elkhorn River confluence is the Platte River ≥ 52 rkm, downstream of the Elkhorn River confluence includes the Platte River < 52 rkm and the Missouri River, and tributaries refer to the Loup and Elkhorn rivers. Note that most movements to/from tributaries occurred for the Elkhorn River (see Table 13 for sample sizes).

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MDH: Platte Segment 2 to / from **Elkhorn**, Loup, and central Platte rivers. These transition probabilities are driven largely by Elkhorn data since there are few transitions into the Loup or central Platte.

MDH: Platte Segment 1 to / from **Elkhorn**, Loup, and central Platte rivers. These transition probabilities are driven largely by Elkhorn data since there are few transitions into the Loup or central Platte.

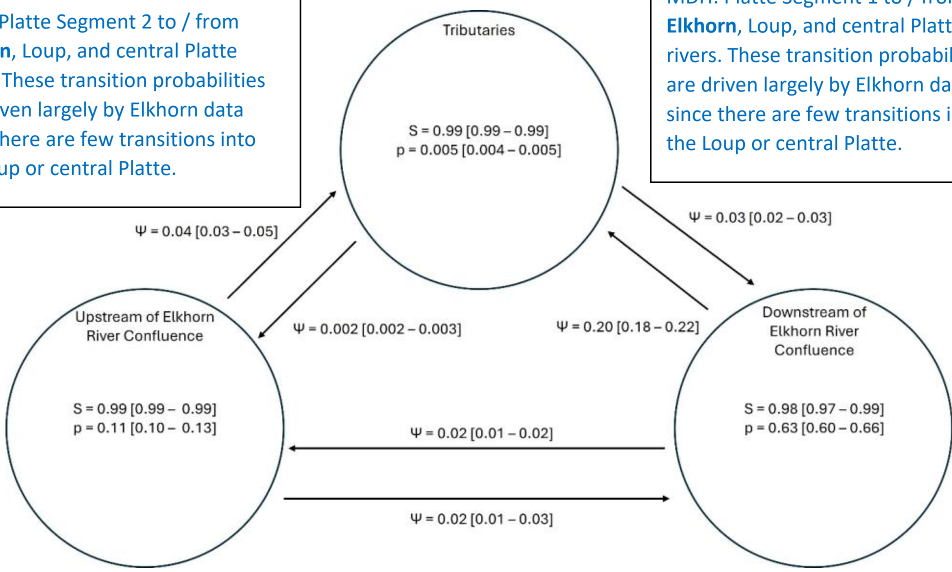


Figure 12. Multistate model depicting the probabilities of survival (S), detection (p), and transition (ψ) with 95% confidence intervals for three states within the Platte River system using a daily time step. Upstream of the Elkhorn River confluence is the Platte River ≥ 52 rkm, downstream of the Elkhorn River confluence includes the Platte River < 52 rkm and the Missouri River, and tributaries refer to the Loup, Elkhorn, and Central Platte rivers.

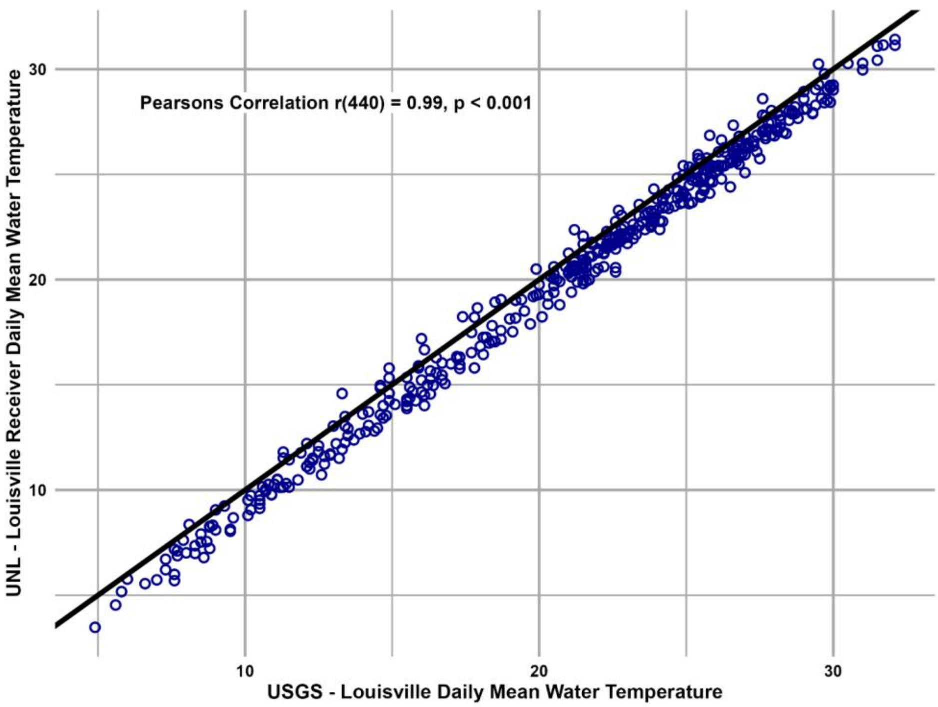


Figure 15. Platte River mean daily water temperature comparison between the USGS gage station (station number - 06805500) and a UNL telemetry receiver in the same general proximity of the Platte River near Louisville, Nebraska during 2022-2024. Black line indicates a 1:1 correlation. Less than 2% of the paired daily mean temperature data points differed by > 2 ºC.

See 9_Appendix 1 from Pallid Sturgeon annual report_1_23_25. Actel outputs from passive telemetry array from all Platte River system detections through October, 2024. Information provided herein provides measures of efficiency of the listening array, timing of movement, residency, and general summary of movements for each individual detected in the listening array.

