Missouri River Recovery Program

2019 ESA Adaptive Management Compliance Report

for Endangered Species Act Compliance, Adaptive Management Implementation, and Fish & Wildlife Mitigation

U.S. Army Corps of Engineers
Northwestern Division

24 April, 2020

The Missouri River Recovery Program (MRRP) enables the USACE to operate the Missouri River Mainstem Reservoir System in accordance with the Missouri River Master Water Control Manual, operate and maintain the Missouri River Bank Stabilization and Navigation Project, and operate the Kansas River Reservoir System to meet their authorized purposes, while also complying with the requirements of the Endangered Species Act and other federal laws and regulations.

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EXECUTIVE SUMMARY

INTRODUCTION

The annual ESA Adaptive Management Compliance Report for the Missouri River Recovery Program (MRRP) serves two primary purposes: 1) it documents activities undertaken on the Missouri River by the U.S. Army Corps of Engineers (USACE) to fulfill requirements of the Endangered Species Act (ESA), including the implementation of the MRRP Science and Adaptive Management Plan (SAMP), and 2) it provides the foundation for discussions and decisions regarding adjustments to the MRRP Strategic Plan under an adaptive management (AM) framework.

This report was prepared under the 2018 biological opinion (BiOp) and associated incidental take statement (ITS) issued by the U.S. Fish and Wildlife Service (USFWS) for the effects of Operation of the Missouri River Mainstem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project (BSNP), Operation of the Kansas River Reservoir System, and Implementation of the Missouri River Recovery Management Plan.

The MRRP employs an active AM strategy because it offers the potential for significant improvement in performance, lower costs, and lower risks than conventional approaches to endangered species compliance, including those with passive AM. Accordingly, several adjustments to the MRRP were under consideration in 2019. Concepts regarding interception and rearing complex (IRC) implementation are evolving due to input from stakeholder engagements, as well as monitoring and research results that call into question the need for food and foraging habitat. Through the Fort Peck Environmental Impact Statement (EIS), the USACE is investigating new management actions involving flows at Fort Peck Dam to determine their feasibility to help achieve pallid sturgeon recruitment to age-1 (MRRP sub-objective 1) in the Upper Missouri River. New models developed to support the Fort Peck Environmental Impact Statement (EIS) provide enhanced decision support capabilities for management on both the upper and lower Missouri River. The USACE began exploring new management strategies for emergent sandbar habitat (ESH) that focus on cost-effective improvements to habitat quality, and planned ESH construction was postponed for several years due to new habitat created by high basin runoff and flows, which substantially lowered near-term program costs.

BASIN CONDITIONS FOR THE REPORTING YEAR

Over 60 million acre-feet of runoff was recorded above Sioux City, Iowa for the October 2018 to October 2019 water year, making it the second wettest on record (Figure ES-2). The previous water year, 2018, which had been the third wettest on record, is now fourth. Gavins Point Dam releases reached a maximum daily average of 90,500 cfs following a rain-on-snow event in mid-March. High flows and reservoir pool levels had many implications for the MRRP, as noted throughout this report.

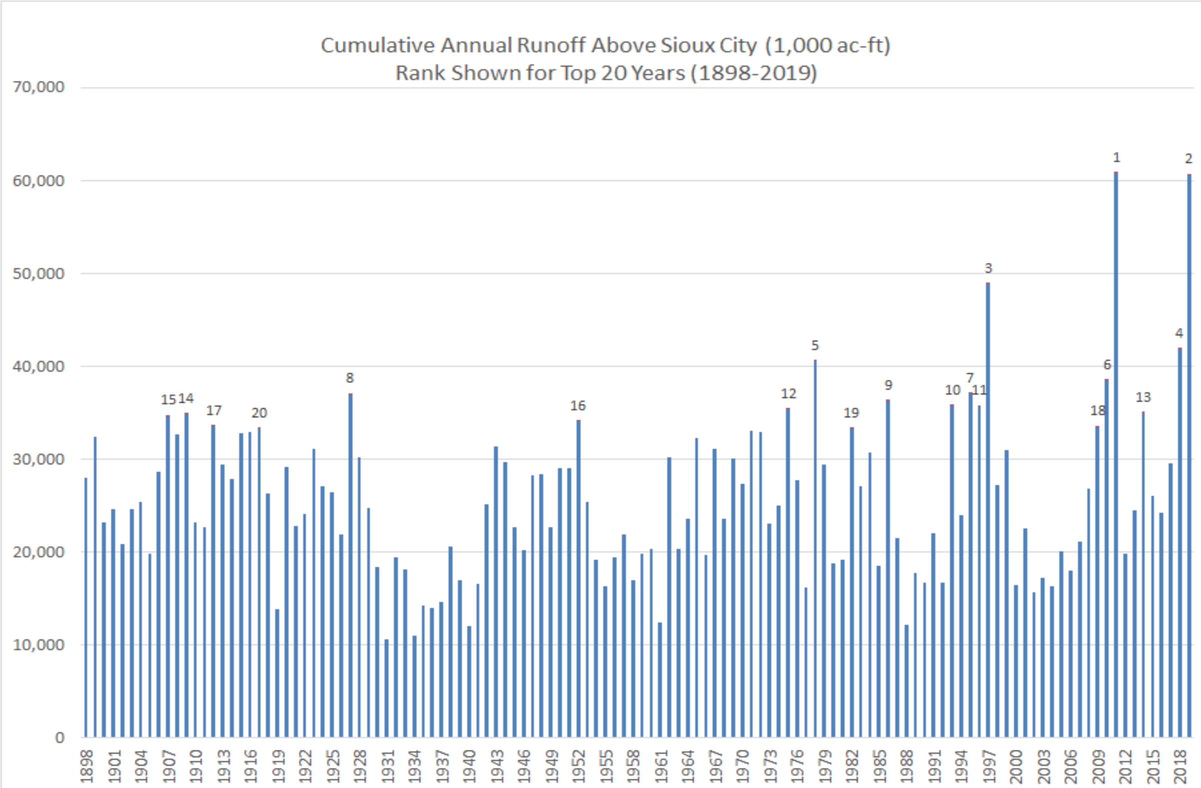

Figure ES-1. Basin runoff above Sioux City and rank for highest 20 water years (1898-2019).

BiOp Compliance

Coordination: USACE and USFWS coordination included regular meetings of the Implementation and Management Teams, two formal in-person In Progress Review (IPR) meetings, the Fall Science Meeting, AM Workshop, and two MRRIC plenary meetings. Actions implemented in 2019 are summarized in Chapter 1. In compliance with its amended Biological Assessment, the USACE investigated test flows from Fort Peck and coordinated the study with the USFWS at several points during the year.

Incidental Take: Incidental take (take) statements in the 2018 BiOp authorized a limited amount of take through Section 9 of the ESA, provided the USACE implements the actions proposed in the Biological Assessment (BA; USACE 2017), undertakes the reasonable and prudent measures (RPMs) described in the BiOp, and does not exceed the indicated levels of take. Figure ES-2 is a dashboard showing the performance of the MRRP relative to take metrics. Metrics are presented for plovers and terns only; the data needed by the agencies to assess incidental take for pallid sturgeon will not be available until full implementation of the Pallid Sturgeon Population Assessment Program (PSPAP) v. 2.0.

The USACE met all 15-yr moving average incidental take metrics for plovers and terns for 2019. Multi-year metrics also fell within anticipated ranges except for plover and tern eggs on riverine segments and plover eggs on reservoir segments (Table 1-5). Because these targets must be met for only two or three years of 15, missing targets for 2019 does not fail the criterion. See Section 1.5.1 for further discussion.

Incidental Take

1. Inundation of eggs and chicks

Aim is to be below the Benchmark take %

Species	Habitat	Latest Situation: 2019 15 yr ave %	B'Mark take %	% Below B'mark in 2019	Progress: Running Tally 2018-2032	Requirement: Must be below Benchmark...	Status	Key messages
Plover	River	4.0%	7.6%	3.6%		Every year	✓	USACE attempts to minimize all take. It must below a 15 yr ave of 4% every year.
			3.4%	-0.6%		At least 3/15 years	✓	Take must be below this benchmark in at least 3 years in the period 2018-2030; a slight reduction will accomplish this aim.
Plover	Reservoir	18.4%	27.3%	3.6%		Every year	✓	
			18.0%	-0.4%		At least 2/15 years	✓	Take needs to be below this benchmark twice in the period 2018 to 2032.
Tern	River	2.5%	6.9%	4.4%		Every year	✓	
			1.1%	-1.4%		At least 2/15 years	✓	These are multi-year metrics and take must be below the indicated value only two of the next 13 years to meet both benchmarks.
			3.1%	0.6%		At least 3/15 years	✓	
Tern	Reservoir	9.9%	15.6%	5.7%		Every year	✓	
			11.8%	1.9%		At least 6/15 years	✓	

2. Suppression of natural disturbance dynamics

Aim is to be above the Benchmark # birds

Species	Lifestage	Latest Situation: 2019 15 yr ave # birds	B'Mark # birds	% Above B'mark in 2019	Progress: Running Tally 2018-2032	Requirement: Must be above B'mark...	Status	Key messages
Plover	Adults	725	402	180%		Every year	✓	
			600	121%		At least 3/15 years	✓	Plover populations remain well above targets despite a decline in the Northern Region in recent years likely related to flow and reservoir pool condiitons.
			500	145%		At least 8/15 years	✓	
Plover	Fledglings	409	226	181%		Every year	✓	
			300	136%		At least 12/15 years	✓	
Tern	Adults	672	488	138%		Every year	✓	
			600	112%		At least 3/15 years	✓	
			500	134%		At least 14/15 years	✓	Tern populations remain above targets in both regions.
Tern	Fledglings	294	228	129%		Every year	✓	
			257	114%		At least 7/15 years	✓	

Figure ES-2a. MRRP incidental take dashboard for plovers and terns.

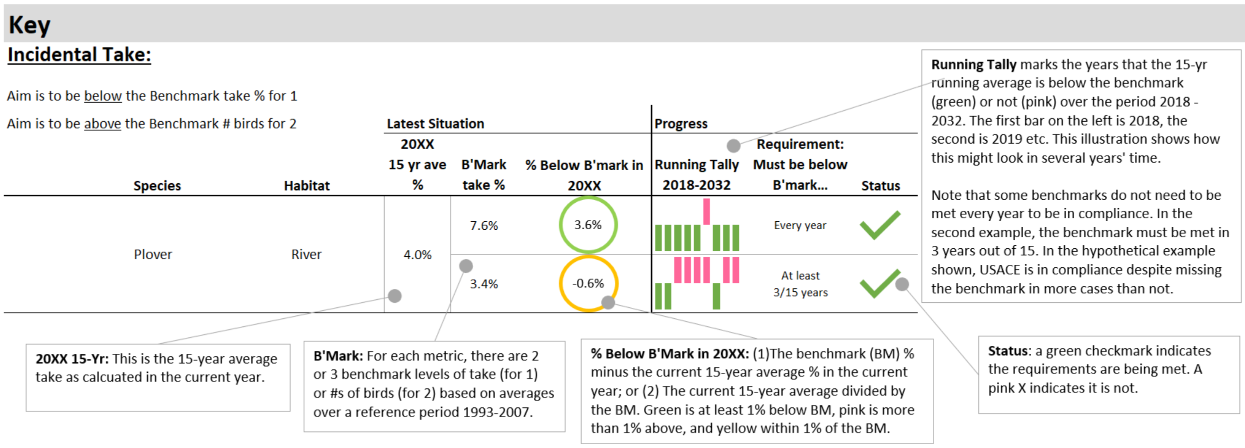

Figure ES-2b.   Key to MRRP incidental take dashboard for plovers and terns.

Apparent survival in the Upper River* and apparent survival and catch per unit effort (CPUE) in the Lower River are the primary metrics for establishing take of the pallid sturgeon. Growth rate, fish condition, reproductive cycling, and abundance (Upper River only) serve as secondary metrics to help understand conditions but do not determine take. Although the USACE and USFWS have worked to identify the information needs and reporting requirements, they will not be able to assess incidental take for pallid sturgeon until full implementation of the PSPAP v. 2.0 after 2020.

Conservation Recommendations: Section 18 of the 2018 BiOp provides conservation recommendations for the USACE to consider during project implementation. Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a Management Action on listed species or critical habitat, to help implement recovery plans, or to develop information. Chapter 1 summarizes the actions implemented as part of the Section 7(a)(1) plan, and Appendix 1 summarizes the status regarding the conservation recommendations. High runoff in 2019 severely limited opportunities to implement certain actions or operations, but the USACE remained active in addressing conservation recommendations involving studies, data acquisition, and coordination, etc. (see Table 1-2).

Progress towards Targets and Objectives

Figure ES-3 is a dashboard summary of metrics relevant to the MRRP sub-objectives for piping plovers. Targets for ESH were met again in 2019 for both regions despite low values of available ESH due to high flows. The 3-year average population growth rate and fledge ratio were below target values in both regions, reflecting the low availability and decreasing quality of ESH and reservoir shoreline habitat over that timeframe resulting from high flows as well as the related effects of nest inundation and predation.

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* As applied in the BiOp, "Upper Missouri River" and "Upper River' denote the Missouri River upstream from Lake Sakakawea. "Lower Missouri River" and "Lower River" denote the Missouri River from Gavins Point Dam, South Dakota, to confluence with the Mississippi River near St. Louis, Missouri. "Middle Missouri River" is used for the remainder of the river dominated by impoundments and inter-reservoir reaches.

Targets and Objectives

Sub-Objective	Metric	Location	2019 #	Ave #	Target #	% of Target	10-yr Trend	Progress Requirement	Status	Key messages
SUB-OBJECTIVE 2: Population	Standard ESH (acres)	North	1,346	NA	450	299%		3/4 yrs > target	✓	High flows in 2017-2019 have increased standard ESH acreage, reversing the post-2011 trend of diminishing ESH. See Section 2.2.2.1.
		South	9,786	NA	1,180	829%			✓	
SUB-OBJECTIVE 2: Population	Available ESH (acres)	North	4 out of 4 thresholds met	NA	4 out of 4 thresholds met	4/4		Exceeds 4 acreage thresholds over 12 yrs	✓	Exceptionally high runoff for 3 consecutive years has limited habitat availability despite an increase in standard ESH. See Section 3.2.2.2.
		South	4 out of 4 thresholds met	NA	4 out of 4 thresholds met	4/4			✓	
SUB-OBJECTIVE 3: Population Dynamics	Piping Plover Growth rate (λ)	North	0.68	0.66	1	66%		3 yr geo mean ave > 1	✗	Despite a slight increase over 2018 for the Northern Region, a declining growth rate in both regions is consistent with trends in available ESH (Section 2.2.3.2).
		South	0.90	0.97	1	97%			✗	
SUB-OBJECTIVE 4: Reproduction	Piping Plover Fledge ratio	North	0.64	0.60	1.14	56%		3 yr arith mean ave > 1.14	✗	Fledge ratios improved in 2019, but remain well below targets. An increase is expected if runoff returns to more normal conditions.
		South	0.68	0.75	1.14	60%			✗	

Key

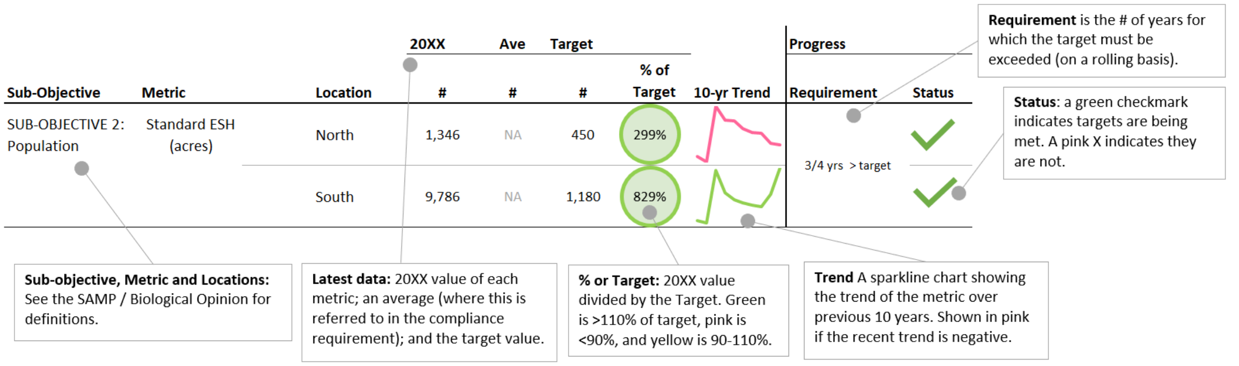

Figure ES-3. Dashboard for 2019 ESH and plover targets and objectives.

High runoff in 2019 resulted in flows and reservoir levels that severely limited shoreline and ESH availability during the nesting season for terns and plovers. Limited nesting opportunities and resulting high predation rates have depressed fledge ratios and population growth rates since 2017. However, new sandbar habitat created by high flows may temporarily reverse the declining ESH acreage trend since 2011. The likelihood of increased ESH availability next year suggests that fledge ratios would increase. Birds nesting on newly-created sandbars or sandbars with habitat quality improved by high flow may experience less predation, but predation will likely remain a stressor.

Figure ES-4 provides a dashboard summary of metrics relevant to the MRRP pallid sturgeon sub-objectives. New metrics are available in 2019 as a result of the implementation of PSPAP v. 2.0 (Section 3.2.4), and other metrics are anticipated soon as the pallid sturgeon population model (Section 3.5) is further developed.

Targets and Objectives

Sub-Objective	Metric	Location	2019 #	95% CI #	Target #	% of Target	10-yr Trend	Progress: Requirement	Status	Key messages
SUB-OBJECTIVE 1: Recruitment	Catch rate of naturally produced age-0/1 PS (Sections 3.2.2.1, 3.2.2.4).	Upper River	NA	NA	>1			Measurable recruitment	✗	No naturally reproduced PS have been captured in the Upper River, no measurable recruitment to age 1. 2019 genetics not complete.
		Lower River	NA	NA	>1				✓ / ⓘ	Direct evidence of natural reproduction and survival to exogenously feeding stage. Despite no direct confirmation, recruitment to age 1 is supported by four indirect lines of evidence that survival past age 1 has occurred (section 3.2.1.1).
	Abundance of naturally produced age-0/1 PS using data for age 0-4 fish	Upper River	NA	NA	>1		not available	Measurable recruitment	ⓘ	This metric is pending further development of the pallid sturgeon model and refinement of age-length keys.
		Lower River	NA	NA	>1		not available		ⓘ	
	Survival of naturally produced PS to age-1, using data for age 0-4 fish	Upper River	NA	NA	TBD		not available	Measurable recruitment	ⓘ	This metric is pending further development of the pallid sturgeon model and refinement of age-length keys.
		Lower River	NA	NA	TBD		not available		ⓘ	
SUB-OBJECTIVE 2: Population	Abundance of wild-origin plus hatchery-origin palid sturgeon adults (section 3.2.2.1)	Upper River	1,124	157 / 12,668	>5000	22%	not available	>5000 self-sustaining, genetically diverse adult PS in each MU for 2 generations (20-30 years)	✗	2019 estimates from PSPAP v 2.0; past estimates from various studies show declining wild population (see Appendix). Population not self-
		Lower River - Central Lowlands	19,095	3,175 / 100,363	>5000	382%	not available		✓ / ⓘ	Exceeds numerical target. Not known if population is self-sustaining or sufficiently genetically diverse.
		Lower River - Interior Highlands	1,726	128 / 11,085	>1,666 to 5,000	35% to 104%	not available	> 1,666 to 5,000 self-sustaining, genetically diverse adult PS	ⓘ	Lower target (1,666) assumes adults are distributed in proportion to linear lengths of LMOR and mid-Mississippi. Higher target assumes all adults are in LMOR. Assessment depends on target. Not known if population is self-sustaining or sufficiently genetically diverse.
	Catch rates of pallid sturgeon by size class and origin (section 3.2.2.3)	Upper River	0.000	NA	Not defined			Not defined	ⓘ	Upper River shows no significant trend in CPUE for wild or hatchery fish, but zero wild CPUE in 2010, 2011, 2018 and 2019. Wild CPUE shown.
		Lower River	0.015	NA	Not defined				ⓘ	Positive trend in Lower River CPUE for wild fish (shown, may be related to removal of harvest), negative trend for hatchery fish (likely due to less stocking).

Key

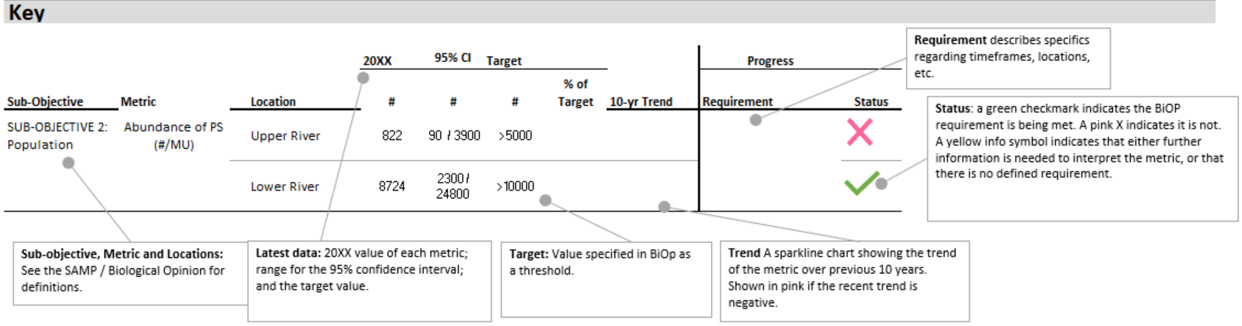

Figure ES-4. Dashboard of progress toward pallid sturgeon objectives.

Recruitment of naturally produced pallid sturgeon to age-1 (a fundamental objective) has not been confirmed in the Upper Missouri River for many years despite some evidence of successful spawning (13 drifting free embryos collected from 2011-2019) and the capture of one fish in 2018 that was stocked during the 2016 drift experiment as a 1-day old larvae. Genetic testing of age-0 sturgeon sampled subsequent to the stocking of 1-day and 5-day old pallid sturgeon downstream of Ft. Peck during the 2019 drift study is not complete as of the drafting of this report. The 2014 and 2018 sampling of genetically confirmed age-0 pallid sturgeon in the Lower Missouri River (4 free embryos and 7 exogenously feeding individuals) has provided evidence of successful spawning in that reach, but the lengths of sampled fish (up to 48 mm) are less than the lengths of age-1 fish. Genetic testing of samples from PSPAP v. 2.0 and other trawling efforts in 2019 is not complete as of the drafting of this report, so additional evidence of successful reproduction and recruitment may develop. While there is no direct evidence of age-1 pallid sturgeon captured in the Lower Missouri River, Section 1.1.1.1 summarizes four indirect lines of evidence indicating that pallid sturgeon that spawned in the Lower Missouri must have reached age-1, likely in the mid-Mississippi River (a hypothesis to be evaluated by trawling in the mid-Mississippi). It is unknown at this point whether natural recruitment to age-1 in the lower river is sufficient to support a self-sustaining population due to remaining uncertainties regarding the level of natural reproduction, contributions of stocking, fish movement, and effective population size (which considers genetic diversity).

For sub-objective 2 (Maintain or increase numbers of pallid sturgeon as an interim measure until sufficient and sustained natural recruitment occurs, Figure 3-2), PSPAP population estimates for wild plus hatchery-origin pallid sturgeon adults in 2019 (Table 3-3) can be compared to the target of 5,000 fish for each management unit (Figure ES-4). An important caveat is that these numerical comparisons do not assess whether each population has sufficient genetic diversity and is self-sustaining. A self-sustaining adult population does not exist in the Upper Missouri River because no natural recruitment has been documented in decades; the median estimates of wild plus hatchery origin pallid sturgeon adults are 22% of the target. Although the 2019 estimates of wild plus hatchery-origin pallid sturgeon adults have considerable uncertainty (see 95% CI in Figure ES-4), the median estimate for the Central Lowlands management unit (19,095 adults) exceeds the target of 5,000. Estimates for the Interior Highlands management unit (1,726) are close to the target of 1,666 (based on pro-rating the relative lengths of the Missouri and Mississippi River within this unit). An intensive mark-recapture effort was completed in the Upper and Lower Basins in 2019. This effort is part of the PSPAP v. 2.0, which will render improved estimates of relevant metrics in the future.

The MRRP has historically relied on catch per unit effort (CPUE)[*] as an indicator of population status and trend, but estimates of absolute abundance will replace CPUE as the primary metric for evaluating progress in the future, providing a more direct comparison to MRRP sub-objective 2 for pallid sturgeon. In the Upper River, there is no evidence of a long-term trend in CPUE for either hatchery (p-value = 0.70) or wild fish (Figure 3-8). In the Lower River, there is strong evidence of a long-term decreasing trend in CPUE for hatchery fish (about 8% per year; p=0.0003) that likely reflects stocking practices (Section 3.3.1). There is also evidence of a long-term increasing trend for wild fish (about 7% per year; p=0.03), which may suggest recruitment, recovery from historic harvesting, or changes in catchability due to year to year changes in temperature or flow at the time of sampling. Population estimates and improved understanding of immigration/ emigration will provide improved understanding of CPUE trends versus catch data alone.

Relative size distribution (RSD), which provides insight into whether recruitment is occurring to adult reproductive populations, shows a progressive increase in the proportion of sub-adult and adult pallid sturgeon for the Upper River, likely due to recent reductions in stocking and aging of previously stocked fish (Figure 3-10). Sub-adult and adult pallid sturgeon have dominated RSD in the Lower River (Figure 3-11). Low proportional catches of pallid sturgeon in the 0-200 mm class suggest little natural recruitment within the Missouri River. This may also be due to sampling issues, mortality of pallid sturgeon stocked at lengths < 200 mm, or other factors.

[*] CPUE represents the number of pallid sturgeon captured using standardized methods for a standardized amount of effort (e.g., number of nets, area trawled, or number of hooks, for example).

Management Action Summary

USACE postponed plans for a 25-acre ESH project in the Garrison segment in 2019 when modeling and field observations confirmed that ESH created by high flows in 2017 and 2018 temporarily reversed post-2011 trends of ESH loss in the segment. Model projections indicate > 0.5 probability of meeting ESH targets without additional construction through 2024 in the Northern Region and 2025 in the Southern Region.

High runoff during 2019 affected management actions in much the same way it did in in 2018. Herbicide application and other vegetation management for ESH could not be implemented due to high flows and stages. Predator management was suspended for study purposes, while human restriction measures were implemented as they have been in past years. Tern and plover monitoring program (TPMP) crews moved or raised 57 at-risk plover nests and 4 tern nests.

Figure ES-5 provides a dashboard for the status of pallid sturgeon management action implementation. More than one million larval pallid sturgeon from 29 families were released for a larval drift experiment below Fort Peck Dam in 2019, bringing the total age-0 releases since 1994 in the Upper Missouri River to more than 2.6 million pallid sturgeon. For the Lower Missouri River, 3,458 age-1 pallid sturgeon (2018 year class) from 13 families were stocked to meet annual targets; totals since 1994 for the reach are approximately 101,858 age-0 and 86,006 age ≥1 pallid sturgeon. Several studies were conducted in 2019 to improve hatchery operations and fish health.

Release of the Pallid Sturgeon Conservation Propagation and Stocking Program (CPSP) Guidance and Planning Document in 2019 by the USFWS fulfilled a major milestone. The CPSP Evaluation Plan (USFWS 2019) outlines how the CPSP program is reported, evaluated, and adapted to contribute to program and pallid sturgeon recovery goals. The USFWS and USACE are collaborating to ensure the evaluation framework and science needs inform and align with the SAMP framework.

No new IRCs were constructed in 2019. IRC sites planned for implementation in 2018 and 2019 on the Lower River were delayed to comply with Section 1226 of the America's Water Infrastructure Act of 2018, which prohibited construction of these habitat projects until the Secretary of the Army submitted a report to Congress regarding the impacts of pallid sturgeon IRC habitat construction on navigation, flood control, and other authorized purposes and the recovery of pallid sturgeon population. The USACE provided a draft report to the Assistant Secretary of the Army (Civil Works) in October 2019 and it was submitted to Congress on March 18, 2020. In the meantime, the USACE developed designs for Straubs Bend (RM 105) and Providence Bend (RM 168) after consultation with stakeholders.

Monitoring continued at proposed and control sites and the two existing IRC sites. Analysis of the existing dataset shows no significant differences in CPUE between treatment and control sites (see Appendix 3.3.2.1). This result was expected; the ability to detect a change from only two sites with little time to evolve is limited. A full evaluation of IRC performance will not be possible until more IRC sites have been implemented and given time to develop, as described in Appendix E1 of the SAMP. Delayed construction has extended the timeframe for this staircase study from 8 years to 10 years.

Construction of the bypass channel at Intake Diversion Dam started in July of 2019 and it is estimated the new weir and by-pass channel will be completed no later than in 2023. The Fort Peck AM Framework, which was released in December 2018, was reviewed by the ISAP and the USACE determined that it would investigate flow alternatives to improve pallid sturgeon recruitment potential on the Upper Missouri River. New advection/dispersion models that incorporate temperature modeling and temperature-dependent development of pallid sturgeon were developed to support the Fort Peck

EIS. The pallid sturgeon demographic population model was parameterized for the EIS to assess the effects of alternatives on population levels for the upper basin.

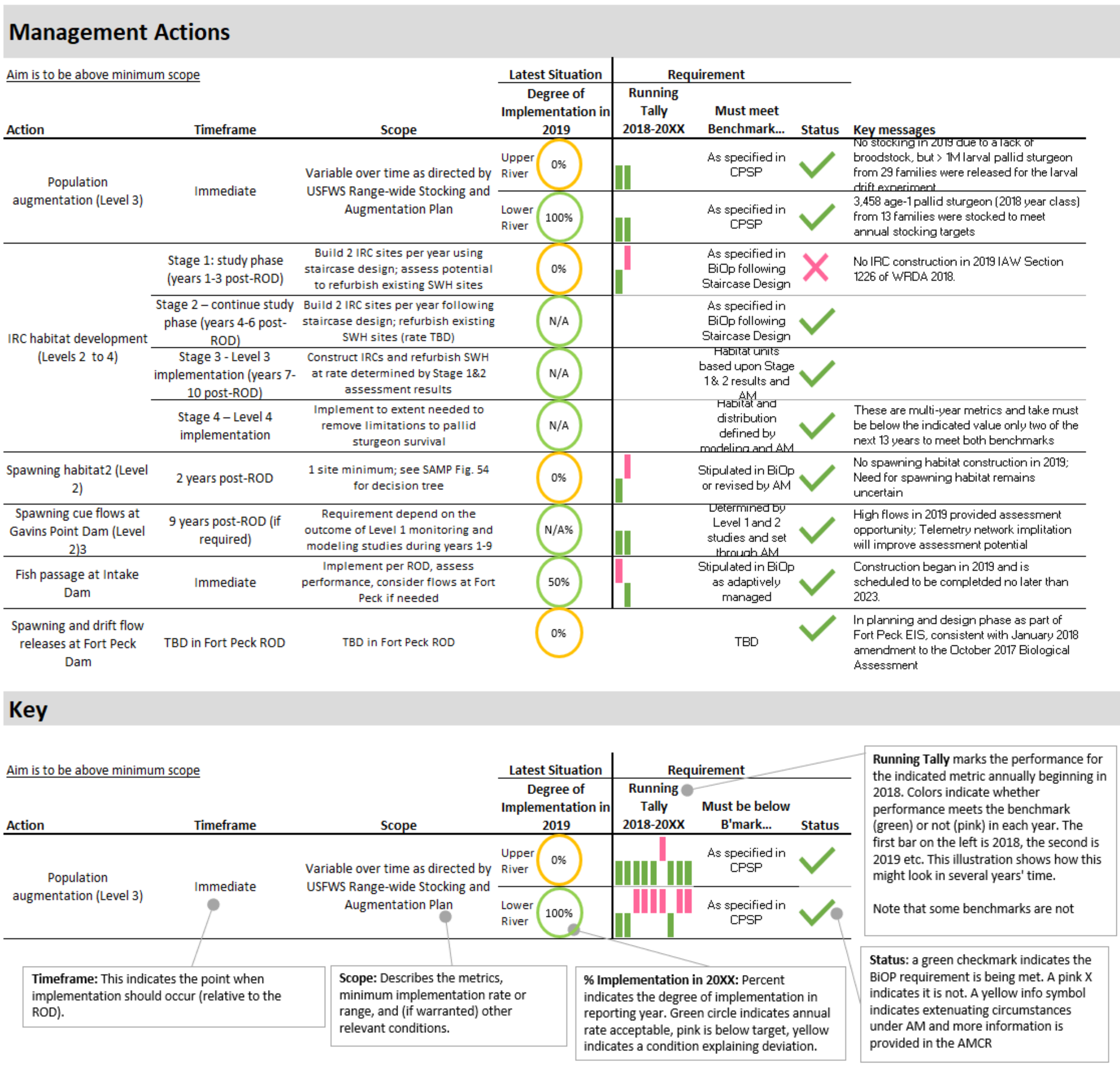

Figure ES-5. Dashboard for the implementation status of pallid sturgeon management actions.

KEY ISSUES FOR 2020

In preparation for its annual Fall Science Meeting, the MRRP identifies a set of "Key Issues" that require analysis and discussion throughout the annual AM governance process in order to inform decisions reflected in the MRRP Strategic Plan. Topics identified for this level of engagement are summarized in Table ES-1 and described in Sections 2.7.1 and 3.7 for the birds and pallid sturgeon, respectively.

Table ES-1. Summary of Key Issues for 2020.

Issue	Brief Description	Decision Relevance
Birds		
Monitoring	Population and effectiveness monitoring strategies for the birds and bird management actions have been prepared; decisions on their implementation are contingent upon their testing on the Gavins Point segment in 2020.	Monitoring is fundamental for evaluating program progress, provides essential information to future decisions, and is a substantial program cost.
Need for ESH construction	High flows have deferred ESH construction needs, but projections indicate construction may be needed for the Northern Region in 2022 or 2023 (75% chance of exceeding targets).	Decisions regarding acreages, locations, and risk management strategies are necessary for budgeting and planning purposes.
Habitat quality	A better accounting for habitat quality could lead to improvements in monitoring, modeling, and management of ESH for plovers and terns.	Explicit accounting for habitat quality could refine estimates of ESH construction/management need and may lead to alternative management practices.
Dispersal and off-channel habitat	Plovers in the Northern Region use prairie pothole wetlands as well as ESH and reservoir shorelines. Observed dispersal among these habitats has been higher than previously thought.	Understanding the effects of dispersal could lead to adjustments to target criteria in the Northern Region.
Predation management	Predation rates, impacts on productivity, and effectiveness of predator control under different conditions remain uncertain.	Predation management may increase productivity and provide a cost-effective supplement to ESH, particularly when habitat is limited.
Pallid Sturgeon		
Passage at Intake Dam and Flow Management at Fort Peck Dam	The Fort Peck EIS will be completed in 2021 and construction of the Intake Fish Passage project completed no later than 2023. The former involves considerable coordination and the latter requires effectiveness monitoring.	Passage at Intake and flow management at Fort Peck are actions that, if effective, could contribute to recruitment for the upper basin.
IRC construction	No IRC projects were constructed in 2018 or 2019 pending submittal of the IRC Report to Congress. Ten sites needed to complete the staircase study have been identified; two are in design.	Whether, and when, to proceed with IRC construction and evaluation. Use of surrogates vs. use of age-0 pallid sturgeon to evaluate various hypotheses and focal questions.
Food and foraging habitat	Level 1 research confirms the preliminary results in 2018 showing similarities between shovelnose and pallid sturgeon habitat use and diets, and that age-0 fish (almost entirely shovelnose) do not appear to be food-limited.	Potential revisions to the criteria used to define habitat that needs to be associated with IRCs (or modified shallow water habitat (SWH) sites).
Population monitoring and modeling	PSPAP v. 2.0 is coming online and significant enhancements have been made to the population model. New data and new analytical capabilities may shed significant light on critical uncertainties.	Monitoring strategies will likely require some adjustments, and this is a significant program cost. New insights from analyses could alter targets and actions.
Stocking and augmentation	Release of the CPSP Guidance and Planning Document and the Evaluation Plan provides new direction on stocking numbers and ages, genetics, and other considerations.	Changes a key management action with ramifications for monitoring, assessment, and potentially other program elements.

Issue	Brief Description	Decision Relevance
Spawning habitat	No spawning habitat projects have been planned or designed. Level 1 research showed that spawning and reproduction have occurred and that habitats similar to the Fairview site on the Yellowstone River are prevalent in the channelized Lower River. Additional confirmation and quantification of reproductive success is needed.	Need to continue to evaluate data to assess need for spawning habitat and risks of creating spawning habitat in areas where some successful spawning is occurring; current consensus is that near-term implementation is not warranted.

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PREFACE

The MRRP Technical Team prepared significant components of this report. Technical Team Members included: Kate Buenau, Pacific Northwest National Laboratory; Graham Long, Compass Resource Management Ltd.; and David Marmorek, ESSA Technologies Ltd. Additional assistance from the following is acknowledged: technical editing (Carol Murray, ESSA Technologies Ltd.); assembly and presentation of data on flows (Mike Swenson, USACE); assembly and presentation of data on birds (Chantel Hofer and Coral Huber, USACE); assembly, presentation and synthesis of data and research on pallid sturgeon (Marc Nelitz, Brian Ma and Darcy Pickard, ESSA Technologies Ltd.; Mike Colvin and Sara Reynolds, Mississippi State University; Ed Bulliner, USGS; Kirk Steffensen, Nebraska Game and Parks Commission; Nate Gosch, Tim Welker and Todd Gemeinhardt, USACE; Landon Pierce, USFWS).

ACRONYMS AND ABBREVIATIONS

AM................................Adaptive management
AOP ....Annual Operating Plan
BiOp..............................Biological Opinion
BQ ....Big Question
BSNP.............................Missouri River Bank Stabilization and Navigation Project
CEMs ....Conceptual ecological models
cfs ....Cubic foot (feet) per second
CPUE ....Catch per unit effort
CSRP ....Comprehensive Sturgeon Research Project
EA ....Effects Analysis
ESA ....Endangered Species Act
EIS ....Environmental Impact Statement
ESH ....Emergent sandbar habitat
ESHER...........................Emergent Sandbar Habitat Evaluation and Ranking
ft...................................foot (feet)
HCs ....Human considerations
IRC ....Interception and rearing complex
ITS..................................Incidental take statement
kcfs ....Thousand cubic feet per second
MRRIC...........................Missouri River Recovery Implementation Committee
MRRP............................Missouri River Recovery Program
MSL...............................Mean sea level
NWK ....USACE Kansas City District
NWO.............................USACE Omaha District
NEPA.............................National Environmental Policy Act
PEIS...............................Programmatic Environmental Impact Statement
POR...............................Period of record
PSDMS..........................MRRP Pallid Sturgeon Data Management System
PSPAP ....Pallid Sturgeon Population Assessment Program
RM ....River mile
RPMA ....Recovery Priority Management Area
RPMU ....Recovery Priority Management Unit
RSD ....Relative size distribution
SAMP............................Science and Adaptive Management Plan
SWH..............................Shallow water habitat
TPMP............................Tern and Plover Monitoring Program
USDA ....United States Department of Agriculture
USACE...........................United States Army Corps of Engineers
USFWS...........................United States Fish and Wildlife Service
USGS.............................United States Geological Survey
WRDA...........................Water Resources Development Act

1 2019 Compliance

1.1 Background

The Missouri River Recovery Program (MRRP) 2019 ESA Adaptive Management Compliance Report (AMCR) was prepared under a Biological Opinion (BiOp) and associated incidental take statement (ITS) issued by the U.S. Fish and Wildlife Service (USFWS) on April 13, 2018 for the effects of operation of the Missouri River Mainstem Reservoir System, operation and maintenance of the Missouri River Bank Stabilization and Navigation Project, operation of the Kansas River Reservoir System, and implementation of the Missouri River Recovery Management Plan. This BiOp (USFWS 2018) supersedes the 2003 Amended BiOp and associated ITS dated December 16, 2003. ESA Compliance and AM reports prior to 2018 were prepared under the 2003 Amended BiOp and historical data presented in this report reflect those requirements.

The Science and Adaptive Management Plan (SAMP) is a critical component of the MRRP and the 2018 BiOp, and it identifies the process and criteria for implementing and assessing MRRP management actions. Additionally, the U.S. Army Corps of Engineers (USACE) has committed to implementing conservation measures and a Section 7(a)(1) plan that will further avoid and minimize effects to the listed species (see Section 1.4).

The 2018 BiOp is complex because the MRRP Management Plan has a long duration and includes both immediate actions and a SAMP to test hypotheses, assess the effects of actions, and propose implementation of possible future actions in the Missouri River system. The MRRP Management Plan analyzed in the recent consultation fits the description of a mixed programmatic action because it includes immediate actions and anticipates, through adaptive management (AM), changes to current actions and/or identification of future actions that may be subject to consultation under Section 7 of the Endangered Species Act (ESA).

As the need to change current actions is identified, or when potential future actions are defined, the consultation requirement under Section 7(a)(2) of the ESA may be triggered even though those changes or future actions are intended to benefit the likelihood of survival and recovery of listed species. As described in the 2018 BiOp, the most appropriate and efficient way to review future actions is through annual reporting and review. The AMCR presents an examination by the action agency of how the activities in the reporting year have aligned with the action proposed under the consultation. It also presents results of monitoring and analysis of the effectiveness of those actions relative to BiOp objectives and summarizes changes in relevant scientific understanding. The USFWS uses the AMCR, together with a Strategic Plan that identifies proposed changes and additional actions for the immediate future, to assist the USACE in satisfying additional compliance with Section 7(a)(2). That assistance is likely to take the form of a statement of consistency with the framework and conclusions of the 2018 BiOp and a statement of exemption of take as necessary.

1.2 Purpose and Scope

The Annual ESA Adaptive Management Compliance Report for the MRRP serves two primary purposes: it documents activities undertaken on the Missouri River by the USACE to fulfill requirements of the ESA, and it provides the foundation for discussions and decisions regarding adjustments to MRRP actions (and the Strategic Plan) under an AM framework.

1.3 Conditions During Reporting Year

Runoff into the reservoir system in 2019 was 60.9 million acre-feet (MAF), the second-highest runoff in 121 years of record-keeping (1898-2018). This runoff was exceeded only in 2011 (61.0 MAF). System storage ranged from 56.0 to 68.5 MAF.

Gavins Point releases generally ranged from 18,000 cfs during the winter of 2019 to 70,000 cfs in the summer and fall. There was a short period with daily average releases as high as 90,000 cfs following the rain-on-snow event in mid-March (Figure 1-1). Because of the high runoff, releases from Gavins Point were made to evacuate water from the reservoir system following Master Manual guidance. Releases were mostly in the 70,000 to 80,000 cfs range from late May through November. The higher releases ensure evacuation of stored flood water. Gavins Point releases are shown in Figure 1-1. Fort Randall releases generally followed the Gavins Point releases less the inflows between the two projects.

