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Prepared in cooperation with the Missouri River Recovery Program

The Missouri River *Scaphirhynchus albus* (Pallid Sturgeon) Effects Analysis

What is an Effects Analysis?

The Missouri River Pallid Sturgeon Effects Analysis (EA) was designed to assess how Missouri River management has affected—and may affect—the endangered *Scaphirhynchus albus* (pallid sturgeon) population. The idea of an EA is practical and conceptually simple. An EA integrates three components to achieve a better understanding of a listed species and what can be done to improve its status (Murphy and Weiland, 2011):

- Collection of reliable scientific information,
- Critical assessment and synthesis of available data and analyses, and
- Analysis of the effects of management actions on listed species and their habitats.

The Missouri River Pallid Sturgeon EA emerged from the recognition that the direction and focus of the Missouri River Recovery Program would benefit from an updated, thorough evaluation of what is known, what is not known, and what needs to be known for effective actions (Doyle and others, 2011).

The Missouri River Pallid Sturgeon EA core team consists of sturgeon and river experts from the U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and Mississippi State University. The EA core team has also benefited from extensive collaboration and reviews by experts from State agencies and universities.

The EA deliberations and results have been documented in an integrative report (Jacobson and others, 2016a), which is envisioned as the initial report in an ongoing series of updates that will support adaptive management of the Missouri River. The integrative report is a synthesis of the three parts of an effects analysis, with an emphasis on development of lines of evidence for how future management actions are likely to affect the pallid sturgeon population. The integrative report received thorough technical peer review by seven experts and the Independent Science Advisory Panel (ISAP) of the Missouri River Recovery Implementation Committee.

Three additional reports have been published by the EA core team to serve as the foundation for the integrative report (fig. 1). The first report (Jacobson and others, 2015a) is a compilation and assessment of available information and quantitative models that can be used to understand historical and future changes of pallid sturgeon populations. The second report (Jacobson and others, 2015b) describes conceptual ecological models (CEMs) developed to document and illustrate a global set of ecological relations for Missouri River pallid sturgeon. The third report (Jacobson and others, 2016b) documents the process of filtering the global set of hundreds of hypotheses that emerged from the CEMs. The EA used expert-opinion surveys and existing evidence to formulate and filter hypotheses, converging on an initial 21 working management hypotheses. The EA integrative report assesses these 21 working management hypotheses to document existing knowledge and explore potential actions (table 1).