JUNE UPDATE:

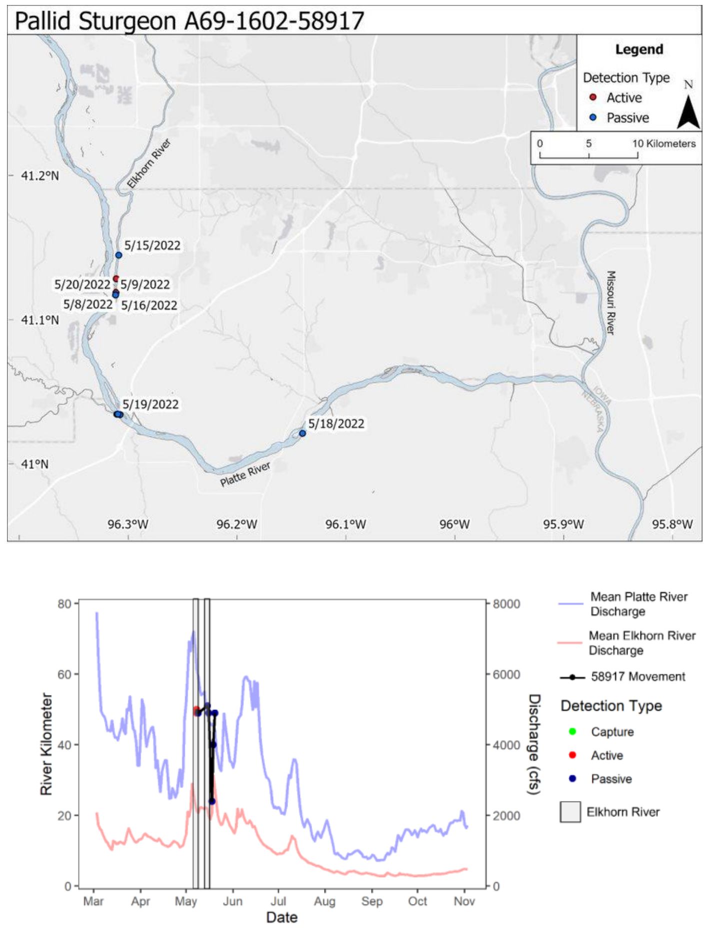


Figure 16. Capture location and relocations of Pallid Sturgeon A69-1602-58917 in the lower Platte River during 2022 (top). Green dot indicates location and date of capture, red dots indicate locations made during active tracking, and blue dots indicate detections at passive receivers. The bottom graph 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.

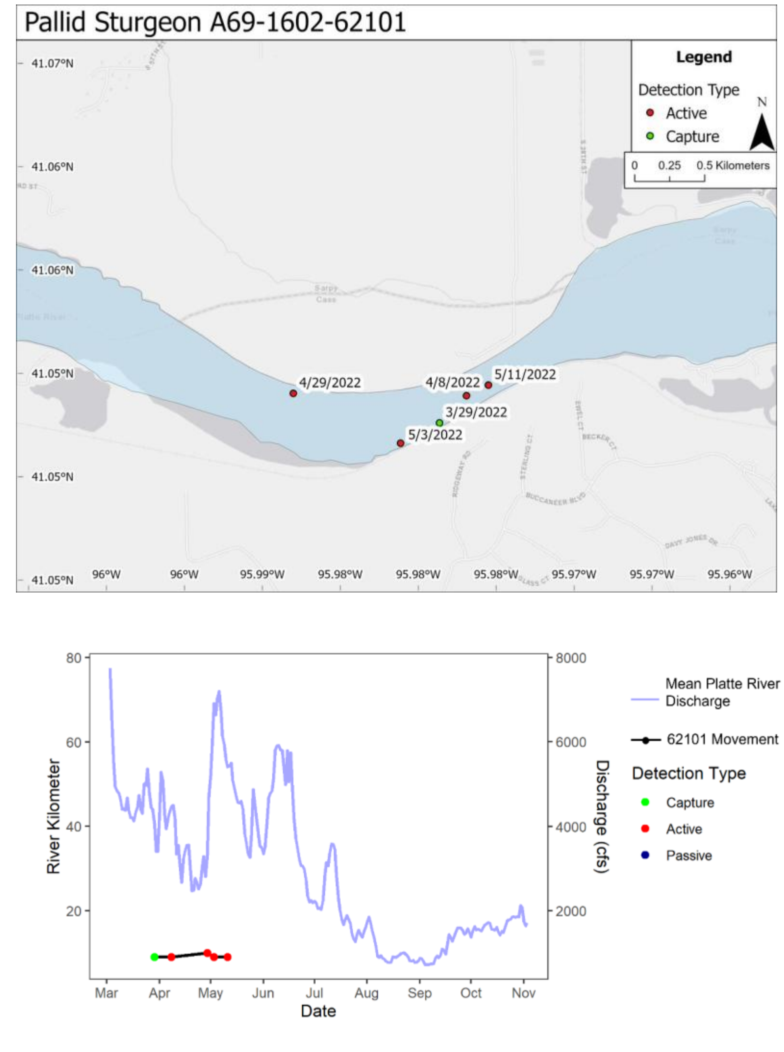


Figure 17. Capture location and relocations of Pallid Sturgeon A69-1602-62101 in the lower Platte River during 2022 (top). Green dot indicates location and date of capture, red dots indicate locations made during active tracking, and blue dots indicate detections at passive receivers. The bottom graph 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