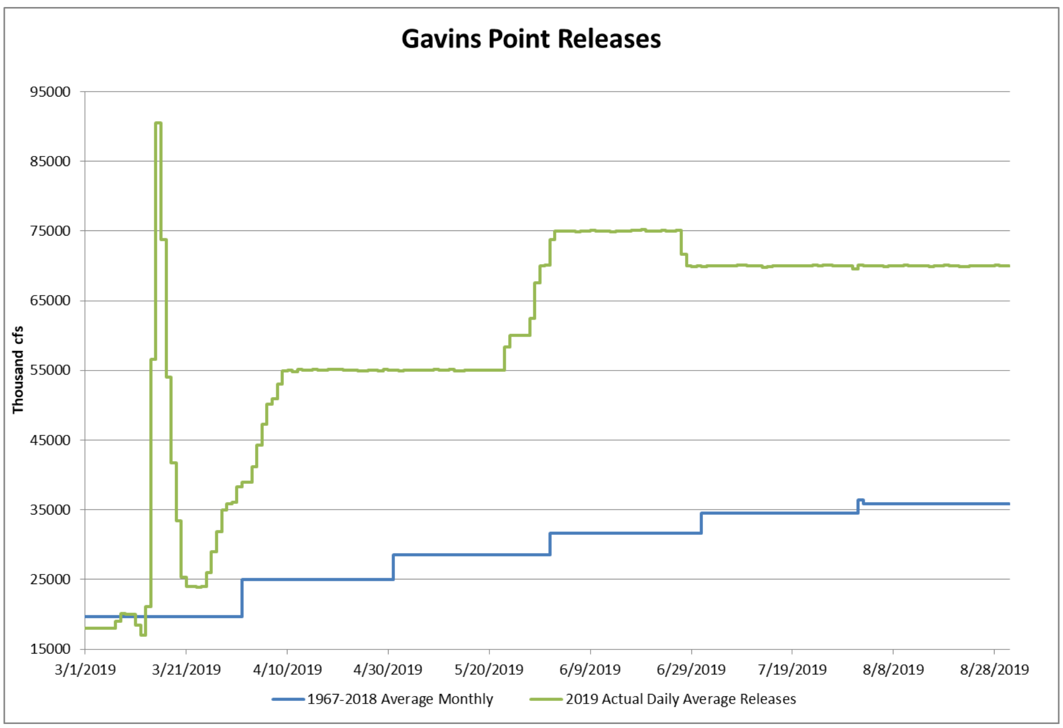


Figure 1-1. Flow releases from Gavins Point.

Fort Peck summer releases (June-August) ranged from 15,000 cfs to 20,000 cfs, compared to a long-term daily average of 10,300 cfs for those months. Garrison summer releases (June-August) ranged from 40,000 to 60,000 cfs, also exceeding the long-term averages of about 25,000 cfs for this period. Releases from Fort Peck and Garrison are shown in Figure 1-2 and Figure 1-3.

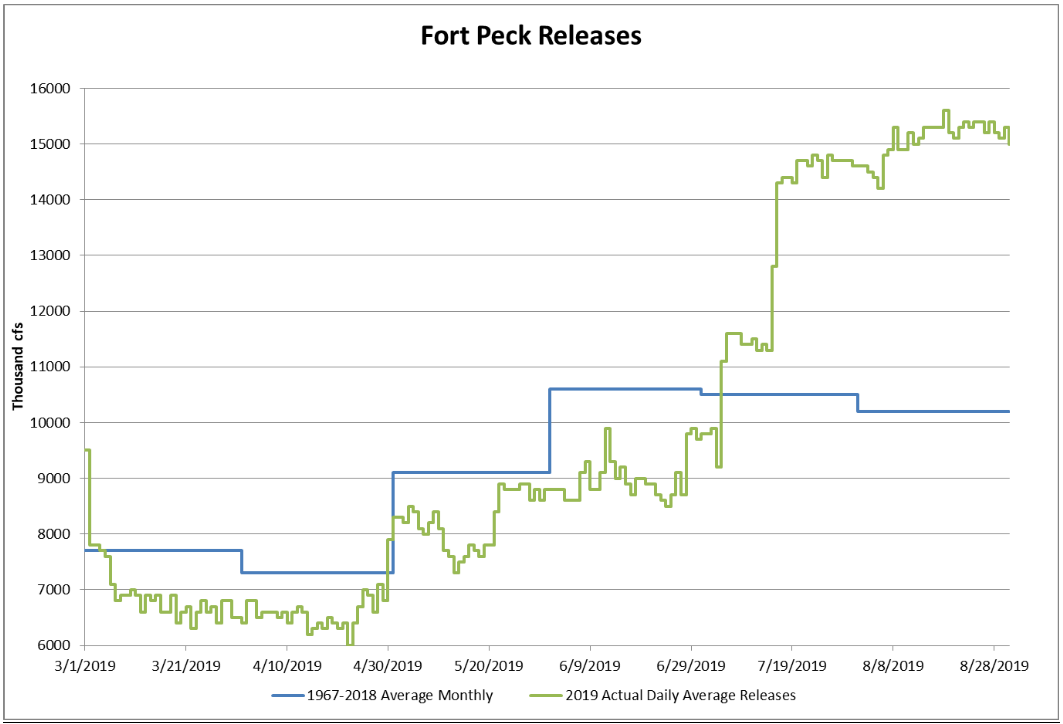


Figure 1-2. Flow releases from Fort Peck.

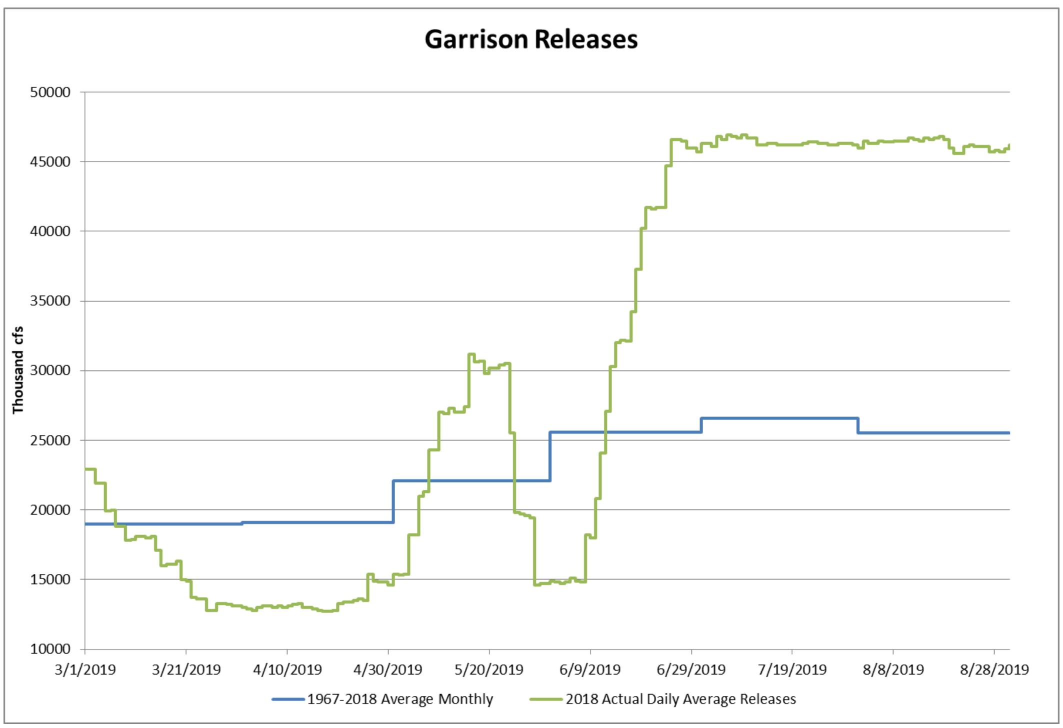


Figure 1-3. Flow releases from Garrison.

Fort Peck, Garrison, and Oahe reservoir pool levels reached or were near the base of their respective Annual Flood Control and Multiple Use Zones prior to the start of the 2019 runoff season. The reservoir level at Fort Peck rose from 2234.3 feet in early March to a peak elevation of 2246.8 feet in July, 0.8 feet into the Exclusive Flood Control Zone that extends from 2246 to 2250 feet. The reservoir at Garrison climbed from an elevation of 1836.9 feet in mid-March to a peak elevation of 1852.5 feet in early July, 2.5 feet into the Exclusive Flood Control Zone, which extends from 1850 to 1854 feet. The Oahe reservoir pool elevation ranged from 1605.8 feet (1.7 feet below the base of the Annual Flood Control and Multiple Use Zone) in February to a peak of 1618.8 feet in May (1.8 feet in the Exclusive Flood Control Zone which extends from 1617 to 1620 feet). From the beginning of May to the end of June, Fort Peck and Garrison reservoir levels rose 5.8 and 5.4 feet, respectively. The Oahe reservoir pool elevation peaked in May, and then began to decline, ending in June 0.2 feet higher than at the beginning of May. Garrison and Oahe reservoir elevations for the May-August period for 2016-2019 are shown in Figure 1-4 and Figure 1-5.

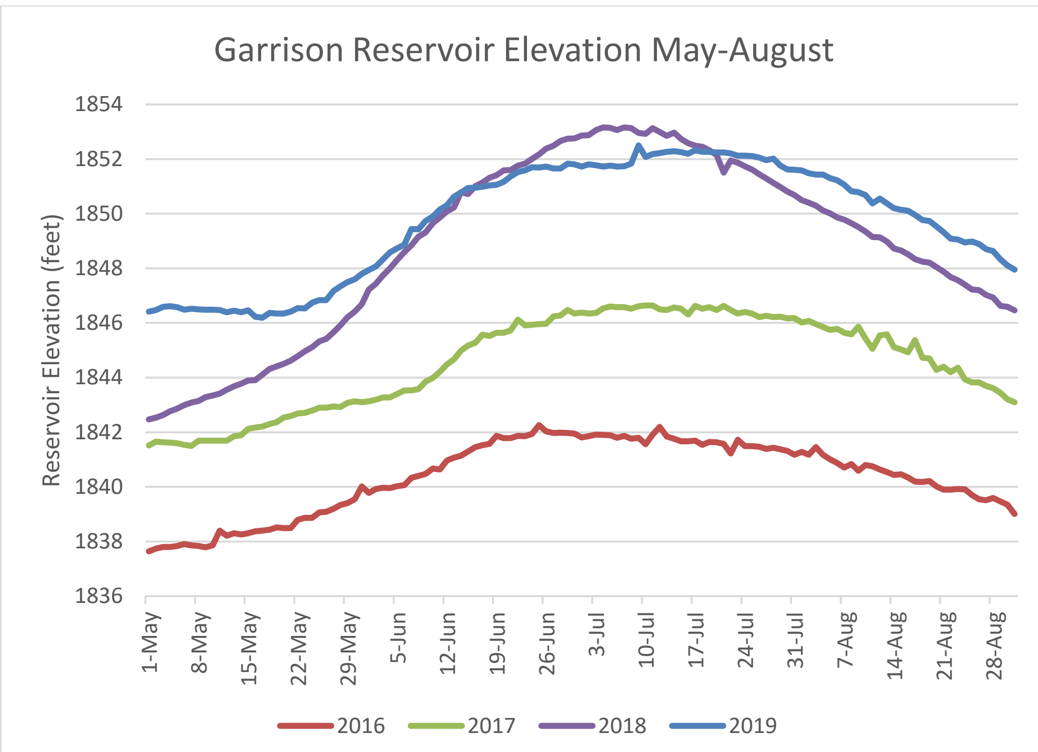


Figure 1-4. Garrison reservoir pool elevations May-August.

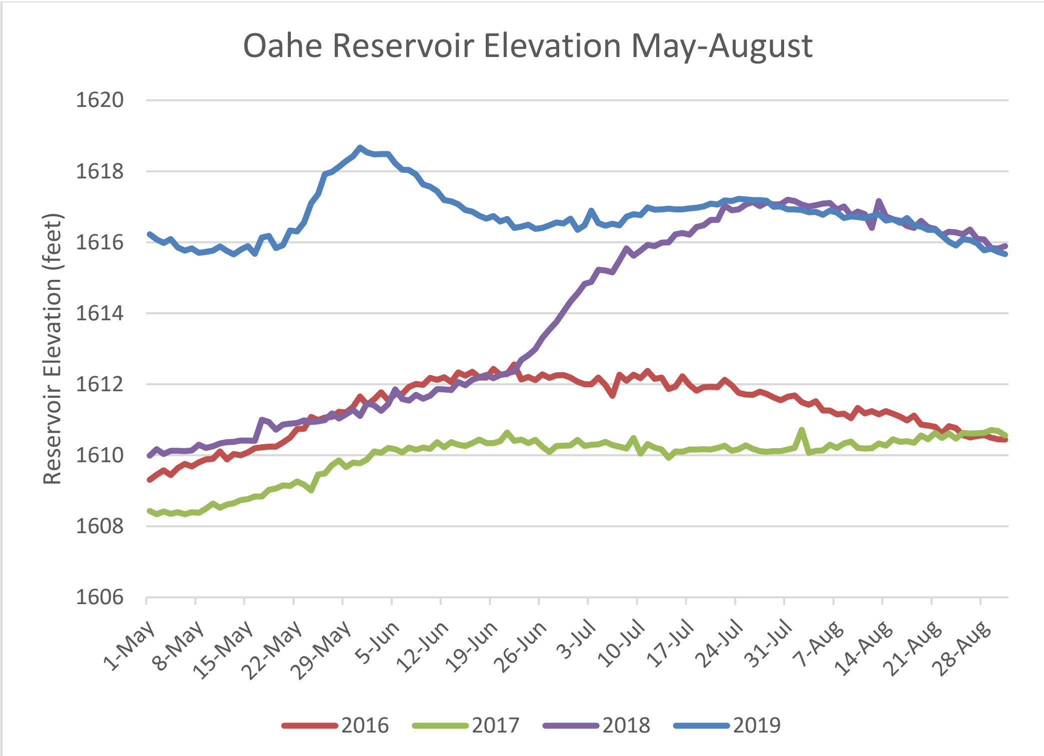


Figure 1-5. Oahe reservoir pool elevations May-August.

1.4 Compliance Activities in Reporting Year 2019

Topics included in this section are part of the annual review and reporting process required by the BiOp. Section 1.4.1 lists site-specific projects for actions covered under the BiOp that were implemented in the reporting year, proposed changes for future years, and any changes from what is described in the BiOp. A brief description of actions or studies conducted in the reporting year, planned studies or actions not conducted, recommendations or "lessons learned" to improve processes described in the SAMP, and suggestions to improve coordination among both agencies are included.

Conservation recommendations pursuant to Section 18 of the 2018 BiOp are presented in Section 1.4.2 . The management action included a Section 7(a)(1) conservation plan for a variety of ESA listed species in the Kansas City and Omaha Districts. These actions are summarized in Section 1.4.3 .

1.4.1 USACE Management Plan Including Adaptive Management

Table 1-1 summarizes the actions implemented in the reporting year as part of the Management Plan. High flows precluded work on the BSNP in the Kansas City District during 2019. Changes or potential changes to the Management Action are described in responses to questions below the table.

Table 1-1. USACE management actions implemented in reporting year 2019.

Operations & Maintenance of the Bank Stabilization and Navigation Project	
Types of O&M	# Implemented in Reporting Year
Routine Maintenance of Existing Rock Filled Structures	
Revetments	1
Dikes	2
Sills	0
Crossing Control Structures (Kickers)	0
Changes to the Footprint of Structures	
Landward Dike Extensions	1
Riverward Dike Extensions	0
Hardpoints	0
Construction of New Dikes	0
Piles	0
Structure Lowering	0
Additional Information: The above numbers are within the estimates provided in the 2018 BiOp.	
Least Tern and Piping Plover Management Actions[1]	
Action	Description of Implementation
Mechanical ESH Creation, Augmentation or Modification	None planned or implemented
Vegetation Management	Suspended due to high runoff
Flow Management to Reduce Take	None due to flood evacuation
Nest and Chick Relocation	61 nests moved or raised
Predator Management	No removal; limited nest caging
Human Restriction Measures	68 sites posted
Pallid Sturgeon Management Actions[2]	
Propagation and Augmentation	See Chapter 3 of this report.
Spawning Habitat	None planned or implemented
Interception Rearing Complex	None – suspended for congressional report
Adaptive Management Studies in Reporting Year 2019	
Spatial variation in population dynamics of Northern Great Plains Piping Plovers (Section 2.4.2.1)	
Geomorphic Investigation of ESH in the Garrison Reach (Section 2.4.2.1)	
Monitoring Plan for Piping Plovers (Charadrius melodus) on the Missouri River (Section 2.4.3)	
Implementation Monitoring of Created and Managed ESH in the Missouri River (Section 2.4.3)	
Dietary assessment of age-0 pallid sturgeon and shovelnose sturgeon: implications for surrogacy (Section 3.4.1)	
Development of Pallid Sturgeon and Shovelnose Sturgeon Free Embryos Reared in the Laboratory (Section 3.4.2)	
Physical Characteristics and Simulated Transport of Pallid Sturgeon and Shovelnose Sturgeon Eggs (Section 3.4.3)	
Improved genetic identification of acipenseriform embryos with application to the ESA (Section 3.4.4)	
Assessment of telemetry technologies for monitoring Missouri River pallid sturgeon (Section 3.4.5)	
Integrated A/D and temperature modeling and population growth for Fort Peck EIS (Section 3.5)	
2019 Pallid Sturgeon Drift and Dispersal Experiment in the Upper Missouri (Section 3.6.1)	

1 – see Section 2.3 for details

2 – see Section 3.3 for details

1. **Have any changes to the Management Plan Occurred in Reporting Year?**

   No.

2. **Are there changes proposed for the next reporting year?**
   There are no changes proposed to the management action at this time. However, the USACE is evaluating potential management actions at Fort Peck that could result in test flows for pallid sturgeon spawning and recruitment. Discussions were held in 2019 regarding the need for additional food-producing and foraging habitat for pallid sturgeon in the Lower River; proposed changes to the targets for these habitat types are likely to come from the USACE in 2020. Discussions are also ongoing regarding the need to construct spawning habitat.

3. **What coordination occurred between the USACE and USFWS, and are improvements needed?**
   Coordination occurred between the USACE and the USFWS during 2019 at both staff and management levels, primarily through the MRRP governance process. Participation by USFWS personnel remained challenged in 2019 due to staffing limitations. As implementation of the SAMP proceeds, there will be a continued need for active engagement and effective communication between the agencies.

1.4.2 Conservation Recommendations

Section 18 of the 2018 BiOp provides conservation recommendations for the USACE to consider during project implementation. Although these actions are discretionary, the USACE discusses opportunities to implement these actions when funding or situations allow. Table 1-2 summarizes the status of conservation recommendations included in Section 18 of the 2018 BiOp.

Table 1-2. 2018 BiOp Conservation Recommendations Annual Reporting Form

Conservation Recommendations	Status
Coordinate pallid sturgeon monitoring efforts and information with those entities working on the Mississippi River. **Additional information**: The USACE continues to work with entities working on the Mississippi River. During 2019 USACE staff met with Mississippi River pallid sturgeon research and monitoring crews to discuss standardization of pallid sturgeon sampling efforts between both rivers. USACE staff from the Northwestern and Mississippi River Valley Divisions continue to meet annually to discuss pallid sturgeon monitoring. The USACE Science lead continues to serve on the Rangewide Pallid Sturgeon Recovery Team and USACE staff attended Middle Basin Workgroup activities which include part of the Mississippi River. USACE Science lead is working with partners on the Mississippi River to implement at least some of PSPAP v2 monitoring on the middle Mississippi River.	In Progress
Continue to pursue the completion of fish passage at Intake Dam on the Yellowstone River as authorized by the Water Resources Development Act (WRDA) (2007). **Additional information:** Construction of the fish passage project at Intake Dam was initiated in 2019.	In Progress
Implement recovery actions for pallid sturgeon, piping plover, interior least tern, and other listed species, in coordination with the USFWS, as identified in the most recent recovery plans for those species. **Additional information:** The USACE continues to implement recovery actions for the Missouri River ESA listed species. This includes participation on species recovery teams, implementing the Section 7(a)(1) plan, and actions proposed in the biological assessment.	In Progress

Conservation Recommendations	Status
Consider sturgeon and sicklefin chub when implementing project actions, research, and monitoring. Gathering data on these species will inform future listing decisions. **Additional information:** The USACE funds field crews to collect data on sicklefin and sturgeon chubs as time allows during monitoring efforts.	In Progress
Support the collection of data (i.e., contaminant hazards) necessary for the development of a risk assessment for pallid sturgeon. **Additional information:** During 2019, the USACE funded a pallid sturgeon health study to be conducted by staff at Montana State University and USFWS staff at the Bozeman Fish Technology Center.	In Progress
Support studies to increase the accuracy of estimations of piping plover annual survival rates. **Additional information:** A meta-population study continues through 2020 in the Northern Region. USACE is assisting Virginia Tech by continuing to provide them with resight data from the Southern Region. Virginia Tech continues to analyze and report findings.	In Progress
Determine whether it would be feasible to manage flows to create shoreline habitats, backwater areas, inter-sandbar channels, and ephemeral pools and whether engineered habitats may be designed, located, and constructed to maximize the likelihood of creating these habitat components. **Additional information:** The 2019 runoff to the Missouri River above Sioux City, IA was the 2nd highest of record, exceeded only by 2011. The USACE will utilize this event to evaluate the effects of flows on the habitat types listed above. This information will be utilized to improve the planning and design of future habitat areas created by the USACE as a component of the MRRP.	Under Evaluation
Increase gravel and cobble on areas of mechanically created sandbars and consider the removal of gravel from areas that may function as sinks for nesting plovers. **Additional information:** The USACE initiated a preliminary planning exercise in 2019 focused on innovative and cost-effective means for achieving plover objectives. This includes opportunities to improve habitat quality through mechanisms such as substrate manipulation for enhanced nesting success.	Under Evaluation
Consider addressing shortcomings in remote sensing data (i.e., habitat quality) so suitable nesting habitat for piping plovers is estimated with sufficient accuracy. **Additional information:** A geomorphic assessment was initiated in 2018 to improve the discharge-area relationship used for flow correction and may result in updates to ESH models.	In Progress
Adaptive management priorities should be assigned to monitoring and to the analysis of the Missouri River ESH targets based on modeling that considers the entire piping plover population unit, including birds on river segments, reservoirs, alkali lakes, and other breeding areas. **Additional information:** Efforts are underway to explore expanding the scope of the bird models. Objectives include estimating the importance of dispersal with other breeding areas to population dynamics modeling, examining the importance of assumptions about dispersal, improving the understanding of how dispersal affects MRRP objectives and targets, and improving our ability to predict population dynamics based on drivers of dispersal.	In Progress
Adaptive management priorities should be assigned to develop a monitoring scheme to understand dispersal between the Northern Region of the Missouri River and other breeding areas to properly inform habitat targets. **Additional information:** An evaluation of several options for a monitoring program is underway and includes methods for estimating dispersal and adult survival, but partnerships will be necessary as USACE does not have the authority to monitor plovers off the Missouri River and reservoirs.	In Progress

1.4.3 Section 7(a)(1) Conservation Plan

Section 7(a)(1) of the ESA directs Federal Agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a Management Action on listed species or critical habitat, to help implement recovery plans, or to develop information. Table 1-3 summarizes the actions implemented as part of the Section 7(a)(1) plan.

Table 1-3. Section 7(a)(1) Conservation Plan Annual Reporting Form.

Conservation Strategy	Summary of Implementation
Identify opportunities to operate the System to benefit listed species.	In 2019, opportunities to operate the system to benefit the listed species were precluded by the large runoff into the system (2nd highest since 1898). Given the sandbars development from these conditions, available emergent sandbar habitat should be above targets set forth in the 2018 BiOp if flows are average or below average in 2020.
Support the Pallid Sturgeon Propagation and Augmentation Program in addition to the Biological Assessment Management Action.	The USACE has continued to support the Pallid Sturgeon Propagation and Augmentation Program.
Identify opportunities to maintain the BSNP in a manner that could contribute beneficially to aquatic habitat.	Little BSNP maintenance occurred during 2019 due to the high flow conditions.
Prioritize lands for acquisition that contribute to meeting pallid sturgeon habitat requirements when consistent with BSNP Fish and Wildlife Mitigation Project authority.	No additional lands were acquired under the BSNP Fish and Wildlife Mitigation program authority in 2019.
Consider Indiana bat (IB) and northern long-eared bat (NLEB) habitat needs in planning of site-specific habitat development for Mitigation Project lands.	When developing site-specific restoration plans on Mitigation Program lands, measures to maintain and or improve habitat for IBs/NLEBs are incorporated. These include: reviewing existing information on known hibernacula and maternity roost trees early in the planning process; maintaining existing riparian corridors and, where possible, increasing the width; maintaining suitable roost trees for use by NLEBs/IBs; utilizing tree species preferred by IBs in tree plantings where appropriate; developing wetlands in riparian areas where appropriate.
Evaluate the potential for levee modifications at existing and future mitigation sites.	The Kansas City District (NWK) is currently working with the Missouri Department of Conservation to assess potential habitat restoration efforts at their Columbia Bottom Conservation Area, which may include potential levee modification. However, this effort has been delayed given high water conditions in 2018 and 2019.
Determine if there is potential to operate the Kansas River projects in a manner that would increase benefits to native species.	NWK has continued to partner with The Nature Conservancy under the Sustainable Rivers Program to evaluate the potential to provide more environmentally beneficial flows on the Kansas River. In 2019, USACE staff participated in a USACE/TNC Sustainable Rivers workshop in Des Moines, IA to discuss challenges and opportunities in implementing environmental flows. Also, a draft literature review and synthesis of existing scientific information from the Kansas River basin was completed and, when finalized, will be used to further discussions on potential opportunities to implement environmental flows on the Kansas River.

Conservation Strategy	Summary of Implementation
Avoid adverse impacts to gray bat, IB, and NLEB while maintaining District projects.	In accordance with the current 7(a)(1) Plan, NWK and the Omaha District ((NWO) have shifted tree removal, with the rare exception of hazardous trees, to outside the timeframe when IBs/NLEBs are present, completing tree clearing between 1 NOV and 31 MAR. During site management sufficient buffers along riparian areas are maintained. During prescribed burns/routine O&M trees suitable for use by IBs/NLEBs are preserved. NWK continues to undertake activities that help maintain listed bat species populations at Beck and Blackwell Caves on the Harry S. Truman Project in Missouri and the Rocheport Cave on the Missouri River Fish and Wildlife Mitigation Project in Missouri. Entry to the Beck/Blackwell caves requires a permit and that all proper protective clothing and procedures are followed by individuals entering caves for official reasons to prevent the introduction of white-nosed syndrome. NWK works closely with MDC biologists to support survey efforts at these caves. At Truman, NWK has also worked with the Cave Research Foundation to inventory bat species and complete cartography (mapping) of additional caves. During the 2019 high water event at the Harry S. Truman Lake Project, the three pumps that prevent flooding of Beck Cave experienced a power line failure. In consultation with the USFWS, USACE staff implemented emergency measures to restore power to the pump system and prevent flooding of the cave. Lessons learned through that effort have been used to develop a plan to repair that system to ensure future performance. Emergency funding has been secured and the USACE, in consultation with the USFWS, plans to complete that work in early 2020.
Coordinate, communicate and cooperate among entities responsible for conserving pallid sturgeon, least tern, and piping plover.	The USACE continues to participate on the pallid sturgeon and piping plover recovery teams (Joe Bonneau and Chantel Hofer). NWD and MVD once again met to discuss opportunities for partnering on the Missouri and Mississippi Rivers. NWK/NWO staff also coordinated with Mississippi River pallid sturgeon research and monitoring crews to discuss the standardization of sampling across both rivers. The USACE anticipates additional age-0 pallid sturgeon monitoring to occur on the Mississippi River in 2020.
In coordination with Friends of the Wild Whoopers (FOTWW) biologists, identify measures to maintain/improve whooping crane (Aransas-Wood Buffalo population) migration stopover habitat on project lands. Implement these measures as funding allows.	USACE HQ signed an MOU with FOTWW to assess migration stopover habitat on USACE lands. NWK has already completed coordination with the USFWS on one of those projects, Big Bottoms Wetland Restoration Project, at Kanopolis Lake, KS which will provide approximately 232 acres of wetland habitat in an area that has consistently been used by whooping cranes in the preceding 5 years. Construction originally scheduled for fall/winter 2018 has been delayed by high water events but we hope to resume construction in the upcoming year. NWK continues to partner with the Twin Valley Weed Management District to control invasive phragmites and salt cedar on the shores of Harlan County Lake, NE to conserve water for irrigation and which also provides ancillary benefits to native vegetation, waterfowl, and shorebirds, including the whooping crane during migration stopover. In 2019, FOTWW biologists and NWO Natural Resource Management Staff conducted onsite habitat evaluations at all of the mainstem reservoirs (Lewis & Clake Lake, Lake Francis Case, Lake Sharpe, Lake Oahe, Lake Sakakawea, and Fort Peck Lake) and Pipestem Lake. These assessments verified that a great deal of suitable habitat was currently available at these lakes and the primary measures that should continue to benefit whooping cranes would be the control of invasive plant species on shallow water/sandbar habitat and restricting illegal off-road vehicle use on the shoreline. These visits increased the awareness of NRM staff concerning the needs of whooping cranes during migration and what measures they may take to maintain/improve those habitat conditions.

1.4.4 Agency Coordination on BiOp Compliance

Inter-agency in-progress review meetings (IPRs) will continue to be used as a mechanism for the agencies to identify and discuss concerns or issues related to compliance with the ESA and the 2018 BiOp. The IPRs involve discussions among key staff from each agency. Issues that cannot be resolved in these IPRs may be elevated to the appropriate District/Division commands for the USACE or the Regional Director(s) for the USFWS for resolution. The agencies report any significant issues and their resolution as appropriate at MRRIC meetings. At this time, there are no issues that necessitate dispute resolution.

1.5 Incidental Take

In 2019, incidental take for plovers and terns fell within the anticipated range specified in the 2018 BiOp. The Technical Team is continuing to evaluate approaches to achieving the existing ITS for pallid sturgeon.

1.5.1 Take for Plovers and Terns

Metrics for incidental take of least tern and piping plover are reported as 15-year moving averages (15YA; Figure 1-6). Criteria include threshold values for the 15YA, as well as values that must be met for a portion of the next 15 years (beginning in 2018). In 2019, the 15YA reflects data from 2005-2019. Criteria applying to subsets of years (e.g., a threshold must be met 8 out of 15 years) anticipate take over the next 15 years starting in 2018, so only the first two years of that period are included in this report.

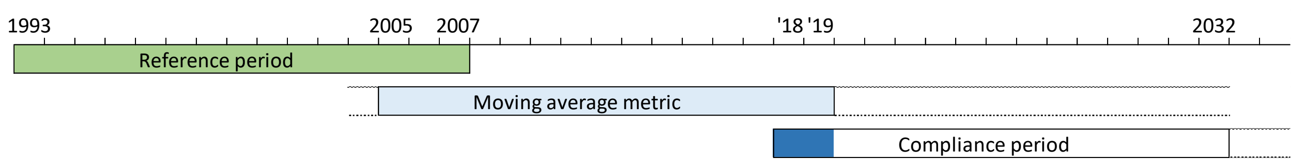


Figure 1-6. Time frames of the reference period used to determine IT criteria, the 15-year moving average reported annually, and the 15 year period in which the criteria for complying with the ITS apply.

Tern and plover take on riverine reaches due to the suppression of natural disturbance dynamics, the unintended effects of nest caging (plover only), and hypolimnetic releases on the Garrison and Fort Randall segments (plover only) are measured by the 15YA of the number of adults observed and the number of fledglings produced (Table 1-4). If the adult and fledgling numbers meet or exceed those measured from 1993-2007, incidental take is regarded to be within anticipated (acceptable) levels. Take caused by the inundation of nests or chicks due to daily dam operations - including storage, releases, and flood control - is measured by the 15YA of egg and chick loss (Table 1-5). Acceptable levels are based upon what occurred during the period 1993-2007. Take for both reservoir and riverine segments are presented as a percentage of eggs lost.

*Table 1-4. Incidental take criteria and observed metrics for plovers and terns on ESH.**

Year	**Plover adults 15-year average**	≥ 402 plover adults every year	> 600 plover adults at least 3 years	> 500 plover adults at least 8 years	**Plover fledglings 15-year average**	≥ 226 plover fledglings every year	> 300 plover fledglings at least 12 years
2018	692	✓	✓	✓	414	✓	✓
2019	**725**	✓	✓	✓	**409**	✓	✓

Year	**Tern adults – 15-year average**	≥ 488 tern adults every year	> 600 tern adults at least 3 years	> 500 tern adults at least 14 years	**Tern fledglings – 15-year average**	≥ 228 tern fledglings in every year	≥ 257 tern fledglings at least 7 years
2018	654	✓	✓	✓	298	✓	✓
2019	**672**	✓	✓	✓	**294**	✓	✓

* Metrics are 15-year moving averages; take is due to suppression of natural disturbance dynamics, hypolimnetic releases, and unintended consequences of nest caging.

*Table 1-5. Incidental take criteria and observed metrics for the inundation of eggs and chicks due to daily dam operations, including storage, releases, and flood control.***

Year	**River Plover eggs incidental take 15-year average**	≤ 7.6% of river eggs every year	< 3.4% of river eggs at least 3 years	**Reservoir Plover eggs incidental take 15-year average**	≤ 27.3% of reservoir eggs every year	< 18% of reservoir eggs at least 2 years
2018	2.7	✓	✓	16.5	✓	✓
2019	4	✓	✗	18.4	✓	✗

Year	**River Tern eggs incidental take 15-year average**	< 6.9% of river eggs every year	≤ 1.1% of river eggs in at least 2 years	< 3.1% of river eggs in at least 3 years	**Reservoir Tern eggs incidental take 15-year average**	≤ 15.6% of reservoir eggs every year	< 11.8% of reservoir eggs in at least 6 years
2018	2.2	✓	✗	✓	9	✓	✓
2019	2.5	✓	✗	✓	9.9	✓	✓

** Metrics are 15-year moving averages

For 2019, all 15YA values fell in the anticipated ranges of incidental take for annual criteria (i.e. met the criteria in the threshold column of Table 1-4 and Table 1-5). The values also fell within the anticipated ranges for multiyear criteria except for the percentage of plover eggs inundated on the river and reservoir segments, and the percentage of tern eggs inundated on the river segments (Table 1-5). However, those criteria must be met for only 2 or 3 of the next 15 years, so 2019 take does not exceed anticipated levels.

1.5.2 Take for Pallid Sturgeon

Progress was made in 2019 on approaches to assess incidental take for pallid sturgeon, but take estimates have not been generated because the necessary data will not be available until full implementation of the Pallid Sturgeon Population Assessment Program (PSPAP) v. 2.0 after 2020. A discussion of the relevant metrics and conditions in 2019 is provided below.

Apparent survival (both basins) and catch per unit effort (CPUE; Lower Basin only) are the primary metrics for incidental take of pallid sturgeon identified in the 2018 BiOp (USFWS 2018). Secondary metrics such as abundance (Upper Basin only) and condition, growth rate, and reproductive cycling (both basins) are also specified. Secondary metrics do not have specified benchmarks and are not used to evaluate whether take was exceeded, but they provide context for the primary metrics.

The benchmark for apparent survival is the 3-year running average of annual apparent survival estimates and the associated standard error of the average for age-4+ fish. PSPAP monitoring is designed to provide data for annual apparent survival estimates, but the benchmark has not been calculated. Existing apparent survival estimates for the Upper Basin (Rotella 2017) were not generated for this purpose and therefore require some reanalysis. While more years of PSPAP data will be helpful for computing apparent survival, the primary need is for more staff time to analyze existing information.

Mean CPUE for the Upper Basin and Lower Basin is reported in Section 3.2.2.3 , with details in Section 3.2.1.1 of the Appendix, including 3-year running averages and cubic spline curves showing trends. Associated standard errors have not yet been estimated due to complexities in the hierarchical structure of CPUE data. Secondary metrics include abundance (Section 3.2.2.1), fish condition (Section 3.2.5), growth rate, and reproductive cycling (see Section 3.2.3.2). These are discussed in the indicated report sections but are not collectively evaluated for incidental take.

Table 1-6 lists the metrics, data sources, and status. Section 3.2.3 further discusses the status of incidental take for pallid sturgeon.

Table 1-6. Pallid sturgeon information gathering progress notes.

Metric	Type	Data sources	Status
Apparent survival	Primary	Capture/recapture information from PSPAP	PSPAP v. 2.0 is on track to provide underlying data. Some additional decisions are needed about the specific model to calculate apparent survival and responsibilities for calculations and reporting. The primary need is for more resources to analyze existing data.
CPUE adult wild sturgeon	Primary (Lower River only)	Capture/recapture information from PSPAP	PSPAP v. 2.0 is on track to provide relevant data; see Section 3.2.2.1 for 2019 estimates. Future years of data will provide insights on the year-to-year variability in estimates of population abundance.
Abundance	Secondary (Upper River only)	Capture/recapture information from PSPAP	PSPAP v. 2.0 is on track to provide relevant data; see Section 3.2.2.1 for 2019 estimates. Future years of data will provide insights on the year-to-year variability in estimates of population abundance.
Condition	Secondary	Capture/recapture information from PSPAP	PSPAP v. 2.0 is on track to provide relevant data; see Section 3.2.5 for predicted weights over the period from 2003 to 2019.
Growth rate	Secondary	Capture/recapture information from PSPAP; stocking database; genetics database	PSPAP v. 2.0 is on track to provide some of these data. Additional decisions are needed about specific analyses and calculation and reporting responsibilities. A primary need is for more resources to analyze existing data.
Reproductive cycling	Secondary	Capture/recapture information from PSPAP; broodstock collection data; supplementary telemetry data	PSPAP v. 2.0 is on track to provide some of these data. Additional decisions are needed about specific analyses and responsibilities for calculations and reporting. Contributions from the broodstock program will depend on stocking decisions. Telemetry data collected as part of PSPAP will provide supplementary, longitudinal data on cycling. Though some data are available for telemetered fish, blood samples to infer reproductive status are not collected as part of the PSPAP.

Notes: Metrics are from the 2018 BiOp (USFWS, 2018). “On track” indicates that data will be available with full implementation of the PSPAP v. 2.0 after 2020. Unless otherwise noted in the “type” column, metrics apply to both the Upper and Lower River segments.

2 Adaptive Management for Birds

2.1 Overview of the Bird Program

2.1.1 Geographic Scope

The scope of the MRRP for piping plovers and least terns, as specified in the 2018 BiOp (USFWS 2018), consists of three riverine segments, the shorelines of two reservoirs, and the delta of another reservoir, extending from Lake Sakakawea in North Dakota to river mile (RM) 754 near Ponca, Nebraska (Figure 2-1). These segments are grouped into the Northern Region (Lake Sakakawea, Garrison, Lake Oahe) and the Southern Region (Fort Randall, Lewis and Clark Lake, and Gavins Point). No changes were made to the geographic scope of management in 2019.

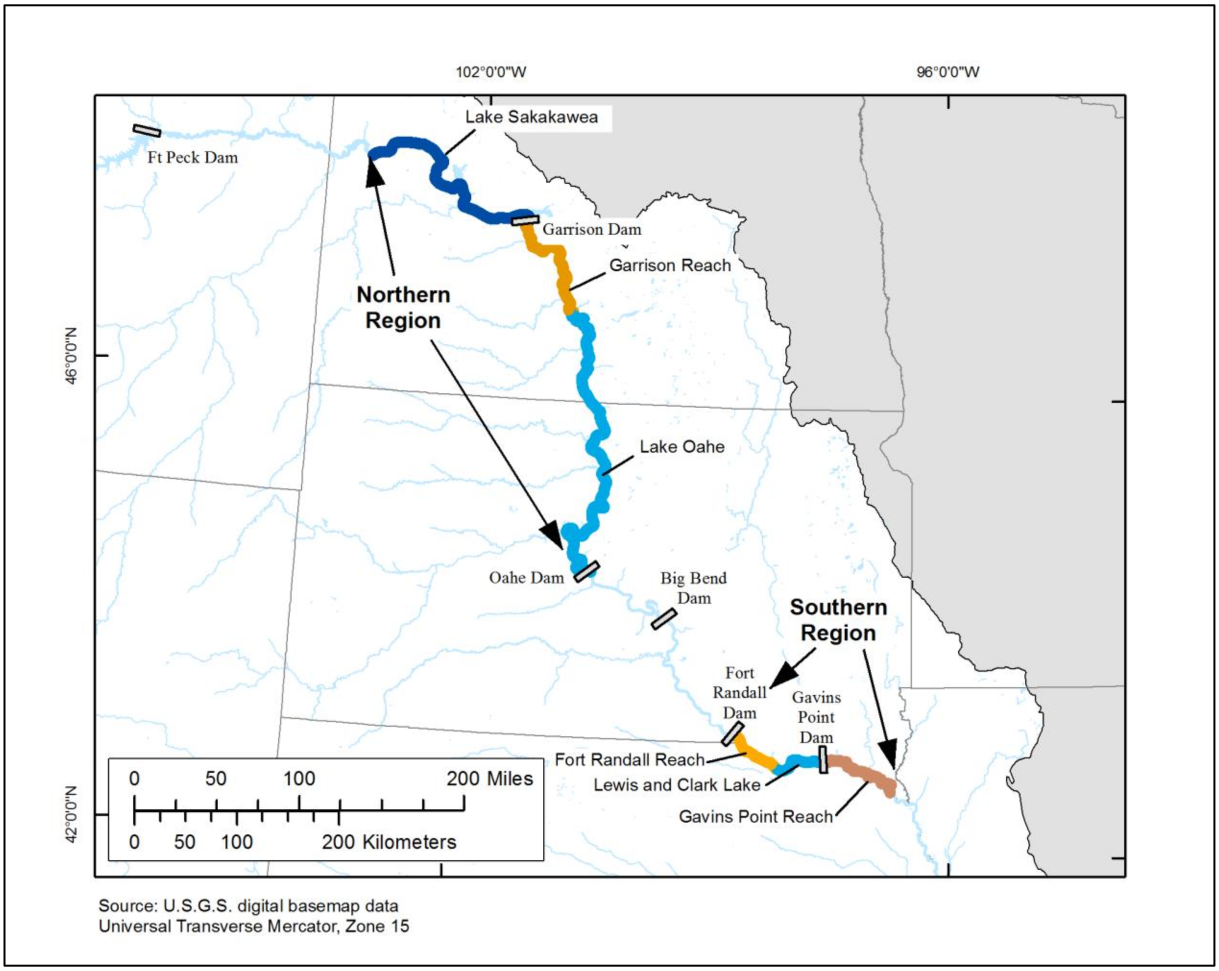


Figure 2-1. Piping plover and least tern nesting segments included in BiOp target specifications and monitored for fledgling production as part of the MRRP. The colors differentiate the segments; light and dark brown for the riverine segments and blue for the reservoir segments.

2.1.2 Objectives and Metrics

Objectives and metrics have been defined for the MRRP by the USFWS (Table 2-1; USFWS 2018). All sub-objectives and targets apply only to piping plovers. The USFWS has determined that meeting plover habitat objectives will also fulfill least tern habitat needs on the Missouri River (USFWS 2018).

Fundamental Objective: Avoid jeopardizing the continued existence of piping plovers and least terns due to the USACE actions on the Missouri River.

Table 2-1. Summary of piping plover sub-objectives, metrics, and target criteria.

#	Sub-objective	Means objective	Metric	Target	Timeframe
1	Maintain the geographic distribution of plovers in the river and reservoirs where they currently occur	Meet #2, 3, 4 in both the Northern and Southern Regions	N/A	N/A	N/A
2	Maintain a population of Missouri River piping plovers with a modeled 95% probability that at least 50 individuals will persist for at least 50 years in both the Northern and Southern Regions	Provide sufficient ESH (in-channel riverine habitat) on the Missouri River to meet the persistence target	Estimated standard and available ESH acres	See	Standard ESH: 3 of 4 years Available ESH: Percentage over 12 years
3	Maintain a stable or increasing long-term trend in population size in both regions	N/A	Population growth rate λ	1	3-year geometric mean
4	Maintain fledgling production by breeding pairs sufficient to meet the population growth rate objective	N/A	Fledge ratio	1.14	3-year arithmetic mean

Table 2-2. Target acreage distributions for standardized and available ESH acres for the Northern and Southern Regions. Median targets (bold) are the values considered in target compliance. Percentiles (%iles) are for planning guidance.

Standardized ESH Acres		Acres of ESH					
		Northern Region			Southern Region		
		2.5%ile	Median	97.5%ile	2.5%ile	Median	97.5%ile
		190	**450**	2160	330	**1180**	4720
Available ESH Acres Exceeded for Percentage of Years	**75%**	170	**270**	555	300	**430**	720
	50%	420	**680**	1295	500	**740**	1550
	25%	960	**1920**	2670	750	**1410**	3075
	10%	1965	**3000**	5165	1125	**2240**	4945

2.1.3 Uncertainties

Conceptual ecological models and associated hypotheses were used to develop overarching uncertainties (specified in the SAMP and updated as needed) about the species and habitat dynamics. These reflect broad uncertainties about population responses to habitat dynamics and natural variability, particularly the sub-population utilizing the Missouri River. The MRRP is currently focusing on the following overarching uncertainties because these are directly relevant to decision making; the full list is provided in Appendix 2.1.3.2. Descriptions of the numbered uncertainties have been updated from the 2018 AMCR but the concepts remain similar; details have been added in bullet points.