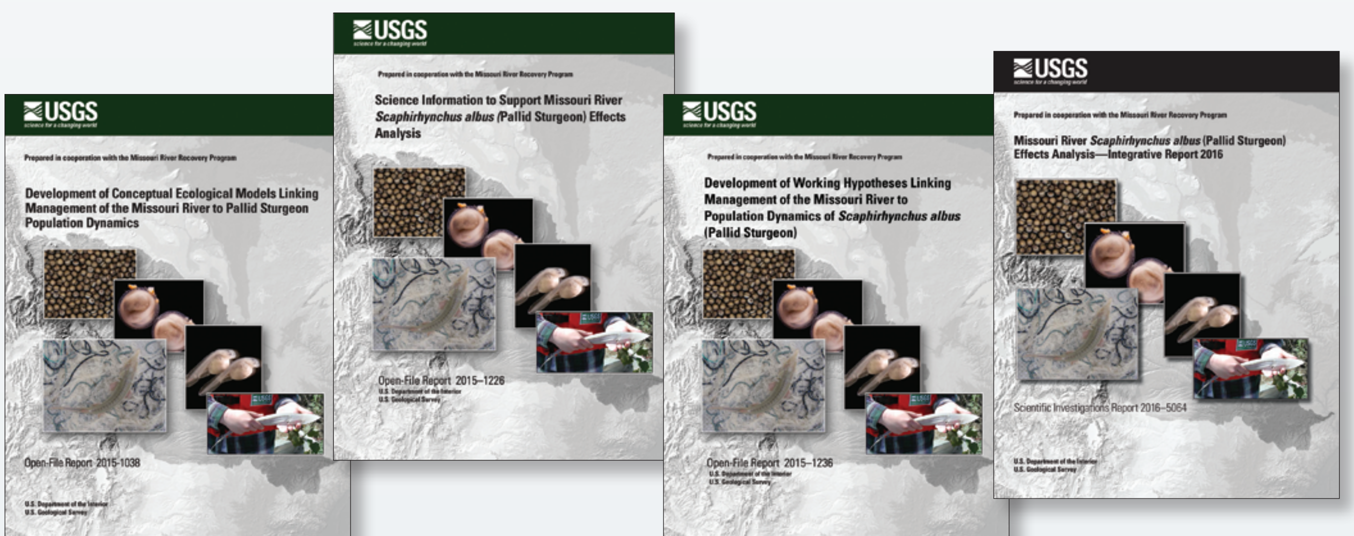

Figure 1. Published reports from the Missouri River Pallid Sturgeon Effects Analysis.

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Table 1. Summary table of working action hypotheses, findings, and routings (modified from Jacobson and others, 2016a).

Number	Working management hypothesis	Findings	Potential routing
		Upper Missouri River	
		Alter flow regime at Fort Peck Dam	
1	Naturalized flows, food and energetic demands	Theoretical support but inadequate data to model and forecast population response	Research on bioenergetics, hydrodynamic models, comparative field experiments
2	Spring flow pulses, aggregation and spawning cues	Theoretical support, inference from other sturgeon species, but inadequate data to model and forecast population response	Research, monitor responses to events, possible pulsed flow experiment
3	Decreased spring flows and velocities, reduced drift	Potential effective action, subject to contingent information	Research to resolve anoxia, use of Yellowstone, interstitial hiding, retarded drift
		Temperature control at Fort Peck Dam	
4	Increased temperature, increased productivity	Theoretical support but inadequate data to model and forecast population response	Research on bioenergetics, hydrodynamic models, comparative field experiment
5	Increased temperature, increased growth, decreased drift	Potential effective action, subject to contingent information	Research to resolve anoxia, use of Yellowstone, interstitial hiding, retarded drift
		Sediment augmentation at Fort Peck Dam	
6	Increased turbidity, decreased predation	Theoretical support, but laboratory data equivocal; no specific models for population response	Research on predation egg, embryos, free embryos
		Yellowstone River	
		Passage at Intake Diversion Dam	
7	Increased potential dispersal distance	Potential effective action, subject to contingent information	Implementation likely. Complement with research, robust monitoring and evaluation
		Upper Missouri and Yellowstone Rivers	
		Propagation in the upper basin	
8	Improved stocking strategy, size classes	Potential effective action, subject to hatchery capacities	Implemented, validate with monitoring, assessment. Research on optimization
9	Improved stocking strategy, genetic diversity and population viability	Theoretical support, no specific data, models to forecast population response	Implemented, validate with monitoring, assessment. Research on linking parentage and population viability
		Lake Sakakawea	
		Drawdown at Lake Sakakawea	
10	Increased potential drift distance	Potential effective action, subject to contingent information.	Research to resolve anoxia, use of Yellowstone, interstitial hiding, retarded drift
		Lower Missouri River	
		Alter flow regime at Gavins Point Dam	
11	Spring flow pulses, aggregation and spawning cues	Theoretical support, inference from other sturgeon species, but inadequate data to model and forecast population response	Research, monitor responses to events, possible pulsed flow experiment
12	Naturalized flows, increased productivity	Theoretical support, inference from hydrodynamic models, but data inadequate to model, forecast population response	Research on bioenergetics, comparative field experiments, possible pulse flow experiment.
13	Naturalized flows, decreased energetic demands	Theoretical support, inference from hydrodynamic models, but data inadequate to model, forecast population response	Research on bioenergetics, comparative field experiments, possible pulse flow experiment.
14	Decreased spring flows and velocities, reduced dispersal	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Research into drift dynamics
		Temperature management at Gavins Point Dam	
15	Naturalized temperatures, increased aggregation and spawning cues	Theoretical support, inference from other sturgeon species, data equivocal about magnitude of change, population response	Research, monitor responses to events
		Channel reconfiguration	
16	Reconfigure channel for spawning habitats	Theoretical support, support from sturgeon species, hydrodynamic models, but data are equivocal as limiting factor and population response	Research in spawning dynamics, comparative field experiment
17	Reconfigure channel for food-producing habitats	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Implemented in part, comparative field experiment, validate with monitoring, assessment
18	Reconfigure channel for foraging habitats	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Implemented in part, comparative field experiment, validate with monitoring, assessment
19	Reconfigure channel for interception habitats	Theoretical support, inference from hydrodynamic models, but data are equivocal as limiting factor and population response	Possibly implemented in part, validate with monitoring, assessment, comparative field experiments
		Propagation in the lower basin	
20	Improved stocking strategy, size classes	Potential effective action, subject to hatchery capacities.	Implemented, validate with monitoring, assessment. Research on optimization
21	Improved stocking strategy, parentage and fitness	Theoretical support, no specific data, models to forecast population response	Implemented, validate with monitoring, assessment. Research on linking parentage and population viability