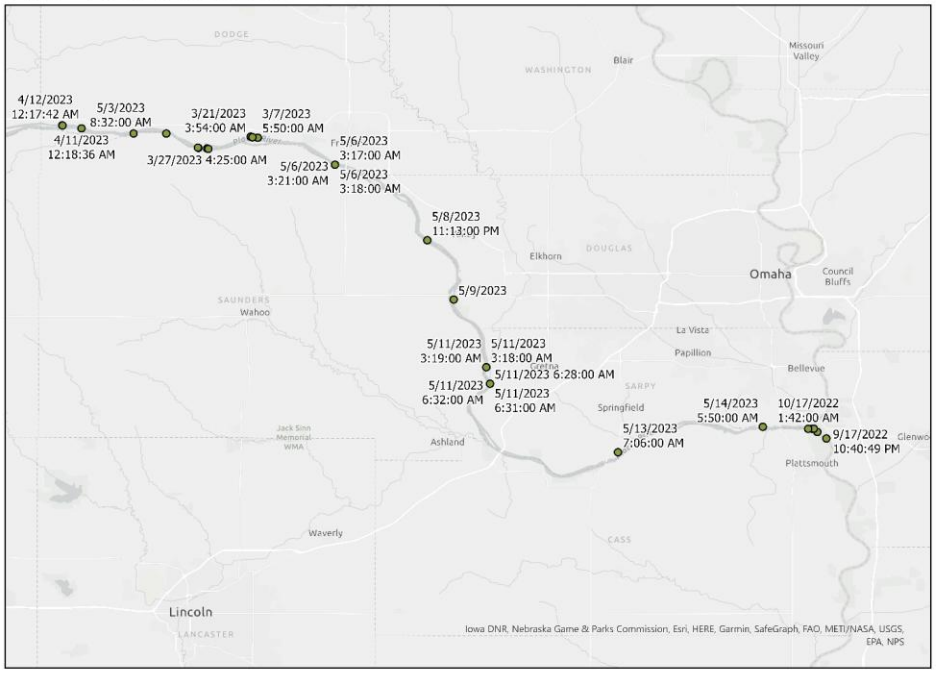


Figure 18. Relocations of A69-1604-30383 through Fall 2022 to Spring 2023.

A69-9001-54336

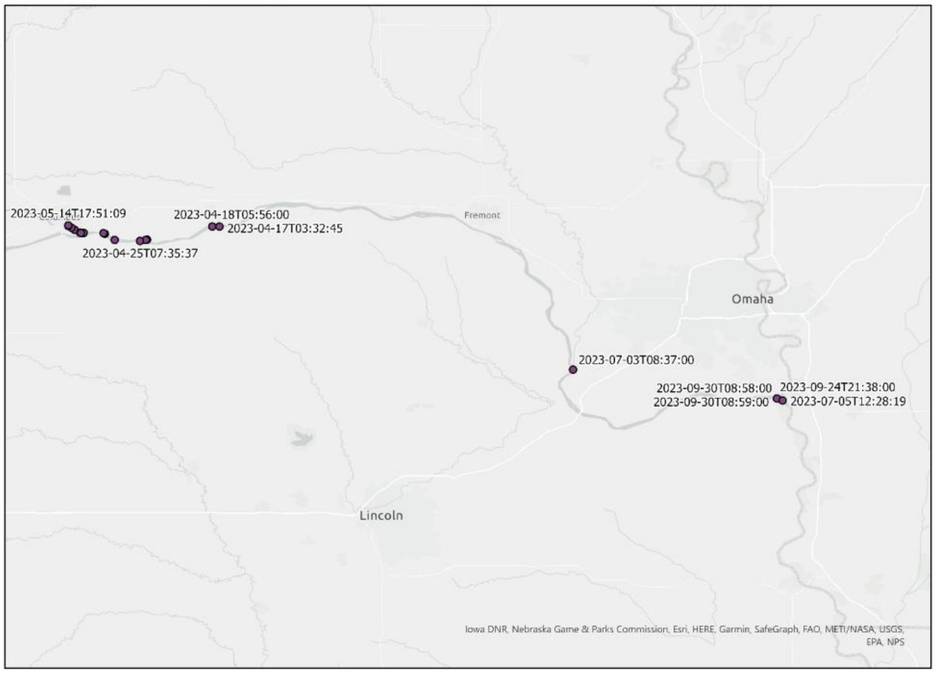


Figure 19. Relocations of A69-9001-54336 throughout the spring of 2023.