1a) How should plover and tern habitat be quantified and what determines habitat quality?

- How can ESH be more accurately quantified, especially in the Northern Region? Some areas of sandbars are counted as ESH because they are bare sand, but the substrate is not suitable for nesting (i.e., fine sand in the Garrison segment) or they are surrounded by unsuitable substrate. Satellite imagery is insufficient to distinguish sediment type.
- Can a meaningful index of habitat quality using nest-site, sandbar, and landscape-level features be developed to improve ESH management and predictions of reproductive success?

1b) What is the relationship between habitat quality and fledgling productivity and survival on river and reservoir habitat?

- How do habitat quality features affect site selection (at a landscape scale), nest success, and chick survival to fledging?
- How do habitat conditions for breeding plovers affect chick and juvenile (fledgling) overwinter survival?
- Can an improved understanding of habitat quality increase the efficiency of management efforts at increasing nest success and chick survival?

1c) How do factors (e.g. high nest density, static habitat) affect predation of plover and tern eggs and chicks and can they be manipulated to reduce predation?

- How do predation rates change with habitat age and quality?
- How do predation rates change with plover density over time?
- Do any vegetation cover types/extents improve chick survival?

2b) How do habitat conditions in other breeding areas and dispersal to and from those habitats affect the Missouri River breeding sub-population?

- What are the plover dispersal mechanisms in the Northern Region and prairie pothole wetlands (i.e., what determines where plovers nest and why)?
- What are the effects of dispersal on plover abundance and reproductive success in the Northern Region?

Management uncertainties of interest during the reporting year are summarized in Table 2-3. These uncertainties relate to specific management actions. They identify research needs and risks associated with programmatic and implementation decisions. Reducing these uncertainties improves planning and management efficiency. Management hypotheses and details about uncertainties and potential research activities are included in Appendix 2.1.3.3 and 2.3. A detailed and prioritized list of research questions for action effectiveness is under development (see Appendix 2.4.3 for details).

*Table 2-3. Summary of uncertainties specific to management action effectiveness.**

Management Question	Actions	Management Uncertainties
Can ESH be mechanically created in an effective and sustainable manner?	Mechanical ESH creation on riverine segments	The area of ESH needed to meet sub-population objectives; definition of habitat quality; optimal location and design (e.g. foraging habitat); constructability; efficiencies for cost reduction
Can ESH maintenance practices improve habitat and support production? How do they compare to newly created habitat?	Modification or augmentation of existing ESH	Cost-effectiveness relative to new construction; definition of habitat quality and modifications that improve quality; predation on maintained ESH
	Vegetation removal on ESH	Habitat quality of treated areas and nest site selection; effects on forage quality and predation; effects of management on vegetation succession, bar erosion, and dune formation
Can flow management be effectively used to reduce inundation of nests and chicks?	Flow management	Flow effects on reproductive success; implementation potential during high runoff; effectiveness with incomplete nest detection; limited forecasting capability
	Nest relocation	Effectiveness relative to effort/time
What methods of predation control and human restriction measures are the most practical and effective?	Predator removal	Predator population dynamics and distribution in relation to plover and tern abundances; landscape influences; predation rates with and without removal; effectiveness of removal approaches; availability of contractors
	Nest caging	Effectiveness on nest protection relative to eventual fledgling production; potential for negative effects on adult and chick survival; optimal proportion and distribution of nests that are caged
	Human restriction	Effectiveness of signing; availability of enforcement; non-lethal effects of human disturbance

Note: *Only actions included in the ROD are listed.

The uncertainties addressed in Table 2-3 are the focus of continued evaluation through monitoring, assessment, and in some cases ongoing research (see Section 2.4.2). Reducing decision-relevant uncertainties remains a primary objective of the MRRP.

2.2 Status and Trends of Birds and Their Habitats

This section reports the ESH and plover performance metrics relative to target criteria. Also included are additional metrics that do not have targets specified but are necessary for understanding habitat and species trends and management needs. Definitions of metrics and additional figures, including metrics separated by habitat type and segment, are in Appendix 2.

2.2.1 Overview

All ESH targets were met in 2019 (Figure ES-3 and Table 2-4). Neither the fledge ratio nor population growth rate targets were met in either region. Metrics below targets are attributed to high flows in 2017-2019. These conditions are expected to occur occasionally as part of the natural disturbance regime as described in the BiOp, which anticipated increased reproduction after high-flow events to compensate for low reproduction during the event. The SAMP target specification and decision criteria (SAMP Section 3.5.6) have provisions for not meeting targets because of short-term disturbances such as high flows. Because ESH target criteria have been met, it is anticipated that fledge ratios and population growth rates will recover once flows are lower.

Table 2-4. 2019 performance metrics, compliance metrics, and change from previous years.

Standard ESH Acres							
Region	Target	Timeframe	2016	2017	2018	2019	Targets Met?
North	450	3 out of 4 years	**2,337**	**2,307**	**1,485**	**1,346**	**Yes**
South	1,180		**3,233**	**3,061**	**5,224**	**9,786**	**Yes**

Available ESH Acres								
Region	2019 Acres	Target	Time-frame	9 years (75%)	6 years (50%)	3 years (25%)	2 years (10%)	Targets Met?
North	675	Exceed target acres*	12 years	**11 years**	**8 years**	**5 years**	**2 years**	**Yes**
South	961			**10 years**	**9 years**	**7 years**	**6 years**	**Yes**

Plover Population Growth Rate							
Region	Target	Timeframe	2017	2018	2019	Mean	Targets Met?
North	1	3-year geometric mean	0.66	0.64	0.68	0.66	**No**
South	1		1.03	0.97	0.90	0.97	**No**

Plover Fledge Ratio							
Region	Target	Timeframe	2017	2018	2019	Mean	Targets Met?
North	1.14	3-year arithmetic mean	0.83	0.33	0.64	0.60	**No**
South	1.14		1.08	0.48	0.68	0.75	**No**

Notes: Green text indicates target criteria are met; red text indicates target criteria have not been met.
*See Section 2.2.2 for available ESH exceedance targets.

Trends: Recent trends in habitat and plover and tern abundance on the Missouri River are dominated by the effects of multiple years of high runoff, producing above-average flows in the Northern Region for three years and in the Southern Region for two years.

ESH availability has been low, but the high flows are expected to have created sandbars that will provide new ESH in 2020 and may have scoured vegetation from existing bars. Reservoir shoreline habitat was also scarce and nest inundation rates have been high from several years of pool elevation increases. If reservoir elevations were to decrease in 2020, suitable nesting habitat should be abundant due to the extended inundation limiting vegetation.

Missouri River plover abundance has declined slightly in the Southern Region, and more dramatically in the Northern Region where reservoir habitat strongly influences population size and productivity. Northern Region plover abundance reached its most recent peak in 2016, the last year Lake Sakakawea had favorable nesting conditions. Fledge ratios have been below target during the past three years, corresponding with high runoff in the upper basin. Emigration from Missouri River segments to nearby breeding areas or early returns to winter habitat may have contributed to the observed decreases in adults. When runoff decreases, increased habitat availability will likely attract plovers from other areas and plovers that did not breed in 2018 or 2019.

The population growth rate in the Southern Region has declined since 2012 and was below 1.0 (indicating a decreasing subpopulation) in 2018 and 2019. This pattern is expected after a large habitat-creating event such as the one in 2011. Fledge ratios had been above or well above target until 2017, a pattern that aligns well with trends in available ESH.

High flows in 2018 and 2019 are expected to have increased standard ESH area through deposition and potentially the scouring of vegetation. If basin runoff in 2020 is less than in 2018 and 2019 (currently the 4th and 2nd highest years since 1898), available ESH should increase in 2020. Fledge ratios would be expected to improve, followed by an increase in the population growth rate in 2021, lasting several years if flows in subsequent years are average to low. Lower runoff would also improve nesting conditions on reservoirs. If runoff is high again in 2020, demographic patterns similar to the last two years would be expected.

Table 2-5 presents a management guide based on habitat and population metrics. Two years of high runoff and resulting high river stages and reservoir elevations have disturbed habitat and limited habitat availability. Because Missouri River plover abundance had been relatively high prior to the high flows, habitat limitation has reduced the fledge ratios and population growth rates below target levels. In years with high flows, habitat status for subsequent years may not be known until the disturbance has ended and ESH can be quantified. Management needs identified for this condition in Table 2-5 are to maintain or augment ESH depending on flow outcomes.

When Missouri River habitat availability is low, observed numbers of birds using the Missouri River may be reduced because of emigration to other breeding areas and/or birds returning early to wintering grounds after failure to breed or nest loss. Such declines may reverse when conditions improve, and birds return. However, the rates of migration are uncertain.

Table 2-5. Current status and needs for the Northern Region and Southern Region (bold/thick outline). Acres are standard ESH. Population metrics are fledge ratio (FR) and population growth rate (λ). High flows exceed the threshold expected to create habitat.

Status	Low to Average Flows				High Flows
	ESH acres < lower bound	Lower bound < ESH acres < median	Median < ESH acres < upper bound	Upper bound < ESH acres	
GROWING POPULATION Plover FR and λ > target	On track *Status:* Small population OR density dependence less than expected *Need:* Continue pace of habitat creation	Meeting objectives *Status:* Moderate population, not habitat limited *Need:* Continue habitat creation at a current or slower pace	Meeting objectives *Status:* Moderate to large population, not habitat limited *Need:* Maintain existing acreage and quality	Exceeding *Status:* More birds and much more habitat than needed *Need:* Maintain habitat quality	Habitat disturbance *Status:* Population not limited by ESH inundation *Need:* Maintain habitat created by flows
STABLE POPULATION Plover FR and λ ≈ target	Unlikely to meet *Status:* Small to moderate population, becoming habitat limited *Need:* Increase rate of habitat creation	Meeting objectives *Status:* Moderate population, habitat may become limiting *Need:* Continue pace of habitat creation	Meeting objectives *Status:* Moderate to large population *Need:* Maintain existing acreage and quality	Exceeding *Status:* More birds and more habitat than needed *Need:* Maintain habitat quality	Habitat disturbance *Status:* Population mildly limited by ESH inundation *Need:* Maintain habitat created by flows
DECLINING POPULATION Plover FR and λ < target	Will not meet *Status:* Small to large population, very habitat limited *Need:* Rapidly increase the rate of habitat creation	Unlikely to meet *Status:* Moderate to large population, habitat limited *Need:* Increase pace of habitat creation	Potential reversal *Status:* Large population returning towards equilibrium *Need:* Continue pace of habitat creation and maintain habitat	Reversal *Status:* Large population returning towards equilibrium OR density dependence higher than expected *Need:* Maintain habitat quality and quantity	**Habitat disturbance** ***Status:* Population temporarily limited by ESH inundation** ***Need:* Maintain or augment habitat created by flows**

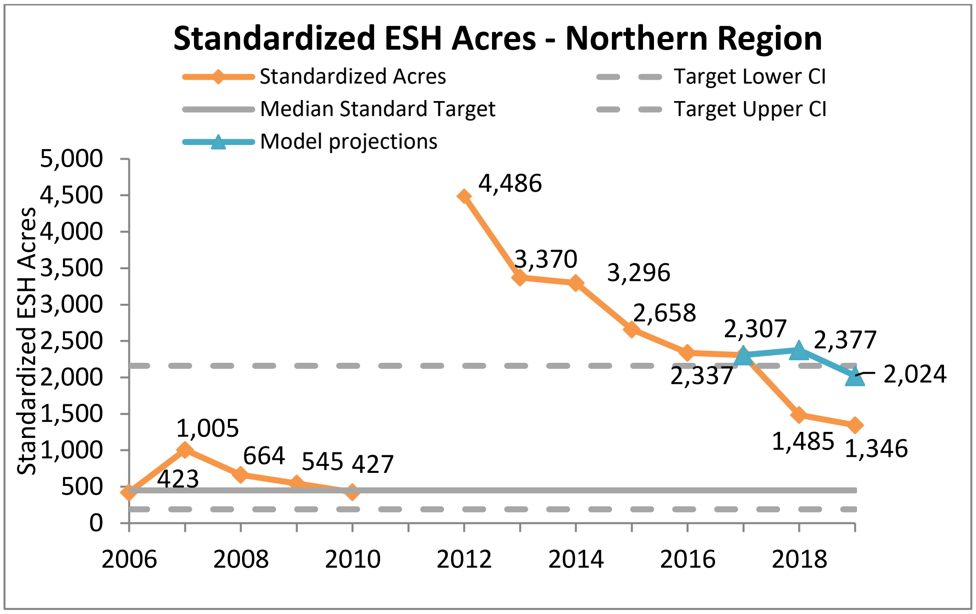
2.2.2 Habitat

ESH habitat metrics are tracked using satellite imagery and adjusted to standard and available flows using a relationship between reservoir releases (discharge) and ESH area. The reservoir shoreline habitat metrics are calculated from changes in reservoir pool elevations. Targets are specified only for ESH, but all habitat metrics are used to support population dynamics estimates and management planning.

The ESH accounting and flow correction process was improved and automated in 2019. Discrepancies in previous ESH estimates were addressed; adjustments were generally less than 10%. Details are provided in Appendix 2.2. Estimates for the Northern Region were adjusted using a new discharge-area curve (see Section 2.5.1) based on 2017 LiDAR data. The ESH estimates are more reliable with the new curve. Further adjustments may be made once the 2018 LiDAR data are processed. None of these changes affected compliance with ESH targets.

2.2.2.1 Standardized ESH

Targets for standardized ESH have been met since 2012 in both regions (Figure 2-2), although estimated acreage declined from 2011 through 2019 in the Northern Region and 2011 through 2017 in the Southern Region. Quantifications in July 2019 indicated a small decrease in standard ESH in the Northern Region from 2018 acres and a large increase in the Southern Region. Estimates for 2019 are more uncertain than in most other years because of the high river stages.



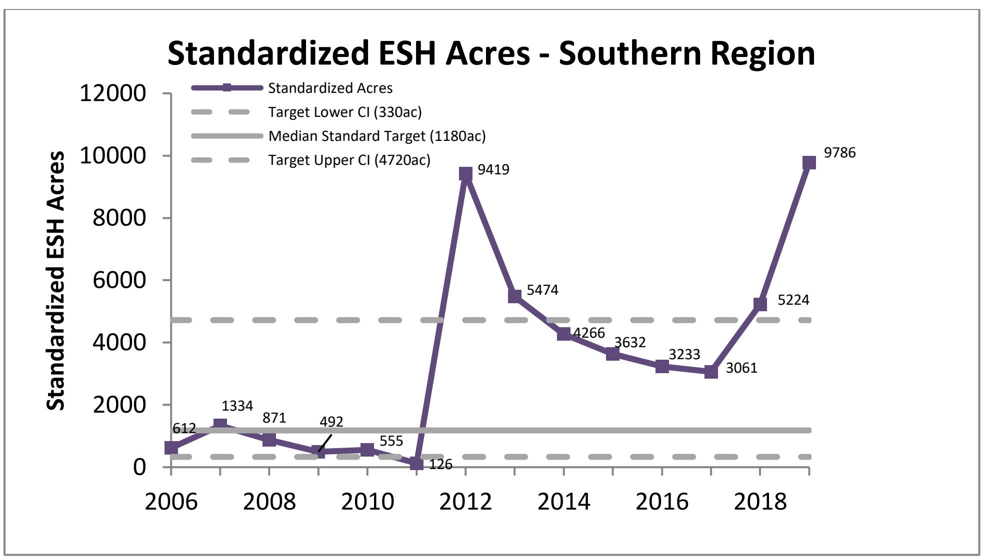


Figure 2-2. Standardized ESH estimates (acres) for a) Northern Region, and b) Southern Region from 2006 - 2019. Model projections for the Northern Region for 2018 - 2019 are also shown (blue triangles). The median is shown in solid gray and 95% confidence interval is shown with a dashed gray line in relation to ESH targets. Line markers indicate years when the target criteria were met.

In the Northern Region, river stage peaked in July of both 2018 and 2019. Therefore, estimates of available ESH (defined as acreage exposed during maximum July flows) can be accurately estimated from imagery that is acquired in July. Standard ESH acreage, which was underwater during imagery acquisition, is harder to accurately ascertain from monitoring. Consequently, model estimates for standardized ESH in 2018 and 2019 supplement acreage estimated from imagery in Figure 2-2 (see Section 2.2.1.2 in the appendices). Garrison flows were high enough to create new ESH in late spring of 2018, but erosive flows persisted for several months before and after, resulting in only a small net increase in modeled standard acreage. Field observations at lower flows in 2018 suggest that ESH was created (supporting model estimates rather than imagery acreage estimates) but that some was at low elevation and/or not with optimal sediment grain size to support nesting.

Flows reached depositional levels again in July 2019, when imagery was taken. The ESH created in 2018 would not be visible in 2019 imagery quantification because it would have been underwater. ESH created in Garrison in 2019 will not be countable until 2020 imagery is available, as flows increased in July and continued until winter; even if visible in July 2019, new deposition had not yet occurred. Model estimates for 2019 reflect the fact that habitat creation was only beginning in July of 2019.

The high acreage estimate for the Southern Region in 2019 is likely an overestimate because of the discharge-area curve not performing as well at high flows in the Fort Randall segment. In that segment, elevation profiles of sandbars are more variable than in the Gavins Point segment, increasing the probability for error, and less information has been collected in the past to improve the correction of acreage from higher stages to standard ESH. The 2019 flows were of sufficient magnitude and duration to create ESH, but the 2019 standard ESH value likely overestimated standard acreage in July. Flows were in the ESH-forming range for 5 months in 2018 and 8 months in 2019 (April-November) but were low enough in the intervening winter to limit erosion. These conditions were more conducive to ESH creation than the conditions in the Garrison segment. Therefore, a sizable increase in standard ESH is possible, but it is not anticipated that these flows would have created as much acreage as was present in 2012.

2.2.2.2 Available ESH

Maximum July flows in the Northern Region in 2019 were lower than in 2018 (46.9 kcfs vs 60.5 kcfs), resulting in a 27% increase in estimated available acres in 2019 (Figure 2-3). Nesting-season flows of 70.1 kcfs contributed to 59% fewer available ESH acres in the Southern Region compared to 2018 (58.1) kcfs). This was the third consecutive year with decreases in available area in the south. However, because of high ESH availability from 2012 to 2016 in both regions, targets for available ESH have been met.

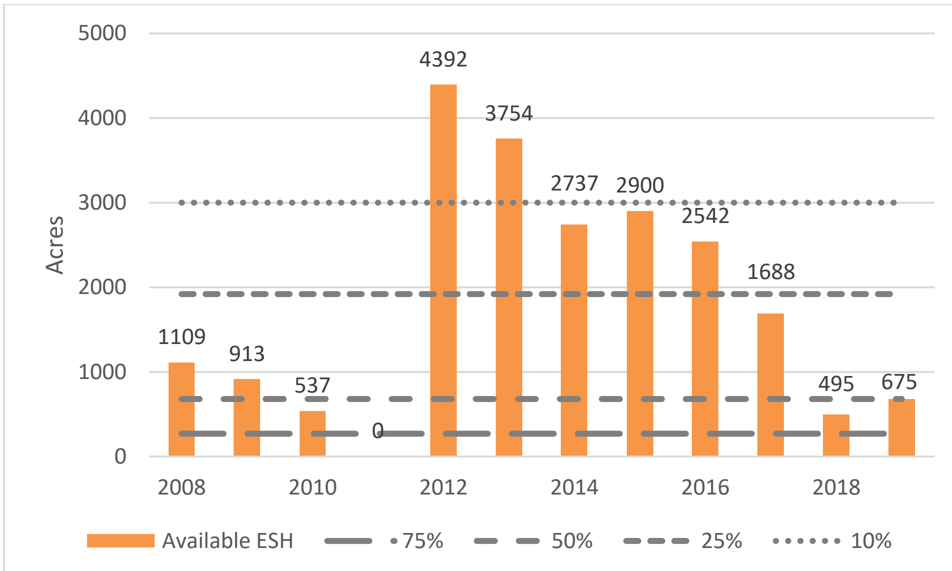
2.2.2.3 Reservoir Elevation and Inundation

Reservoir conditions were poor for nesting in 2019 (Figure 2-4) because high runoff increased reservoir pool levels relative to 2018 and throughout the 2019 nesting season. Increasing elevations resulted in an estimated shoreline availability metric of 0[*] for both Lake Sakakawea and Lake Oahe. The lack of habitat was likely exacerbated by the multiple-year increase, raising water elevations to a shoreline with established vegetation. Reservoir elevation change during the nesting season was +6.37 ft on Lake Sakakawea and +2.84 ft on Lake Oahe, creating a strong nest inundation risk on Sakakawea and

* An available shoreline estimate of 0 does not preclude nesting; however, it suggests habitat quality was poor and of limited attractiveness to birds seeking nesting sites.

moderate risk on Oahe. This continues a trend of habitat limitation in 5 of the past 6 years on Lake Sakakawea and 4 of the past 6 years on Lake Oahe.

a)



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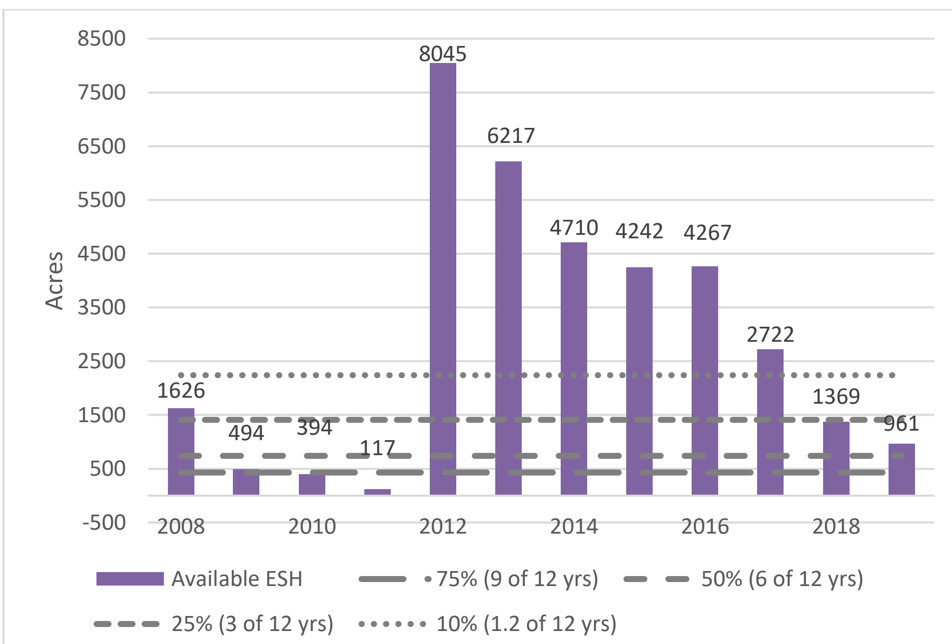
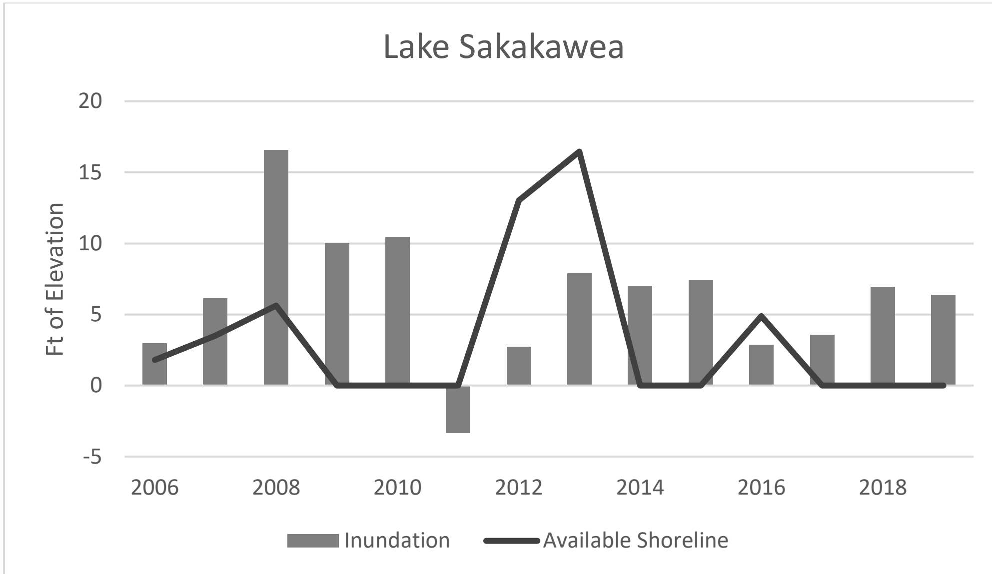
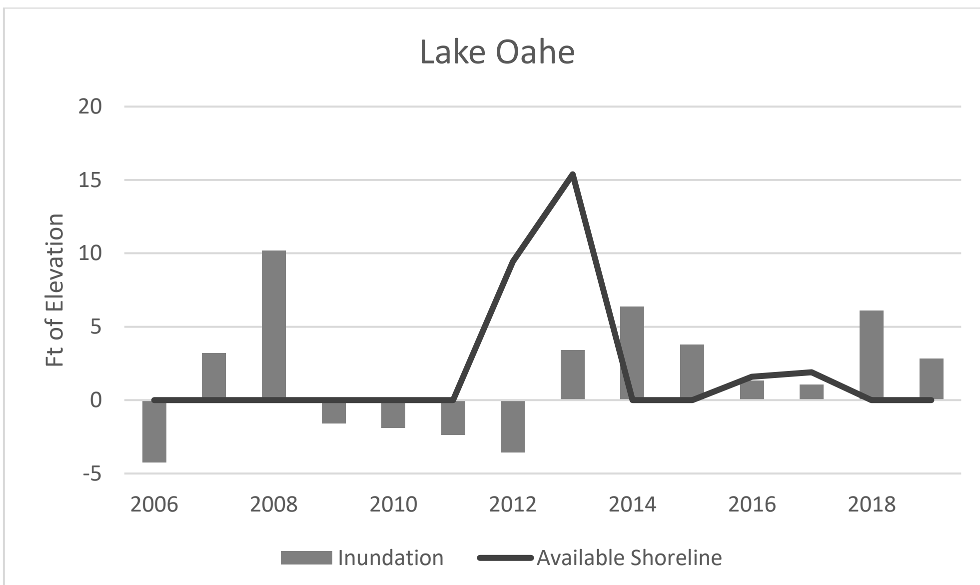


Figure 2-3. Available ESH estimates (acres) for 2007-2019 in the a) Northern Region and b) Southern Region. Dashed lines represent the percent exceedance targets.



a)



b)

Figure 2-4. Reservoir shoreline habitat metrics for a) Lake Sakakawea and b) Lake Oahe from 2006 to 2019. High values of available shoreline (lines) and low to negative values of inundation (bars) are beneficial for breeding birds.

2.2.3 Plovers and Terns

This section addresses plover and tern adult counts, the plover performance metrics listed in Section 2.1.2 , and summaries of nest fate and incidental take. Adult counts and nest fate do not have specified targets, but are helpful for understanding the performance metrics and management needs.

2.2.3.1 Population Dynamics

The 2019 adult plover count during the June 18-July 3 census was 1,065 birds, down 16% from 2018 (Figure 2-5). The greatest decline occurred in the Northern Region (32%). High runoff in 2018 and 2019 limited plover nesting system-wide in both years. The lack of habitat and rising water elevation on the reservoirs contributed to the stronger decline in birds observed in the Northern Region. The adult census count of 277 birds in the Northern Region in 2019 is the lowest recorded adult count since 1999*.

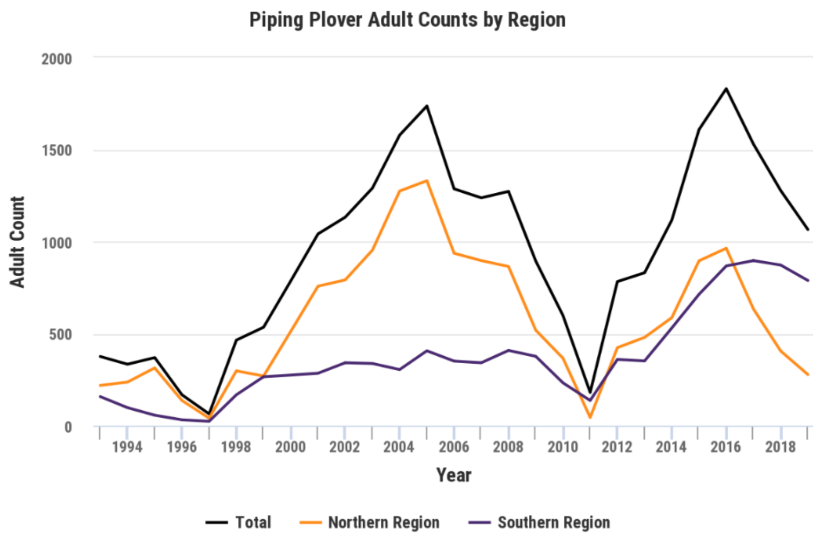


Figure 2-5. Total and regional adult piping plover counts. A complete census was not taken in 2011 because of the lack of access during flooding.

The 2019 least tern adult count decreased 5% from the 2018 count to 939 (Figure 2-6), with a 27% decline in the Northern Region and a 6% increase in the Southern Region from 2018 results. High flows in 2018 limited ESH availability but that limitation did not appear to be an impediment to a relatively stable Southern Region tern population over the past 4-5 years.

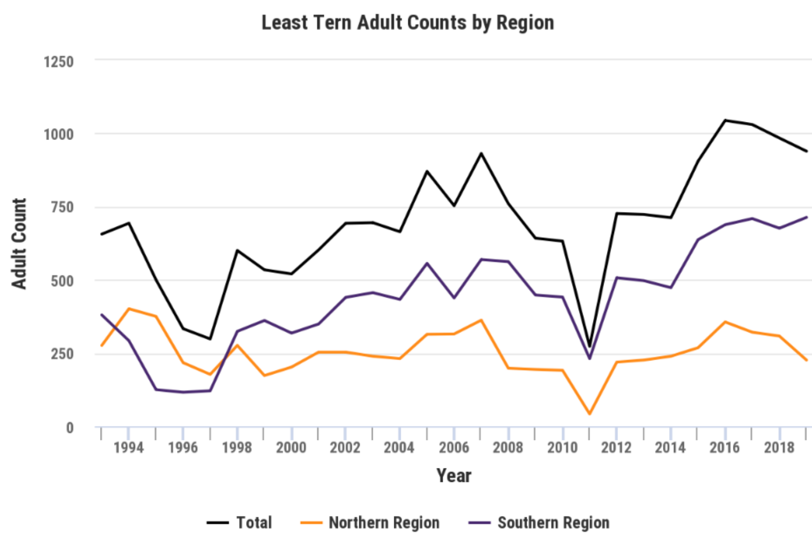
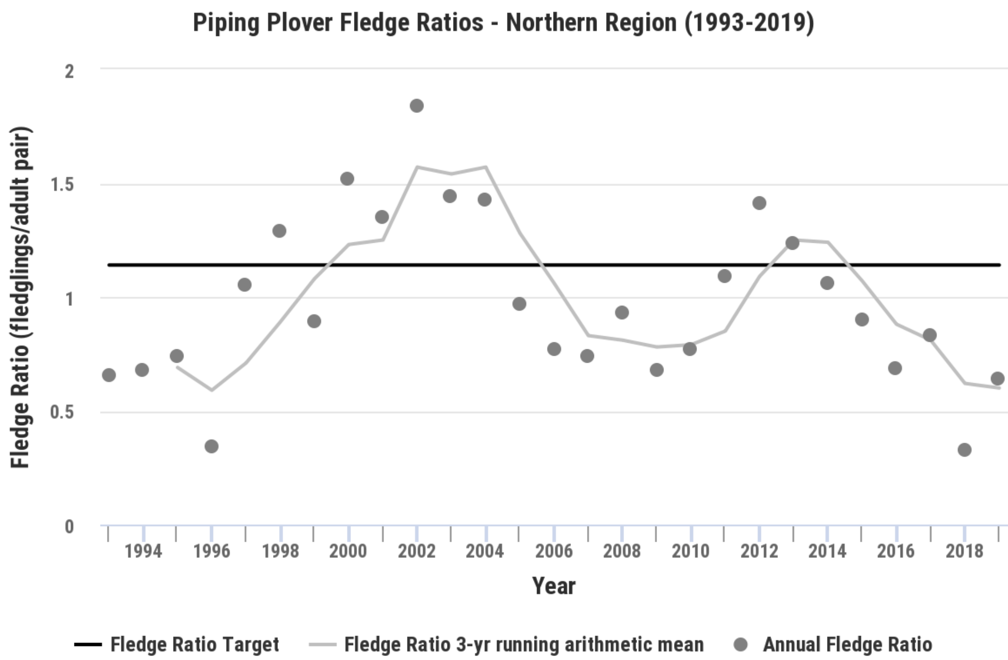


Figure 2-6. Total and regional adult least tern counts. A complete census was not taken in 2011 because of the lack of access during flooding.

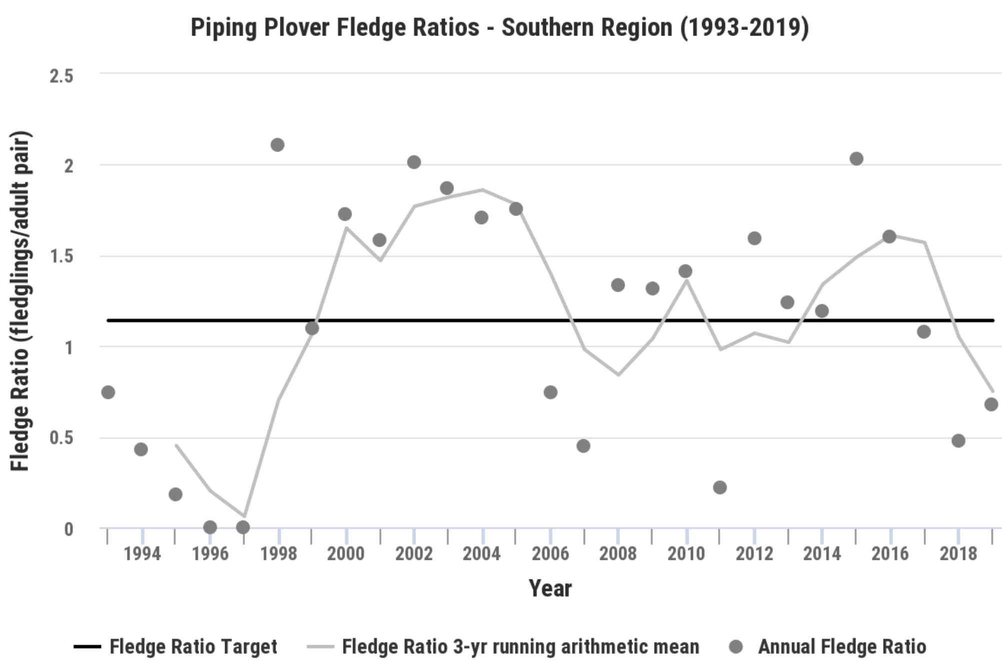
* In 2011 a complete adult census was not possible due to flooding. The 2011 count was lower than the 2019 count but it is not comparable.

2.2.3.2 Plover Performance Metrics

In the Northern Region, habitat limitation, nest inundation, and predation reduced the 2019 fledge ratio to its third lowest annual value since surveys began in 1993 and the lowest 3-year mean observed since 1996 (Figure 2-7). The target, 3-year arithmetic mean fledge ratio of 1.14, has not been met in the Northern Region since 2014. These fledge ratios have contributed to the observed decline in the Northern Region adults since 2016.



a)



b)

Figure 2-7. Plover fledgling counts and 3-year running average fledge ratios for a) the Northern Region and b) the Southern Region.

Although the number of fledglings observed in the Southern Region increased 27% in 2019, the 3-year arithmetic mean of the fledge ratio (solid line) was below target and was the lowest recorded value since 1998. High flows, decreases in ESH quantity and quality, and predation have contributed to this trend. Because the fledge ratios have been below target for only 3 years and were high the previous 2 years, the effect on the number of adults has been less than in the Northern Region[*].

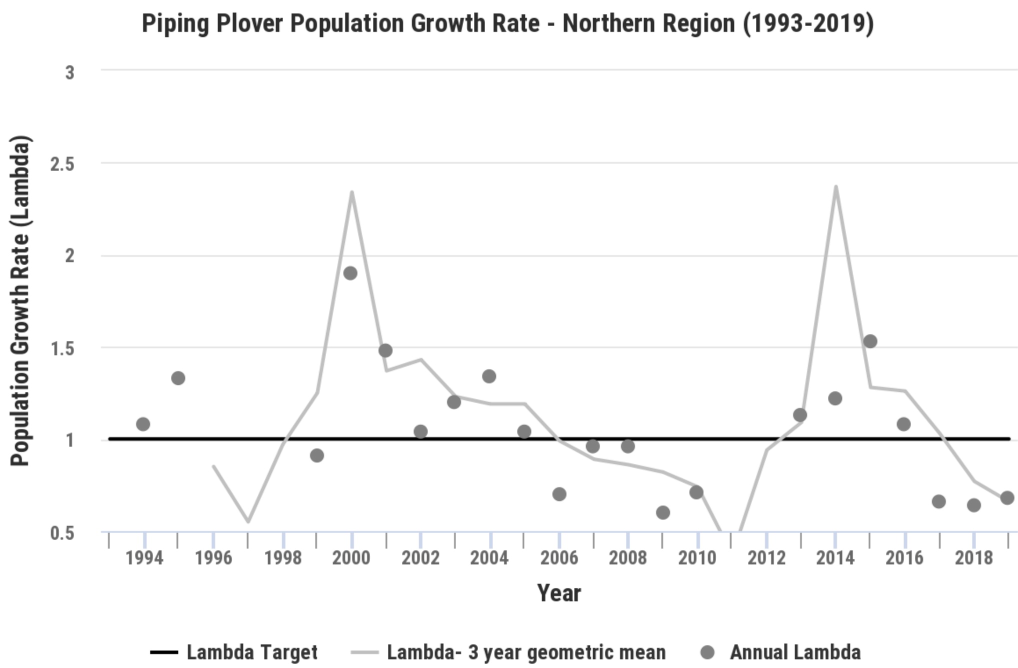
Estimated annual population growth rates in 2019 were below 1.0 in both regions, reflecting the observed decrease in adult abundance (Figure 2-8). Annual population growth rates have decreased since 2015, though the Northern Region annual rate increased from 0.64 to 0.68 in 2019. The three-year average was below the target of 1.0 in the Northern Region in 2018 and 2019 and below 1.0 in the Southern Region in 2019.

This pattern aligns well with trends in available ESH in the Southern Region: a 37% decrease in available ESH in 2017 and a 50% decrease in 2018. The number of adult plovers observed in the Southern Region was similar in those two years, but the fledge ratio declined 33% in 2017 and 56% in 2018.

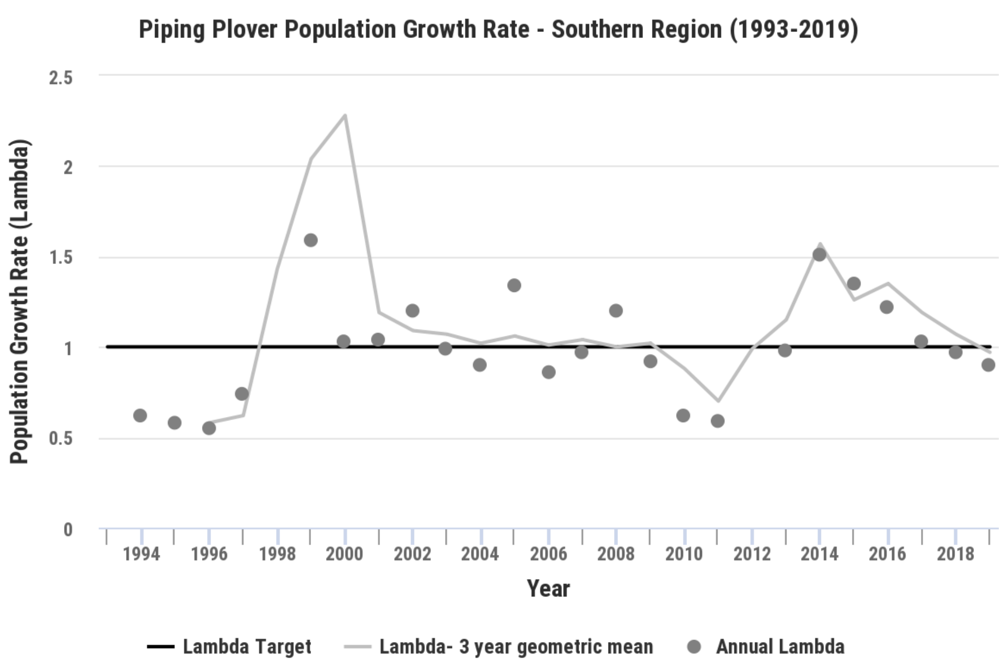
In 2019, Lake Sakakawea and Gavins Point were the only segments with observed increases, albeit small ones, in plover adults. The adult count for Lake Sakakawea increased from 18 piping plovers in 2018 to 29 in 2019, and the Gavins Point count increased from 448 to 486 (more details about segment scale data are included in Appendix Section 2.2.2.) The overall declining trend in adult abundance has been influenced by low ESH and reservoir shoreline availability due to high runoff since 2017 and the resulting effects on fledge ratios.

If basin runoff is less in 2020 (which is likely since 2019 runoff was the second-highest recorded), newly created sandbars and decreasing reservoir elevations will likely provide enough habitat to reverse the decline. If runoff is also high in 2020, a decline in breeding activity may continue on the Missouri River. However, the total number of piping plovers breeding on the Missouri River is still high, with adult numbers above the median (55th percentile) of counts since 1993. In the Southern Region, adult counts remain at the 89th percentile of survey years.

[*] The extent of immigration and emigration in the Southern Region in the past 5 years is not known, but previous studies have indicated that movement to and from the Southern Region segments and other breeding areas is much lower than has been observed for the Northern Region.



a)



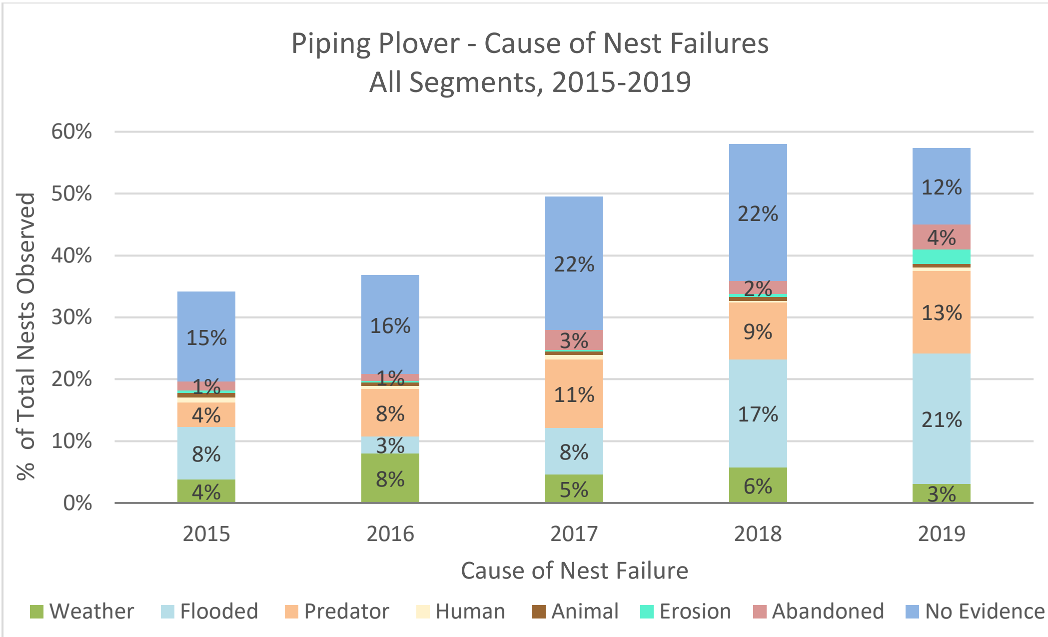
b)

Figure 2-8. Annual (points) and running geometric mean (line) of the plover population growth rate for the a) Northern and b) Southern Regions. The horizontal line indicates the target of λ = 1. High annual values for the Northern Region in 1998 (7.4) and 2012 (9.6) are not shown for reasons of scale; these values reflect the low numbers of birds counted in the survey during floods and their subsequent return.