The geographic scope of the EA is the Upper Missouri River main stem from Fort Peck Dam in Montana to the headwaters of Lake Sakakawea, the Yellowstone River upstream from the confluence with the Upper Missouri River, and the Lower Missouri River main stem from Gavins Point Dam to the confluence with the Mississippi River at St. Louis, Missouri. The scope also includes an unspecified distance downstream in the Mississippi River and various tributaries to these river segments that might be occupied by pallid sturgeon (fig. 2).

Figure 2. Geographic scope of the Missouri River Pallid Sturgeon Effects Analysis (Jacobson and others, 2016b).

Information Gaps—A Key Finding

A key finding of the EA has been the extent of uncertainties in pallid sturgeon biology. Fundamental information gaps limit the ability to quantify how management actions will propagate to changes in the pallid sturgeon population. This does not mean that scientists have not made progress in understanding pallid sturgeon. In fact, the EA reports document that a substantial body of pallid sturgeon science has been developed during the past 20 years. The challenge to the science has been to understand critical population processes of a very rare fish that lives in a deep, fast, and muddy river where direct observation is nearly impossible.

Hypotheses, Lines of Evidence, and Models

Despite these gaps, a specific charge to the EA team was to develop a framework of the best models available to guide decision making and evaluate costs and benefits of management actions. Even in the presence of substantial predictive uncertainties, a modeling framework is useful for structuring hypotheses, exploring sensitivities of populations to management actions, prioritizing science needs, and synthesizing information from monitoring data. The EA integrative report presents the best-available quantitative models and other lines of evidence to predict how future management may affect pallid sturgeon population responses.

For some of the 21 working management hypotheses, lines of evidence are limited to theoretical deduction, inference from rare empirical datasets, or expert opinion. Useful simulation models have been developed to predict the effects of management actions on survival of drifting free embryos in the Upper Missouri and Lower Yellowstone Rivers, and to assess effects of flow and channel reconfigurations on habitat availability in the Lower Missouri River (fig. 3). We have also developed a population dynamics model that can be used to assess sensitivity of the population to survival of specific life stages, evaluate hypotheses related to stocking decisions, and explore other management scenarios.

Consideration of lines of evidence for each of the 21 working management hypotheses includes a discussion of how the degree of uncertainty and risk associated with each hypothesis may guide science and implementation strategies. Strategies may be full implementation in the field, limited implementations as field-scale experiments, or further research (in the case of greatest uncertainty). The EA emphasizes that scientific progress in understanding the reproductive ecology of pallid sturgeon will require coordinated efforts in laboratory and field research. Although field-based research results will be most compelling, some important parts of the pallid sturgeon life cycle cannot be observed in the field, so results will need to be extrapolated from laboratory studies and model-based inferences.

Effects Analysis and Adaptive Management

The considerable uncertainties documented in the pallid sturgeon EA integrative report point to an adaptive-management approach for this rare fish and its ecosystem. Under adaptive management, hypotheses guide implementations of actions that are designed as learning experiments, and new information is used to improve management decisions. Importantly, hypotheses filtered early in the EA process can be resurrected and addressed as needed to explain new observations. Under adaptive management, a persistent EA process can be envisioned as a means to continually assess and assimilate science information and ensure the information is relevant and actionable for decision making.