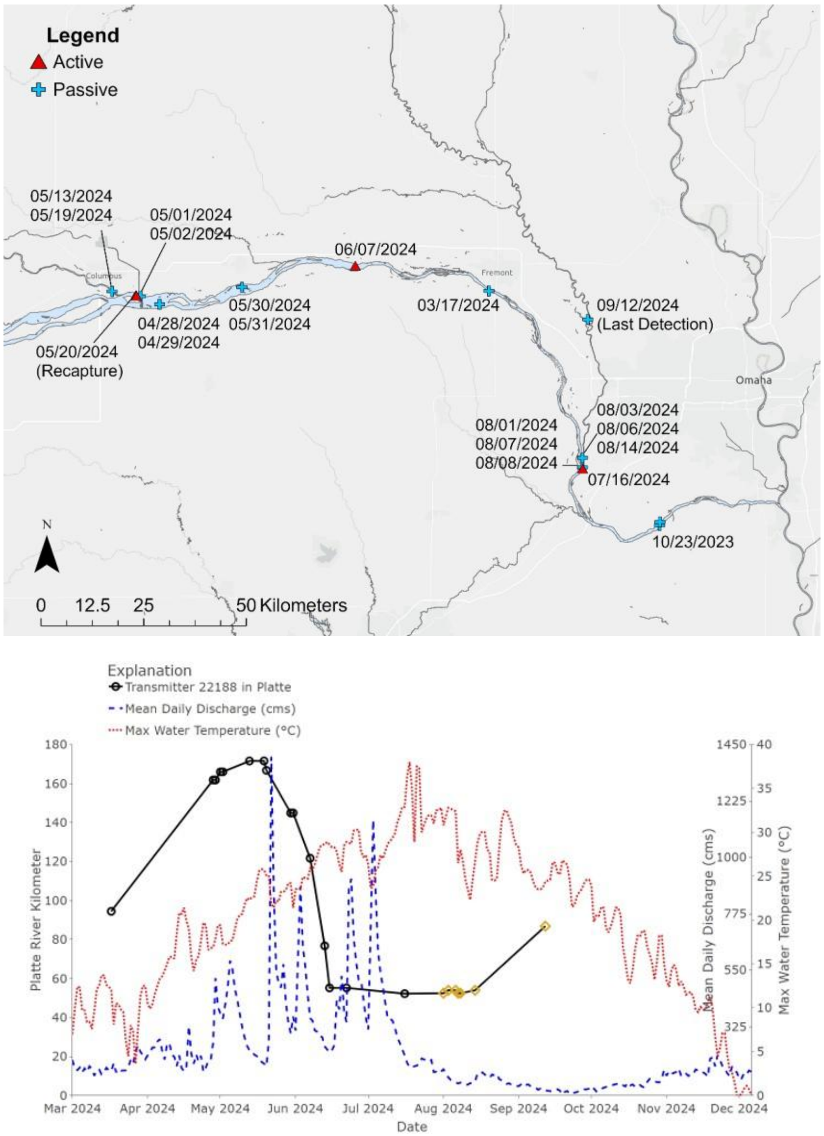
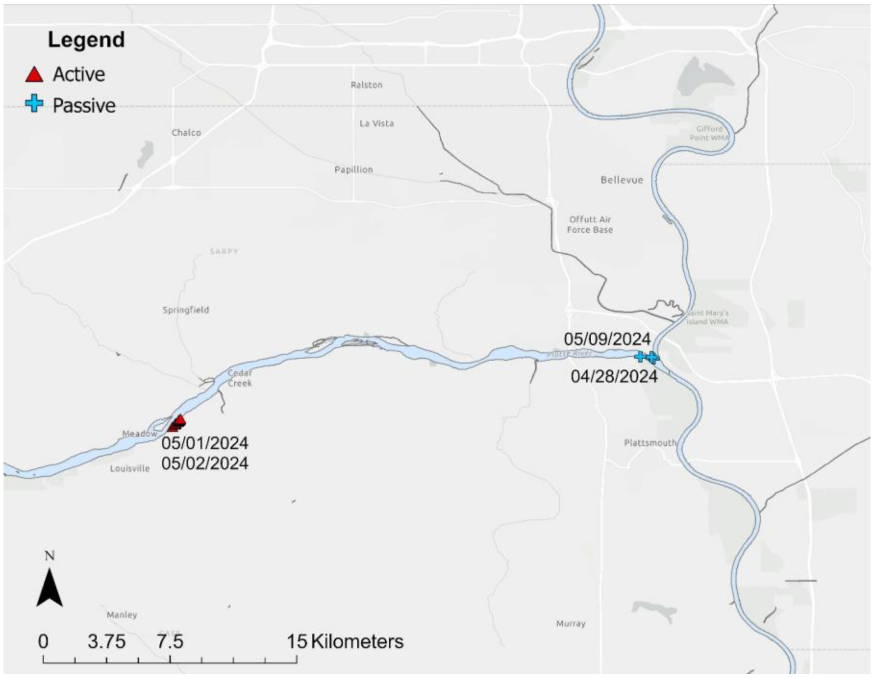


Figure 20. Relocations of Pallid Sturgeon A69-1604-22188 in the lower Platte River during 2024 (top). The bottom graph shows linear movement of the fish through time. Discharge (cubic meters per second; cms) and maximum water temperature are provided for the Platte River over the period of record.



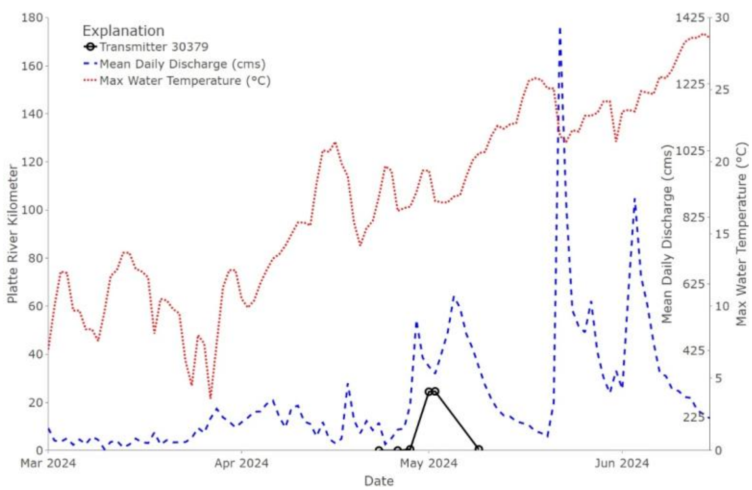


Figure 21. Relocations of Pallid Sturgeon A69-1604-30379 in the lower Platte River during 2024 (top). The bottom graph shows linear movement of the fish through time. Discharge (cubic meters per second; cms) and maximum water temperature are provided for the Platte River over the period of record.