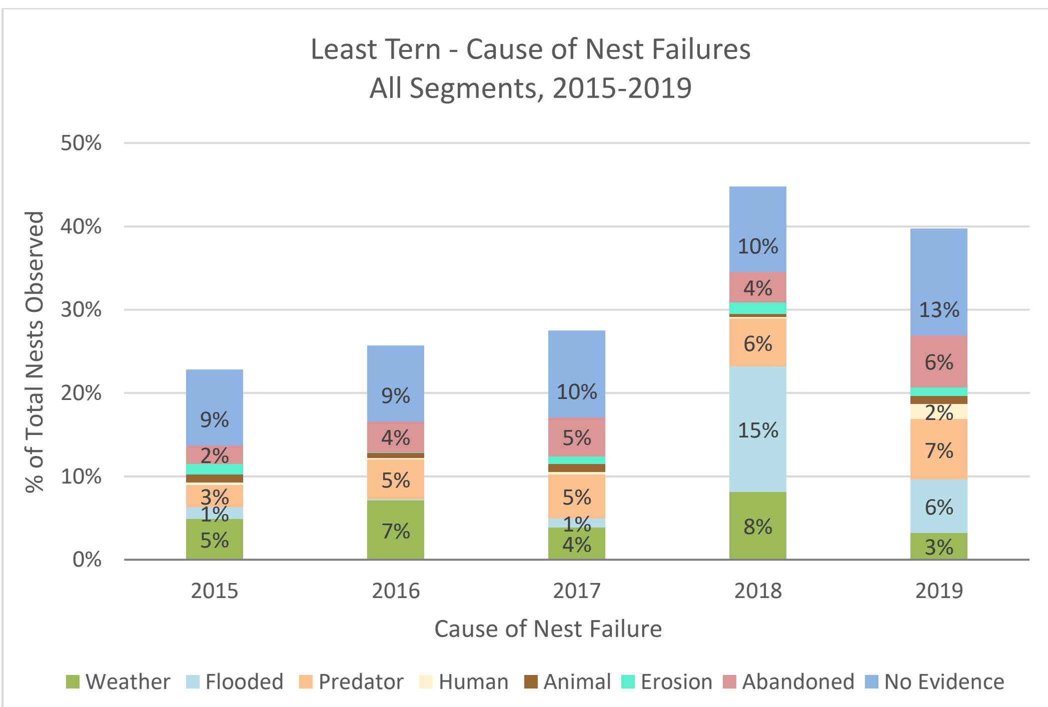
2.2.3.3 Nest Fate

The Tern and Plover Monitoring Program (TPMP) records the fates of nests located during monitoring. While not a performance metric, the percentage of nests that fail and their causes inform the interpretation of fledge ratios and management decisions. Chick mortality is observed less often, and causes are difficult to determine.

In 2019, 577 of 1,005 piping plover nests (57%) observed by TPMP crews failed. Of the 813 observed least tern nests, 323 (40%) nests failed. The largest percentage of piping plover nests that failed were flooded by rising reservoir pools and river releases (Figure 2-9). Inundation of plover nests occurred on all segments, causing the loss of 25% of the 246 total plover nests in the Northern Region and 20% of the 759 plover nests in the Southern Region.



a)



b)

Figure 2-9. Percent of total nests lost by attributed cause for a) plovers and b) terns.

For least tern, the highest overall percentage of nests that failed had no causal evidence and likely failed due to small mammal or avian predators that remove eggs from the nest bowl (Figure 2-9). While the largest cause of least tern nest failures in the Northern Region was the result of flooding (17% of 229 total nests), the majority of least tern nest failures in the Southern Region (15% of 584 nests) had no causal evidence. Only 2% of the least tern nests were flooded in the Southern Region.

The difference in rates of tern nest inundation in the Northern and Southern regions (17% vs 2%) can largely be attributed to the timing of flow increases. On the Garrison segment, flows tripled between June 1 and June 25 (15-46 kcfs), which is the peak of the tern nesting season. On the Gavins Point segment where most Southern Region terns nested, flows were rose to 70 kcfs by June 1 and stayed constant, so tern nests were less subject to inundation. Plovers begin nesting in early May and were more likely to be affected by stage increases in both regions.

2.3 Management Actions

This section summarizes the implementation of management actions and related research for terns and plovers. Actions for 2019 are summarized in Table 2-6. More detail about these actions and information about other management actions related to the birds is discussed in Appendix 2.4. See Section 4.2 of this report for a summary of human considerations related to bird actions. For more information about management strategies and proposed future actions, refer to the Strategic Plan.

Table 2-6. Summary of management actions for 2019.

Management Action	2019 Implementation	Notes
Sandbar Construction	None	Not needed; anticipate sufficient ESH following high flows
Sandbar Augmentation	None	Not needed; anticipate ESH will have been reworked by high flows
Vegetation Management	None	Not implemented because of high runoff and weather events
Flow Management for Nesting	None	Not implemented due to high runoff
Nest and Chick Relocation	42 at-risk plover nests and 4 at-risk tern nests moved; 15 plover nests raised	32% of moved nests were successful
Predator Removal	None	Planned observation year
Nest Caging	Fort Randall (34 nests) and Lewis and Clark Lake (97 nests)	
Human Restrictions	68 sandbars/shoreline areas signed	

2.3.1 Sandbar Construction

No ESH was constructed in 2019. Modeling and field observations suggested ESH created by high flows in 2018 and 2019 deferred the need for construction. Model estimates of construction needs in out-years are presented in Section 2.5 .

Model predictions are presently the most reliable means of quantifying the effects of 2019 flows on ESH. Field confirmation was not possible due to high stages. Field observations and the collection of LiDAR data on sandbar elevations in the Fort Randall and Gavins Point segments will provide insight into ESH status once conditions allow.

2.3.2 Sandbar Augmentation and Modification

Modifications and augmentation of existing sandbars have not been implemented. The 2019 flows are expected to reshape sandbars and increase acreage by depositing additional sediment, reducing or removing the near-term need for modification or augmentation.

Habitat quality concerns in the Garrison segment – mostly related to excess fine sand unsuitable for nesting – have been identified and are being further evaluated in the geomorphology study described in Section 2.4.2 .

2.3.3 Vegetation Management

Herbicides were not applied in 2019 because of high flows and weather events. Prescribed burning was not conducted in 2019 for the same reasons. High flows were of sufficient magnitude and duration to kill and/or scour much of the submerged vegetation. Weather events such as high winds, snow, and an early freeze prevented aerial herbicide application on exposed ESH in both regions.

An analysis of habitat monitoring data from 2012-2018 in the Garrison, Fort Randall, and Gavins Point segments showed statistically significant reductions in vegetation cover on treatment (sprayed) vs untreated ESH when there was at least 5% vegetation cover prior to treatment. The effect increased with prior cover, though most sites had low (<10%) vegetation cover. For example, untreated transects with 25% cover increased to 33% cover, on average, the following year, but treated transects with 25% cover decreased to 20%. For transects with 50% cover, untreated increased to 54% while treated decreased to 34%. There was no significant difference between the three segments evaluated (Lewis and Clark Lake, which had fundamental differences in the treatment design, was excluded from analysis.) There was no significant effect of year on vegetation management effectiveness, but vegetation encroachment was greatest in 2013. Details of this analysis are in Appendix 2.3.

2.3.4 Flow Management to Reduce Nest Inundation

Representatives of the USACE's Missouri River Basin Water Management Division, Threatened and Endangered Species Section, and the USFWS held conference calls during the nesting season to discuss water release schedules, reservoir elevations, nest locations and status, and chick fledging schedules. Near record runoff in 2019 precluded opportunities for flow management to reduce inundation. Reservoir releases were determined based on mainstem reservoir system flood risk management. System and individual project operations were not adjusted for the terns and plovers.

2.3.5 Nest and Chick Relocation

In 2019, 326 plover and 229 tern nests were considered to be at risk of inundation. A majority (84%) were located on the river segments. Only 37% of the at-risk nests succeeded; 57% failed, with 61% of the failed nests lost to inundation or erosion. Six percent of the at-risk nests were undetermined, meaning that they had enough incubation time to hatch and the nest bowl was empty, but no chicks or evidence of hatching were observed. TPMP crews moved 42 at-risk plover nests and 4 at-risk tern nests to higher ground in response to rising water levels. Unfortunately, the majority of these nests could not be moved far enough or high enough to prevent inundation from the high releases and/or the rising tributary flows, and only 32% of the moved nests were successful. Another 15 piping plover nests that could not be moved were raised in place by mounding sand around and under the nest; only 14% of these nests were successful. The majority of the raised nests were on one low-lying sandbar on the Gavins segment and most were destroyed by a predator. Had these nests not been moved or raised, all would have been inundated.

2.3.6 Predation Management

The percentage of tern and plover nests failed due to predation and suspected predation (no evidence) in 2019 was slightly lower than in 2018 (23% vs. 25% in 2018). Predation was higher in the Southern

Region (26%) than in the Northern Region (16%). Nearly a quarter of tern and plover nests in the Northern Region were inundated, so fewer nests were available for predators to find.

Predator control was suspended in 2019 to provide an opportunity to observe predation rates after 2018 high flows caused significant changes to ESH. Because runoff was high again in 2019, the effects of 2018 habitat changes on predation rates could not be observed; newly created ESH was underwater again during the nesting season in both regions.

In 2019, monitoring crews caged 34 piping plover nests on the Fort Randall segment and 97 nests on the Lewis & Clark Lake segment. On the Fort Randall segment, 45% of the 34 caged nests were successful or probably successful, compared to 32% of 80 uncaged nests. On the Lewis and Clark Lake segment, 75% of the 97 caged nests were designated successful or probably successful, compared to 33% of 66 uncaged nests (See Appendix 1.3.4 for more details).

This was the third year of caging piping plover nests on the two segments. Cages improved nest survival in those three years (Schwarz et al. 2019; Appendix 2.3.4). However, there were signs of possible adult predation at eight caged nests in 2019. After 3 years of caging in this area, predators, especially avian predators, may have keyed in on the nest cages. It is also possible that with the record runoff and limited available habitat in 2019, the concentration of birds tending to their nests made them more vulnerable to predators.

The USGS evaluation of nest caging on the Alkali Lakes from 2014-2016 (2019 FSM presentation "Plover Metapopulation Study Update" Mike Anteau, USGS) found that caging resulted in 21% greater cumulative nest survival. There was also a 5.6% increase in survival for uncaged nests near caged nests, suggesting that nest caging may deter predators rather than act as a cue. Chick survival increased and adult survival was unaffected. However, it is unknown how much of the study findings are dependent upon the particular predator community in the Alkali Lakes, which is different from that on the Missouri River, so extrapolating these results to the Missouri River is cautioned.

2.3.7 Human Restrictions

Signs prohibiting entry were placed on 89 sandbars and reservoir sites in 2019. Despite these actions, violations were common on all river segments. During the 4th of July weekend, signs were removed and thrown into the river, 13 nests were destroyed, and fireworks were lit next to caged nests on one sandbar on the Fort Randall segment. Human and canine tracks were observed on 44 of the signed sandbars in both regions. ATV tracks were also observed on several sandbars. Human activity was the attributed cause of failure for 5 plover and 17 tern nests. Sub-lethal effects likely occurred on sandbars frequented by people and dogs, but cannot be quantified. Human disturbance was higher than in 2018, likely due to the reduced availability of ESH for recreationists and for nesting birds.

2.4 Science Activities

The following sections provide summaries of scientific findings related to the biological hypotheses. These focus on physical and biological processes rather than management actions. Where overlaps occur, the main discussion is provided in Section 2.3 and referenced below.

2.4.1 Hypotheses and Conceptual Models

The biological hypotheses and conceptual models for plovers and terns (Appendix Section 2.1.3; see also Buenau et al. 2016) were unchanged in 2019. Biological hypotheses under focused evaluation are discussed in Table 2-7.

Table 2-7. Summary of biological hypotheses, ongoing assessments, and study findings.

ID	Hypothesis	Assessments	Findings
H4	Increased dam releases increase the area of nesting/brood-rearing habitat and foraging habitat, if flows are of sufficient magnitude and duration, by redistributing available sediments.	The effects of increased flows in the Garrison segment in 2017 and 2018, as measured by imagery and field surveys, are under evaluation as part of the geomorphology study. LiDAR was collected in December 2018 for further assessment of morphological changes.	Field observations indicated the creation of lower-elevation ESH in the Garrison segment in 2017. Results from 2017 were used to update the discharge-area curve for the segment. Observations also suggest 2018 flows created and reshaped sandbars; evaluation of LiDAR and other data is underway. (See also Appendix 2).
P2 P3	Increases in the area of suitable nesting/brood-rearing and foraging habitat increases plover survival from egg to chick and chick to fledgling by reducing predation. Increases in the area of foraging habitat increase plover survival from chick to fledgling by increasing food availability.	The relationship between observed nesting density and fledge ratios, and other habitat-based factors potentially contributing to reproductive success is evaluated annually once new monitoring data are available. Details of updates for 2019 are provided in Appendix 2.	Results of 2019 productivity monitoring and updated ESH quantification were incorporated into the productivity analysis. The data continue to support the relationship between adult density and fledgling production as the best-fit and most parsimonious model for explaining observed fledge ratios.
P4	Increases in the area of nesting/brooding and foraging habitat increase the number of plover adults through immigration.	The USGS "metapopulation" study in the Northern Region and alkali wetlands has finished collecting observations for the mark-resight study of piping plovers. A multi-state mark-resight model is being tested and applied to more accurately estimate dispersal and survival.	Preliminary estimates (without the statistical model) are a 15% adult and 47% natal dispersal rate among all Northern Region segments and the alkali wetlands. Average dispersal between the MR and the wetlands during 2015-2019 was 7% for adults and 50% for juveniles, but there is large variation by year and location. These data suggest the Northern Region plovers are more connected to alkali lake plovers than previously thought, but dispersal rates are not consistent over time and the drivers are not fully known. Mark-resight model analysis is necessary to further evaluate the data and is currently underway.

2.4.2 Summary of Research and Publications

This section summarizes MRRP-funded research conducted during the reporting year and the implications of those studies for management and future research. The research described herein relates to the general understanding of species biology, habitat needs, and geomorphology. Research specific to individual management actions is described in Section 2.3 . Other relevant research that is not directly funded by the MRRP but can inform the program, including research on other populations, is also presented. More details on these studies are provided in Appendix 2, and further discussion of their implications is provided in Section 2.6 .

2.4.2.1 Research Funded by MRRP—In Progress

USGS. Spatial variation in population dynamics of Northern Great Plains Piping Plovers. Progress Report.

The purpose of the metapopulation study is to understand plover dispersal among the Northern River segments and the Alkali Lakes and if and how the breeding populations function as a metapopulation. USGS is evaluating how movement and survival relate to water levels, habitat availability, and demographic variation. Resighting was completed in 2019; the final year of the study will consist of data analysis and mark-resight model development. Preliminary results suggest that average natal dispersal (including between northern Missouri River segments) is 47% and adult dispersal is 46.6%, but variability is high between years and segments. On average, adult dispersal on and off the river appears balanced at 7%, but the annual percentages of on-off river dispersal vary 17 percentage points from balanced (13% immigration to 4% emigration) for adults and 84 percentage points (74% immigration to 10% emigration) for first-year breeders. These preliminary results are observations rather than model results, which will account for detection and other factors. The statistical model has been beta-tested and will also estimate true survival.

The USGS has also evaluated renesting (Swift et al. 2020) in their study data. They found a 25% propensity for renesting, which is low compared to some other piping plover populations. Nest success declines sharply with time and so renesting success was lower than first nest success. Fledgling success was very low except on reservoirs with decreasing elevations during the nesting season. Predation reduced the likelihood of plovers renesting.

Another analysis found that the presence of least tern nests increased plover nest success on the Gavins Point and Garrison segments and chick survival on Garrison, Sakakawea, and Gavins Point.

Implications: Dispersal rates among Missouri River segments and with other nearby habitat areas in the Northern Region are likely much higher than originally expected, and vary greatly with time and location. Understanding these dynamics will improve the prediction of population dynamics and help interpret observations, which in turn will inform management decisions. More analysis and modeling are necessary to determine what changes, if any, need to be made to the MRRP in response to this new understanding. However, it is possible that the ESH or demographic targets and/or criteria may need to be adjusted to accurately evaluate the USACE's effectiveness at meeting MRRP objectives. Further effects on the selection and implementation of management actions (aside from adjustments of the level of effort) appear less likely at this time.

The renesting study results emphasize the importance of providing good habitat conditions for first nests and protecting those nests rather than relying on renesting, especially as the season progresses. The positive effects of tern nests co-located with plover nests suggest that providing habitat features to attract terns (e.g. very low vegetation cover, shallow water foraging habitat) can also improve outcomes for plovers.

ERDC. Geomorphic investigation of the Garrison Reach. Progress Report.

The purpose of the Garrison geomorphic study is to collect and evaluate physical data regarding ESH within the Garrison segment and use the results of those evaluations to update the discharge-area curves for ESH, update the ESH prediction models, and assess critical processes associated with ESH development and vegetation development. Early results substantiate the need to update stage-area curves; new curves were developed for use in 2019 strategic planning using data through 2017. New ESH creation from high flows in 2018 has been confirmed by field observations. Hydrographic and LiDAR survey data are being evaluated to determine if there is a need for additional changes in discharge-area relations and to update ESH models. Data have been collected to help with proposed studies of habitat quality, aeolian transport, and vegetation/sedimentation interactions.

Implications: Development of new stage-area curves and updates to ESH models will improve the accuracy of monitoring efforts for ESH and model predictions of ESH availability as a function of flow. New and improved understanding of ESH processes may lead to better management decisions associated with habitat construction and maintenance – particularly vegetation management.

2.4.2.2 Research Funded by MRRP—Publications

Researchers from Virginia Tech published the following three papers related to the projects they conducted on the Gavins Point segment between 2005-2017.

Catlin et al. (2019a) evaluated the effects of nesting density, habitat area, and flow on the likelihood of breeding and apparent survival of 1st-year breeders versus older birds, and breeding versus non-breeding birds. Nesting density had the greatest effect and complex feedback loops resulted from density dependence. Variations in breeding rates weakened the relationship between fledge ratios and population growth, making population dynamics harder to predict. The MRRP plover model accounts for the feedbacks associated with density dependence. Breeding propensity is modeled implicitly; additional factors affecting propensity merit consideration for future modeling.

Catlin et al. (2019b) compared the landscape characteristics of sandbars and nest sites selected by terns and plovers from 2012-2014. The results supported their hypotheses that both species would select sites that reduced predation and flooding risk and plovers would select sites with better foraging prospects relative to random locations. Site selection did not consistently affect nest or chick survival, but abundant high-quality ESH and high survival between 2012 and 2014 likely minimized the importance of selecting good nesting sites relative to years with poor habitat. These findings inform the planning of ESH construction or modification projects and support predictions following natural habitat creation.

Hunt et al. (2019) used video cameras to resight (identify) banded birds following a more intensive mark-recapture study. This method was effective at estimating population size and apparent survival. It required less time and effort in the field, but may underestimate the number of unmarked birds and requires adults to be banded prior to the use of cameras. This method can be considered should future research or monitoring require marking and resighting plovers.

2.4.2.3 Other Relevant Publications

2.4.2.3.1 Research Funded by Others—Missouri River

Robinson et al. (2019) compared irruptions[*] of plovers following habitat-forming disturbances at multiple Atlantic Coast locations and the Gavins Point segment of the Missouri River. Across all sites, populations increased after habitat formation and declined with habitat limitation. Immigration was more important in smaller Atlantic Coast sites and less important on the Missouri River. Gavins Point was the only location at which fledgling production was sufficient to fill available habitat over multiple years, and where population densities decreased after the habitat-forming event. This study puts the Missouri River in context and supports hypotheses about density-dependent population dynamics.

* Irruptions are abrupt, large increases in bird populations.

2.4.2.3.2 Research Funded by Others—Other Locations

Disturbance was also evaluated in the response of plovers to Hurricane Sandy in New York (Walker et al. 2019). Barrier island habitat is very different from Missouri River habitat, but the role of hydrological disturbance in creating landscape factors important for nesting and brood-rearing was similar. Weithman et al. (2019) compared plover demographics at two Atlantic Coast populations and found that demographic rates were different between the sites but the fledge ratios needed for a stable population were similar. The relative importance of vital rates differed between populations, suggesting recovery goals should be location-specific.

2.4.3 Update on Monitoring Methods

No methodological changes were made to the tern and plover monitoring conducted in 2019. Significant work was done in 2019 to develop alternative monitoring protocols for future years; progress is described in the remainder of this section.

The current TPMP protocol (USACE 2009) consists of a single adult census and a multiple-visit productivity survey to estimate fledglings. It does not estimate observation error, which was determined to be an important consideration by Shaffer et al. (2013). Evaluations of alternative monitoring options (Schwarz et al. 2018) demonstrated how changes to the current methods could improve precision and account for potential bias. The “hybrid” plan (Option 3 in Schwarz et al. 2019a) includes adult counts used in the current monitoring protocol and adds the sampling design described by Shaffer et al. (2013) to estimate observation error. Elements of the hybrid monitoring plan (Schwarz et al. 2019a) are proposed to be tested on the Gavins Point segment in 2020 to evaluate the sampling design.

The hybrid monitoring plan, discussed in Appendix Section 2.4, consists of two parts. A single survey of adults is conducted on the entire segment using the current TPMP protocol (USACE 2009). Throughout the nesting season, a stratified random sample of map-units within each segment is more intensively monitored to locate nests and estimate breeding adults and fledgling production, using a protocol that reduces and measures observation error. The adult count continues the legacy time series of TPMP adult surveys and can also be corrected using breeding pair information from the productivity monitoring. The correction factors will also provide some information on how to adjust past data to examine trends over time, although these retrospective adjustments will not be as reliable.

No banding of chicks is planned for 2020. The hybrid monitoring plan estimates fledglings using estimates of non-detection in Shaffer et al. (2013). The program has the option to transition in the future to a protocol where correction factors can be estimated by resighting banded chicks.

The 2018 BiOp ITS was written assuming that egg loss would be monitored according to the current TPMP, in which monitoring crews attempt to locate and monitor all nests. Using the hybrid protocol, incidental take of eggs would only be observed on the selected map-units. Total incidental take could be estimated using the same approach as for the performance metrics. The ITS includes a statement that allows the USACE to change incidental take monitoring with written approval from the USFWS.

In 2019, a series of draft action effectiveness monitoring plans (Schwarz et al. 2019 b, c, d) outlined study designs that would evaluate whether management actions (i.e., predator control, ESH creation/management, vegetation management, human restriction, flow management) are increasing plover population size, nest success and fledgling survival. These management effectiveness evaluations would be separate studies conducted alongside the system-wide population monitoring plan, with responses measured at different scales (e.g., nest or sandbar level). Some data collection may overlap between population and effectiveness monitoring.

2.5 Model Predictions

Model projections of habitat and plover demographics are performed annually to inform updates to the Strategic Plan. Several hydrologic scenarios have been evaluated to illustrate how ESH estimates are affected by the uncertainty about future basin runoff. The model was also run with the full range of hydrological variability in the Period of Record to estimate, probabilistically, when ESH construction might be necessary. Model results are one of many considerations affecting strategic planning and are not implementation plans.

2.5.1 Model Updates

The ESH model has been updated with a new discharge-area curve for the Garrison Reach to improve the adjustment of ESH estimates for different flows (see Appendix 1.7.2 for details). The curve is an interim estimate based on data collected in 2017 for the Garrison geomorphology study. It is expected that this curve and, if warranted, the model equations for standard ESH will be updated again in 2020.

The population model parameters were updated to include observed adult density and fledge ratios from 2019. The ESH acreage values used to calculate population density were updated for all years (2006-2019) as explained in Section 2.2.2 . Parameters, analyses, and their effects on model predictions are explained in detail in Appendix 1.6.1 and 1.7.2.

2.5.2 Management Scenarios

Given the anticipated ESH status following high flows in 2018-2019, the primary management concerns for plovers and terns relate to maintaining ESH quality. ESH construction is not expected to be necessary for several years, but scheduling and budgeting the related planning and design may be needed in the out-years of the Strategic Plan. Given the uncertainty in future flows, when to begin ESH project planning and the scale of potential construction are key questions.

These questions were approached using scenarios that address the variability and autocorrelation in annual basin runoff. Scenarios consisted of multiple 5-year time series from HEC Res-Sim model results (Table 2-8). The "Period of Record" (POR) scenario includes all years from 1930-2012; years after 2012 are being added to the hydrological modeling for use in future reports. Because the POR includes a large amount of variability, it can be difficult to relate the predictions to real-world conditions. Subsets of the POR (a limited number of initial years) representing narrowly-defined situations can be interpreted more readily. "The storage" scenario includes initial years with system storage similar to that of July 2019 (67.9 MAF), because storage reflects recent runoff and influences near-term reservoir operations. The "wet", "decreasing", and "dry" scenarios represent different future runoff possibilities. These scenarios were chosen by selecting sequences of years where the annual runoff above Sioux City (Figure 2-10) met the conditions described in Table 2-8.

Note: the POR scenario uses the full set of HEC-ResSim modeling developed for the MRRMP EIS. This time period was selected to contain multiple high flow and drought periods. It ended in 2012 because the model period was selected in 2014 at the beginning of the MRRMP. In future years, it would be ideal to extend the model to the most recent runoff year to continue capturing a wide range of runoff conditions.

These scenarios are not predictions, but rather ways of illustrating potential outcomes under different circumstances. They clarify the actions that may need to be taken should a particular circumstance occur (e.g. wet years transitioning gradually to dry years). Each scenario was run assuming that vegetation management preserved 12% of ESH area annually.

*Table 2-8. Model scenarios for five types of hydrological conditions.**

Scenario	Conditions	Initial Years
Period of Record	All variability captured in 83-year modeled time frame	1930-2012
Storage	Non-consecutive initial years with historical system storage most similar to end-of-month July 2018 system storage	1970, 1976, 1979, 1983, 1995, 1999, 2010
Wet	Sequences of years with high annual runoff	1967, 1982, 1993
Decreasing	Sequences of years with high annual runoff transitioning to low runoff	1952, 1943, 1998
Dry	Sequences of years with low annual runoff	1954, 1988, 2000

*Models were run with initial years randomly selected from the list.

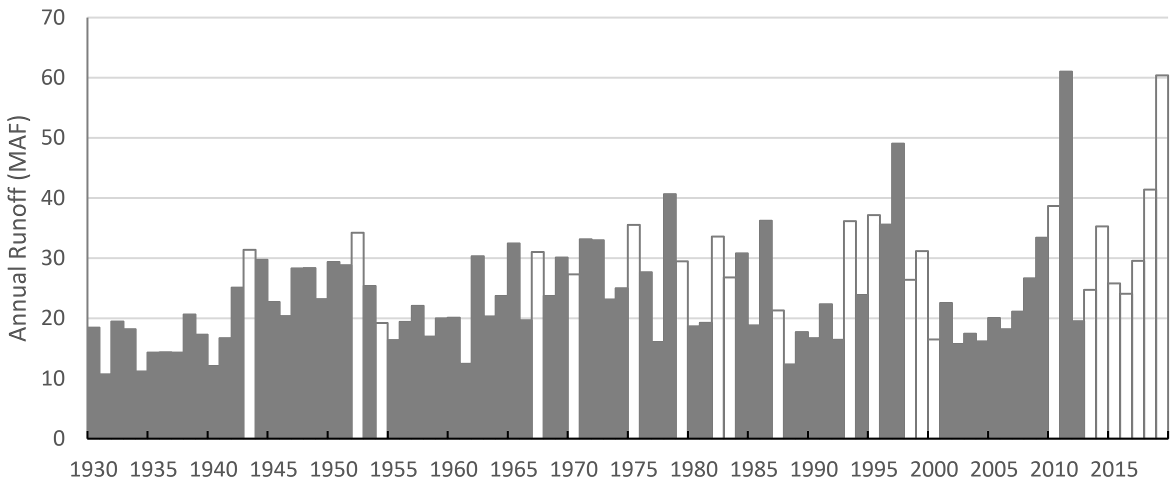


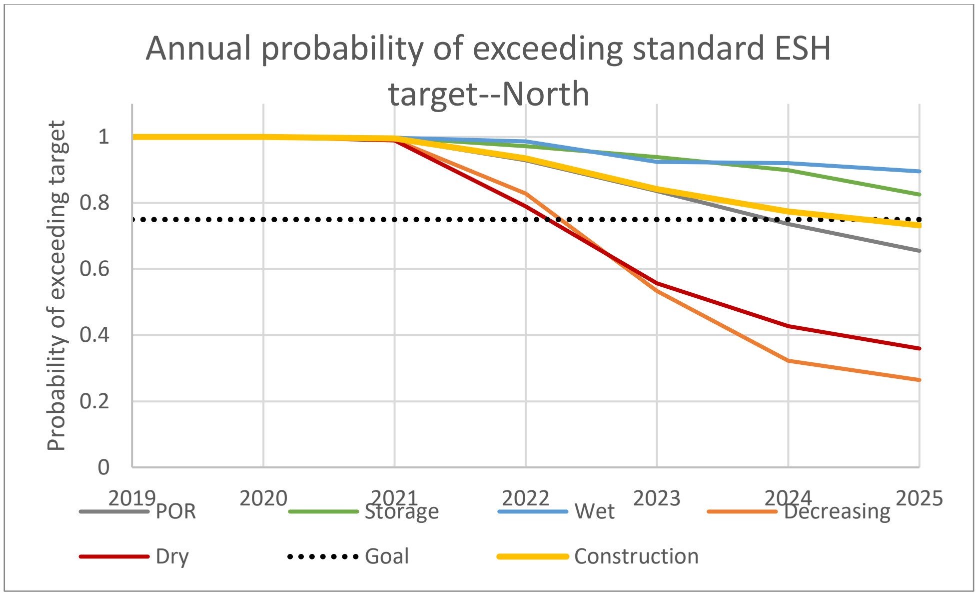
Figure 2-10. Annual runoff above Sioux City with initial years marked by scenario: POR (all colored bars), Storage (green), Wet (dark blue), Decreasing (light blue), and Dry (yellow). Years after 2012 (white) are shown for reference but are not part of the modeled POR.

2.5.3 Results

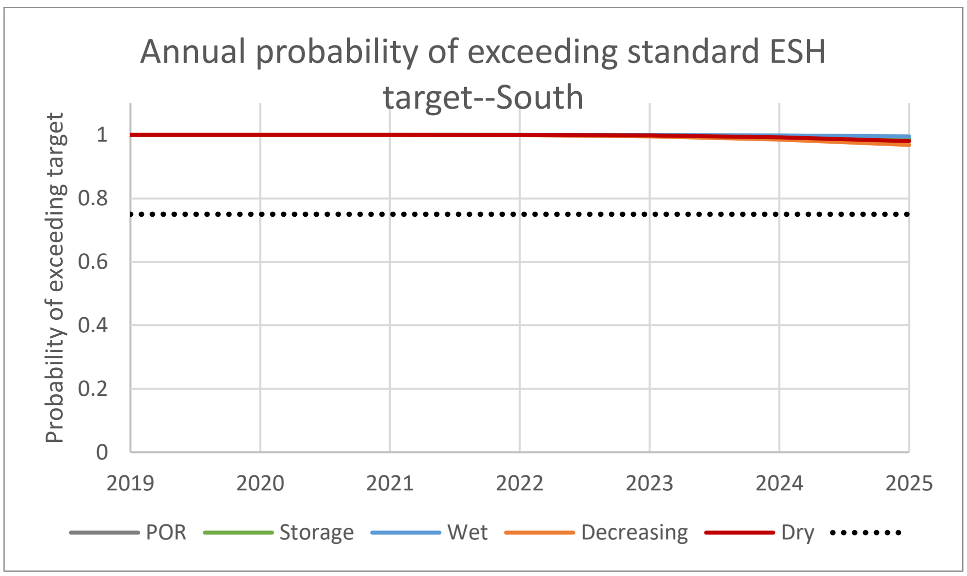
Selected model results and management implications (in **bold**) are summarized in this section, followed by the standard ESH projections. The full set of ESH and demographic projections and probability estimates and detailed explanations are in Section 2.7.3 of the Appendix.

- The estimated probability of meeting standard ESH target criteria in the Northern Region by 2025, without construction, was 65% using the POR scenario (Figure 2-11a).
- Wet conditions improved the probabilities of meeting ESH targets without construction. For decreasing or dry runoff scenarios, the model estimated 26-36% probabilities of meeting targets by 2025.
- **In the Northern Region, the 25th percentile ESH model results, using imagery delineations for 2019 initial conditions, estimated that 30 acres of construction in 2022 and 90 in 2023 (or ~130 acres of construction in 2023) would be needed to meet targets (Figure 2-13a, Table 2-9). That amount corresponds with a 75% chance that targets would be met or exceeded each year.**

- **Alternatively, using model-projected estimates for 2019 initial conditions, the 25th percentile ESH model results estimated that 80 acres of construction would be needed in 2024 to meet targets (Figure 2-14, Table 2-10).**
- **Construction needs in the Northern Region are expected to be strongly influenced by runoff and reservoir releases in the next 5 years. Estimates ranged from 0 acres/year in wet, habitat-forming scenarios to 300 acres of construction in some years in scenarios with high erosion.**
- **Current model estimates suggest that vegetation management at the default 12% level of effectiveness (Appendix 2.5.3) reduced the amount of construction needed by ~150 acres a year in the Northern Region when standard ESH is at or near the target.** The probability of meeting standard ESH targets in the Southern Region over the next 5 years is estimated to be nearly 100% if vegetation management is implemented (Figure 2-11b).
- **Model projections suggest that ESH construction is highly unlikely to be needed in the Southern Region in the next five years. Estimates may change after the ESH acreages resulting from 2019 flows are quantified.**
- In all scenarios, annual fledge ratios were projected to exceed the target from 2020 through 2022 for both regions. Annual population growth rates were projected to exceed the target through at least 2023 in the Northern Region and 2025 in the Southern Region, for most scenarios.
- Model projections suggested the likelihood of meeting plover fledge ratio and population growth rate target criteria (3-year mean values) in 2020 is low because of poor reproductive years in 2017-2019.
- The estimated probability of meeting fledge ratio target criteria (3-year mean values) in the model scenarios increased each year to 80% in the north and 60-80% in the south by 2022; the probability of meeting growth rate criteria increased to 80% in the north and 50-70% in the south by 2023.
- **Fledge ratio and growth rates have a high probability of improving after 2020, even without ESH construction. Meeting targets becomes less likely after 2023 if vegetation spraying is implemented but no ESH construction, ESH modification/augmentation, or habitat-forming flows occur.**



a)



b)

Figure 2-11. The modeled probability of meeting standard ESH target criteria for five hydrological scenarios for the a) Northern and b) Southern regions, using 2019 initial conditions estimated from satellite imagery habitat delineations.

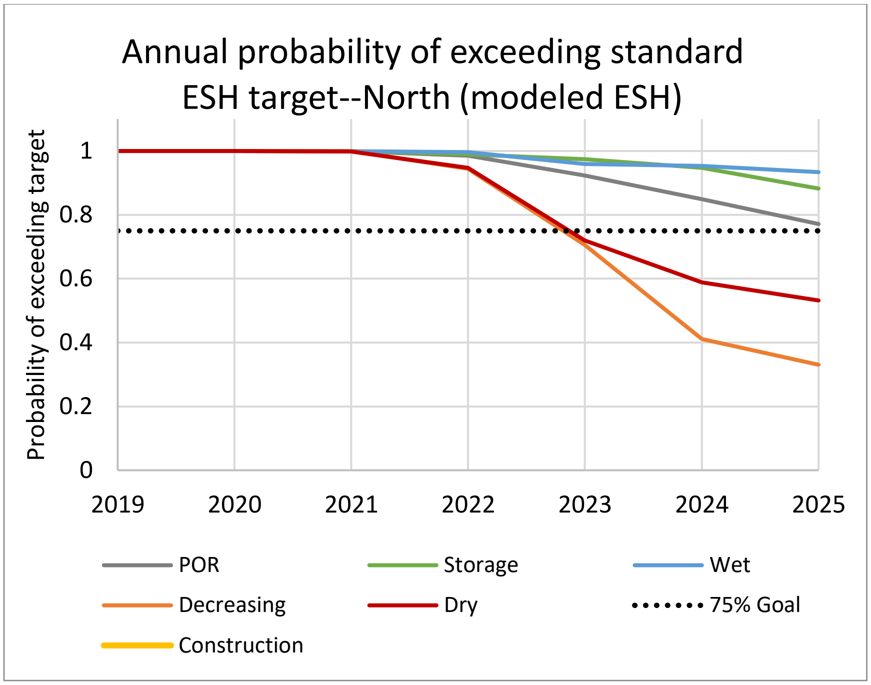
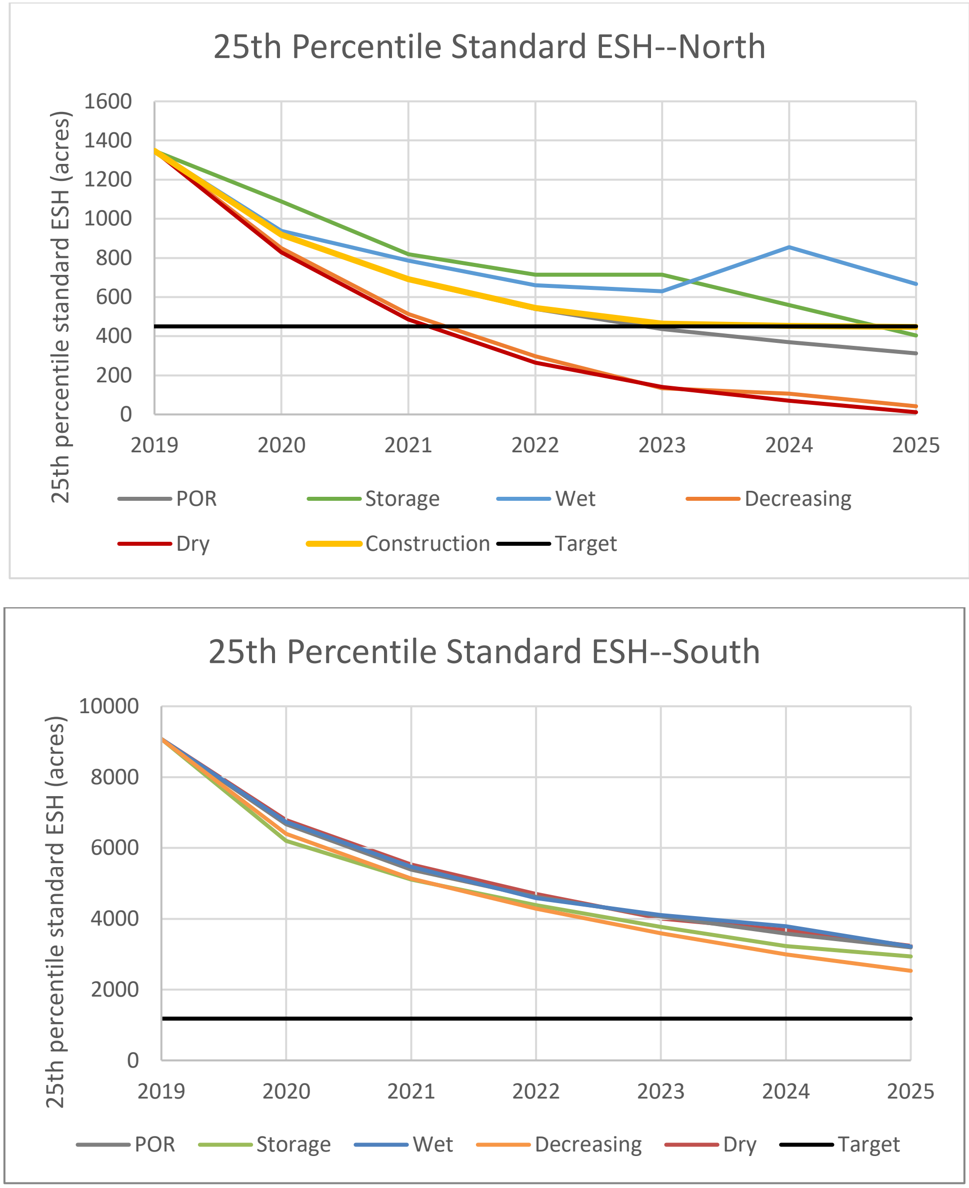


Figure 2-12. The modeled probability of meeting standard ESH target criteria for five hydrological scenarios for the a) Northern and b) Southern regions, using 2019 initial conditions from ESH model estimates for 2018 and 2019.

a)


b)

Figure 2-13. The 25th percentile of standard ESH model projections for the five hydrological scenarios for the a) Northern and b) Southern regions, using 2019 initial acreage estimated from delineation of satellite imagery. The standard ESH target for each region is indicated by the black line.

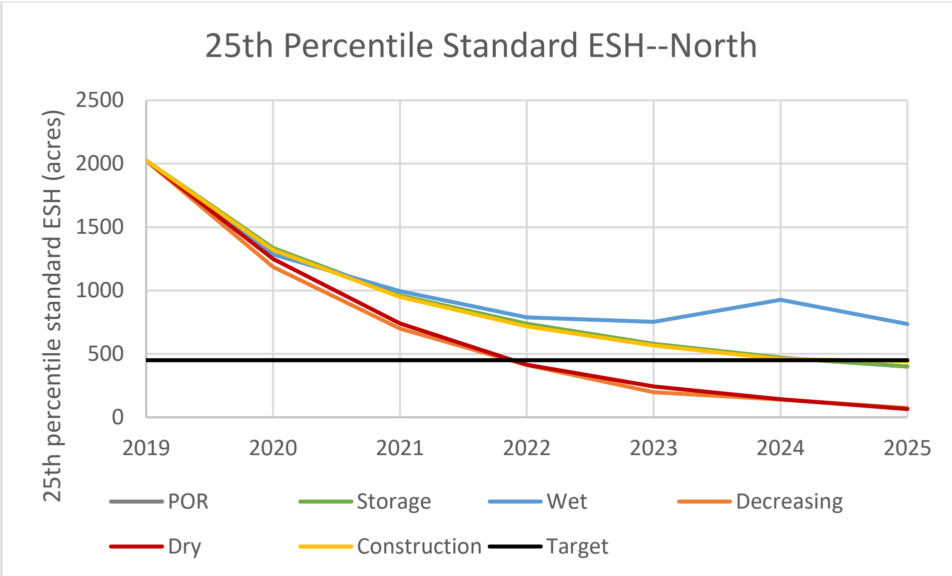


Figure 2-14. The 25th percentile of standard ESH model projections for the five hydrological scenarios for the Northern region, using 2019 initial acreage estimated from 2018-2019 modeled ESH. The standard ESH target is indicated by the black line.

Table 2-9. Estimated amount of ESH construction needed in the Northern Region to stay above standard ESH targets using the 25th percentile model results and 2019 ESH estimates from habitat delineation of satellite imagery.

Year	POR	Storage	Wet	Decreasing	Dry
2020	0	0	0	0	0
2021	0	0	0	210	250
2022	30	0	0	300	230
2023	90	0	0	270	220
2024	100	50	0	210	200

Note: Amount indicates acreage to be constructed in the fall of the specified year.