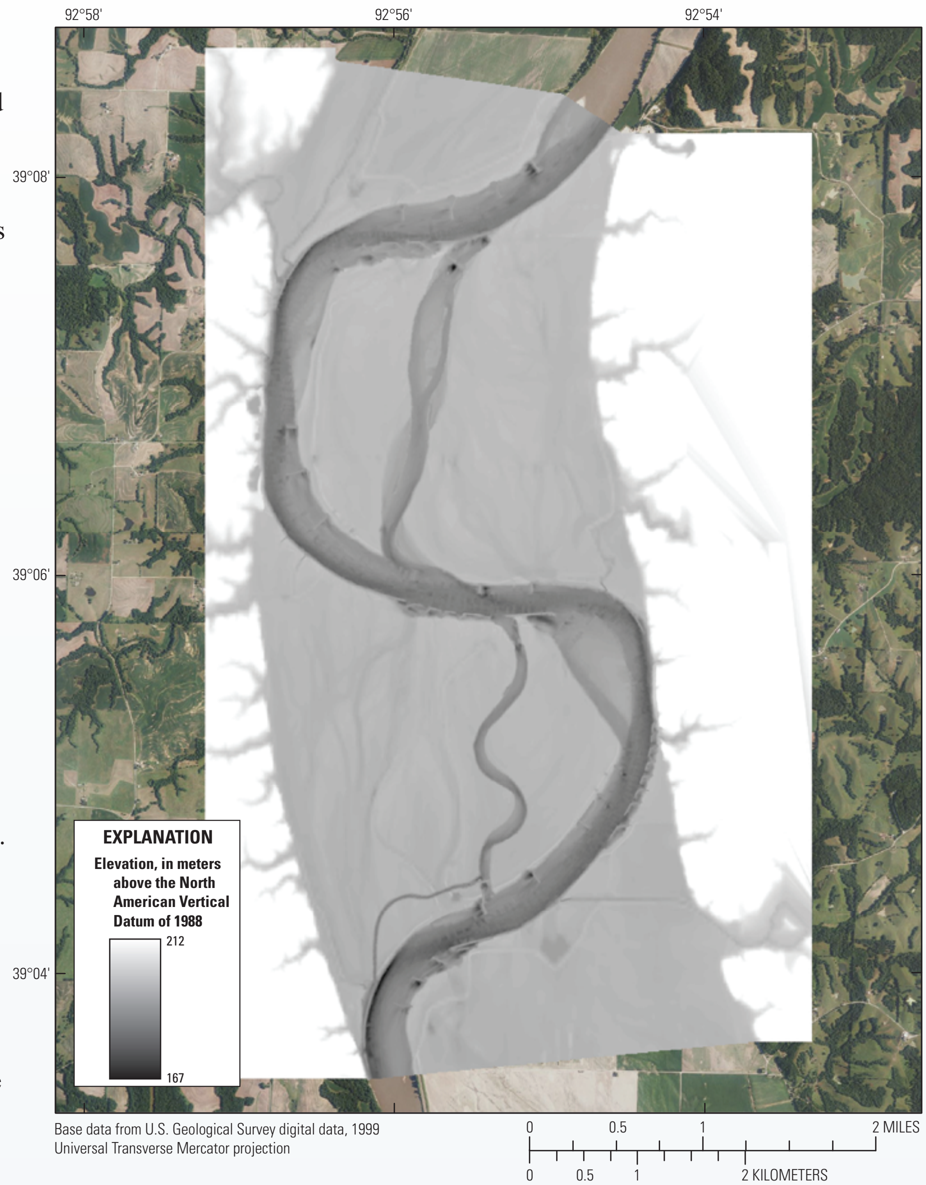

Figure 3. Example of a 2-dimensional hydrodynamic modeling reach used in the Missouri River Pallid Sturgeon Effects Analysis (Jacobson and others, 2016a).

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