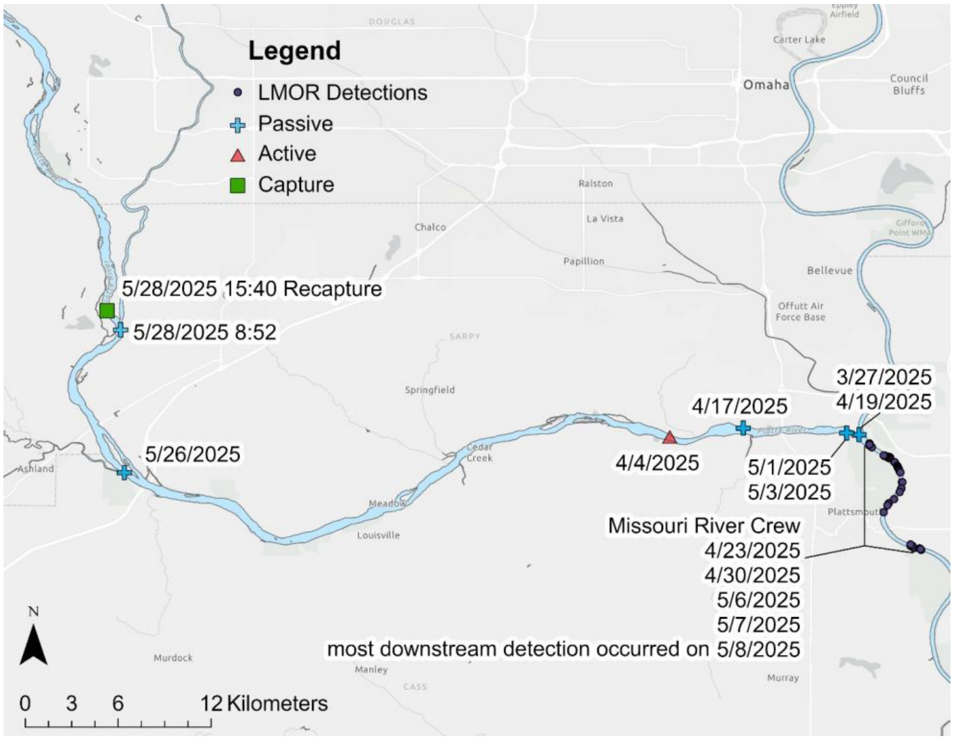


Figure 22. Detections for high priority female A69-1602-63085 throughout the lower Platte and Missouri rivers through the time of recapture on May 28, 2025.

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.

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.

Guidance and/or contacts that can assist with multi-state model analyses. These models are appealing because they provide a means to estimate transition probabilities and survival simultaneously. So far, we have used a multi-state model at a daily timestep to evaluate transition probabilities among river reaches. However, these models are data hungry and limit the capacity to incorporate covariates like environmental conditions. We anticipate a continuous-time multi-state model would improve model performance and may facilitate inclusion of environmental variables better than a discrete time-step version. The continuous models are derived using a Bayesian approach. 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.

An analytical hurdle currently mitigated for the multistate model analyses is that a consistent timeline of adding or removing transmitters from the analysis does not exist. That is, most of the smaller transmitters implanted in juvenile Pallid Sturgeon in the Platte River and some of the transmitters implanted in larger individuals by Missouri River field personnel have expired during this study. Further, new transmitters are being added annually. The default is that if a transmitter is not present, the model views the status as a "mortality" no matter the situation. The issue presents itself as a "transmitter expired – no mortality" type scenario where tags are counted throughout the study because the multistate model requires that all transmitters have an equal number of sampling occasions. Here, that currently equates to 1,171 days thus far. Therefore, we will likely refine the multistate model to include a hidden state to denote expired transmitters or similar but seek further input from ISAC on alternative approaches.

We have been presenting both binary (e.g., immigration event or not) and continuous (count data for daily events) transition analyses at the Missouri River-Platte River interface. Both approaches are easily performed but may or may not provide similar outcomes. Is there a preferred approach to help answer program questions?