Table 2-10. Estimated amount of ESH construction needed in the Northern Region to stay above standard ESH targets using the 25th percentile model results and 2019 ESH estimates from model estimates of 2018 and 2019 acreage.

Year	POR	Storage	Wet	Decreasing	Dry
2020	0	0	0	0	0
2021	0	0	0	50	60
2022	0	0	0	310	220
2023	0	0	0	270	200
2024	80	0	0	240	200

2.6 Progress in Learning and State of the Science

High flows in 2019 limited opportunities for new information collection but provided additional learning opportunities about habitat and population responses to high flows. Conditions also limited the types of actions that were implemented and impeded some planned analyses, including evaluation of predation after a habitat-forming flow and field data collection regarding ESH created in 2018 or 2019. However, each nesting season provides useful, unique data that contribute to the overall set of information about habitat and population dynamics.

2.6.1 Progress on Overarching Uncertainties

New knowledge or capabilities related to critical program uncertainties are summarized below.

1a) How should plover and tern habitat be most accurately quantified and what determines habitat quality?

- Updates to the discharge-area curve for the Garrison segment improved the ability to calculate and project standard and available ESH acreage delineated from satellite imagery. The new estimates are much more realistic - especially for higher flows - and reduce uncertainties in ESH construction planning for the Northern Region.
- The ESH quantification process was automated, which corrected some inconsistencies in past estimates. These corrections did not have a large effect on model parameters but will improve estimates in the future.
- High flows in 2019 prevented field data collection to address questions about how to quantify ESH in the Northern Region, but investigations are underway to characterize fine sand that appears to be ESH in imagery but is not suitable for nesting.

1b) What is the relationship between habitat quality and fledgling productivity and survival on river and reservoir habitat?

- Catlin et al. (2019b) found that both plovers and terns were attracted to sandbar- and landscape-scale ESH features expected to reduce predation and inundation risk and improve plover foraging. They did not find a clear correlation between habitat selection and nest and chick survival, but their study covered 2012-2014 when ESH was abundant, survival rates were high, and site selection likely had less effect because most of the habitat was suitable.

1c) How do habitat-related factors supporting predation (e.g. nest density, static habitat) affect egg and chick mortality; are there factors that could be manipulated to reduce predation?

- Multiple years of high flows have demonstrated effects of habitat limitation on nest predation. Assessment of nest loss data is underway; however, data collection limitations (i.e. nests lost to predation before they were located by monitoring crews, difficulty in observing chick mortality and attributing causes) may limit the conclusions that can be drawn from monitoring data.

2b) How do habitat conditions in other breeding areas and dispersal to and from those habitats affect the Missouri River breeding population?

- Preliminary results from the USGS metapopulation study suggest that dispersal rates on and off the Missouri River are higher and more variable than previously understood in the Northern Region. Rates differ by location and year, likely due to habitat conditions at each breeding area.

Dispersal but may also be affected by other factors; the full data analysis will be completed in 2020, after which the effects on MRRP decisions may be considered.

- A set of hypotheses and a modeling plan have been developed for evaluating the metapopulation study results in the predictive population modeling context. Initial modeling work and sensitivity analysis will take place in 2020 while awaiting the metapopulation study results.

2.6.2 Status and Progress on Action Effectiveness

The current understanding of effectiveness for actions in the Strategic Plan and the information learned in 2019 is summarized in Table 2-11. More detail is provided in Section 2.3 and Appendix 2.3.

Table 2-11. Summary of the state of knowledge and new understanding gained in 2019 for plover and tern management actions included in the Strategic Plan.

Management Action	Current State of Knowledge	Learned in 2019
Sandbar Construction	Evidence supports effectiveness for site selection by nesting birds and for fledgling production. Questions remain about optimal location, design, and efficient construction.	High flows have limited the need for construction activities, and have provided evidence for bar formation processes and dynamics.
Sandbar Augmentation/Modification	Evidence suggests potential effectiveness; questions remain about project designs and the effects of prolonging sandbar longevity on predation.	High flows have limited the need and opportunities for mechanical interventions, and provide insights into processes that can be manipulated.
Vegetation Management	Spraying of emergent vegetation is effective at reducing cover. Effectiveness on Lewis and Clark Lake is less certain because of different vegetation structure and dynamics. Uncertainties remain about bird use and success on managed habitat.	Habitat monitoring data confirm significant reduction of vegetation cover on treated sandbars on Garrison, Fort Randall, and Gavins Point. Effects are equivalent among those segments, with little difference in effectiveness across years studied.
Flow Management to Reduce Nest Inundation	Flow management to reduce nest inundation is effective when runoff conditions allow flows to be managed in this way; during high runoff flood risk management takes priority over nest protection.	High runoff conditions that require flood risk reduction affected the ability to manage flows to avoid inundation; plover nests on both reservoir shorelines and ESH were at high risk of inundation in 2019.
Nest and Chick Relocation	Effectiveness depends on inundation extent and access to sufficiently high-elevation habitat. Nest success is typically low because of lack of locations to move nests that would not also be inundated. While success is low, all nests would have been lost if not moved or raised.	A third (18 of 57) of relocated plover nests and 0 of 4 relocated tern nests were successful. Nests failed because of inundation or predation; 13 nests on the same low sandbar were raised and 10 were found by a predator.
Predator Removal	Predators can be removed, but it is not clear that they can consistently be removed prior to nest loss, or that they will not quickly be replaced by other predators. Overall effects on fledgling production are still unclear.	The intent to evaluate predation on newly-created ESH could not be met because of high flows in 2019. Evidence of predator presence was collected by TPMP crews. Nest predation rates in the past three years have been consistent in the Northern Region and decreased in the south, in absence of predator removal. High rates of nest inundation may have limited predation opportunities.

Management Action	Current State of Knowledge	Learned in 2019
Nest Caging	Evidence for effectiveness at reducing predation on nests. Mixed evidence on effects on chick and adult survival. The effects on overall fledgling production are still uncertain.	Cages placed on nests in the Fort Randall and Lewis & Clark Lake segments in 2017-2019 improved nest survival in those three years (Appendix 2.3.4). However, there were signs of adult predation at eight caged nests in 2019. Analysis of data collected on alkali wetlands in 2014-2016 showed increases in survival for caged nests and nearby uncaged nests, increases in chick survival, and no effects on adult survival. Study results may be specific to the alkali lakes predator community.
Human Restrictions	Restriction measures are often ignored, but overall effectiveness is uncertain (i.e. unknown rate of obeying restrictions). Enforcement support by other agencies needed. Nest loss to human-related causes is localized and proportionally low. Sublethal effects are unknown and difficult to quantify.	Disturbance increased in 2019, likely because limited sandbar availability concentrated both nesting birds and recreating humans.

2.7 Key Issues and Technical Recommendations

2.7.1 Key Issues and Potential Management Implications for Terns and Plovers

In preparation for the MRRP Fall Science Meeting, the MRRP Integrated Science Program (ISP) reviews important scientific and technical issues with program management implications. They draw from topics that were a focus of interactions during the previous year's governance activities as well as new topics arising from monitoring, assessment and research activities during the year. A brief description of the key issues identified for plovers and terns is provided below.

- Need for ESH construction: High flows in 2017 through 2019 have delayed the need for ESH construction. Model projections using delineated ESH estimates from satellite imagery for 2019 suggest 120 - 130 acres of ESH construction may be needed in the Northern Region in 2023 or divided between 2022 and 2023 (Table 2-9). Projections based upon modeled ESH estimates for 2019 suggest 80 acres of construction needed in 2024 (Table 2-10). Construction in the Southern Region is not anticipated for the Strategic Plan timeframe. Improvements to the models and acreage estimates are ongoing and may provide new information.

- Habitat improvement: Discussions regarding opportunities for cost-effective, efficient mechanisms to reduce ESH construction and/or improve bird productivity by enhancing habitat quality began in 2019. Examples include modifications that alter the shape or structure of a sandbar and augmentation of existing sandbars to improve substrate, provide more area at suitable nesting elevations, etc. A habitat optimization study is scoped and could begin when funding is available to further explore related opportunities.

- Predation management: Predator management strategies may enhance productivity and thereby reduce habitat construction and management expenses. Appropriate experimental designs (as described in the action effectiveness monitoring plans) can be used to evaluate predation management effectiveness.

- ESH geomorphology: Improved understanding of the processes that create and maintain ESH can be used to improve planning and design and may lead to the development of innovative and cost-effective management alternatives. LiDAR acquisition is planned once conditions are suitable, and evaluation of habitat formed in the cumulative 2017-2019 flows, coupled with results of the Garrison Geomorphic Study, should provide useful information.

- Research development and prioritization: Tables summarizing potential research activities were developed in 2019 to identify and prioritize research needs for plovers (Appendix 2.4.3). Ongoing development, review, and prioritization of research needs is necessary for the strategic planning process and program management decisions, including identifying studies that are ready to be initiated if funding becomes available.

- Dispersal: The USGS metapopulation study will be completed in 2020. Initial modeling work in 2020 will explore dispersal mechanisms and sensitivity. No further actions or decisions are necessary at present, but changes to targets are possible and alternative management strategies may emerge depending on the analysis results.

2.7.2 Technical and Scientific Recommendations

There is no compelling rationale for updating the conceptual ecological models or hypotheses related to the birds at this time. Results from ongoing studies may warrant some updates in 2021.

Given the substantial flows that have occurred in 2019 (and to a lesser degree since 2017), obtaining new data on sandbar conditions (LiDAR, hydrographic surveys, satellite imagery, etc.) would improve understanding of related processes and foster updates to the ESH models and (where appropriate) discharge-area curves.

Existing data should be evaluated to assess critical habitat quality relationships. These might be further advanced with the new monitoring program for the birds. This information supports ongoing habitat maintenance activities and potentially new and innovative strategies for achieving objectives through potentially cost-effective habitat enhancement actions.

3 Adaptive Management for Pallid Sturgeon

This chapter summarizes progress towards MRRP targets and objectives, the status of pallid sturgeon populations, the status of management actions, progress on the Big Questions (BQs), and implications of progress for management decisions.

3.1 Program Overview

There were no changes in 2019 to the geographic scope of pallid sturgeon management actions under the MRRP or the fundamental objectives of the MRRP for pallid sturgeon. This chapter discusses metrics and targets related to fundamental objectives and means objectives (ways of achieving the fundamental objectives), although many of the targets have yet to be determined given the high degree of uncertainty in pallid sturgeon population processes.

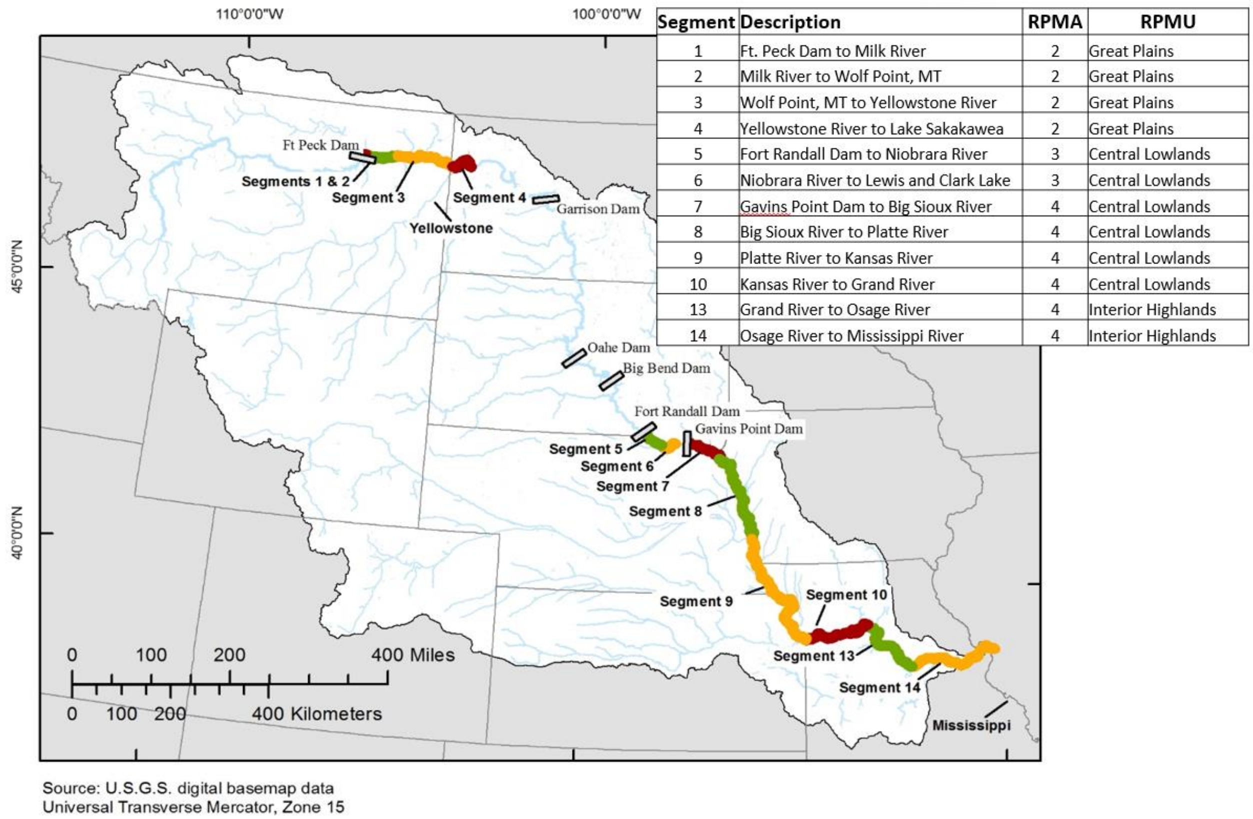
3.1.1 Geographic Scope

The geographic scope of the MRRP for pallid sturgeon is shown in Figure 3-1 and includes:

- the Upper Missouri River below Fort Peck Lake to Lake Sakakawea (sampling segments 1-4,) and the Yellowstone River from Intake Dam at Intake, Montana to its confluence with the Missouri River, both in the Great Plains Recovery Planning Management Unit (RPMU);
- the unchannelized Missouri River from Fort Randall Dam, SD, to the headwaters of Lewis and Clark Lake (segments 5 and 6, in the Central Lowlands RPMU); and
- the portion of the Lower Missouri River from Gavins Point Dam to the confluence of the Missouri and Mississippi Rivers (segments 7 to 10 in the Central Lowlands RPMU and segments 13 and 14 in the Interior Highlands RPMU).

Segments 5 and 6 are not prioritized in the SAMP because minimal MRRP actions have been proposed in those areas.

Because the geographic distribution of pallid sturgeon extends beyond the MRRP's domain, understanding the performance of MRRP actions may require consideration of reproduction and recruitment beyond the MRRP river segments, for example in the Yellowstone River upstream of Intake Dam and in the Mississippi River. Relevant literature and ongoing research from outside the geographic area of the MRRP is utilized to inform the evaluation of hypotheses and potential management actions. Other than the Yellowstone River, monitoring of tributaries is not part of the scope of the MRRP.



Segment	Description	RPMA	RPMU
1	Ft. Peck Dam to Milk River	2	Great Plains
2	Milk River to Wolf Point, MT	2	Great Plains
3	Wolf Point, MT to Yellowstone River	2	Great Plains
4	Yellowstone River to Lake Sakakawea	2	Great Plains
5	Fort Randall Dam to Niobrara River	3	Central Lowlands
6	Niobrara River to Lewis and Clark Lake	3	Central Lowlands
7	Gavins Point Dam to Big Sioux River	4	Central Lowlands
8	Big Sioux River to Platte River	4	Central Lowlands
9	Platte River to Kansas River	4	Central Lowlands
10	Kansas River to Grand River	4	Central Lowlands
13	Grand River to Osage River	4	Interior Highlands
14	Osage River to Mississippi River	4	Interior Highlands

Figure 3-1. Location map for the Missouri River basin, showing dams and sampling segments. The inset table shows Recovery Priority Management Areas (RPMAs) and RPMUs.

3.1.2 Objectives and Metrics

Objectives for pallid sturgeon within the MRRP can be categorized into fundamental objectives and sub-objectives (the desired outcomes of the program in terms of biological response), means objectives (ways of achieving the fundamental objectives, namely the actions which could be implemented), and learning objectives (information critical to achieving other objectives). Status and trend monitoring assess overall progress towards the fundamental objectives and sub-objectives, as a consequence of the cumulative effects of human activities and natural variability. Effectiveness monitoring assesses the degree to which specific management actions are effective in moving populations closer to the fundamental objectives and sub-objectives. MRRP learning objectives seek to reduce critical uncertainties related to management actions, metrics, and targets. The following sections discuss these categories of objectives and associated metrics and (where applicable) targets.

3.1.2.1 Fundamental Objectives

The goal, fundamental objective, and sub-objectives for pallid sturgeon are summarized in Figure 3-2 (from Section 4.1.1 of the SAMP).

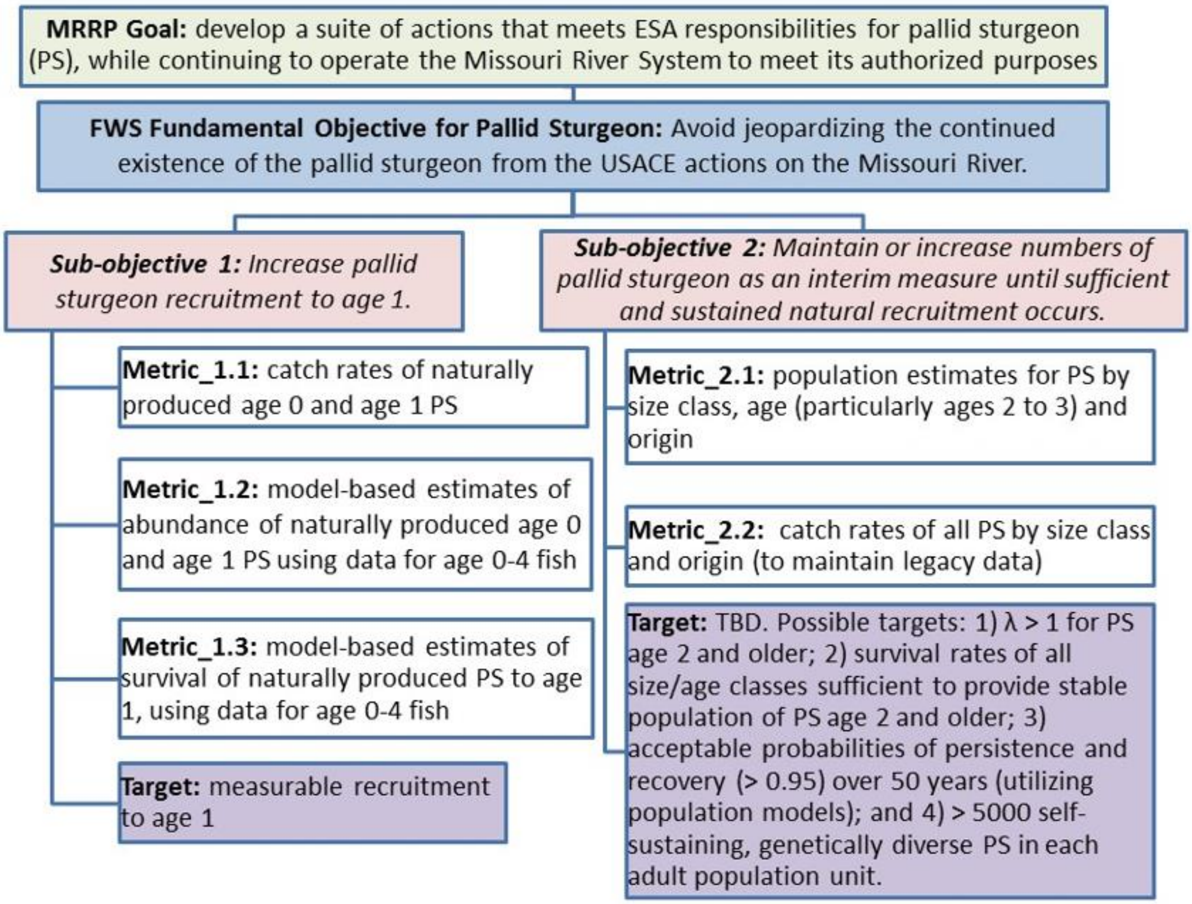


Figure 3-2. Hierarchy of goals, objectives, metrics, and targets for pallid sturgeon. PS = pallid sturgeon.

Subobjective 1 focuses on increasing the recruitment of wild (naturally reproduced) pallid sturgeon to age-1. Recruitment to age-1 has not been confirmed in the Upper Missouri River for many years despite evidence of successful spawning (USACE Biological Assessment 2017, pg. 134-136). In the Lower Missouri River, the capture of four pallid sturgeon drifting embryos and three exogenously feeding larvae in 2014, all genetically confirmed (USACE Biological Assessment 2017, pg. 136-137, Gosch et al. 2018) provided evidence of successful natural spawning, and more recent sampling has confirmed an additional four age-0 pallid sturgeon in the Lower Missouri (Gosch et al. 2019). While these data confirm reproduction, survival to age-1 has not been documented. Difficulty in accurately aging pallid sturgeon currently impedes the ability to accurately assign recruitment to the year in which it occurred and thereby determine the magnitude of recruitment to age-1 for sub-objective 1. Conclusions regarding the abundance and survival of pallid sturgeon to age-1 for sub-objective 1 must be inferred from multiple metrics, some measured in the field and others estimated from models (Figure 3-2). The primary metric currently available for sub-objective 1 is metric 1.1, catch rates of naturally produced age-0 and age-1 pallid sturgeon. Further modeling is planned for metrics 1.2 and 1.3.

More recently, Steffensen et al. (2019) used genetic analysis to assess the potential that recruitment has occurred in the Lower Missouri River, and if so, the extent of such recruitment. Between 2003 and 2015, 4,487 fish physically identified as pallid sturgeon were caught by PSPAP in the Lower Missouri River, including the lower reaches of the James, Big Sioux, Platte, Kansas, Grande and Osage rivers (Steffensen et al. 2019). Of this total number captured, 358 (8%) were determined to be "presumptive wild-origin" pallid sturgeon (Figure 3-3). Most (80.4%) of the 358 presumptive wild-origin fish were considered adults (> 800 mm), with 18.7% classified as sub-adults (600-800 mm) and 0.8% as juveniles (< 600 mm). This size composition contrasts with the hatchery-origin fish, where 91.6% were of juvenile or sub-adult size. These results indicate that PSPAP was capable of capturing smaller size categories of fish, but did not find as many wild-origin fish in these size classes (Section 3.1.2 of the Appendix provides a graph comparing the sizes of wild-origin and hatchery origin fish). Steffensen et al. concluded that the absence of younger age classes of wild pallid sturgeon in the Lower Missouri River could be due to a small breeding population, high mortality of early life stages, hybridization with shovelnose sturgeon, or transport of drifting free embryos or larvae into inhospitable habitats. It is also possible that smaller size classes/younger age classes rear in the Mississippi River, and return to the Missouri River when they are larger/older, though existing information is not sufficient to determine where the presumptive wild-origin fish reared, or where they were spawned (Kirk Steffensen, NGPC, Pers. Comm. December 2019). Porreca et al. (2015) found that most of the naturally reproduced *Scaphirhynchus* sturgeon collected in the middle Mississippi River were hatched in the Lower Missouri River; Love (2016) had similar findings. Extension of PSPAP v. 2.0 to the Mississippi River (Section 3.2.4.3) should, over time, reduce uncertainties regarding the life history of pallid sturgeon.

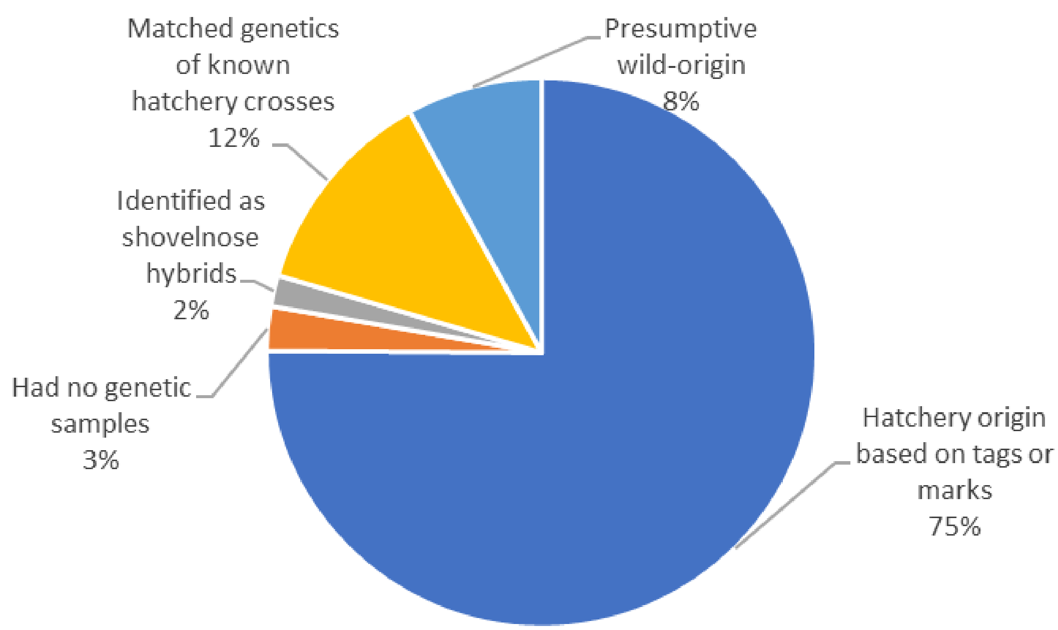


Figure 3-3. Classification of 4,487 fish that were collected by PSPAP between 2003 and 2015 in the Lower Missouri River, and considered to be pallid sturgeon based on their physical appearance. Chart created from data in Steffensen et al. (2019).

Subobjective 2 is intended to ensure there are enough pallid sturgeon of all sizes and age classes for natural recruitment to sustain the population when the current barriers to recruitment are understood and addressed. A variety of metrics are used to assess sub-objective 2 (Figure 3-2). Metrics 2.1 and 2.2 were both available in 2019, and are reported in Section 3.2 . Targets have not yet been determined and may change as information is gathered and evaluated to test management hypotheses (e.g., the target for pallid sturgeon population per unit may depend on carrying capacity).

At present, the pallid sturgeon recovery plan calls for an adult population size of 5,000 in each management unit, based on the theory of effective population size (USFWS 2014). Based on the organization of management units (Figure 3-1), this implies 5,000 self-sustaining, genetically diverse, naturally produced adults in the Upper River and between 5,000 and 10,000 in the Lower Missouri River, which contains more than 1 but less than 2 management units. If adjusted by proportional lengths of the Missouri and Mississippi Rivers within the Interior Highlands management unit, the management target would be ~6,666 naturally produced adults. The pallid sturgeon recovery plan cautions that the target of 5,000 per management unit should be considered interim until data are evaluated and incorporated into an appropriate population viability analysis to derive adult population estimates (USFWS 2014 (p. 56)).

3.1.2.2 Learning Objectives and Metrics

Scientific uncertainties about the limiting factors for pallid sturgeon are of critical concern for the MRRP. Reducing these uncertainties is crucial for correctly identifying the actions needed to avoid jeopardizing the species. Learning, therefore, is an explicit program objective and adaptive management is the primary means for meeting this objective. Key uncertainties have been expressed in terms of six Big Questions for the Upper River, and seven Big Questions for the Lower River. Each Big Question is associated with one or more high-level hypotheses. Altogether there are thirty high-level hypotheses in the SAMP (see SAMP Tables 4 and 5). To determine the best way to evaluate management actions, the Big Questions and their associated high-level hypotheses were converted into finer-level focal questions and testable hypotheses for each action, which become the focus of effectiveness monitoring (see Appendix E of the SAMP).

Metrics are subject to change as learning proceeds under adaptive management. Uncertainty in estimates of recruitment to age-1 remains high for three reasons. First, the pallid sturgeon is rare and lives in a large river system that is difficult to sample. Second, recruitment to age-1 may be occurring in the Mississippi River rather than in the Missouri River (this is likely to be gradually resolved as PSPAP v. 2.0 is extended to the Mississippi River; see Section 3.2.4.3). Third, a pallid sturgeon of a given length cannot be confidently assigned to a specific age due to the large variability in the relationships between size and age. Documenting recruitment will be easier than determining when it occurred, and it may be statistically challenging to document recruitment to age-1. In the interim, progress toward learning objectives is a practical measure of MRRP progress.

3.1.3 Evidentiary Framework for Evaluating Progress

A fundamental challenge for adaptive management of the pallid sturgeon in the Missouri River is the limited understanding of how physical and biological processes affect survival and population growth, and how management actions can best influence these processes and support progress towards the learning objectives, means objectives, and ultimately the fundamental objectives.

There are four levels of implementation of actions for managing pallid sturgeon in the Missouri River (as outlined in the SAMP). These actions range from science activities (Level 1) to full-scale implementation of management actions (Level 4):

- **Level 1.** Basic or applied research to address critical uncertainties related to the pallid sturgeon.
- **Level 2.** In-river testing of hypothesized management actions to evaluate whether or not there are measurable ecological responses.

- **Level 3.** Scaled implementation at a level where a population response can be detected.
- **Level 4.** Ultimate scale of implementation to remove one or more limiting factors.

Information for addressing uncertainties, evaluating management actions, and tracking progress toward objectives is derived from three sources:

1. **Science Activities** –research that addresses uncertainty more efficiently or effectively than monitoring.
2. **Effectiveness Monitoring** – monitoring applied to specific management actions to determine if the action results in the desired outcome.
3. **Population Monitoring** – status and trends monitoring of the pallid sturgeon population to determine if the population shows signs of improved reproductive and/or recruitment success (i.e., PSPAP v. 2.0).

An additional information source, the Pallid Sturgeon Integrated Population Model (see Section 3.5.1), provides a quantitative framework for integrating these other information sources and allowing for an exploration of the implications of leading hypotheses and related uncertainties on management decisions.

<table>
<tr><th>Implementation Level</th><th colspan="3">Methods of Learning</th></tr>
<tr><td>Level 1: Research</td><td></td><td rowspan="4">Science Activities</td><td rowspan="4">Population Monitoring</td></tr>
<tr><td>Level 2: In-River Testing</td><td rowspan="3">Effectiveness Monitoring</td></tr>
<tr><td>Level 3: Scaled Implementation</td></tr>
<tr><td>Level 4: Ultimate Required Scale of Implementation</td></tr>
</table>

Given the complexity of the linkages among physical habitats and population processes, no single research, monitoring, or modeling activity is likely to provide convincing, unambiguous evidence about the effectiveness of an action, or about the responsiveness of the population to a single or set of management actions. Collectively, however, these information sources provide multiple, converging "lines of evidence" for evaluations of action effectiveness and progress towards population sub-objectives.

To provide consistency and transparency in the way each line of evidence is considered, the Fish Technical Team has developed a unified evidentiary framework for evaluating program progress (see Figure 3-4 and Section 3.1.3 of the Appendix). The Pallid Sturgeon Evidentiary Framework provides a structure for combining different lines of evidence (i.e., population monitoring, population modeling, Level 1 and Level 2 science, action effectiveness monitoring) to evaluate testable hypotheses related to both actions and population sub-objectives (2019 FSM Lower and Upper River Presentations; Marmorek, et al. Evidentiary Framework). The Evidentiary Framework is focused on the effectiveness of management actions and the achievement of MRRP sub-objectives. The Evidentiary Framework links different lines of evidence to actions, action-driven hypotheses (from the Effects Analysis [EA] and SAMP), and action-driven focal questions (from Appendix E of the SAMP). These elements are derived directly from the EA and its Conceptual Ecological Models (CEMs), and represent successive refinements in problem definition. An example of these linkages for IRCs is provided in Table 3-4 of Section 3.1.3 in the Appendix. The Appendix also contains evaluations of the current status of each of the action-driven hypotheses included in the EA and the SAMP (Tables 3-7 and 3-8 in Section 3.1.4 of the Appendix).

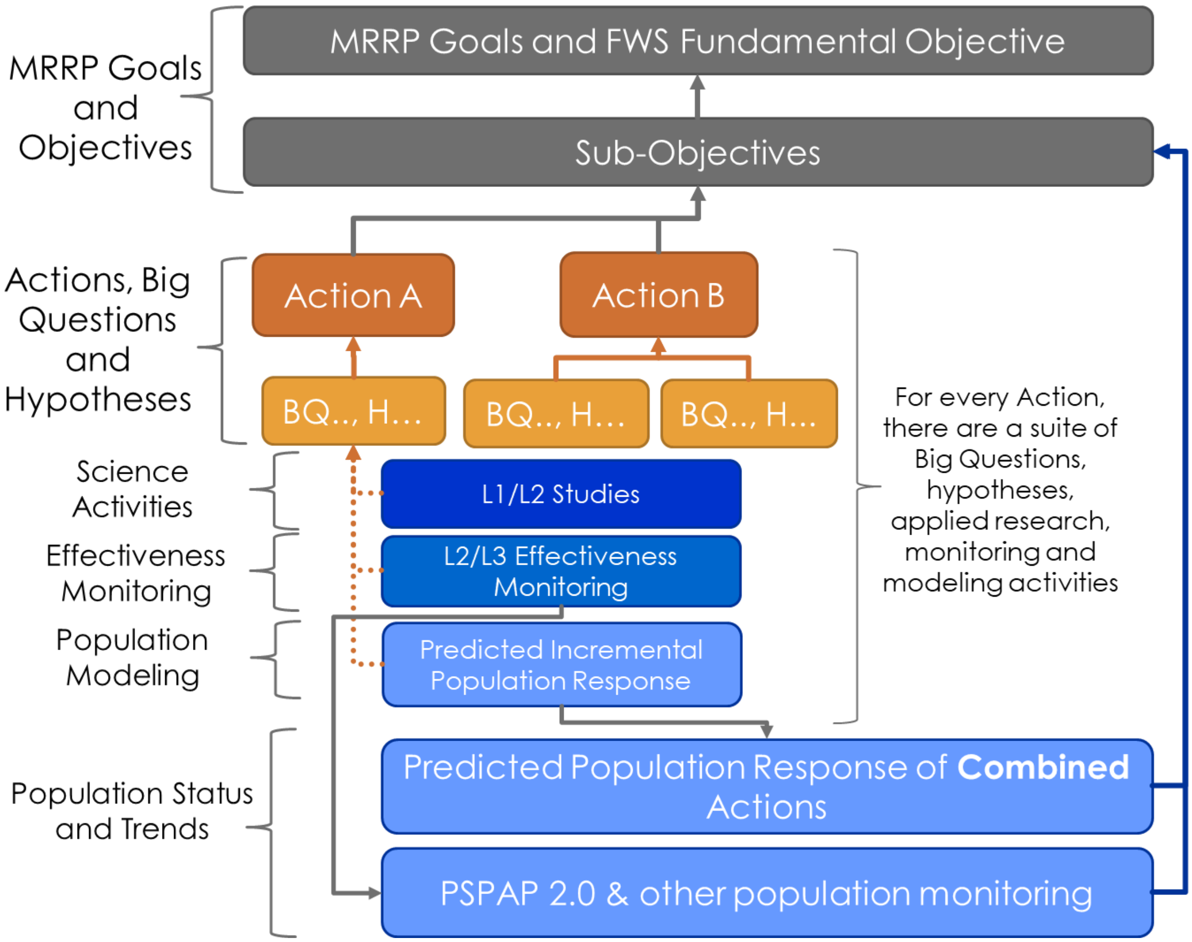


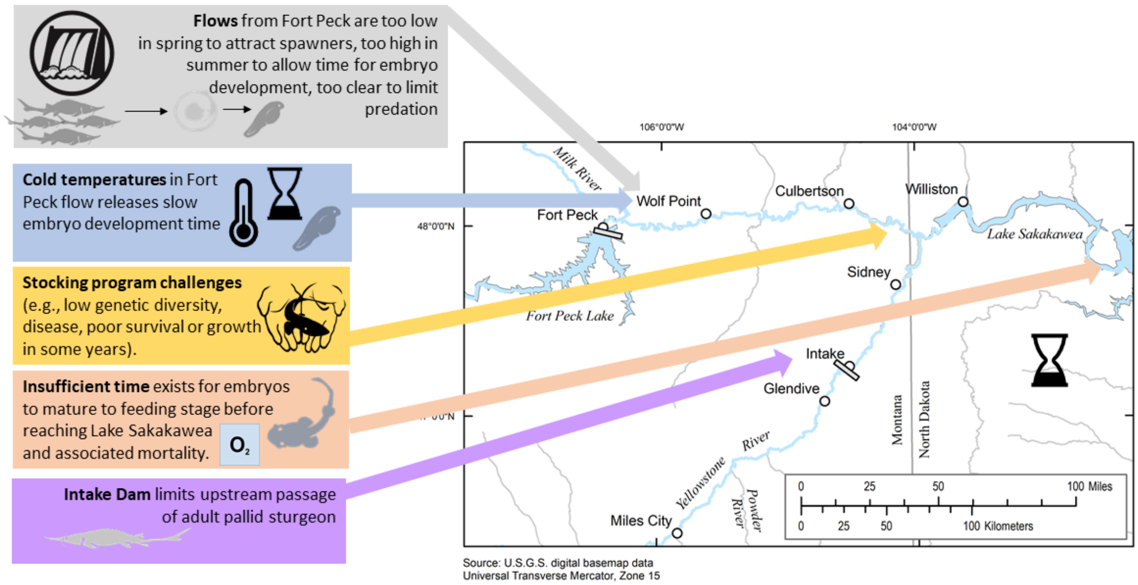
Figure 3-4. Conceptual diagram of the Pallid Sturgeon Evidentiary Framework, showing how science activities, effectiveness monitoring, and population monitoring information sources are combined and integrated with the population modeling to reduce critical uncertainties and achieve the fundamental Goals and Objectives of MRRP.

3.1.4 Factors Limiting Pallid Sturgeon and 2019 Progress on These Factors

3.1.4.1 Upper Missouri

Figure 3-5 summarizes some of the factors hypothesized in the EA (Jacobson et al. 2016) to be limiting pallid sturgeon recruitment in the Upper Missouri River, and progress on the development of actions and scientific understanding to address these limiting factors. The subset of limiting factors chosen from the EA are those that are currently considered to be primary limiting factors in the Upper River. The table below the map includes the Big Questions and action-driven hypotheses identified in the EA or SAMP for each limiting factor. Focal questions for each action (which are more specific than the action-driven hypotheses) are described under Section 3.3 . The first column of the table in Figure 3-5 lists the Big Questions (BQ) and associated hypotheses (H) identified in the EA for each listed limiting factor in the Upper River. Section 3.1.4.1 of the Appendix summarizes the current status of evaluations of each hypothesis.

Stocking and augmentation has been essential to the conservation of pallid sturgeon in the Upper Missouri, given the lack of natural recruitment, and is not a limiting factor. However, challenges within the stocking program (e.g., disease, low genetic diversity, physiological stress, altered behavior; see pg. 87 in Jacobson et al. 2016) can in some years limit the survival, growth and eventual natural reproduction of stocked fish. These challenges are directly addressed by the recently revised Conservation Propagation and Stocking Program.



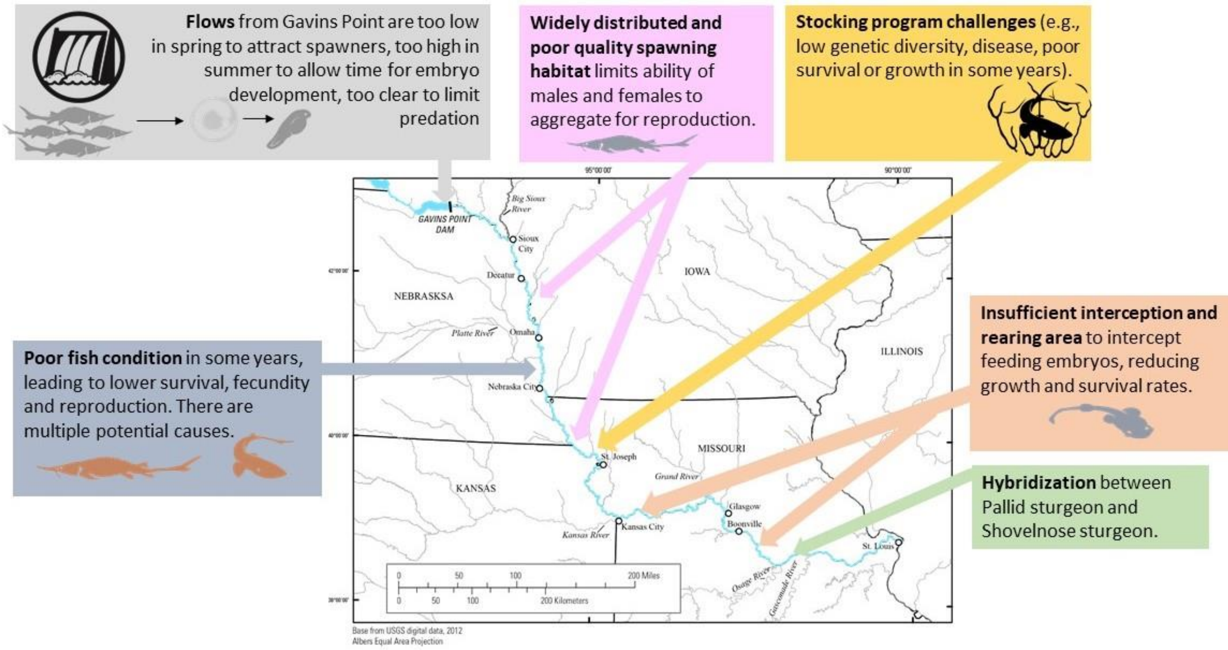
Limiting Factor	Development of Actions	Tools and Science to Reduce Uncertainty and Help Decisions
Flows from Fort Peck (BQ1 - H2, BQ2 - H1, BQ4 – H6, BQ5 – H3, H10);	Fort Peck Adaptive Management Plan released and reviewed Work on Fort Peck EIS underway	• Models now link Dam Operation → Advection / Dispersion / Temperature → Population Response • Over 50 scientists collaborated to release >one million free embryos in 2019. Some embryos transitioned from drifting to benthic settling. To date, 84 pallids identified from 886 fish captured (others shovelnose); all pallid sturgeon were 5 days post-hatch (dph), none were 1 dph • Flume studies have improved understanding of embryo transport (older fish more benthic) • Innovative 2D and 3D particle-tracking models have been developed to document how embryos drift, structure transferable to Yellowstone (Intake) and Lower River (IRCs) • Population monitoring of multiple size classes and life stages. Telemetry tracking deployed to evaluate movements, survival, and abundance of adults. • Effectiveness monitoring plans developed for flow experiments (SAMP Appendix E4)
Cool Temperatures (BQ3 - H4, H5)	Exploration of operations to increase temperatures	• Lab experiments have improved understanding of the effects of temperature on rates of free embryo development, which have been incorporated into Drift and Settling Model (DSM) for Upper Missouri
Stocking Program Challenges (BQ6 – H8, H9)	Release of Rangewide Stocking and Augmentation Plan	• Improved procedures have been developed to increase genetic diversity of stocked fish, improve survival and growth, and monitor effectiveness of these procedures • No stocking in 2019 in Upper Missouri (except drift experiment) • Research is underway on factors affecting growth and survival of stocked individuals
Intake Dam (BQ5 – H7, H10)	Construction of passage underway at Intake	• Population monitoring has been implemented in the Yellowstone • Effectiveness monitoring plans have been developed (SAMP Appendix E5) • Translocated adults have been tracked upstream as far as the Powder River

Figure 3-5. Main factors hypothesized to be limiting recruitment of pallid sturgeon in the Upper Missouri River, and progress on the development of actions and scientific understanding to address these limiting factors.