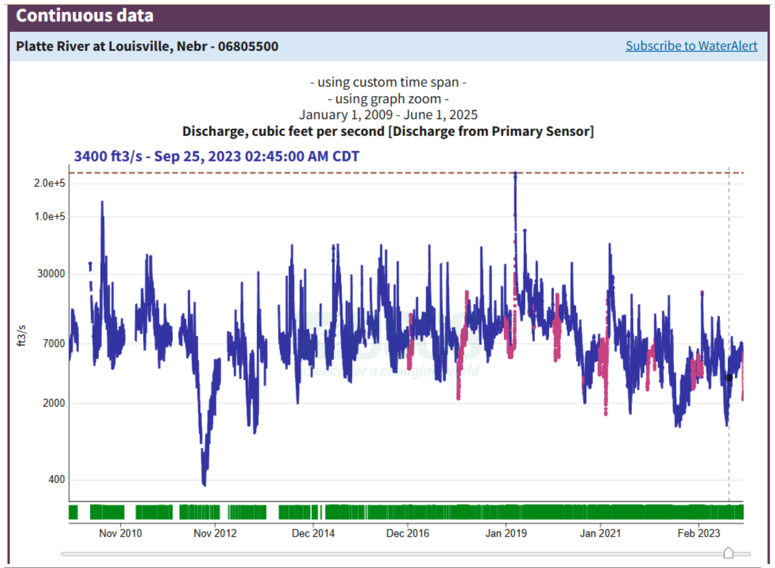
ISAC Comments and Suggestions

Pallid Immigration, Emigration, movement through the Platte System

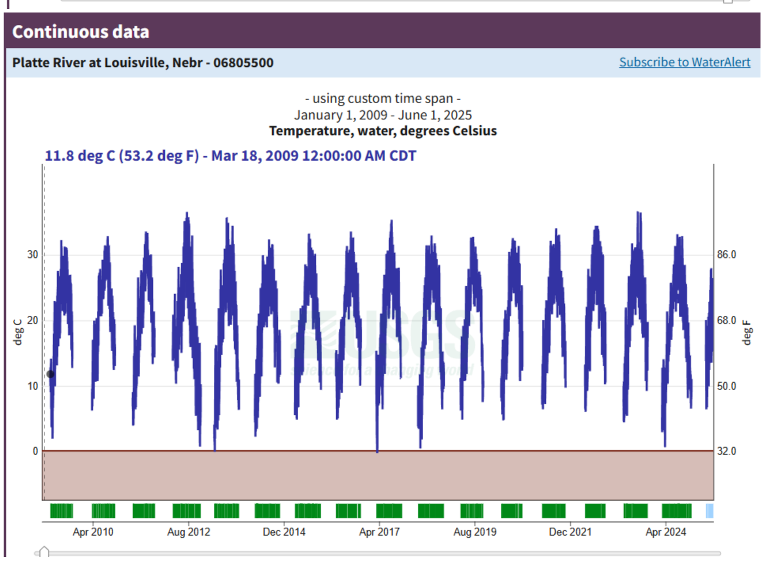
1. For UNL - **Objective 1**, based on all the work you've done, what do you think are the best correlates of movement of pallid sturgeon in the lower Platte River (including entering and leaving the Platte, moving into / out of tribs, moving from one LPR reach to another)? To what extent do you think that the low to median flows during the period of the UNL study (Concerns - page 6 of 2025 UNL Progress Report) limits your ability to draw conclusions? [From Dave]
2. For UNL and HDR - **Objective 1**: Water temperatures are strongly affected by air temperatures. Given the strong correlations of pallid sturgeon immigration and emigration with maximum water temperature, is it fair to conclude that air temperatures (driven by weather / climate change) will likely have a stronger effect on PS immigration / emigration than LPR flows, at least for the range of flows you observed during this study? Is it important for the PRRIP to have a model (e.g. 1D HEC-RAS temperature module) that can predict water temperatures in the LPR, to distinguish the relative importance of air temperatures and flow in affecting water temperatures? Or, to save money and time, can some simple empirical analyses show the relative importance of flow and air temperature in affecting maximum water temperature in the LPR?
    a. *Background:* In the Upper Missouri River, 1D HEC-RAS modeling by Craig Fischenich has shown that air temperatures have a very strong effect on water temperature once you move beyond the influence of Fort Peck Dam powerhouse releases (cold water from the bottom of Fort Peck reservoir). Craig has had to debug the HEC-RAS temperature module, so it may be better to start with simple empirical analyses.[From Dave]
3. For UNL: Following on from Dave's question 1, has your recent data suggested any surprising or different conclusions about pallid sturgeon use in the lower Platte compared to your 2014 paper (Hamel, Spurgeon, Pegg, et al) which was based on 2009-11 data? [From Jennifer] Is there any way to meld the 2009-2011 data sets with those from 2022-2025 to get a broader range of flows? [From Dave]
    a. Background: In Hamel et al. 2014, temperature metrics were much less important than flow metrics in explaining the probability of presence of pallid sturgeon in the LPR [a slightly different dependent variable from Pr(immigration) or Pr(emigration)]. This may

be because there was greater variation in flows during 2009-2011 than during 2022-2025 (flows at Louisville gauge shown below, from here). The range of water temperatures appears similar between the two time periods, but a more detailed analysis is warranted (also shown below, from here).

Commented [1]: Question for someone else from ISAC (from Dave's plots): discharge has dramatically decreased since 2019. Is it worth asking about this?



b.



c.

4. 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?
5. For UNL: What factors constrain adult pallid sturgeon from migrating further up the Platte River, even potentially into the PRRIP AHR? They are certainly capable of traveling longer distances than the length of the lower Platte. Do you think it is habitat, flow, temperature, barriers or some combination of these factors? Or perhaps simple diffusion of so few individuals? Do the Loup River hydrocycling flows induce some sort of "stop sign" for further migration up the Platte? [From Gary]
6. Michal: Can hydrocycling "on" and 'off' periods be analyzed explicitly for behavioral contrasts?
7. For UNL: Advice from Jennifer on multi-state models, as requested under "ISAC assistance" on page 8 of the 2025 UNL progress report. Summary of Jennifer's suggestions: I'd rather see UNL fit a simpler model that you feel comfortable with (e.g., the non-Bayesian model) than try to fit a more complicated model where you don't understand how to check for model fit, Markov chain Monte Carlo (MCMC) convergence and more. If you feel comfortable with a Bayesian multi-stage model great, but if not then you may need to seek a lot of help from Clint Leach or ask him to fit the model himself. See document from Jennifer for the 7/2/25 meeting for further detailed comments for UNL on this issue. [*Dave: If datasets are insufficiently large to parameterize multi-state models, what simpler analytical methods could be used to answer key questions? That is, could UNL adapt the scale of the tools to the scale of the data?*]
8. 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]
9. 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]
10. 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]
11. 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]

12. 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?
13. 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?
14. Is it possible to quantify detection probability by habitat type to correct for bias in habitat selection models?
15. Is there an energetic cost of fish repeatedly moving in/out of the Platte under high temperature conditions?
16. Are there plans to analyse depth and velocity combinations, not just single metrics?
17. 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? DM Response: 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.
18. Do PS live in the LPR year around or just seasonally? DM Response: Some of the tracked PS have overwintered in the Platte or Elkhorn, while others have only occupied the Platte seasonally, entering in about May and leaving in July or August.

2D Hydrodynamic Model

1. For EDO: See question 2 above for UNL and HDR. Has HDR done any statistical analyses of how maximum water temperature in the LPR varies with flow and air temperature? [from Dave]
2. For EDO: From Tables 3 and 4 in the 2025 Progress Report, the flow metrics which showed the highest correlation with Pr (immigration) and Pr(emigration) were the daily CV of flow, the slope of flow, 1-day lagged flow and 7-day lagged flow, all measured at the Louisville gage. Can your hydrology model generate estimates of these metrics at the Louisville gage for alternative water years and PRRIP water management scenarios? If so, it should be possible for UNL to assess what changes in Pr (immigration) and Pr(emigration) might occur across a range of years and water management scenarios. That assessment would ideally include predicted temperatures at the Louisville gage. If temperatures are largely independent of flow (see question 1), then UNL could just use the temperatures associated with each water year [from Dave].
3. For EDO: The 20+ degree F daily fluctuations in river water temperatures (Figures 9 and 10) are rather stunning, as are temperatures that can exceed 90 degrees in mid-summer in the Platte. How are these related to discharge (see question 1 above also), hydroelectric flows, epilimnetic reservoir discharges, and other factors? [From Gary]