3.1.4.2 Lower Missouri

Figure 3-6 summarizes some of the factors hypothesized in the EA (Jacobson et al. 2016) to be limiting pallid sturgeon recruitment in the Lower Missouri River, and progress on the development of actions and scientific understanding to address these limiting factors. The subset of limiting factors chosen from the EA are those which are currently considered to be the primary limiting factors in the Lower River. The first column of the table in Figure 3-6 lists the Big Questions (BQ) and associated hypotheses (H) identified in the EA for each listed limiting factor in the Lower River. Poor fish condition (BQ7) was identified as part of the New Information process in 2017, as described in the SAMP. Section 3.1.4.2 of the Appendix summarizes the current status of evaluations of each hypothesis.

As noted above for the Upper Missouri, stocking is also essential to the conservation of pallid sturgeon in the Lower Missouri, though some natural recruitment does occur. Challenges in the stocking program can however in some years limit the ability of stocked fish to survive, grow and eventually reproduce successfully in the Lower Missouri. These challenges are directly addressed by the recently revised Conservation Propagation and Stocking Program (CPSP).



Limiting Factor	Development of Actions	Tools and Science to Reduce Uncertainty and Help Decisions
Flows from Gavins Point (BQ1 – H11, BQ3 – H12, H13; BQ4 – H14)	Work on Fort Peck flows also relevant to Gavins Point flows	• Flume studies have improved understanding of embryo transport • Population monitoring of multiple size classes and life stages. Telemetry tracking deployed to evaluate movements, survival, and abundance of adults • Effectiveness Monitoring plans have been developed for flow experiments
Spawning habitat (BQ5 – H16)	No work on specific actions in 2019	• Analyses of spawning habitats used in the Yellowstone have provided design criteria for habitat construction • 8% of pallid sturgeon captured during 2003-2015 were from natural reproduction, indicating that spawning and recruitment are possible in existing habitat • Pallid sturgeon spawn preferentially in deep, fast water on revetment, gravel, sand or bedrock. Spawning success not known. • Lab studies show a resilience of eggs and free embryos to abrasion and burial by sand
Lack of interception and rearing habitat (BQ3 – H17, H18; BQ4 – H19)	Creation and evaluation of IRCs continues, with 2 of 12 treatment-control pairs of IRC sites implemented, and monitoring at 4 pairs of sites. No IRCs built in 2019	• Two detailed draft reports (USACE 2019a, 2019b) document the rationale for IRCs and their continuing evaluation with effectiveness monitoring • Detailed studies suggest that age-0 shovelnose and pallid sturgeon have similar diets, developmental rates, and total prey consumption, but differ in physiology and anatomy. • Work is ongoing to determine when it is acceptable to use age-0 shovelnose as surrogates, and when only pallid sturgeon should be used • Sampling has documented that most intercepted age-0 sturgeon are well-fed • PSPAP v. 2.0 population monitoring was partly extended to the Mississippi River • Progress was made in refining criteria for defining foraging habitat
Stocking program challenges (BQ6 – H20, H21)	Release of CPSP Guidance and Planning Document; improved hatchery procedures	• Improved procedures have been developed to increase genetic diversity of stocked fish, improve survival and growth; CPSP evaluation plan released • Research is underway on factors affecting growth and survival of stocked individuals
Poor fish condition (HFC1 to HFC9)	No specific management actions warranted at this time	• Monitoring of adult fish condition was continued; research underway at Montana State to better understand potential causes for poor fish condition • Little change in predicted weights since 2018

Figure 3-6. Main factors hypothesized to be limiting recruitment of pallid sturgeon in the Lower Missouri River, and progress on the development of actions and scientific understanding to address these limiting factors.

3.2 Status and Trends of Pallid Sturgeon

This section reports the status and trends of key metrics for assessing progress towards MRRP's goal and objectives for pallid sturgeon, specifically sub-objectives 1 and 2 (Figure 3-2). A comprehensive information base would include multiple direct measures of population status (e.g., counts of fish; measures of health, age distributions, and genetic diversity, with clear delineations of subpopulations). Given the challenges in obtaining these direct measures of population status, the current state of knowledge is based on a combination of direct measures and indicators, including adult and sub-adult abundance, genetic diversity, catch per unit effort* (CPUE, an indicator of relative abundance), relative size distribution (an indicator of age-structure), and occupancy (the distribution of age-0 and age-1 fish, an indicator of spawning and recruitment as well as an early indicator of abundance).

The term "trend" can be interpreted in a variety of ways, but in this report, refers to the directional movement of an indicator over time. Section 3.2 in the Appendix provides a generic discussion of trends analysis and alternative approaches for obtaining reliable inferences on trends.

3.2.1 Overview of Progress Toward Goals and Fundamental Objectives

Table 3-1 summarizes the status of metrics relevant to the MRRP sub-objectives shown in Figure 3-2. The metrics in Table 3-1 reflect the cumulative effects of past and present management actions, as well as natural environmental variability. Stocking is the primary MRRP action that might affect the metrics in Table 3-1, if stocked fish have reproduced naturally. We would not expect the existing 2 IRC sites to have changed any of the metrics shown in Table 3-1 for the Lower River; metrics describing habitat and biological conditions are discussed in Section 3.3.2 on IRCs. The IRC staircase design is a Level 2 experiment involving (ultimately) 12 treatment-control pairs (see Section 3.3.2), which is not expected to have a population level effect. Several new metrics are available in 2019 as a result of PSPAP v. 2.0 implementation (Section 3.2.4) including estimates of absolute abundance for sub-adults and adults, and estimates of occupancy for age-0 and age-1 sturgeon. Other metrics are anticipated in the near future as the pallid sturgeon population model (Section 3.5) is further developed and better methods are developed to infer fish age from fish length. The confidence intervals on estimates of absolute abundance are wide but will shrink in future years as more tagged fish are recaptured in the PSPAP v. 2.0 monitoring.

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* CPUE represents the number of pallid sturgeon captured using standardized methods for a standardized amount of effort (e.g., number of nets, number of hooks)

Table 3-1. Summary of the status of metrics relevant to the FWS sub-objectives shown in Figure 3-2. Estimates may change later in 2020 as genetics analysis are completed and improvements are made to the estimation procedure.

Metric	Target	Status
***Sub-objective 1:* Increase pallid sturgeon recruitment to age 1.**		
Metric 1.1: PSPAP catch rates of naturally produced age-0 and age-1 PS	Measurable recruitment to age 1	PSAP sampling in the Upper Missouri failed to capture any pallid sturgeon in the smallest size class (<200 mm) during 2010-2019, therefore there is no evidence of recruitment (Figure 3-10). In the Lower Missouri, PSPAP sampling also has not detected any pallid sturgeon < 200 mm (Figure 3-11), whereas nonrandom sampling has yielded individuals on the lower end of this size class, including individuals that had successfully transitioned to exogenous feeding (Table 3-4). In 2018, some of the fish < 200 mm may include hatchery-origin embryos deliberately released in research experiments. Indirect evidence indicates that recruitment to age 1 has occurred in the Lower Missouri (Section 1.1.1.1). Mid-Mississippi trawls should help to clarify where and when fish reach age 1.
Metric 1.2: model-based estimates of abundance of naturally produced age 0 and age 1 PS using data for age 0-4 fish	Measurable recruitment to age 1	This metric is pending further development of the pallid sturgeon model and refinement of age-length keys.
Metric 1.3: model-based estimates of survival of naturally produced PS to age 1, using data for age 0-4 fish	Measurable recruitment to age 1	This metric is pending further development of the pallid sturgeon model and refinement of age-length keys.
***Sub-objective 2:* Maintain or increase numbers of pallid sturgeon as an interim measure until sufficient and sustained natural recruitment occurs.**		
Metric 2.1: population estimates for PS by size class, age (particularly ages 2 to 3) and origin	Self-sustaining, genetically diverse population of 5,000 adult Pallid Sturgeon within each management unit for 2 generations (20 - 30 years); (UFSWS 2014, pg. 54). For Interior Highlands management unit, target could be from 1,666 to 5,000 (see Section 3.1.2.1)	Proxy metric is the number of pallid sturgeon > 800 mm in size* that are genetically confirmed to not be hybrids. 2019 median abundance estimates for wild, unknown, and hatchery-origin pallid sturgeon (Table 3-3) are: **Great Plains** (PSPAP segments 1 - 4) – 1,124; **Central Lowlands** (PSPAP segments 5 - 10) – 19,095; **Interior Highlands** (PSPAP segments 13 - 14) –1,726.
Metric 2.2: catch rates of all PS by size class and origin (to maintain legacy data)	Not defined.	No wild pallid sturgeon were caught in the CPUE sampling for the Upper River in 2019; CPUE (+/-2SE) for wild pallid sturgeon in the Lower River: 0.01512 (0.00767, 0.02257) (Section 3.2.2.3).

* Size is currently used as an indicator of age and fish >800 mm considered adults (Section 3.2.2.4). This size criterion may overestimate the number of adults in the Upper Basin, as many fish of 800mm size are not mature (Upper Basin Pallid Sturgeon Working Group, pers. comm. March 2020).

3.2.1.1 Discussion of Sub-Objective 1 for the Lower Missouri River

The BiOp (USACE 2017, pages 71-72) and SAMP (Fischenich et al., 2018b, pages 256-257) state that, for sub-objective 1, “the short-term target is to demonstrate measurable recruitment to age-1” and that “the long-term target for recruitment (i.e., necessary levels and frequency of recruitment over time) will be informed by the EA (Jacobson et al. 2016a) and the collaborative population model”. This Section describes the indirect evidence that the short-term target has been met in the Lower Missouri River. Further work is required to determine the long-term target and the extent to which it is being met.

Direct evidence of recruitment to age 1 does not exist in the Lower Missouri River. It is difficult for PSPAP gear to capture fish < 200 mm in size, including hatchery fish (Figure 3-10 and Figure 3-11). Table 3-4 shows captures of 11 age-0 fish up to 48 mm in length, which confirms that reproduction has occurred (an important result), but the lengths of these fish are below those for fish at age-1 (approximately 100 to 400 mm).

While it isn’t known where and when pallid sturgeon reach age-1, there are four indirect lines of evidence indicating that fish spawned in the Lower Missouri are surviving to and past age-1 (likely reaching age 1 in the mid-Mississippi). These four indirect lines of evidence are trends in the CPUE for wild fish (Section 3.2.2.3), PSPAP estimates of population abundance by size class (Section 3.2.2.1), data on relative size distributions for wild fish (Appendix Section 3.2.2.4), and long term trends in PSPAP data (discussed in Section 3.1.2.1):

1. The CPUE for wild fish in the Lower River has been generally stable and recently increasing (Figure 3-9, significant trend at $p=0.03$), which would not be the case if there were no survival of wild fish through age-1.
2. Estimates of absolute population abundance provide evidence of wild sub-adults and possibly juveniles in the Lower Missouri River, which also would not occur if there were no survival to age-1. The median estimate of wild/unknown fish across all size classes in the Central Lowlands Management Unit is 8,108 (Table 3-2), while the median estimate of the number of adult fish > 800 mm (Table 3-3) is 5,559. The difference between these two numbers indicates that there are many fish < 800 mm in this management unit. Table 3-11 in Section 3.2.1.1 of the Appendix provides population estimates by size class and origin for each management unit in the Lower Missouri.
3. The relative size distributions of wild fish in the Lower River show that 9 of the last 11 years had fish in the 400-800 mm size class (sub-adults and juveniles), which could only have occurred if fish were able to survive through age-1 (Appendix Section 3.2.2.4 . However, no fish were found in the 200-400 mm size class in the Lower Missouri, which may be because this size class is predominantly in the mid-Mississippi River.
4. Steffensen et al. (2019, summarized in AMCR Section 3.1.2) found that 8% of fish in the Lower River sampled by PSPAP over 2003 to 2015 were "presumptive wild-origin" fish, 18.7% as sub-adults, and 0.8% as juveniles. To have reached the sub-adult stage, these fish must have survived to age-1.

Therefore, while there is no direct evidence of survival to age-1 in the Lower Missouri, four indirect lines of evidence support the hypothesis of survival through age-1. Information from trawling in the mid-Mississippi River will help answer questions about when and where recruitment to age-1 is occurring.

3.2.2 Indicators of Population Abundance, Distribution and Composition

3.2.2.1 Population Abundance Estimates

Sub-objective 2 (Figure 3-2) provides possible targets for the abundance of self-sustaining, naturally reproduced, genetically diverse pallid sturgeon in each adult population unit. While most pallid sturgeon are currently of hatchery origin, they may potentially reproduce naturally. Estimates for the combined abundances of wild plus hatchery adult pallid sturgeon in each population unit can be compared to proposed numerical targets to assess progress towards sub-objective 2 (Table 3-3), with the important caveat that the target involves more than just numbers of adults (i.e., populations must be self-sustaining, naturally reproduced, and genetically diverse). This section presents updates to previous population estimates appearing in the literature and summarized in Section 3.2.1.1 of the Appendix.

An intensive mark-recapture effort was completed in the Upper and Lower Basins in 2019. This effort involved randomly selecting and then sampling 25.2% of the bends within each segment of each basin over multiple days. Bend-level pallid and shovelnose sturgeon abundances were estimated and aggregated up to a segment-level estimate using a hierarchical estimator that accounted for pallid sturgeon origin (i.e., hatchery, wild, hybrid) and size class. Segment-level abundance estimates were aggregated to the basin and management unit level. Management unit-specific estimates of abundance are preliminary and restricted to the mainstem Missouri River. The estimates are provided in Table 3-2 (all size classes) and Table 3-3 (just fish >800mm). The population estimates for the Upper River do not include the Yellowstone River.

Table 3-2. Preliminary management-unit level abundance estimates for wild/unknown, hatchery, and hybrid pallid sturgeon in 2019 (all size classes), with 95% Bayesian Credible Intervals (BCI). The Central Lowlands Management Unit includes segments 5-10, but segments 5 and 6 are only sampled once every five years and are not included in population estimates.

Management Unit (Segments)	Origin of Fish	Lower 95% (BCI)	Median	Upper 95% (BCI)
Great Plains (Segments 1-4)	Wild / unknown	49	**275**	4,873
	Hatchery	2,459	**7,233**	46,243
	Hybrid	0	**0**	0
Central Lowlands (Segments 5-10)	Wild / unknown	1,734	**8,108**	51,239
	Hatchery	7,630	**29,037**	129,716
	Hybrid	984	**4,235**	42,154
Interior Highlands (Segments 13-14)	Wild / unknown	212	**1,530**	7,062
	Hatchery	1,994	**11,137**	47,246
	Hybrid	479	**2,781**	11,698

Table 3-3. Preliminary management-unit level abundance estimates for wild/unknown, hatchery, and hybrid adult fish in 2019 (> 800mm only[*]), with 95% Bayesian Credible Intervals (BCI), and targets. The Central Lowlands Management Unit includes segments 5-10, but segments 5 and 6 are only sampled once every five years and are not included in population estimates.

Management Unit (Segments)	Origin of Fish	Lower 95% (BCI)	Median	Upper 95% (BCI)	Median vs. Target [%]	Target
Great Plains (Segments 1-4)	Wild / unknown	4	107	4,693	n.a.	n.a.
	Hatchery	121	875	9,628	n.a.	n.a.
	Hybrid	0	0	0	n.a.	n.a.
	Wild / unknown + Hatchery	157	**1,124**	12,668	**1,124 [22%]**	**5,000**
Central Lowlands (Segments 7-10)	Wild / unknown	998	5,559	42,659	n.a.	n.a.
	Hatchery	1,738	10,809	75,589	n.a.	n.a.
	Hybrid	56	505	6,181	n.a.	n.a.
	Wild / unknown + Hatchery	3,175	**19,095**	100,363	**19,095 [382%]**	**5,000**
Interior Highlands (Segments 13-14)	Wild / unknown	43	721	4,522	n.a.	n.a.
	Hatchery	65	1,005	6,407	n.a.	n.a.
	Hybrid	68	1,117	7,662	n.a.	n.a.
	Wild / unknown + Hatchery	128	**1,726**	11,085	**1,726 [35% - 104%]**	Between **1,666** and **5,000** (see Section 3.1.2.1)

Reported abundance estimates are preliminary and subject to change following confirmed genetic resolution of unknown-origin fish, continued estimator development, incorporation of legacy and future data, and integration of the mark-recapture program with the telemetry program. The redesign of PSPAP (from PSPAP v. 1.0 to v. 2.0) to evaluate MRRP objectives will retain the ability to compare catch rates over time and the confidence intervals are expected to narrow.

Management unit boundaries do not delineate subpopulations of the pallid sturgeon, which have been documented to move between these management units (DeLonay et al. 2009). In the Upper River, the current median estimate of 1,124 wild/unknown -plus hatchery-origin adult pallid sturgeon is 22% of the target of 5,000 naturally producing, self-sustaining, genetically diverse adults for the Great Plains Management Unit (Table 3-3). The large gap between the current population estimate and the target suggests that it may not be necessary to have annual population estimates of the same level of precision. Options for reducing the intensity of PSPAP v 2.0 might include: a rotating panel design with some status and trend monitoring every year; sampling fewer segments per year, fewer bends per segment, or fewer sites per bend; and/or full basin sampling only in years when flooding risk is low, to improve sampling efficiency and safety. However, reductions in the intensity of PSPAP v. 2.0 sampling in

[*] As noted above, the 800 mm size criterion may overestimate the number of adults in the Upper Basin, as many fish of 800mm size are not mature (Upper Basin Pallid Sturgeon Working Group, pers. comm. March 2020). These preliminary estimates will be revised.

the Upper River could reduce the quality of information available on the growth, survival and condition of hatchery fish, which are the future source of reproduction.

In the Lower River, the current median estimate of wild/unknown plus hatchery origin adult pallid sturgeon (19,095) is 382% of the 5,000 target for the Central Lowland Management Unit. It isn't known however if the population in this management unit is sufficiently genetically diverse and self-sustaining. Importantly, the Interior Highlands Management Unit contains a portion of the Mississippi River so there is not a 1:1 match between the Lower Missouri River and the management unit. In addition to numbers of pallid sturgeon, another objective of recovery is that the population should be genetically diverse (see Section 3.3.1.1 on propagation and stocking efforts), so minimal population size targets may be exceeded to maximize genetic diversity. While the Technical Team has not yet evaluated options for reducing the intensity of PSPAP v. 2.0 in the Lower River, the data suggest that more frequent / precise population estimates are required in the Lower River than in the Upper River, given the status of wild populations relative to targets. Genetic Diversity of the Pallid Sturgeon Population

3.2.2.2 Genetic Diversity of the Pallid Sturgeon Population

The effective population size (N_e) is defined as the size of an ideal population with the same rate of loss of genetic diversity as the real population being studied (Husemann et al. 2016). Put simply, N_e is a count of the number of individuals that contributed to the next generation, adjusted for violating the assumptions of an ideal population[*]. An individual contributes to the next generation if it has at least one offspring that survives to maturity[†]. Effective population size is a metric of genetic diversity of the population and is relevant to tracking progress towards sub-objective 2 (Figure 3-2). The SAMP specifies a possible target of 5,000 self-sustaining, genetically diverse, adult pallid sturgeon in each management unit. This target is consistent with the downlisting criteria in the revised Pallid Sturgeon Recovery Plan (USFWS 2014, pg. 54) and is based on two assumptions related to effective population size:

1. an $N_e \geq 500$ is necessary to maintain genetic variability, conserve localized adaptations, and preserve rare alleles (Franklin 1980), and
2. the ratio of the effective population size to the census adult population size ($N_e : N$) is approximately 1:10 (Frankham 1995).

Importantly, this potential SAMP target of *N*=5,000 can only be met once the population is self-sustaining, which requires natural recruitment and relies upon estimates of effective population size based on **naturally-produced, wild** fish. PSPAP v. 2.0 can provide estimates of the adult population (*N*), by segment, management unit and basin. However, the adult population considered in PSPAP v. 2.0 estimates is not necessarily self-sustaining and genetically diverse. A strategic question of interest is whether it's also worth considering estimates of N_e computed from naturally-produced, wild fish by management unit and basin as an additional metric for SAMP sub-objective 2 with associated targets. A target N_e of 500 would be consistent with the Pallid Sturgeon Recovery Plan (USFWS 2014), though such a target has not been set by the USFWS and could only be evaluated for the Lower River, as there is no

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[*] In the genetics sense, an ideal population (with no mutation, selection, or migration) is one in which all individuals are mature adults, the sex ratio is equal, generations are discrete, the population size is constant, and mating is random with a variance in reproductive success of 2.

[†] Or, in a stricter sense, an individual contributes to the next generation if it has at least one offspring that survives to maturity and contributes to the next generation.

natural reproduction in the Upper River. Background information relevant to a discussion of this question is presented in Section 3.2.1.2.1 of the Appendix.

In cases with no natural recruitment, monitoring the effective population size of **broodstock fish** is useful for producing a genetically diverse population that may one day be self-sustaining. The computations for N_e estimates of broodstock fish are based on stocked pallid sturgeon offspring and are described in detail in Appendix Section 3.2.1.2.2. Recent stockings slightly increased the N_e for broodstock pallid sturgeon in the Upper River (RPMA 2), as calculated from yearling equivalents (i.e., number of individuals expected to survive to age-1 without accounting for subsequent survival) by parent (Figure 3-7). In the past 8 years, the Upper River cumulative N_e has increased an average of about 1 fish per year, a much slower rate of increase than in the previous 8 years (nearly 6 fish per year). The current cumulative N_e estimate is 66 and is computed from stocking data that consists of individuals from year classes ranging from 1997 to 2019.

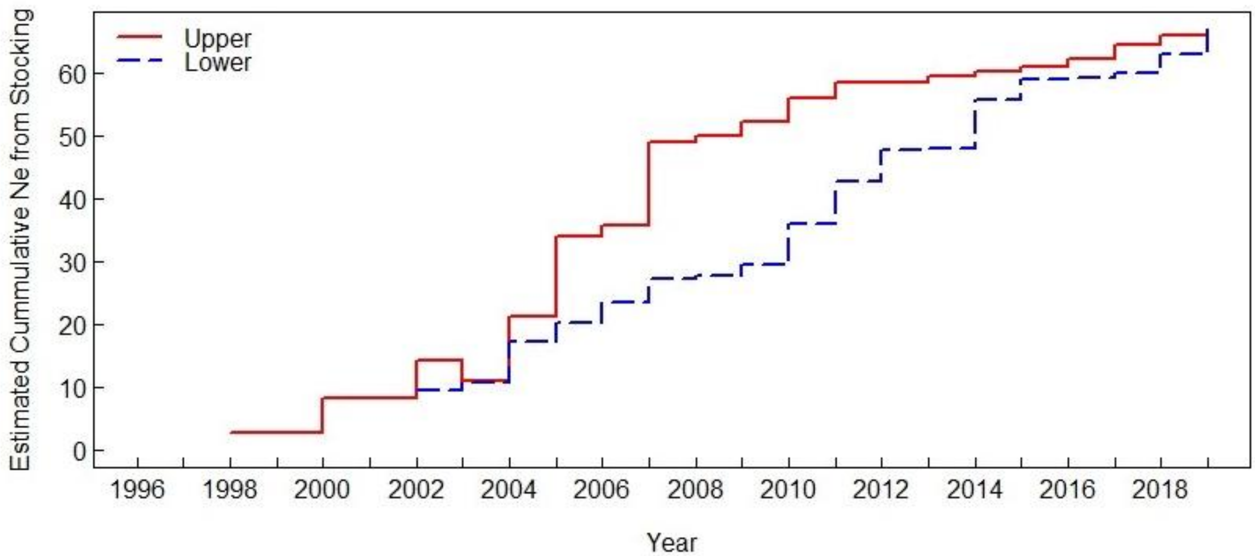

Figure 3-7. Effective population size for broodstock pallid sturgeon in the Upper and Lower Missouri Rivers based on age-1 equivalents at the time of stocking, assuming no natural recruitment. No stocking occurred in the Upper Missouri River in 1999, 2001, and 2012. Yearling equivalents stocked in the Lower River prior to 2002 were excluded from cumulative Ne calculations due to uncertainties in parentage. Annual changes reflect all of the stocking activities that occurred during that year, though these don't take place all at once. Data source: Ryan Wilson, USFWS, as of November 2019.

In the Lower Missouri River (RPMA 4, which includes portions of the Central Lowlands and the Interior Highlands RPMUs) the cumulative N_e of broodstock pallid sturgeon, as computed from stocked yearling equivalents, continues to increase steadily (Figure 3-7). Family lots stocked in 2019 increased the cumulative N_e estimate to its current value of 67, computed from stocked fish of year classes from 1997 to 2018[*]. Under circumstances of no natural recruitment, this N_e estimate for broodstock pallid sturgeon can be interpreted similarly to the Upper River estimate (i.e., as for wild, legacy fish). However, given evidence of ongoing natural recruitment in the Lower Missouri River (Steffensen et al. 2019), it is important to recognize that cumulative N_e estimates for broodstock fish are useful for maximizing genetic diversity of stocked fish but that the most relevant N_e estimates would be computed from naturally-produced, wild fish by genetic approaches (Appendix Section 3.2.1.2.1).

3.2.2.3 Relative Population Abundance (CPUE)

The MRRP has historically relied on CPUE as an indicator of population status and trend (Figure 3-8, Figure 3-9). Section 3.2.1.3 of the Appendix describes the methods used to calculate CPUE. In 2019, estimates of absolute abundance (Section 3.2.2.1) were generated using capture/recapture data from PSPAP v. 2.0. Over time, estimates of absolute abundance will replace CPUE as the primary metric for evaluating progress towards sub-objective 2. Estimates of CPUE are still possible for some gear types using data collected from PSPAP v. 2.0, allowing comparison with legacy datasets and an early indication of population responses. Trends in CPUE for hatchery origin fish reflect the effects of several factors including the history of stocking (which has declined in recent years, see Section 3.3.1), year to year variability in survival, as well as annual variation in catchability of fish (which can vary with both flow and temperature). The CPUE of wild origin fish is affected by the latter two factors, but not the first.

* There is a difference between a year class (i.e., the year in which eggs were fertilized in a hatchery) and the year of stocking.

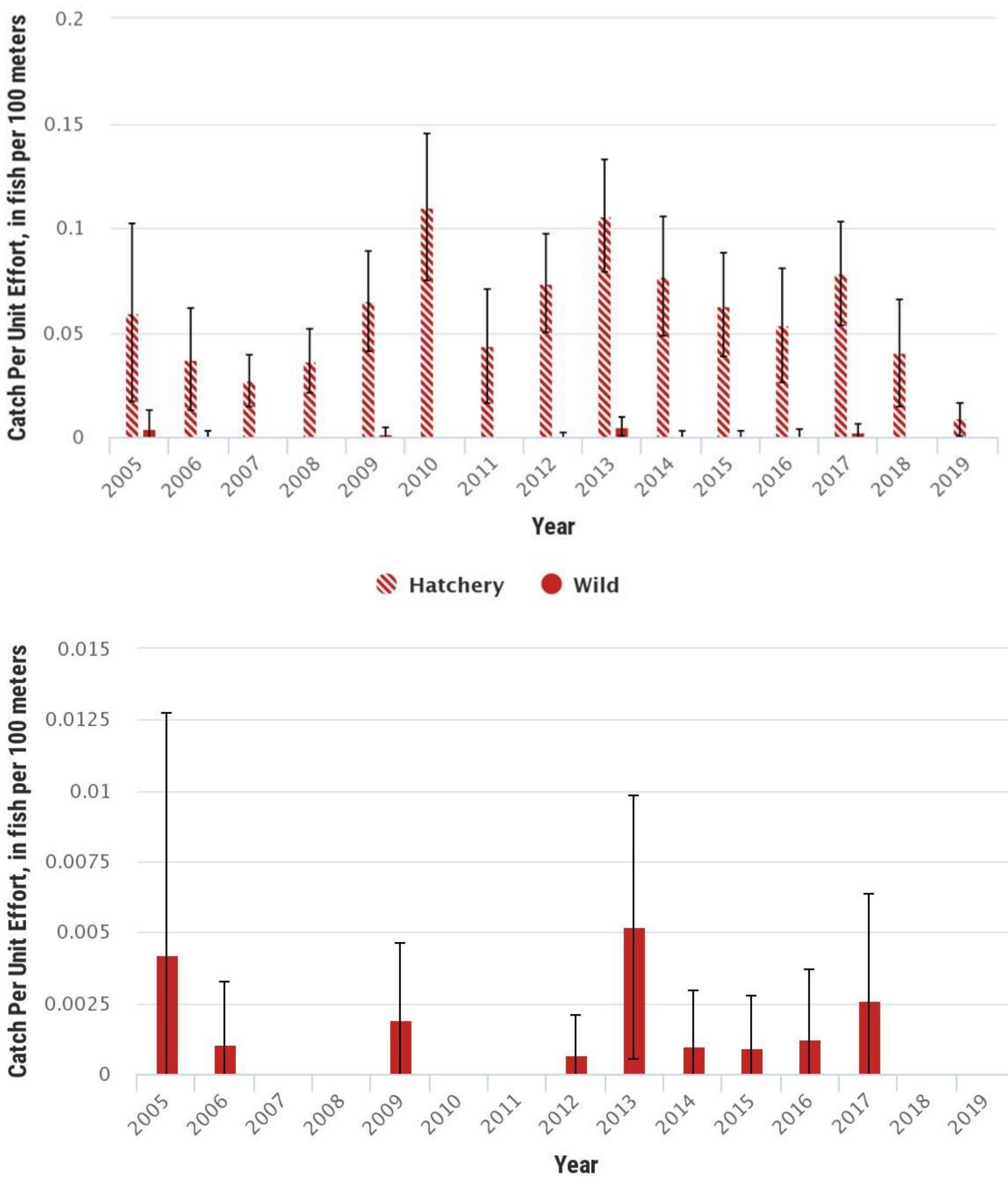

Figure 3-8. Upper River CPUE using drifted trammel nets, sturgeon season (fish-community season excluded), standard random sampling, segments 2, 3, and 4. The lower panel zooms in on wild pallid sturgeon. Error bars are two standard errors. Data source: MRRP– Information Management System – PSPAP, as of December 2019.

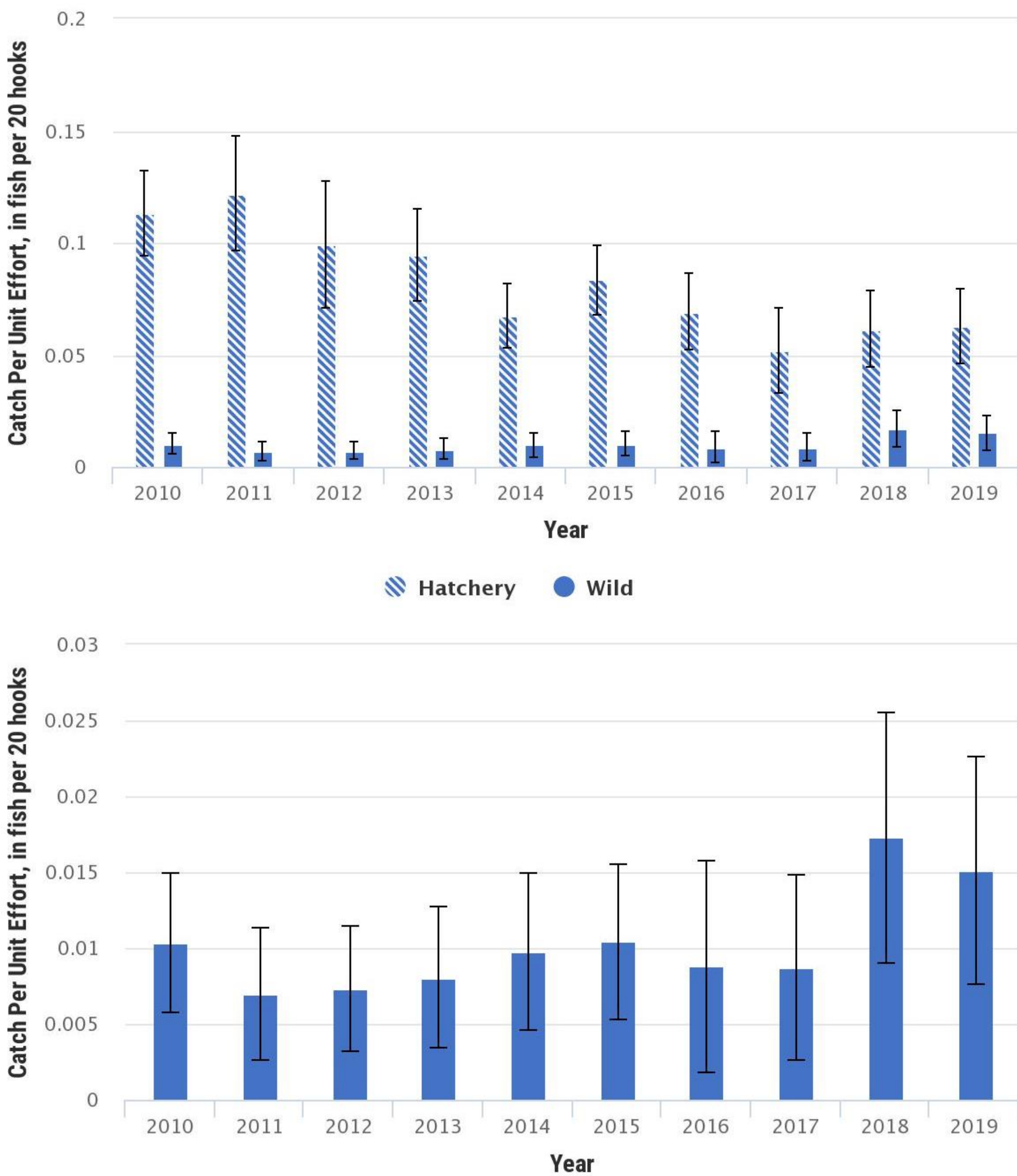

Figure 3-9. Lower River CPUE using trotlines only, sturgeon season (fish community season excluded), standard random sampling, and combined segments 7, 8, 9, 10, 13, and 14. Note that segments 13 and 14 were not sampled in 2016 and 2017. The lower panel zooms in on wild pallid sturgeon. Error bars are two standard errors. Data source: MRRP – Information Management System – PSPAP, as of Dec. 2019.

In 2019, the CPUE data underwent quality control and standardization through the MRRP Information Management System (IMS). Detailed methods are included in Section 3.2.1.3 of the Appendix. Figure 3-8 and Figure 3-9 only include PSPAP fish captured through standardized protocols to allow meaningful comparisons across years. In the Upper River, standardized CPUE data are available from 2005-2019. In the Lower River, standardized CPUE data are available from 2010-2019.

In the Upper River, CPUE of wild fish is sporadic, with no catch in six of the 15 years sampled, and substantially lower observed estimates than for hatchery fish. The average CPUE (+/- 2SE) across all years for hatchery fish is: 0.062 (0.047, 0.076) roughly 50 times the estimate for wild fish: 0.0013 (0.0004, 0.0021). There is no evidence of a long-term linear trend in CPUE for either hatchery (p-value = 0.70) or wild fish (p-value = 0.62); methods are described in Section 3.2.1.1.1 of the Appendix. Smoothing approaches were used to identify periods of increasing or decreasing behavior and suggest that the hatchery CPUE is in a period of local decline (Section 3.2.1.3 of the Appendix). No wild fish were observed during CPUE sampling in 2018 or 2019; the frequent observations of zero CPUE (2007, 2008, 2010, 2011, 2018, 2019) are a concern.

In the Lower River, catch of wild fish has been consistent throughout the standardized dataset (which includes only trotline gear, as gill nets were dropped from standard random sampling in 2018). Estimates are lower for wild fish than hatchery fish but the margin is smaller. The average CPUE (+/- 2SE) across all years for hatchery fish is: 0.083 (0.068, 0.098) roughly eight times the estimate for wild fish: 0.0103 (0.008, 0.012). There is strong evidence of a long-term decreasing trend (slope = -0.007)[*] in CPUE for hatchery fish (p-value <0.001). This likely reflects changes in stocking practices (Section 3.3.1) , but other factors (e.g., reduced survival or catchability) may also play a role. There is also evidence of a long-term increasing trend (slope = 0.00076)[†] for wild fish (p-value = 0.03) which may be due to recruitment to the population, recovery of the pallid sturgeon population following the elimination of commercial harvest of shovelnose sturgeon in 2010 (if adult pallid sturgeon not harvested had reproduced)[‡], or changes in catchability due to variability in temperature or flow. With recent high flows in 2018 and 2019, we would have expected a decline in CPUE, not an increase in CPUE, so changes in flow cannot explain the increasing trend in wild CPUE. As genetic analyses have not all been completed for 2018 and 2019 (still 40 unidentified adult fish out of 599), some presumed wild-origin fish may be reclassified as hybrids, which could affect the long-term trend in CPUE.

3.2.2.4 Relative Size Distribution

Relative Size Distribution (RSD) can provide insights into whether recruitment is occurring to adult reproductive populations. Its utility for long-lived species with low adult mortality has been questioned, however. Another important caveat is that the figures below include both wild and hatchery origin fish, and therefore fish in the smaller size classes likely represent the results of stocking actions rather than reproduction. The general size classes defined for RSD are for age-0 fish (0-200 mm), juvenile fish (200-400 mm), sub-adults (400-800 mm, when fish are thought to switch from an invertebrate-dominated diet to a fish-dominated diet [French et al. 2013; Grohs et al. 2009]), and potentially reproductive adults (> 800 mm). The RSD data can be affected by differential catchability for different size classes.

In 2019, the CPUE data, which informs the RSD, underwent quality control and standardization through the MRRP IMS. Detailed methods are included in Appendix 3.2.1.3. Figure 3-10 and Figure 3-11 only include fish captured on all days of sampling through standardized PSPAP protocols to allow for meaningful comparisons across years.

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[*] This represents a decline in CPUE of 0.007 each year, which is roughly 8% of the long-term average.

[†] This represents an increase in CPUE of 0.00076 each year, which is roughly 7% of the long-term average.

[‡] A proposal to list shovelnose sturgeon as threatened due to their similarity of appearance to pallid sturgeon appeared in the Federal Register on January 14, 2010 (https://www.govinfo.gov/content/pkg/FR-2010-01-14/pdf/2010-565.pdf) and became effective on October 1, 2010 (https://www.fws.gov/policy/library/2010/2010-21861.html). The effects of harvest reductions on shovelnose sturgeon are discussed in Phelps et al. (2016) and Green et al. (2019).

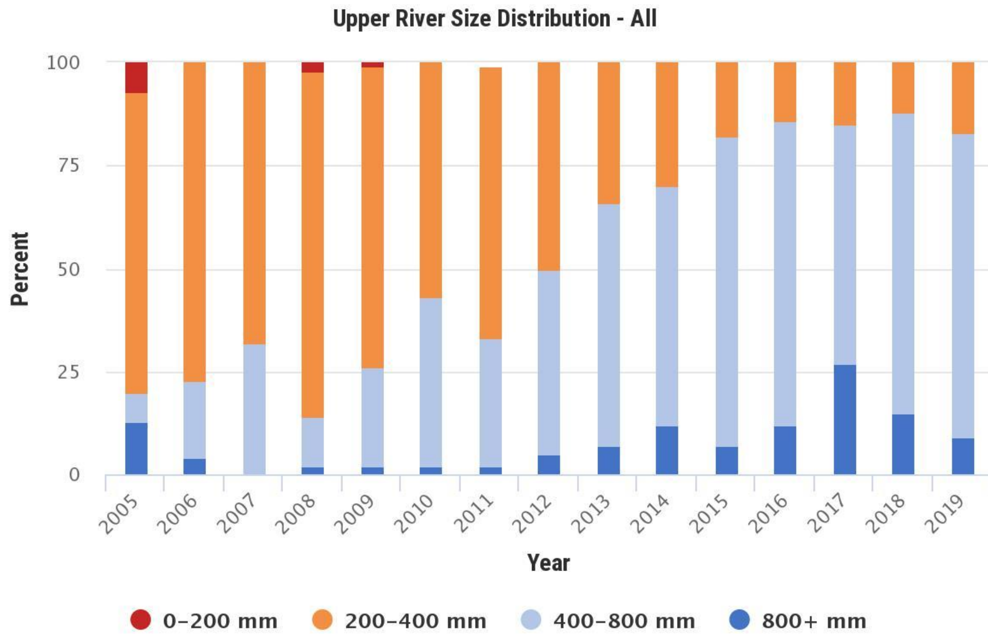

Figure 3-10. Relative size distribution for the Upper River, showing % of the sampled CPUE by size classes, wild plus hatchery origin. Data source: MRRP– Information Management System – PSPAP, as of December 2019.

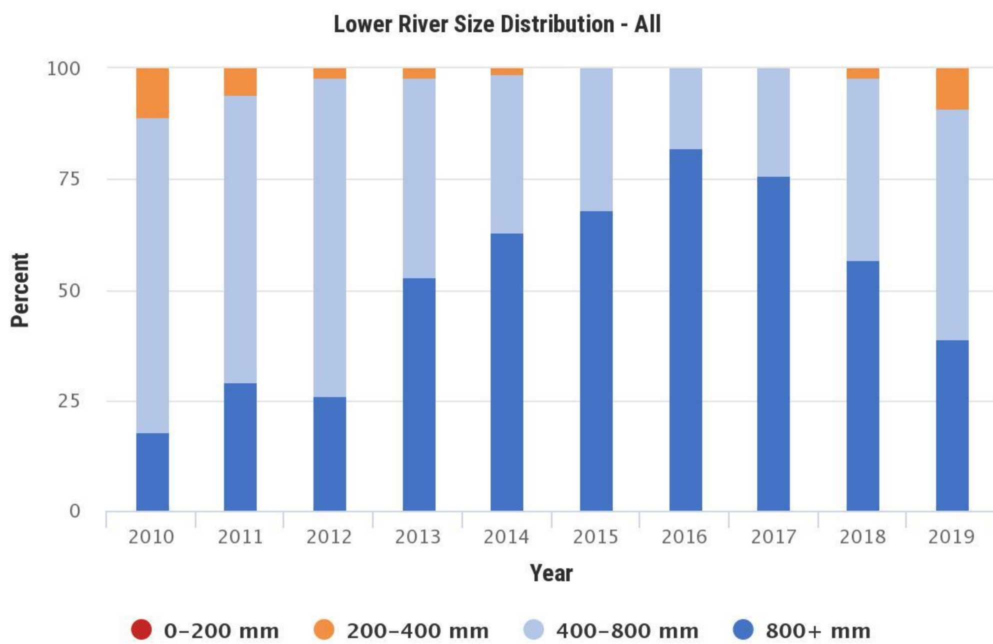

Figure 3-11. Relative size distribution for the Lower River, showing % of the sampled CPUE by size classes, wild plus hatchery origin. Data source: MRRP– Information Management System – PSPAP, as of December 2019.

The RSD in the Upper River (Figure 3-10) shows a progressive increase in sub-adult and adult pallid sturgeon, likely due to reduced stocking rates in recent years and aging of the hatchery-origin population. The RSD in the Lower River (Figure 3-11) has consistently been dominated by sub-adult and adult pallid sturgeon. The proportion of potentially reproductive (i.e., 800+ mm size class) sturgeon is consistently greater in the Lower River (39% in 2019) than the Upper River (9% in 2019). Low numbers of pallid sturgeon in the 0-200 mm class may be explained by a combination of factors including sampling issues (past PSPAP sampling gear was not optimized to capture the 0-200 mm size class (Schapaugh and Tyre 2011), PSPAP v. 2.0 is intended to address this issue); lack of natural recruitment; mortality of pallid sturgeon stocked at lengths < 200 mm; lack of stocking of pallid sturgeon < 200 mm; and/or growth in numbers of pallid sturgeon in larger length categories.

In order to enable meaningful comparisons across years, Figure 3-10 and Figure 3-11 only use data obtained from standardized PSPAP protocols. However, given that observations of wild pallid sturgeon <200mm are extremely rare, any observation (regardless of the protocol) is an important source of evidence. Table 3-4 summarizes all observations of wild origin pallid sturgeon <200mm regardless of how they were captured. They are particularly relevant to the MRRP sub-objective 1 (recruitment to age-1). Even a single observation of a wild-origin drifting free embryo confirms successful reproduction.[*] Likewise, observations of wild origin exogenously feeding pallid sturgeon confirm successful transition from endogenous to exogenous feeding. Observations in Table 3-4 were not collected using a random design or standardized level of effort and therefore should not be used to make inference beyond the observations themselves. Variations in flow conditions and temperatures across years can affect capture probabilities.