4. For EDO: From the LIDAR, is there evidence of gaining and losing reaches in the lower Platte (independent of tributary inputs) that could potentially provide thermal refugia during peak summer temperatures? [From Gary]
5. For EDO: it looks like the difference in Observed vs modeled WSE at Louisville is somewhere around 0.5 feet, or 6 inches. These WSE uncertainties are on par with the estimated WSE change that PRRIP releases can cause (see "7_30_25 Pallid Sturgeon - Flow - Stage - Tracking figures for September 2025 ISAC") – so to put this another way, do we have confidence that Program releases can actually affect WSE, if the magnitude of those impacts are within the uncertainty of the model itself? This isn't a commentary on the quality of the modeling effort or product, but rather I'm just wondering if, given its bounds of uncertainty, the model can meaningfully inform water depth impacts as they relate to PS? [From Alan]
6. For EDO: The model was run at 40 ft/40 ft resolution (12x12 m). Is this good enough to capture the heterogeneous nature of the Platte River and its hydraulics? Are fishing using features at that scale, or smaller scales? What are the computational costs of increasing the resolution? [From Alan]

Pallid Sturgeon/Flow/Stage Tracking figures created by EDO

"7_30_25 Pallid Sturgeon - Flow - Stage - Tracking figures for September 2025 ISAC"

Figure 5 – am I interpreting this right that without EA water, stage at North Bend would be about 6 inches lower at most (during late June/early July), and stage at Louisville would be about 3 inches lower at most (during late June/early July)? Are these big numbers or small numbers in terms of habitat? [From Alan] What level of stage change is *biologically meaningful* for pallid sturgeon habitat use in the Platte?

Figure 6 - As opposed to EA *releases* tangibly affecting stage at North Bend and Louisville, it looks like PRRIP *diversions* do basically nothing to stage. Is this interpretation in line with EDO findings? And if so, how does that square with FWS' position that "*Program water withdrawals will reduce lower Platte River flow and the inability to detect those water withdrawals does not equate to no PS impact."* [From Alan]

Fig 14: definitely need to account for active tracking effort. How are you doing that? [From: Jennifer]

Fig 19: Tell me more about the Lidar voids (missing data) on the Lower Platte Hydraulic Model webmap. Is the HDR modeling valid given all the voids? For example, Fig 19 caption says "Pallid observations/depth measurements disproportionately occurred in areas where hydraulic model topography had to be synthesized because of voids in LiDAR." (from the file 7_30_25 Pallid Sturgeon - Flow - Stage - Tracking figures for September 2025 ISAC.docx) [From Jennifer]

Figure 21 – I'm used to seeing histograms as bins on the x-axes and counts on the y-axis. Can you produce an actual histogram of depth vs. fish locations? These are helpful for interpreting, for instance, Whooping Crane use of various channel widths. [From Alan]

Figure 22 – The scattershot nature of this correlation isn't too surprising, as depth should have relatively little correlation with bottom velocity; that's because velocity goes to zero at near-bed elevations ("Law of the Wall"). Any way to get average water column velocity rather than bed velocity? [From Alan]

Figure 24 – do you think that the capture locations are biased toward deeper, faster, main channels? That is, aren't these the places one would take a boat (and thus sample), instead of all the tiny and tough-to-navigate side channels? [From Alan]

Figure 27 – this isn't technically a plot of slope, it's a plot of elevation against distance. Suggest replacing with a true scatterplot of slope (i.e., where the y-axis has numbers like 0.00001, etc.)

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:

- Pg 7, PS-2 "Unsurprisingly, when there is more water in the lower Platte River system we see more activity." Are you suggesting a causal relationship here or could this be just due to season?
- Pg 8: Multi-state model analyses
  - "The default is that if a transmitter is not present, the model views the status as a "mortality" no matter the situation." That statement must only be for the frequentist model. In a Bayesian model, you should be able to put in an NA (missing data notation) for all the missing observations. Bayesian models are particularly good at filling in missing data and accounting for the additional uncertainty about those data.
  - Clint Leach should be a good resource for these analyses.
  - But it may not be worth the effort to do a Bayesian model. The Bayesian model shoudn't be super hard to fit as you should be able to use an existing R package, but I'm not sure how much more information that you'll gain.
  - My personal opinion that may not be shared by all ISAC members: I'd rather see you fit a simpler model that you feel comfortable with (e.g., the non-Bayesian model) than try to fit a more complicated model where you don't understand how to check for model fit, Markov chain Monte Carlo (MCMC) convergence and more. If you feel comfortable with it great, but if not then you may need to seek a lot of help from Clint or ask him to fit the model himself.
  - That said, the Bayesian model should allow you to fit a model that will allow for inference on the predictors of those transition probabilities. That seems like it could be really useful to the program.
  - Question for the UNL as well as PRRIP including the ISAC: how useful are the results in Fig 12 to the program? To the UNL folks and for Jenna's PhD, same question.
    - If the answer is A LOT, then you should fit the Bayesian model. If not, you might just stick with the current model.

- But no need to try to fit a fancier model if you are pretty confident that you don't have sufficient data (if your sample size is too small). The off diagonal values in Table 7 are all quite small - at least with the data you have to date.

  Dave says: While I don't get much insight from Figure 12, I'm interested in seeing the results of applying the multistate model to different water years and different PRRIP water management scenarios, that is, does PRRIP water management have any effect on the distribution of pallid sturgeon, particularly in very dry years where PRRIP flow manipulations may be a larger fraction of total flow.

- Pg 8, 'Should we use a binary (e.g., immigration event or not) or continuous (count data for daily events)' model? My answer is below:
  - Continuous response models are almost always preferred because continuous data have more information than binary data. If you have to choose, fit only the continuous model. If you don't have to choose, both models can be informative.
  - A zero-inflation model that accounts for both the counts and the 0's differently may be useful. I'm more familiar with zero-inflated models in other contexts, and have used them for transition probability models, but I have found them very useful in those other contexts.