Currently, there is no known natural recruitment in either the Yellowstone or Missouri Rivers above Lake Sakakawea despite evidence of successful reproduction. Pallid sturgeon drifting free embryos have been collected from these areas in 2011-2019 (n=13; Table 3-4), however, there have been no observations of exogenously feeding individuals.

In the Lower Missouri River, there have been several observations of drifting free embryos (n=4) as well as exogenously feeding individuals (n=7) (Table 3-4). While these numbers are small, they confirm natural reproduction and transition to exogenous feeding. Further sampling over time will be required to determine if these events have produced recruitment to age-1.

The limitations in using RSD for assessing recruitment for pallid sturgeon on the Missouri River is acknowledged. In the future, the pallid sturgeon population model could be used to explore the age structure of a stable population, and this could be converted into the size classes shown here to provide a template of the desired RSD for a healthy population.

[*] Appendix E of the SAMP defines spawning as (aggregation-fertilization) and reproduction as (incubation-viable embryos).

Table 3-4. Summary of all observations of genetically confirmed wild pallid sturgeon <200mm observed regardless of sampling approach, since 2009. These counts represent actual observations and are an estimate of the minimum number (i.e., there are at least this many). They should not be extrapolated to make estimates about the density or total number of wild pallid sturgeon <200mm. Observations are further categorized by stage as either free embryos or exogenously feeding larvae.

Upper River	2011	1	Free Embryos	Mainstem (n=1) collected at Frazer, Montana by Dave Fuller, MTFWP; ~7mm in length and collected at RM 1707 on July 12	Eichelberger et al. 2014; Delonay et al. 2014
	2012	1	Free Embryos	Yellowstone River (n=1); collected by Pat Braaten, USGS on June 25, 2012 near Fairview, MT	Eichelberger et al. 2014; Delonay et al. 2016 (Synthesis of science)
	2013	4	Free Embryos	Yellowstone River (n=4); collected by Pat Braaten, USGS on June 25 (2), 26 (1) and 29 (1), 2013, near Fairview, MT	Eichelberger et al. 2014; Delonay et al. 2016 (2013 annual report)
	2015	3	Free Embryos	Yellowstone River (n=3); collected by Pat Braaten, USGS on June 25 (2) and June 26 (1), 2015, near Fairview, MT	Delonay et al. In Revision. (2015 Annual report)
	2017	4	Free Embryos	Yellowstone River (n=4); collected by Pat Braaten, USGS on June 15 (1), June 27 (3), 2017, near Fairview, MT	Delonay et al. In Revision. (2017 Annual report)
	2009-2019	0	Exogenously feeding	No confirmed observations	Pallid Sturgeon Data Management System (PSDMS); P. Braaten, Pers. Comm.
Lower River	2014	4	Free Embryos	USGS research project (n=3), lengths: (9.59-10.42 mm) NGPC (n=1), length: ~8mm	Delonay et al. 2016; R. Ruskamp, Pers.Comm.
		3	Exogenously feeding	MDC (n=2), lengths: 24, 48 mm USACE (n=1), length: 20 mm	Gosch et al. 2018; PSDMS
	2018	0	Free Embryos		Gosch et al. 2019; PSDMS
		4	Exogenously feeding	Lengths: 20, 22, 22, 25 mm	Gosch et al. 2019; PSDMS

3.2.2.5 Occupancy Estimates and Spatial Distribution of Age-0 Sturgeon

These monitoring efforts inform MRRP sub-objective 1, "increase pallid sturgeon recruitment to age-1" and estimate $metric_{1.1}$ (catch rates of age-0 and age-1 hatchery and wild origin pallid sturgeon) (Figure 3-2). Trawl catches of age-0 sturgeon require careful analysis: pallid and shovelnose sturgeon cannot be differentiated without genetic analysis at early life stages, and many trawls catch no fish. PSPAP v. 2.0 was designed to estimate this $metric_{1.1}$ using an occupancy approach because it can account for imperfect detection (i.e., false negatives) and estimate occupancy rates (i.e., what proportion of bends within each segment are occupied). Occupancy rates can be monitored over time and used as a proxy for trends in addition to catch rate. It is expected that, as age-0 pallid sturgeon recruitment occurs, occupancy would increase. Results below report occupancy estimates for unknown sturgeon species and will be updated once genetics are resolved.

During the past year, trawling for age-0 pallid sturgeon was fully implemented as a pilot effort in the Upper Basin (segment 4) and the Lower Basin (segments 10, 13, and 14 and part of segment 9). Segments trawled within each basin were selected as part of the design to reflect drift dynamics and historical distribution of age-0 shovelnose sturgeon. In short, 25.2% of the bends within a segment were randomly selected and at least 24 trawls were performed in the inside bend-channel border and channel cross-over-channel border macrohabitats. A period of random sampling was performed until a peak in age-0 sturgeon abundance was observed and then the field crews performed 2 weeks of targeted, nonrandom trawling to increase the likelihood of capturing a pallid sturgeon. The monitoring efforts were designed so as to estimate the spatial distribution of age-0 pallid sturgeon and their relative abundance (CPUE).

Segment-level estimates varied among basins and segments (Figure 3-12). These metrics link to MRRP sub-objective 1 by informing whether recruitment occurred by changes in distribution and what level of recruitment occurred by catch rate. Genetic results are pending for all age-0 sturgeon and therefore estimates are not yet available. More details about this monitoring effort are provided in Section 3.2 of the Appendix.

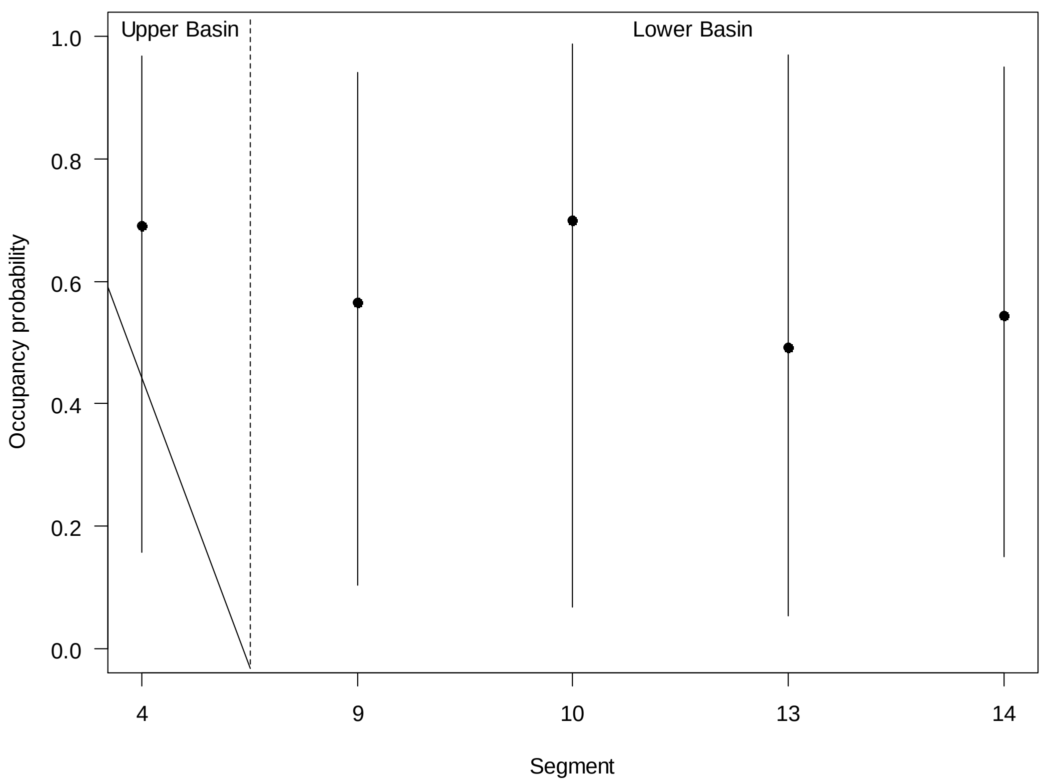

Figure 3-12. Segment specific occupancy estimates for unknown sturgeon species. The points represent point estimates and the vertical bars are 95% Bayesian Credible Intervals. Estimates are from data collected during the 2019 PSPAP v. 2.0 trawling efforts, an exceptionally high flow year. Estimates and Credible Intervals are preliminary and will change once genetic assignment to species is resolved and as the occupancy estimator is further developed in subsequent years. An occupancy probability of 0.7 would mean that 70% of the 24 bends in a segment (i.e., 17 bends) were occupied by age-0 or age-1 sturgeon.

3.2.3 Estimates of Incidental Take for Pallid Sturgeon

The 2018 BiOp (USFWS 2018) lists apparent survival in the Upper Basin, and apparent survival and CPUE in the Lower Basin as primary metrics for incidental take (IT). Secondary metrics such as abundance (Upper Basin only) and condition, growth rate, and reproductive cycling are also specified. Basin-specific benchmarks were included in the 2018 BiOp that, when exceeded, take was exceeded. Secondary metrics do not have specified benchmarks and are not used to evaluate if take was exceeded, but they provide context for the primary metrics.

Efforts to redesign the PSPAP (from PSPAP v. 1.0 to v. 2.0) to estimate metrics related to MRRP objectives (Figure 3-2) also included considerations to estimate primary and secondary metrics needed to evaluate IT. The sections below detail basin-specific primary and secondary metrics and progress towards using these metrics to assess take.

3.2.3.1 Primary Metrics

Apparent survival (i.e., survival not accounting for temporary emigration of fish out of the sampled area) is the primary metric specified for the Upper and Lower Missouri River basins. The benchmark for this metric is the 3-year running average of annual apparent survival estimates and the associated standard error of the average for age-4+ fish. This benchmark has not been calculated yet but current PSPAP v. 2.0 monitoring is designed to provide data for annual apparent survival estimates for the Upper and Lower basins. Future technical team efforts are planned to attempt to estimate annual apparent survival for the Upper and Lower basins. Apparent survival estimates exist for the Upper Basin (Rotella 2017) but were not generated to specifically estimate this benchmark and therefore some reanalysis of these estimates may be necessary.

The Lower Basin primary metrics also include CPUE of adult wild-origin pallid sturgeon due to the more open nature of the Lower Basin relative to the Upper Basin (i.e., fish movement among Missouri River tributaries and the Mississippi River). Mean CPUE for the Lower Basin is reported in Section 3.2.2.3 . The 3-year running averages have been calculated (Section 3.2.1.1 of the Appendix), but associated standard errors have not yet been estimated due to complexities in the hierarchical structure of CPUE data where gear deployments are nested within sampled bends, sampled bends are nested within segments, and segments must be averaged together to provide a basin-level average. The hierarchical nature of the CPUE data tends to underestimate the variability in the mean. Since take is exceeded if average CPUE exceeds 2 standard errors of the 3-year running average, effort needs to be taken to appropriately estimate the uncertainty around the running average and is planned for future work. Additionally, there is uncertainty in age assignment with size; this needs to be further resolved and incorporated into the analysis as part of calculating the CPUE benchmarks provided in the 2018 BiOp (USFWS 2018).

3.2.3.2 Secondary Metrics

Secondary metrics include abundance, fish condition, growth rate, and reproductive cycling. The 2018 Biological Opinion describes the general form of benchmarks that will be developed for these secondary metrics to provide thresholds for incidental take. Estimates for secondary metrics need to be calculated in units that will be comparable to the future benchmarks. Abundance, specified as estimates of annual abundance, is a secondary metric for the Upper Basin and is reported in Section 3.2.2.1 for 2019. Condition is a secondary metric for the Upper and Lower basins and will be estimated as the annual stage-specific (e.g., juvenile, subadult, adult) mean predicted weight and 2 standard errors calculated for 2 periods: January to June and July to December for age 1+ fish. These estimates have not been calculated but are planned as part of future Technical Team efforts. Predicted weights by length classes are presented in Section 3.2.5 using methods described in Section 3.2.1.2 of the Appendix. Growth rate is estimated as age-specific mean length of known age hatchery fish and 2 standard errors of the mean using the same stage and time-specific criteria used for condition. Growth estimates have not been calculated but are planned as part of future technical team efforts. Lastly, reproductive cycling represents how many years it takes for a pallid sturgeon to become reproductive again after spawning. This metric relies on a variety of data sources (e.g., blood samples, ultrasound, telemetry) that are being compiled from various sources. The benchmark for reproductive cycling is the proportion of reproductively ready female sturgeon. This proportion has not been calculated but is planned as part of future Technical Team efforts. Blood samples to estimate reproductive status are not routinely taken as part of PSPAP v. 2.0.

3.2.4 Status of PSPAP v. 2.0

PSPAP 1.0 was redesigned to v. 2.0 focus on information needed to evaluate and support decisions related to the pallid sturgeon fundamental objectives identified in the 2018 BiOp (Section 3.1.2.1), inform the integrated pallid sturgeon population model that will be used to evaluate and screen management actions, and provide additional support to key science efforts (e.g., evaluate pallid sturgeon population augmentation, evaluate pallid sturgeon reproductive success and recruitment in relation to flow/spawning cues; SAMP, attachment E.4, pgs. 603-633). PSPAP v. 2.0 has three related components: a trawling component to estimate distribution and relative abundance of age-0 pallid sturgeon; a mark-recapture component to estimate abundance and demographic rates of juveniles, sub-adults, and adults; and a telemetry component to estimate capture probabilities and immigration/emigration rates. Progress made in 2019 and preliminary estimates of relevant metrics for the trawling component and the mark-recapture component are summarized in Section 3.2.2.3 . Plans for the telemetry component are outlined below. Estimated metrics will be subject to change as metric estimators are further developed and the data receives full genetic resolution. During 2019, river flows were higher than normal, exceeding the 90% discharge (daily discharges have been summarized since it was initiated in 2003) for most of the sampling efforts. Despite the suboptimal conditions for the pilot basin-level implementation of PSPAP v. 2.0, sufficient data were collected to estimate the relevant metrics. Further work is required to understand the effects of high flows on capture probabilities and population estimates, and to determine safe conditions and procedures for field sampling. More details are presented in Appendix 3.2. Pilot implementation of PSPAP v. 2.0 started on the Yellowstone River in 2019 by Montana Fish, Wildlife and Parks.

3.2.4.1 Telemetry

Abundance estimates rely on recaptures of shovelnose sturgeon to estimate capture probabilities as pallid sturgeon recapture is rare. As part of PSPAP v. 2.0, a telemetry component is being implemented to 1) provide additional information to estimate pallid sturgeon capture probability and 2) provide information on pallid sturgeon movement (immigration/emigration) in and out of the mainstem Missouri River. In addition, the telemetry component has ancillary benefits in contributing to effectiveness monitoring and for documenting demographic parameters for population modeling. In 2019, USGS-Columbia Environmental Research Center provided recommendations for telemetry technologies for the Lower Missouri River and will recommend a system (see Section 3.4.5) that best meets the requirements of the PSPAP v. 2.0 and the species objectives for the MRRP. Field crews acquired the equipment and telemetry tags necessary to perform the telemetry operations prioritized under the sample design as identified in the SAMP. Progress made during 2019 included training of field crews in telemetry equipment operations and surgical tagging, implanting telemetry tags, and implementing pilot bend-level and segment-level telemetry sweeps.

3.2.4.2 PSPAP v. 2.0 Timeline

Full implementation of the mark-recapture and age-0 elements is expected in 2020. The telemetry components related to the estimation of capture probability (i.e., bend sweeps during mark-recapture) and immigration/emigration out of segments (i.e., river sweeps during mark-recapture) is expected for the 2020 sample season. However, the telemetry component that supports big questions and management actions (i.e., SAMP, attachment E.4, pgs. 603-633) is ongoing and efforts to further build capacity (i.e., equipment and training, portfolio of telemetry fish) will continue in 2020. Figure 3-13 provides a timeline of completed and proposed milestones for the PSPAP v. 2.0.

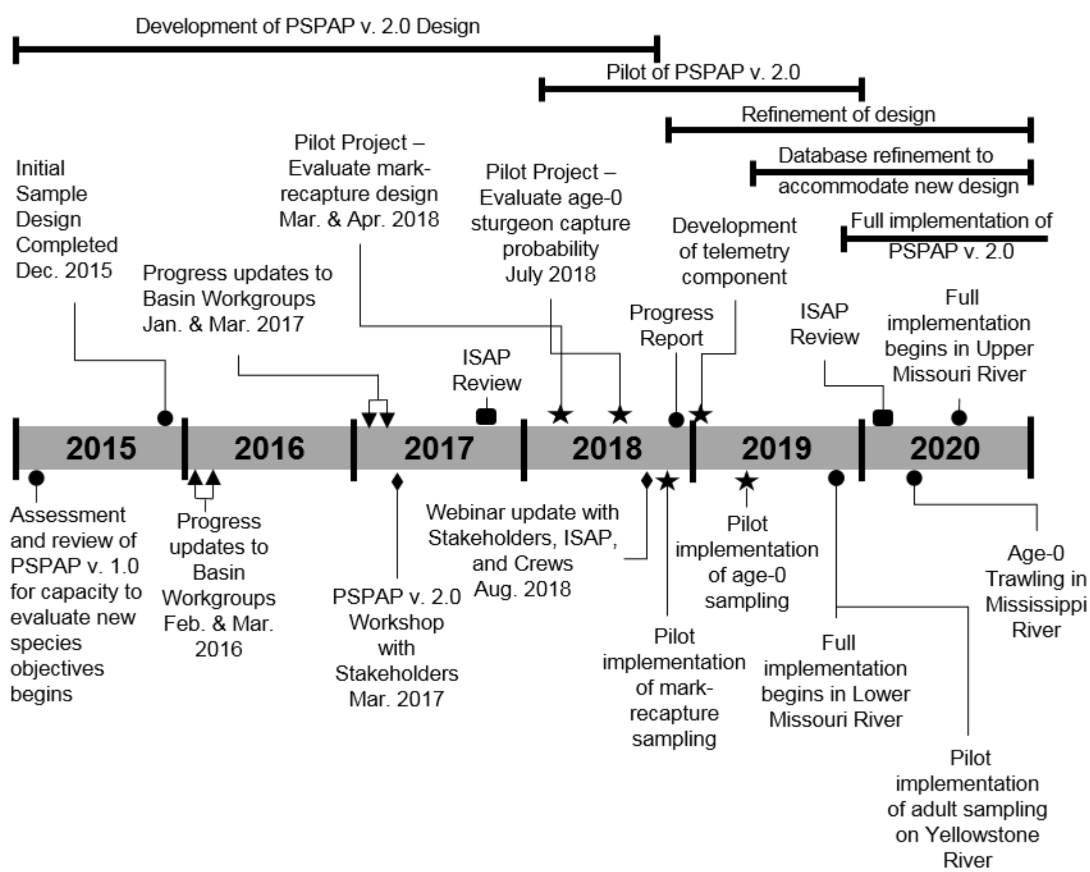

Figure 3-13. Timeline of PSPAP v. 2.0 milestones.

3.2.4.3 Sampling Outside of the Missouri River

Monitoring of areas outside the Missouri River, specifically the Mississippi River as well as the Yellowstone and Platte Rivers, is especially important in tracking progress toward meeting the MRRP fundamental objectives and understanding recruitment of pallid sturgeon (Delonay et al. 2016a). Fin ray microchemistry from sub-adult and adult pallid sturgeon (602-881mm; n=5) suggests at least some recruitment of Missouri River pallid sturgeon occurs in the Mississippi River (Porreca et al. 2015), but the accuracy of natal origin assignments may decrease with increased fish age or size (Steffensen et al., 2018 FSM presentation). Additionally, Phelps et al. (2012) indicated that 30% (n=9 of 30) of undifferentiated age-0 *Scaphirhynchus* caught in the Middle Missouri River originated from the Missouri River. A pilot effort to estimate adult abundance in the Yellowstone River was coordinated in 2019 with Montana Fish, Wildlife and Parks. In 2019, PSPAP v. 2.0 mark-recapture protocols were used to sample a 3.22 km reach below Intake Dam, and one bend above Intake. This work was done by Montana Fish, Wildlife and Parks with 2019 funding from the Western Area Power Association and the Bureau of Reclamation. Trawling for age-0 pallid sturgeon is planned for the middle Mississippi River in the spring of 2020 and is being coordinated with the appropriate state and federal entities. This should be considered an initial step as part of a potentially broader effort to improve our understanding of recruitment dynamics for lower Missouri River pallid sturgeon and the contribution of the Mississippi River. Mark-recapture and telemetry efforts are not currently planned outside the Missouri River. However, stationary receivers at key tributary mouths will provide information about movement into those systems and the transition to VEMCO telemetry equipment in the LMOR will allow tagged pallid sturgeon to be detected by the passive VEMCO telemetry array currently in place on the middle Mississippi River.

3.2.5 Condition of Pallid Sturgeon

Predicted weights are summarized for six example lengths in Figure 3-14 and Figure 3-15 (for the Upper and Lower Missouri River respectively). The only statistically significant changes since 2018 were a decrease in predicted weights for the 200 mm length in the Lower Missouri, and an increase in predicted weights for the 1200 mm length in the Lower Missouri.

Predicted weights for each segment are generally stable (see Section 3.2.1.6 of the Appendix). When compared to 2018, the 2019 results indicate no statistically significant decreases in predicted weights for any of the six analyzed lengths in any of the eight segments with data for both 2018 and 2019. (Segment 13 only had data for 2015 and 2019, but also did not show any statistically significant decreases in predicted weights. Segment 14 was missing data for 2016 and 2017.) There were only two cases with statistically significant increases in predicted weights: 400 mm fish in segment 3; and 800 mm fish in segment 8. Future work may lead to other statistical methods for analyzing these data, as discussed in Section 3.2.1 of the Appendix.

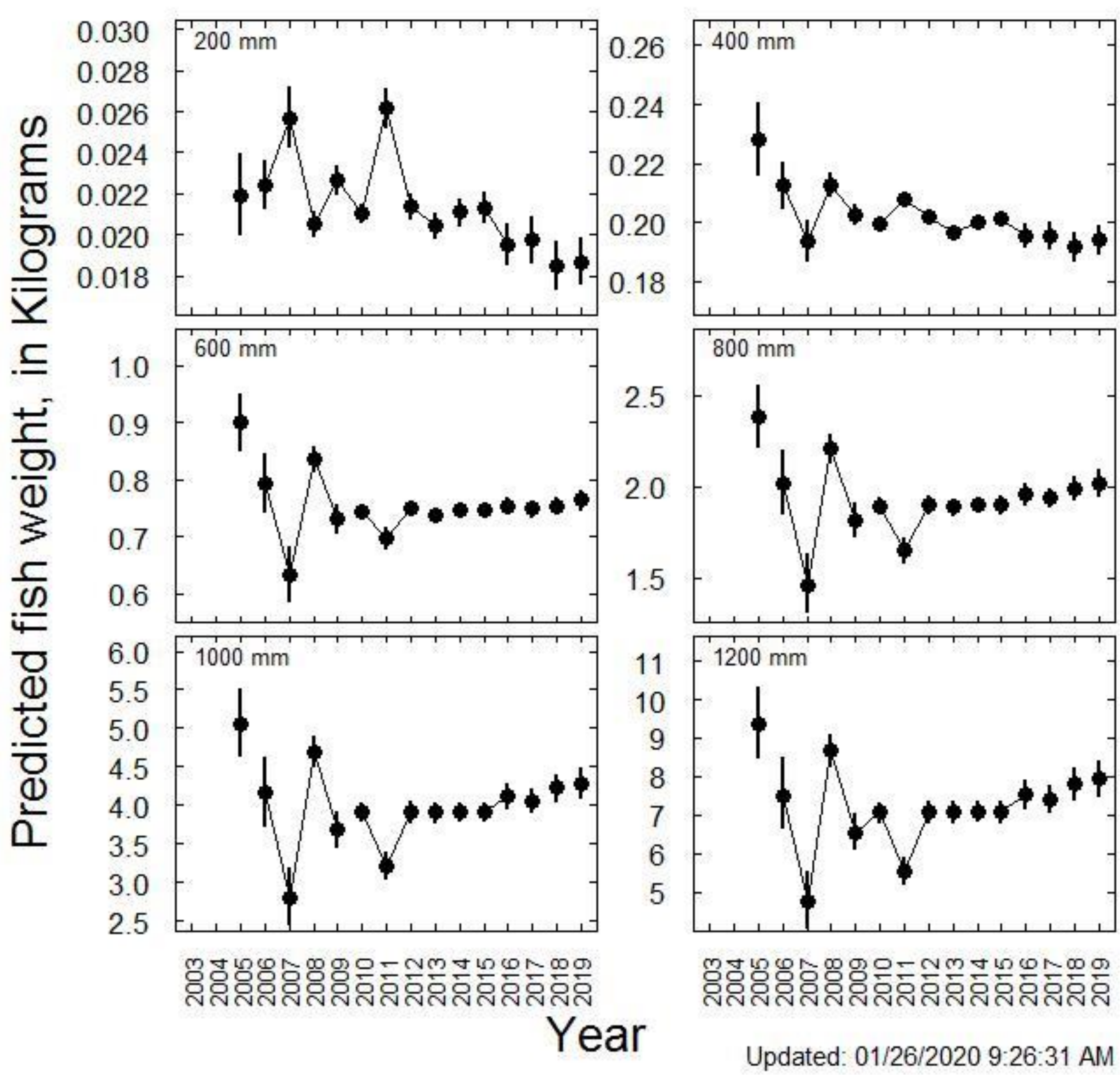

Figure 3-14. Predicted weights of pallid sturgeon for six example lengths, in the Upper Missouri. Vertical bars are 95% confidence intervals; values connected by diagonal lines are significantly different at of 0.05.

α

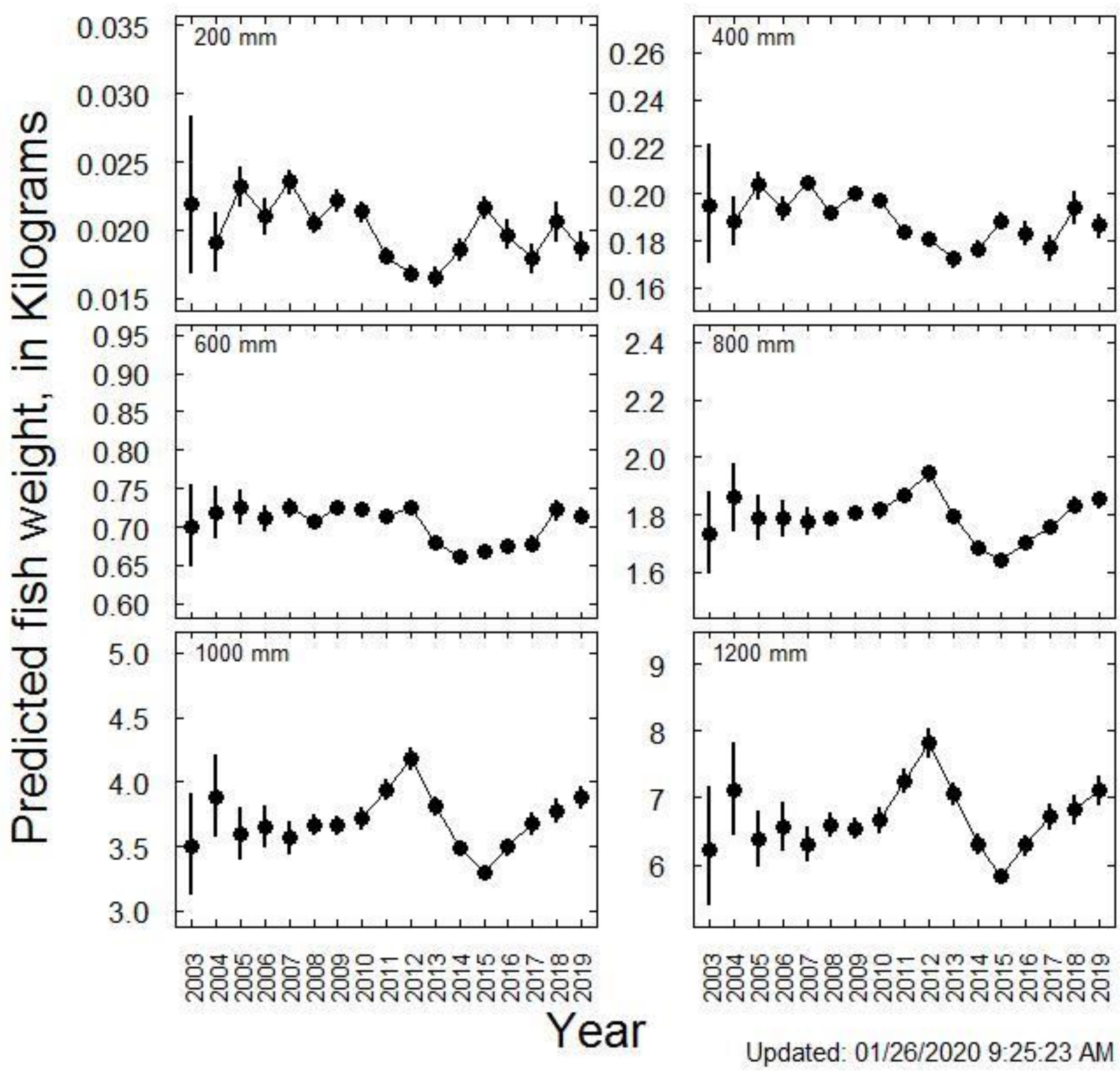

Figure 3-15. Predicted weights of pallid sturgeon for six example lengths, in the Lower Missouri. Vertical bars are 95% confidence intervals; values connected by diagonal lines are significantly different at of 0.05.

3.3 Management Actions

Management actions include those listed as "high priority" in the SAMP, Table 40, and identified as actions in the BiOp (USFWS 2018) and the Biological Assessment (USACE 2017):

- Population augmentation, Upper and Lower Rivers – currently at Level 4 (essential to maintain the Upper and Lower River populations until natural reproduction makes population augmentation unnecessary); described in Section 3.3.1

- Channel reconfigurations for IRCs, Lower River – currently at Level 2; if successful would move to Levels 3 and 4; described in Section 3.3.2
- Channel reconfigurations for spawning habitats, Lower River – currently at Level 1 (design), originally intended (SAMP, Table 43) to move to Level 2 implementation in 2020, now being reconsidered; described in Section 3.3.3
- Construct passage at Intake Diversion Dam on the Yellowstone River, Upper River – Level 4 implementation; described in Section 3.3.4
- Flow management at Gavins Point Dam in Lower Missouri – Level 1 research with potential implementation in 2027 (nine years after the ROD); described in Section 3.3.5
- Flow management at Fort Peck Dam in Upper Missouri – Level 1 research and NEPA evaluation of alternatives, with ROD anticipated in March 2021; described in Section 3.3.6

Table 1-1 presents a summary of management action implementation for the reporting year. Figure 3-16 illustrates the links among actions, monitoring, and research with the underlying big questions and management hypotheses underpinning the pallid sturgeon recruitment sub-objective of MRRP. The following sections describe the status and progress in implementing management actions and summarize the results of monitoring and associated research.

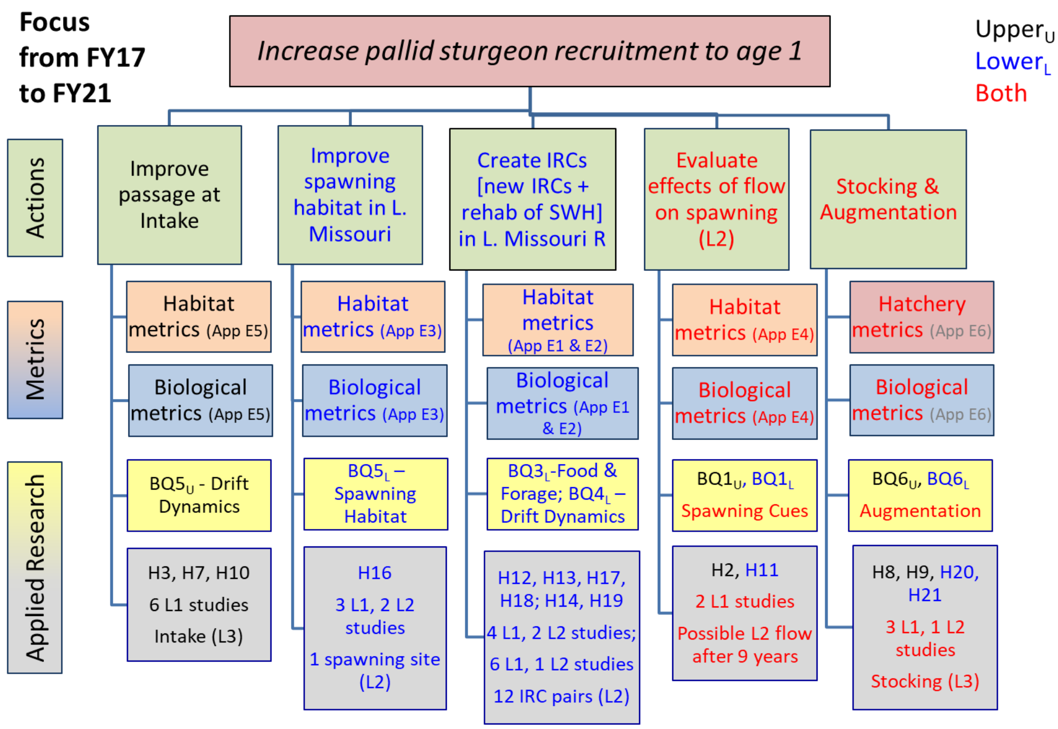

Figure 3-16. Overview of the links among management actions, big questions, management hypotheses, and applied research studies being used to inform action implementation for pallid sturgeon. Metrics for evaluating the effectiveness of actions are described in SAMP Appendix E. Items applicable to both Upper and Lower Missouri are shown in red, those that apply only to the Upper Missouri in black, and only to the Lower Missouri in blue (from SAMP, Figure 53).

3.3.1 Propagation and Augmentation

Propagation and augmentation are essential to maintaining pallid sturgeon until sufficient natural reproduction occurs. Propagation and augmentation are relevant to both sub-objectives listed in Section 3.1.2 , particularly sub-objective 2.

In 2019, the USFWS released the Pallid Sturgeon CPSP Guidance and Planning Document. The overarching goal of the CPSP is to support efforts to achieve a self-sustaining wild population of Pallid Sturgeon. Specifically, the program's objectives are to 1) Increase the number of individuals in specific management units where the population is deemed demographically threatened by low numbers; 2) establish multiple year-classes in specific management units that do not have a self-sustaining population; 3) achieve a genetically diverse and representative effective population size across the species' range that can maintain a self-sustaining, wild-reproducing population into the future; 4) establish and/or maintain refugia populations within the species' historic range to provide against future catastrophic loss in any one unit; and 5) understand and learn about life history, habitat and flow needs, and effectiveness of management actions through strategic stocking.

The EA (Jacobson et al. 2016; pages 33-42) used the pallid sturgeon population model to explore a range of stocking actions, and found a wide range of possible outcomes given the uncertainty in population parameters. Stocking targets in the USFWS stocking plan are based on multiple sources of information, including population modeling that incorporates updated survival estimates and demographic data (USFWS 2019, pg. 9).

3.3.1.1 Implementation Status

To date, approximately 2.6 million age-0 pallid sturgeon (including approximately 2.3 million for larval drift studies) and 69,611 age ≥1 pallid sturgeon have been stocked in the Upper Missouri River downstream of Fort Peck Dam (Figure 3-17). Since 1994, approximately 101,858 age-0 and 86,006 age ≥1 pallid sturgeon were stocked in the Lower Missouri River (Figure 3-18). In 2019, age-1 pallid sturgeon were not stocked into the Upper Missouri River for population augmentation due to a lack of broodstock in 2018, but 1,046,100 larval pallid sturgeon from 29 families were released for the larval drift experiment. For the Lower Missouri River, 3,459 age-1 pallid sturgeon (2018 year class) from 13 families were stocked to meet annual stocking targets. Gavins Point National Fish Hatchery (NFH) spawned six wild female and five wild male pallid sturgeon and created 12 unique family lots from these individuals and cryopreserved milt, resulting in 107,386 eggs for population augmentation in 2020. Milt from 8 males at three national fish hatcheries was cryopreserved for future propagation efforts. Gavins Point NFH is currently holding 12 wild females and 6 wild males, and Neosho NFH is holding 3 males and 1 female for 2020 propagation efforts.

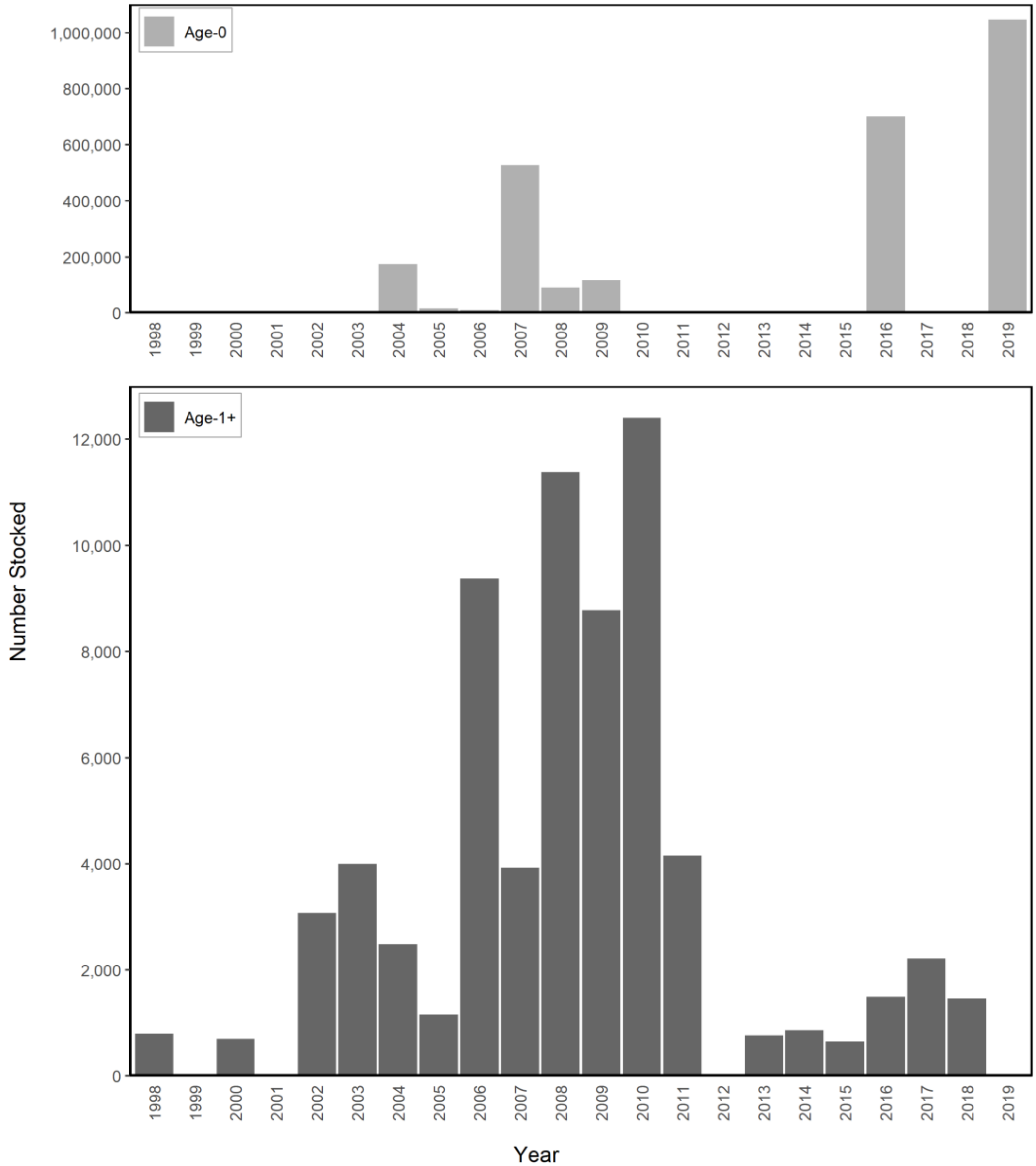

Figure 3-17. Stocking history of the Upper River downstream from Fort Peck Dam, 1998-2019. Data source: USFWS National Pallid Sturgeon Database, as of December 2019.

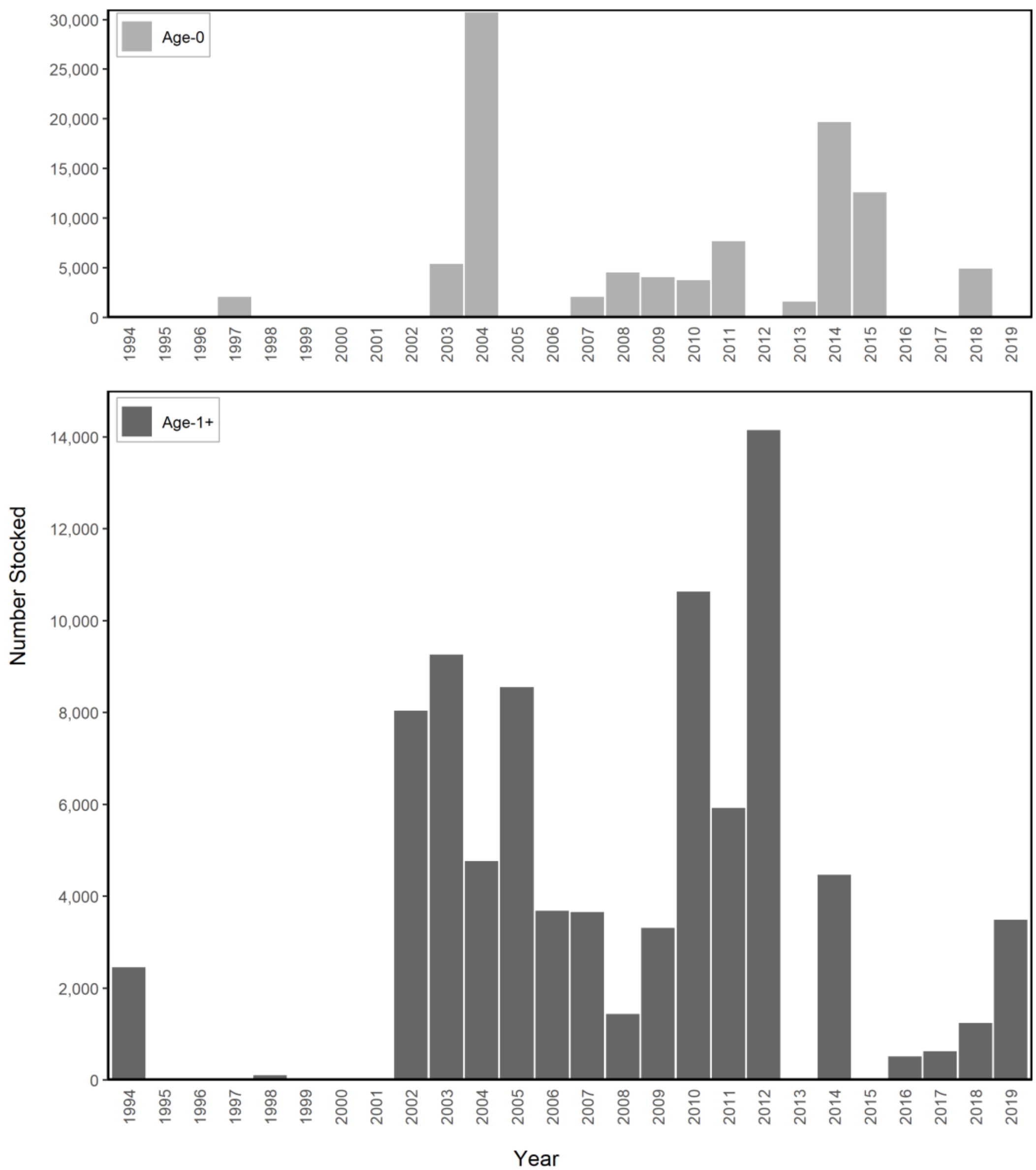

Figure 3-18. Stocking history of the Lower River downstream from Gavins Point Dam, 1994-2019. Data Source: USFWS National Pallid Sturgeon Database, as of December 2019.