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

Response Variables:

- Have all data from captures, active tracking, and passive receivers been integrated to better inform state assignments, timing, and directionality?
- How are your detections upstream and downstream of the Elkhorn confluence distributed through time? Do they span a broad range of seasons and conditions?
- Chris Pullano's thesis demonstrated that detection ranges and probabilities are different at North Bend, in the Elkhorn, and at Louisville. In addition, ability to detect is very dependent upon receiver line of sight which is in turn dependent upon water coverage and water depth. Any thoughts on how to account for discrepancies in sampling effort and detection probability across states?
- Please review how you assign detections to states or segments of the Platte system and assign directionality of movement. Which receivers, where located, series of detections required to

assign to a state and decision rules in place for assignments. How are gaps in detections dealt with in terms of assigning directionality and timing of movement? For example, if a fish was detected at Louisville and the next detection was at North Bend 3 days later, how do you assign a date/time to the state transition at the Elkhorn? Let's say you detect a fish at Louisville, and the next consecutive detection is just upstream of the Elkhorn, but 3 months have passed, now how do you deal with these data? How large are gaps in detections within the dataset? When are data eliminated or not used and why?

- How do you deal with fish that remain stationary?

Explanatory Variables: Linking up detections with explanatory variables in space and time to test hypotheses.

UNL Describe: Current thoughts on spatially and temporally appropriate explanatory variables based upon formal hypotheses, patterns and dynamics of the Platte system, and pallid movement/behavior patterns. How do we translate gradually changing conditions sampled by fish as they move through time and space in a linear system into explanatory variables? What are the appropriate time periods and spatial extents over which to explain pallid sturgeon movement? Can you use patterns in detection histories to inform this choice?

- Choice of gages, specific metric, and time point for sources for information
    - Data analysis plan indicates use of multiple gages for flow regime data. For the Elkhorn confluence, gages are available at Leshara (incl. temperature) and Ashland (temperature data collection ended in Sept of 2022) for the entire study period.
    - Consider stage rather than discharge?
    - Consider identifying drivers and thresholds rather than means. Max temp and min stage, for example.
    - Consider for which variables broader vs. narrower spatial and temporal scales might be more appropriate based upon patterns of PS movement and variability in the flow regime.
        - Is it possible that PS in the upstream portion of the lower Platte (hydrocycling, less water, and likely greater temperature shifts) are using more immediate cues when compared to those making decisions at the confluence? Or do you think the decision to move into different segments of the Platte system occurs over a broader temporal and spatial scale? Do you think this differs based upon directionality? Ex. Do upstream movements happen more slowly, whereas downstream movements are quick?
        - Ex. A 7-day lag in discharge as important for emigration may indicate fish are making decisions well in advance of the confluence in question.
        - Consider trends across gages and receivers. For example, consistently increasing temperatures may be associated with downstream movement.
        - Consider the time elapsed between consecutive detections at state 1 and state 2 as the period over which you calculate explanatory variables since you do not know anything about fish behavior between those consecutive detections, but

you know sometime between time 1 and time 2 that fish moved from state 1 to state 2. Pros: makes no assumptions about when the decision was made but includes information from the full time period over which the transition occurred. Does not assume the fish was only using cues from destination time and location (movement is not explained solely by conditions fish had not yet experienced). Cons: Assumes the fish remained between station 1 and station 2 and experienced only the conditions occurring there during that time period (though during longer gaps between detections fish may have moved out of the reach and back). Requires that explanatory variables are calculated separately for each state transition over the specific time period associated with that transition.

- Consider quantifying and contrasting characteristics in the "from" location vs the "to" location
    - If these segments are different geomorphologically, hydrologically, and with regard to continuity of detection data, how do we appropriately select explanatory variables that are useful in predicting state transitions (which variables are important) but also provide good variable estimates (what levels of each variable facilitate or impede pallid movement) to connect to Program water management? For example, do you expect the same set of variables to be important for a transition from Segment 1 to Segment 2 and from Segment 1 to the Elkhorn? Do you expect the level of those variables (temperature ranges under which pallids move, for example) to be the same across segments?
- Please summarize the distribution of each of these explanatory variables for immigration events and emigration events.

Examine plots of raw data relevant to testable hypotheses to look for patterns in when, where, and under what conditions you have detections of which fish. Are your predicted patterns evident? Do plots provide insights for tailoring your analyses to better fit your system?

Analytical Framework Options and Initial Results

- Review current model performance. Any limitations that alternative methods might deal with better?
- Consider evaluating state transitions at the Elkhorn confluence alone. There are likely not enough transitions at the Loup confluence for a powerful test of hypotheses and grouping them does not provide good information on potential factors influencing decisions at the Loup confluence because it is driven by Elkhorn data. Do you think the conditions under which fish make decisions at the Loup are similar enough to those at the Elkhorn to lump them in analyses or would a separate analysis provide better information?
- Does this analytical framework allow you to integrate specific characteristics at the "from" location and the "to" location as a choice rather than asking "what are the characteristics in the "to" location alone? Transitions between Segment 1, Elkhorn, and Segment 2 are pretty abrupt changes, so they may be better explained by a suite of diverging to and from conditions.
- Any need to add variables to test effects or parse the data based upon river dynamics or pallid behavior? Would looking at periods with hydrocyling "off" (May- early June) vs "on" be

informative? Is it worth considering different signals for different cohorts (repro adult, adult, juvenile)? Maybe the drive to reproduce trumps potential warning signs thus shows a different pattern than non-reproductive individuals. Do any years or seasons require special consideration because of changes in river conditions or data collection? Can you test for aspects of the flow / temp regime that are seasonally dependent by looking within a season?

- Hypothesis and management-based model selection vs. Lasso approach

Interpretation of results

- Areas of clear signal, high confidence
    - Are they metrics PRRIP can impact?
    - Further work to be done - next steps
- Areas of weak signal, low confidence and uncertainties remaining
    - Warrant further investigation or not?