3.3.1.2 Monitoring and Assessment Results

Although no studies were conducted in 2019 to evaluate specifically how propagation and augmentation decisions affect performance (e.g., growth and survival) of stocked fish in the wild, PSPAP sampling over time enables the assessment of growth and survival (see Section 3.2). Recent year classes (e.g., 2006-2009) have displayed different growth trajectories than those of earlier year classes (e.g., 2001-2003) in the Upper (USACE 2017) and Lower (Steffensen et al. 2019) Missouri River. Whereas early year classes demonstrated continuous growth, recent year classes demonstrate asymptotic growth trajectories, with rapid initial growth that declines after the first few years, as well as a lower predicted maximum length. In the Lower Missouri, survival estimates for age-1 hatchery fish released in recent years are also lower than estimates for earlier releases (Steffensen et al. 2010, 2016, 2019), potentially due to health issues (e.g., viruses, bacterial infections, etc.) arising from hatchery facilities (Steffensen et al. 2019).

In 2019, larval pallid sturgeon from Gavins Point NFH (n= 598,400) and Garrison Dam NFH (n=447,700) were stocked in the Upper Missouri River for the larval drift experiment. Gavins Point NFH also supplied larval pallid sturgeon for various hatchery experiments aimed at improving rearing conditions, particularly related to fin curl[*], as well as for other science needs within and outside of the SAMP. Research was also conducted at Gavins Point NFH to understand the effects of water chemistry on early life-stage mortality, with the goal of improving facility water operations for the program. Research is ongoing at Garrison Dam NFH to understand the effects of diet (feed type) on larval transition to feed and survival. Finally, staff at Bozeman Fish Technology Center and the Montana Cooperative Fishery Research Unit collaborated on a laboratory study to evaluate how diet affects mortality and condition of first-feeding larval pallid sturgeon. The results of these research initiatives will be incorporated into future CPSP implementation. The genetic diversity of stocked pallid sturgeon, estimated by the cumulative effective population size, has gradually been increasing over time (Section 3.2.2.2).

3.3.1.3 Focal Questions and Hypotheses

The CPSP Evaluation Plan (USFWS 2019) is a goal-based, hypothesis-driven framework to evaluate and improve CPSP actions and to identify future science and information gaps. During 2020, the USFWS plans to work with the USACE to ensure the CPSP evaluation framework and science needs inform and align with the SAMP framework for BQ6.

3.3.2 Channel Reconfigurations for IRCs, Lower River

IRCs are intended to test hypotheses regarding the interception, retention, and growth of larval pallid sturgeon. If these tests are successful and IRCs are implemented on a sufficient scale, then IRCs would be expected to improve survival of age-0 fish in the Lower Missouri River and are therefore directly relevant to sub-objective 1 (listed in Section 3.1.2).

3.3.2.1 Implementation Status

No IRC sites were constructed in 2019, which was the second year of delayed implementation. As of 2019, only two of the planned twelve treatment IRC sites have been constructed (Searcys and Moberly bends, constructed in 2017; Figure 3-19). The delay was due to compliance with Section 1226 of the America's Water Infrastructure Act of 2018, prohibiting construction of IRCs until the Secretary of the Army submitted a report to Congress regarding the impacts of pallid sturgeon IRC habitat construction on the navigation, flood control, and other authorized purposes and the population recovery of pallid sturgeon. The 2-year delay in implementation represents a 2-year delay in the assessment of the IRC staircase design, extending the timeline to full evaluation from 8 years to 10 years. The report required by WRDA 2018 was submitted by the Assistant Secretary of the Army for Civil Works to Congress on March 18, 2020. Construction of IRC sites may recommence in 2020.

The potential IRC sites identified in 2017-18 for construction in 2019, based on consultation with stakeholders and the site selection process (Section 4.3.2), were St. Alban's Bend (RM 52) and Pelican Bend (RM 10). The controls for those sites are Morrison Bend (RM 110) and Portland Bend (RM 112)

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[*] Fin curl is a condition developed by some juvenile sturgeon that causes the pectoral fin to bend towards the body, which likely impacts the fish's ability to position-hold, forage and maneuver. The specific causes of the condition are unknown (Deslauriers et al. 2016).

respectively. Design efforts (including the application of multi-dimensional hydrodynamic and particle-tracking models) were initiated at two new IRC sites, which include Straubs Bend (RM 105) and Providence Bend (RM 168). Controls for these sites include Isbell Bend (RM 125) and Gilliam Bend (RM234), respectively. Eight of the 12 sites have been identified, with the remaining four to be determined pending additional consultation with stakeholders. Control and treatment sites were paired based on location within the same river segment and their geomorphic similarity. While control and treatment sites are paired, the statistical analysis of treatment effects can also be completed by having a pool of control sites and a pool of treatment sites (i.e., not pairing). IRC sites were located to provide opportunities to test interception hypotheses at locations adjacent to public lands and while minimizing potential impacts to authorized purposes.

Shallow Water Habitat (SWH) refurbishment into IRC sites, called SWH-IRC to highlight their distinct differences from IRCs in bends, are not currently under construction.

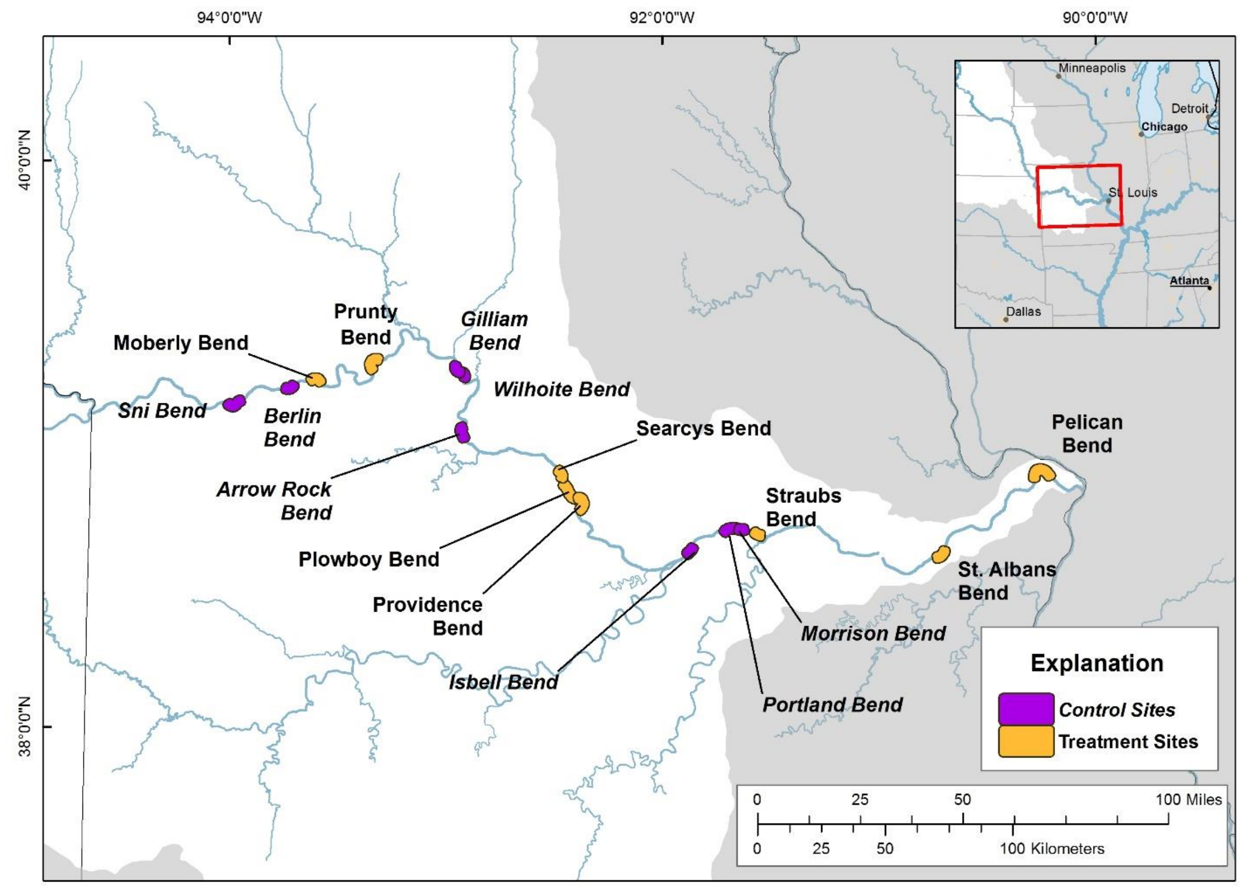


Figure 3-19. Locations of present and potential future IRC treatment and control bends. Searcys and Moberly bend IRCs were constructed in 2017; Wilhoite and Sni bends are the controls for those two sites, respectively.

3.3.2.2 Monitoring and Performance Assessments

Monitoring continues at existing treatment and control sites. Data collected at the two treatment sites are considered treatment data, while data collected at the control and proposed treatment sites are considered control data. The IRC staircase design cannot be fully evaluated until after the 10-year evaluation period is complete. Analysis of the existing (incomplete) dataset shows no significant differences in CPUE between treatment and control sites (Appendix 3.3.2.1). However, these results are not indicative of the full evaluation of the performance of IRCs; twelve IRC treatment sites and twelve control sites are still required, as described in Appendix E1 of the SAMP.

3.3.2.3 Focal Questions and Hypotheses

3.3.2.3.1 Interception and Rearing Complexes (IRCs) Focal questions

IRC-Q1: Within river bends that include IRC habitat restoration sites, does (a) the proportion of free embryos intercepted following IRC construction and (b) the catch per unit effort (CPUE) increase relative to control sites, and pre-construction conditions?

Inconclusive. It is too soon to evaluate the efficacy of IRC sites on age-0 CPUE. Seven more years are necessary to have sufficient statistical power to evaluate the efficacy of IRC sites (Appendix 3.3.2.1). Direct measurement of interception is impractical and therefore evaluation relies on the application of particle-tracking models. Application of these models to evolving hydrodynamic and bathymetric conditions over time will indicate whether interception potential has increased.

IRC-Q2: Within river bends that include IRC habitat restoration sites, does the growth of age-0 sturgeon increase relative to control sites and pre-construction conditions?

Inconclusive. There is currently no direct comparison between treatment and control sites of age-0 sturgeon growth. However, science activities in the Lower Missouri River found (1) a low percentage of undifferentiated age-0 sturgeon that have empty stomachs (Appendix 3.6.2) and (2) little evidence for biologically significant differences in growth from year to year of age-0 sturgeon in the Lower River (Appendix 3.6.2). The latter finding was notable because food producing habitat in the Lower River exceeded what would be produced by IRC habitat because of the high floodplain connectivity in 2019. Both lines of evidence suggest that food availability is not a limiting factor for age-0 sturgeon.

IRC-Q3: Do the hydrodynamics of river bends that include IRC sites increase: (a) the area of foraging habitat, and (b) the area of food-producing habitat, relative to pre-construction conditions?

Areas of foraging and food-producing habitat have decreased. At the specific IRC treatment sites, physical monitoring confirms that the hydrodynamics of the river differs from pre-treatment conditions (2019 FSM Lower River Presentation: Bonneau et al. IRC Monitoring and Concurrent Related Activities). The total area of food-producing and foraging habitats (as currently defined) across the treatment sites is less than pre-construction conditions because the design of IRCs prioritized interception. There is a tradeoff between interception and foraging habitat because interception typically requires higher velocities, which reduce available foraging habitat if the IRC footprint is limited. Another issue is that field observations are not consistent with the current definitions of foraging habitat. As discussed in Section 3.6.2.3 , age-0 sturgeon are found across broader ranges of velocities and depths than suggested by the current definitions of foraging habitat.

3.3.2.3.2 Shallow Water Habitat (SWH) Focal Questions

SWH-IRC refurbishment has not yet occurred, therefore the focal questions are presented here but not answered.

SWH-Q1: Within SWH-IRC sites, does (a) the potential for interception of free embryos (as indicated by particle tracking models), and (b) the catches (CPUE) of age-0 sturgeon increase relative to pre-modification conditions?

SWH-Q2: Within SWH-IRC sites, does the growth of age-0 sturgeon increase relative to pre-modification conditions?

SWH-Q3: Do the hydrodynamics of SWH-IRC sites increase: (a) the area of foraging habitat, and (b) the area of food-producing habitat, relative to pre-modification conditions?

3.3.3 Spawning Habitat Construction

Spawning habitat is intended to improve the rates of reproduction in the Lower Missouri River and is directly relevant to sub-objective 1 (listed in Section 3.2.1).

3.3.3.1 Implementation Status

No spawning habitat projects were planned or constructed in the 2019 reporting year. The next step for this management action is to discuss with the USFWS whether spawning habitat construction remains a priority given evidence of at least limited successful reproduction in the Lower Missouri River. If spawning habitat construction is to occur, project location also needs to be discussed. Although the planned approach was to construct spawning habitat in a location where spawning activity already occurs in order to maximize chances of reproductive adults being in the area, this may not make sense if those spawning efforts are already successful to some degree. If spawning habitat is to be constructed in the next few years, then researchers and engineers will be engaged to evaluate the current state of knowledge and determine where and how a spawning habitat project will be constructed. Appendix E of the SAMP provides an overview of some initial design alternatives and the associated effectiveness monitoring approach.

The pallid sturgeon population model has not yet been applied to the question of the possible benefits of spawning habitat construction. Applying the model given present knowledge would generate a wide range of possible outcomes, depending on the assumed preference of spawning fish for constructed habitats over other existing spawning habitats, the assumed level of male-female aggregation and the assumed relative rates of reproduction at constructed vs existing spawning habitat. Additionally, the locations of potential spawning sites as well as the subsequent flows and temperatures post hatch would cause significant variability in resultant drift and retention, requiring additional modeling (with associated uncertainty). A Level 2 experiment to build spawning habitat, together with targeted effectiveness monitoring (SAMP Appendix E3) could provide the information required to construct a credible model of benefits. At the 2018 Fall Science Meeting, Dr. Ed Bulliner presented a back-calculation of possible spawning locations in the Lower Missouri River, based on approximate ages of larval sturgeon and estimates of drift distances [2018 FSM Presentation: Bulliner et al. Back calculation of spawning on the landscape]. As noted above, the next step for this management action is for USACE and USFWS to discuss whether it remains a priority.

3.3.3.2 Monitoring and Assessment Results

Several relevant science activities occurred in 2019 and are summarized below.

USGS undertook new analysis of past pallid sturgeon spawning events in the Lower Missouri River to describe the physical characteristics (e.g., depth, velocity, position, and substrate) of confirmed spawning locations. The study included ten pallid sturgeon spawning events between 2008 and 2013. Results show pallid sturgeon use habitats that are prevalent in the present-day channelized Lower Missouri River (Elliot et al. 2020).

Spawning indicator tags were evaluated for their potential to confirm spawning and identify spawning locations. The USGS' preliminary studies developed morphometric, non-invasive oviduct implantation techniques for spawning indicator tags that are released by female sturgeon during ovulation. Shovelnose sturgeon females implanted with the transmitters in the laboratory retained the oviduct implants until they were artificially induced to ovulate following hormone injections. See Section 3.4.6

Genetic identification methods were improved making it possible to identify parentage on early-stage sturgeon embryos (Kashiwagi et al. 2019). This will aid in the evaluation of reproduction at spawning locations, including the ability to better define and monitor spawning in response to habitat conditions, environmental cues, and management actions.

Monitoring of telemetered fish is a key strategy for evaluating management actions on the Missouri River (Appendix E, SAMP). It is particularly important for identifying fish behavior in relation to spawning cues and refining understanding of habitat use including the use of spawning habitat (Delonay et al. 2016). Telemetry is also used as an integral part of the PSPAP v. 2.0 to evaluate emigration and for virtual mark/recapture. In addition, reproductive histories of fish in the telemetry database provide a unique source for demographic parameter estimates needed for population modeling. The current monitoring goal is to insert acoustic tags in a total of 80 adults in the Lower Missouri River. Currently, 65 fish with active tags (31 of which are new tags) exist in the Lower Missouri River. Efforts are ongoing to recapture previously tagged fish and replace old tags with new VEMCO acoustic tags.

The NGPC program completed larval drift surveys at the Middle Decatur spawning habitat test site (RM 688) and captured 9 larval sturgeon, which were confirmed to be shovelnose sturgeon (Kirk Steffensen and Jerrod Hall, NGPC Pers. Comm.).

3.3.3.3 Focal Questions and Hypotheses

Focal questions and testable hypotheses to evaluate the effectiveness of constructed habitat were proposed in Appendix E of the SAMP. These questions consider the physical and biological responses of pallid sturgeon to the management action (i.e., constructed spawning habitat). If Level 2 implementation of constructed habitat moves forward, the following focal questions will receive the most emphasis in effectiveness monitoring:

Q1: Can suitable spawning habitat be created and maintained without further intervention?

Q2: Are created spawning habitats selected over other areas?

Q3: Does successful spawning (aggregation-fertilization) occur in the created spawning habitats?

Q4: Does successful reproduction (incubation-viable embryos) occur in the created spawning habitats?

3.3.4 Intake Passage and Translocation

Intake passage and translocation are intended to rectify "take" at Intake Dam, defined as movement impedance at the dam. A desirable outcome of Intake passage would be spawning higher up in the Yellowstone watershed, which would increase the available drift distance for free embryos, and help to improve the chances of recruitment to age-1 (sub-objective 1; Section 3.1.2). While some preliminary advection-dispersion modeling was completed from Miles City to Lake Sakakawea in 2014, there are considerable data gaps (e.g., poor survey data above Intake, likely no survey data for the Powder River, limited water quality data). Considerable work would be required to develop physical and biological models for the Yellowstone and Powder Rivers comparable to those available for the Upper Missouri River below Fort Peck Dam, which have been used to make credible predictions of embryo development to the exogenously feeding stage for spawning at various locations (described in Section 3.5).

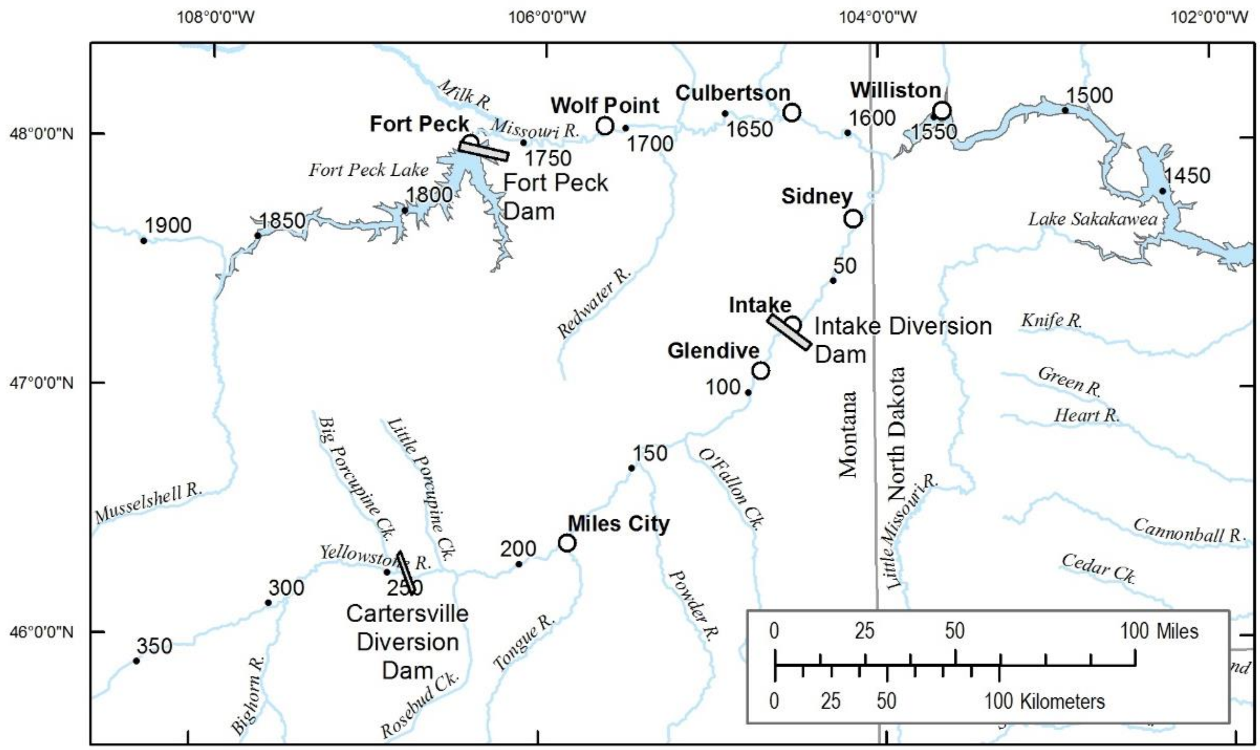
3.3.4.1 Implementation Status

After resolution of two bid protests challenging the contract award, construction of the bypass channel at Intake Diversion Dam started in July of 2019. During the initial phases of construction, issues were encountered with the identified location for a replacement weir, requiring a contract modification be negotiated with the contractor. Remaining work on the weir and the bypass channel is expected to be completed no later than 2023. More detail on the implementation status is presented in Section 4.3.4 .

The Bureau of Reclamation (Reclamation) is the primary entity responsible for the translocation of pallid sturgeon around Intake Diversion Dam. Reclamation, Montana Fish, Wildlife & Parks, and USGS are involved in tracking and detecting fish upstream of Intake. Field crews were deployed from May 1 through June 30 to translocate fish around Intake Diversion Dam. Upstream movement of these fish was tracked most intensely from April to June using a combination of passive telemetry station receivers and manual tracking in boats, with less intensive tracking after the peak spawning period in June. Translocation is expected to continue for the duration of the construction. See Section 3.4.5 for a summary of advances in telemetry technology for the Upper Missouri and Yellowstone Rivers.

3.3.4.2 Monitoring and Assessment Results

In 2019, 12 fish were translocated upstream of Intake Diversion Dam and released at Stipek, Montana between May 4 and May 31, 2019. Of these 12 translocated fish, 2 were wild-origin adult males and 10 were of hatchery-origin. Three fish exhibited long upstream migrations of over 100 river miles. The 2 wild-origin males entered and migrated up into the Powder River (confluence around river mile 150 on the Yellowstone River; see Figure 3-20). One of these fish traveled more than 80 miles upstream into the Powder River, while the other traveled 48 miles upstream. A third fish (hatchery-origin, unknown maturity) traveled up the Yellowstone River to river mile 229.5, nearly to Cartersville Diversion Dam. The remaining translocated fish tended to concentrate in the river segments between Intake Diversion Dam and the Powder River confluence. In addition, 8 fish that were translocated in 2018 or 2019 have remained upstream of Intake Diversion Dam. The reason for remaining upstream is unknown at this time.



Source: U.S.G.S. digital basemap data
Universal Transverse Mercator, Zone 15

Figure 3-20. Map of the Yellowstone and Upper Missouri Rivers with key locations of relevance to the translocation of adult pallid sturgeon and construction of fish passage at Intake Diversion Dam.

3.3.4.3 Focal Questions and Hypotheses

Q1: Do adult and juvenile pallid sturgeon successfully move upstream / downstream past Intake Diversion Dam and through the bypass channel?

Inconclusive. It is not possible to determine the effectiveness of upstream and downstream passage at Intake Diversion Dam until the project construction is complete.

Q2: Does the location of spawning provide sufficient drift distance to allow the development of drifting free embryos into exogenously feeding larvae?

Inconclusive. Translocated pallid sturgeon were observed migrating upstream significant distances into the Powder River. It is, however, unlikely that sufficient numbers of adults were available to aggregate and initiate spawning given that no radio-tagged females were translocated upstream of Intake Dam. No modeling results are available to assess whether these locations could provide the appropriate temperatures, flow conditions, and drift distance to support successful embryo development during the drift phase.

Q3: Does successful spawning (aggregation-fertilization) occur?

Inconclusive. For those pallid sturgeon that were translocated upstream of Intake Diversion Dam, it is unclear whether successful spawning occurred.

Q4: Does successful reproduction (incubation-viable embryos) occur?

Inconclusive. A determination of the reproductive success of pallid sturgeon that were translocated upstream of Intake Diversion Dam was not completed.

Q5: Do free embryos, larvae, and young-of-year successfully move downstream past Intake Diversion Dam and through the bypass channel?

Inconclusive. Juvenile sampling immediately downstream of Intake Diversion Dam was not conducted.

3.3.5 Flow Management at Gavins Point Dam

Flow management at Gavins Point dam is intended to improve the rates of reproduction in the Lower Missouri River and is directly relevant to sub-objective 1 (listed in Section 3.1.2).

3.3.5.1 Implementation Status

Flow management at Gavins Point dam was developed as a one-time Level 2 flow release experiment to be implemented following 9 years of opportunistic evaluation of pallid sturgeon responses to background flow pulses should new scientific information support the need for a managed pulse from Gavins Point Dam.

A critical science activity that supports the evaluation of pallid sturgeon responses to spawning cue flows is a possible redesign of the telemetry network in the Lower River. Work in 2019 led to specific recommendations to improve the integration, detectability, and flexibility of the telemetry system to serve information needs for the MRRP. This study provides a foundation for the 2020 deployment of a system capable of tracking tagged sub-adults and adults in both the Missouri and Mississippi Rivers (see Section 3.4.5 for more details).

High flows (see Section 1.3) and interrupted river access made it more difficult for field crews to track adult responses to water conditions in 2019. However, NGPC field crews were able to conduct river and bend sweeps during the April to May spawning period. In September and October 2019, the field crews responsible for PSPAP v. 2.0 acquired the necessary telemetry equipment, and crews were trained by USGS in telemetry fundamentals including surgical implantation, blood sampling, egg biopsy techniques, and data collection.

3.3.5.2 Monitoring and Assessment Results

In August 2019, at a time favorable for access, the entire Lower Missouri River was surveyed in a river sweep to document the number of telemetered sturgeon. This activity helped provide an understanding of focal river segments and an assessment of reproductive status to inform re-tagging efforts in 2020. A total of 28 unique sturgeon were detected. In October 2019, broodstock fish that had previously been captured and transferred to hatcheries in the fall of 2018 and spring of 2019 were assessed for sex and reproductive status, surgically implanted with tags, and released in the river. All of these fish were adults with known reproductive histories. As of December 2019, there are an estimated 65 pallid sturgeon with active transmitters in the Lower Missouri River. Thirty-one of these fish have new VEMCO transmitters and 34 have legacy Lotek transmitters that will be targeted for replacement in 2020. Of these 65 telemetered fish, seven are female and expected to be in reproductive condition by spring 2020. It is anticipated that these fish will be suitable for evaluating spawning responses to flow.

3.3.5.3 Focal Questions and Hypotheses

Q1: Are there attributes of river flow that are strongly correlated with the upstream movement of reproductive male and female pallid sturgeon?

Q2: Are there attributes of river flow that are strongly correlated with successful spawning (aggregation-fertilization)?

Q3: Are there attributes of river flow that are strongly correlated with synchronous behavior of reproductive male and female pallid sturgeon?

Q4: Are there attributes of river flow that are strongly correlated with successful reproduction (incubation, hatch, viable embryos)?

Inconclusive. In 2019 it was not possible for field crews to track responses of adults due to high flow conditions, and therefore it was not possible to assess whether attributes of river flow are correlated with the biological responses listed in the questions above.

3.3.6 Flow Management at Fort Peck Dam

3.3.6.1 Implementation Status

The Fort Peck AM Framework, released in December 2018 (USACE and USFWS 2018), outlined an approach to formulate and evaluate test flow releases from Fort Peck Dam for pallid sturgeon, using an AM framework consistent with the SAMP to guide implementation. Work in 2019 focused on refining the AM framework, designing alternatives, and analyzing their potential biological benefits and HC impacts. The two key processes for these activities were reviews of the Fort Peck AM Framework by the ISAP, and work on the Fort Peck Environmental Impact Study (EIS).

The ISAP released their review of the Fort Peck AM Framework in August 2019. In general, the review was very positive, with suggestions for improving population modeling, effectiveness monitoring, performance benchmarks, HC monitoring, and data management, as well as describing the governance approach to Level 2 flows at Fort Peck. The ISAP also recommended integrating the Fort Peck AM Framework into the SAMP and designing flow experiments with sufficient “signal strength” to be readily measurable and attributable to the action. The Technical Team provided a response to the ISAP Review in September 2019, clarifying various issues, including progress underway on population modeling (see Section 3.5).

Recognizing the potential need for management of flows from Fort Peck Dam in order to address pallid sturgeon objectives for the upper river, the USACE determined that it would investigate alternatives to improve the potential for pallid sturgeon recruitment on the Upper Missouri River and increase the upper basin pallid sturgeon population relative to its status without intervention. The National Environmental Policy Act (NEPA) requires federal agencies to evaluate and consider a range of alternatives that address the purpose of and need for action.

Alternatives were informed by the current state of pallid sturgeon science as described in the MRRP SAMP (Fischenich et al. 2018a), the associated 2018 BiOp (USFWS 2018), and by the Fort Peck Framework. Alternatives were also shaped by public input received through the scoping process and through MRRIC engagements. Study results show that the USACE’s System Operations have altered 1) water temperatures, 2) flow regime and 3) sediment regime and turbidity such that they may limit recruitment of pallid sturgeon to age-1. The most effective management actions to address these issues would likely result from modifying the operational hydrograph to better replicate historical flow and temperature attributes on the Upper Missouri River. Accordingly, the EIS is evaluating two alternatives (Alt 1 and Alt 2), each with two variations (variation *a* is one week earlier, while variation *b* is one week later).

The NEPA team has conducted detailed analyses of the consequences of the two alternatives and their variants. Hydrodynamic modeling using ResSim and HEC-RAS served as a basis for assessing HC impacts using approaches consistent with those employed in the MRRMP EIS. Benefits to pallid sturgeon were assessed using two connected models:

a. an integrated advection/dispersion and temperature model to estimate the fraction of embryos that would develop to the exogenously feeding stage and be retained in the riverine portion of the Upper Missouri (i.e., upstream of the anoxic zone of Lake Sakakawea; 2019 FSM presentation by Long and Fischenich – Overview of Ft. Peck modeling efforts including retention modeling and effects of temperature; Fischenich 2019); and

b. population modeling to assess what long term population growth rate could be expected given the predicted retention of embryos, and other assumptions about the population (see Section 3.5 and 2019 FSM presentation by Reynolds – Pallid Sturgeon Demographics Population Model; Reynolds and Colvin 2019).

Because work on these models is ongoing at this time, the best source for model results will be the Fort Peck DEIS, which is currently expected to be released near the end of May 2020.

3.3.6.2 Monitoring and Assessment Results

Level 2 flow experiments were not implemented at Fort Peck, so there are no monitoring and assessment results to report. Effectiveness monitoring is expected to be similar to what has been described for flow management at Gavins Point in Appendix E4 of the SAMP. Section 3.6.1 (BQ 1 for the Upper Missouri) discusses the results of the embryo release experiment conducted in 2019. The paired models described above can be used to guide the detailed design of monitoring and evaluation approaches, including the development of qualitative and quantitative performance criteria (an issue highlighted by the ISAP in their review of the Fort Peck AM Framework).

3.3.6.3 Focal Questions and Hypotheses

As described in Section 3.7 of the Fort Peck AM Framework, and Appendix E4 of the SAMP, the focal questions of interest include determining if attributes of river flow and water temperature are strongly correlated with: 1) upstream movement of reproductive males and female pallid sturgeon, 2) successful spawning, 3) synchronous behavior of reproductive male and female pallid sturgeon, 4) successful reproduction (incubation, hatch, viable embryos), 5) increase in effective drift distance and decreased mortality of free embryos and exogenously feeding larvae, and 6) improved recruitment and increased population size for the Upper Missouri River demographic unit?

Consistent with the evaluation of other actions in Appendix E of the SAMP, these focal questions will be informed by more specific testable hypotheses and data analyses that have yet to be specified.

3.4 Science Activities

Research at Level 1 and Level 2 includes science activities that are prioritized and managed to address specific information needs. Some of these activities are specifically identified in the BiOp and Biological

Assessment (for example, the Pallid Sturgeon Population Assessment Program), whereas others are implicit in elements of effectiveness monitoring or in Level 1 and 2 science components. Research actions at Levels 1 and 2 are described in detail in the appendices to the SAMP. Level 1 research is conducted by numerous entities, including the USACE, USFWS, Reclamation, USGS (particularly through the Comprehensive Sturgeon Research Project, CSRP), state fish agencies (e.g., NGPC, MTFWP), the Fish Technical Team, and various academic institutions (e.g., Mississippi State, Montana State, Southern Illinois University). Other scientific advances are described in Sections 3.5 (Model Predictions) and 3.6 (Progress in Learning and State of the Science). For example, the 2019 drift experiment below Fort Peck is described in Section 3.6.1.5 BQ5 Drift dynamics.

3.4.1 Using Shovelnose Sturgeon as a Surrogate

New information specific to IRC hypotheses was provided two papers (the USACE IRC white paper and Gosch et al. 2019), which were both discussed at the 2019 Fall Science Meeting. Based on a small sample of seven wild-origin, exogenously feeding (<48mm) pallid sturgeon, growth of recaptured hatchery-origin pallid sturgeon (>80mm), and reliance on a surrogate species (shovelnose sturgeon), the USACE suggested that age-0 pallid sturgeon may not be food limited. The information prompted a renewed review of what level of evidence is sufficient to make changes to IRC-related hypotheses, targets, and metrics. The USFWS, in coordination with USACE colleagues and pallid sturgeon technical team members, will review decision criteria and propose modifications as needed to ensure that the type(s) of evidence, research and analyses are sufficient to make decisions on hypotheses, targets, and metrics. Because there are varying levels of decisions, it is anticipated that there will be varying levels of evidence. The effort will seek clarity and concurrence between agencies on the suite of decision criteria needed to implement the MRRP SAMP. Initial efforts will focus on IRC-related hypotheses, targets, and metrics using age-0 shovelnose sturgeon as surrogates for age-0 pallid sturgeon, and will be followed by a step-wise review of the full suite of decision criteria in the MRRP SAMP.

The MRRP has used undifferentiated *Scaphirhynchus* sturgeon (pallid sturgeon and shovelnose sturgeon and hybrids) to evaluate the effectiveness of some management actions involving early life-stage pallid sturgeon (Appendix 3.4.1). The main rationale for this is the low numbers of young pallid sturgeon present in the Missouri River, which make it difficult to measure a response to management actions and science activities. Therefore, age-0 sturgeon CPUE is currently the response metric used in IRC monitoring and larval-drift studies. The underlying assumption is that, given similarities in early-life development (Snyder 2002), the two species are likely to exhibit similar transport and interception behaviors.

Evidence that supports the use of shovelnose sturgeon as a surrogate includes the concurrent capture of four genetically confirmed age-0 pallid sturgeon with multiple shovelnose sturgeon during 2018 (Gosch et al. 2019), and recent studies that suggest age-0 pallid and shovelnose sturgeon have similar diets and consume comparable amounts of prey (Gosch et al. 2018, 2019).

There is also evidence that suggests caution should be applied to the use of shovelnose sturgeon as a surrogate for pallid sturgeon. Porreca et al. (2017) found physiological and morphological differences between pallid and shovelnose sturgeon (e.g., oxygen consumption rates, intestine length), which they concluded would require pallid sturgeon to seek higher-energy food resources than shovelnose sturgeon. The range of river locations where the two species settle may be different; age-0 pallid sturgeon have only been captured downstream from RM 321 on the Lower Missouri, whereas exogenously feeding shovelnose sturgeon are routinely captured farther upstream. Earlier research suggested that the development time to benthic feeding of shovelnose sturgeon was about half of that of pallid sturgeon (6 dph as compared to 11-17 dph; Braaten et al. 2008), which is consistent with evidence that free-swimming age-0 shovelnose sturgeon are found further upstream than pallid sturgeon. However, work in 2019 by Chojnacki et al. (presented at the Upper Missouri FSM – Ontogenesis: Development of Pallid Sturgeon and Shovelnose Sturgeon Free Embryos Reared in the Laboratory) showed very similar developmental rates for these two species.

Morphometric and bioenergetic comparisons suggested differences in growth rate potential between large age-0 shovelnose (average length = 166 mm) and pallid sturgeon (average length = 161 mm) when transitioning from gravel to "structureless" sand habitat in laboratory trials (Porreca et al. 2017); however, age-0 pallid sturgeon stocked in the Lower Missouri River at lengths ranging from 80 – 120 mm and later recaptured at lengths ranging from 180 - 400 mm indicated that growth in the river is similar to individuals reared with abundant food resources in a hatchery environment.

The use of shovelnose sturgeon as a reasonable surrogate for pallid sturgeon is a fundamental assumption of much of the science related to drift and dispersal of sturgeon larvae on the Missouri River. The importance of surrogacy indicates a need for further evaluation, and research on various aspects of early life history such as development, drift, and diet (Gosch et al. 2019).

3.4.2 Developmental Stages of Pallid and Shovelnose Sturgeon, and Variation with Temperature

This research relates to BQ3 and BQ5 in the Upper River and BQ4 in the Lower River. It has implications for the design of actions at Fort Peck in the Upper River, and both spawning habitat and IRCs in the Lower River (further details in Sections 3.1.3 and 3.4.2 of the Appendix). The results of several years of laboratory experiments (2019 FSM - Chojnacki and DeLonay - Ontogenesis: Development of Pallid Sturgeon and Shovelnose Sturgeon Free Embryos Reared in the Laboratory) provide a number of insights relevant to these Big Questions.

1) Developmental characteristics and rate of development were similar for pallid sturgeon and shovelnose sturgeon when both were incubated and reared at 17.8°C.

2) The rate of development from hatching through yolk plug expulsion (exogenous feeding) was non-linear for both species, with later stages taking longer than early stages.

3) The cumulative thermal units (CTUs[*]) required for pallid sturgeon free embryos to achieve developmental stages varied with temperature. For example, approximately 275 CTUs (15-20 days) were required for embryos to develop to yolk plug expulsion (exogenous feeding) at 14°C, but only approximately 200 CTUs (8-10 days) are required at 20°C.

4) The proportion of morphologically identified abnormalities was higher at 26°C than at the other temperature treatments (14 °C, 17 °C, 20 °C, and 23°C).

5) Developmental changes are likely linked to behavioral changes and may influence dispersal. This work may help to improve drift calculations and models of embryo dispersal. It also supports the potential benefits of increasing temperatures below Fort Peck Dam, which would lessen the time and distance required for embryos to develop to the exogenously feeding stage, allowing more age-0 fish to be retained in the Upper Missouri River.

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[*] CTUs are the accumulated exposure to water temperatures (e.g., 10 days at 16°C = 160 thermal units (10 * 16), while 10 days at 20°C = 200 thermal units (10*20).

3.4.3 Physical Characteristics and Simulated Transport of Pallid Sturgeon and Shovelnose Sturgeon Eggs

The transport of eggs and embryos is relevant to BQ5 on drift in the Upper River, and to BQ3 and BQ4 related to interception in the Lower River. Chojnacki et al. (in review) conducted laboratory studies to characterize the diameter, shape, settling velocity, and specific gravity of pallid sturgeon and shovelnose sturgeon eggs. Based on these laboratory measurements, they then modeled the potential fate of pallid sturgeon eggs for two field sites where spawning has occurred. Although eggs of pallid sturgeon and shovelnose sturgeon were of a similar size and shape, shovelnose sturgeon eggs had slightly higher specific gravity and faster settling velocity. Differences between species may be due to factors such as environmental conditions and diet. For representative hydraulic conditions at documented spawning sites in the mainstem Missouri and Lower Yellowstone Rivers, eggs of both species will likely be concentrated near the bed although some eggs may be distributed throughout the water column. Simulations indicate that eggs may be transported up to several hundred meters downstream from spawning locations in the length of time required for eggs to become adhesive.

3.4.4 Advances in Genetics to Distinguish Pallid Sturgeon from Shovelnose Sturgeon

Distinguishing pallid sturgeon from shovelnose sturgeon is critical to monitoring the effectiveness of various management actions, to PSPAP v. 2.0 population monitoring, and to various Level 1 research projects. Flamio et al. (AFS conference presentation in October 2019) and Kashiwagi et al. (2019) noted that current molecular markers cannot reliably distinguish among pure species and multigenerational backcrosses. Genotypes from a large panel of unlinked single-nucleotide polymorphisms may provide greater resolution of the two species, although there are technical challenges. Flamio et al. produced pallid sturgeon haploid individuals using irradiated sperm from Paddlefish. DNA sequencing and other techniques will be applied to these haploid individuals to improve genetic discrimination between pure species and multigenerational backcrosses.

3.4.5 Advances in Telemetry Technology

Telemetry is essential to population monitoring under PSPAP v. 2.0, population modeling, as well as effectiveness monitoring and research on the response of adult pallid sturgeon to spawning habitats and flows (BQ1 in the Upper River and BQ1 in the Lower River).

3.4.5.1 Upper Missouri and Yellowstone River

In the Upper Missouri River, the existing telemetry system is based upon the now-discontinued Lotek Wireless SRX400 radio telemetry receiver system. There are approximately 50 wild, adult, heritage fish and 170 hatchery-origin progeny tagged with transmitters. Development of a new telemetry system for the Upper Missouri and Yellowstone Rivers has involved an intensive, coordinated effort by scientists and field crews from multiple entities: USGS CSRP, the Upper Basin Pallid Sturgeon Workgroup, USFWS, Reclamation, Montana Fish, Wildlife and Parks, and Lotek Wireless Inc. Telemetry activities were reviewed to improve manual tracking and detection of sturgeon, to advise on the specific selection of equipment and transmitters, and to increase the effectiveness of passive telemetry receiver stations at simple sites (upstream/downstream movement) and complex sites (upstream/downstream/side and main channel). The recommended system builds upon the existing system and provides a soft migration pathway from existing SRX400 radio receivers to the current SRX800 series receivers with a possible low-cost upgrade to the SRX1200 currently slated for spring 2020 availability.

Following considerable research and a 3-day site visit to review and evaluate best practices for radio telemetry data collection, a telemetry station was established and tested on the Lower Yellowstone River immediately downstream from the Fairview, ND spawning location. This station provides near-real-time, remote communication capabilities for passive radio-telemetry, using methods developed by the USGS. The station is cellular-based and uploads data to a remote server twice per day and can be queried hourly to receive updates on fish detection and movement. The technology is ready for broad application at designated network sites as needed in 2020 to provide near real-time fish movement data. The technology may be adapted for satellite communications to allow for operation at remote sites where cellular coverage is lacking (for example, the Powder River). Alternative versions of higher-powered radio transmitters continue to be tested in sturgeon to improve the reliability of detection during manual tracking and at passive receiver stations, especially during critical migration and spawning periods. Efforts are ongoing to create a unified catalog of pallid sturgeon implanted with telemetry transmitters, develop standard operating procedures for associated telemetry activities, and generate electronic forms for telemetry events including, for example, recapture, implantation, reproductive assessment, and transmitter procurement. Further details on the transmitter technology are included in Section 3.4.5.1 of the Appendix.

3.4.5.2 Lower Missouri River

The Lower Missouri River is extremely challenging for telemetry. Market research and application testing indicate that there is no ideal telemetry system for all studies identified in the SAMP. The USGS, in coordination with the USACE, USFWS, and representatives of the Middle and Lower Basin Pallid Sturgeon Workgroups, developed recommendations for improving the existing telemetry systems in the Lower Missouri River. A "Base" telemetry receiver and transmitter configuration were developed to support Lower Missouri River studies. Selected transmitters are sized to be used in both sub-adult and adult pallid sturgeon with a life-span long enough to capture at least one reproductive cycle with time for recapture and evaluation. Because one telemetry system may not address all SAMP questions, the base transmitters are small enough to allow for double tagging—the implantation of additional transmitters for other telemetry systems or sensors without expected negative consequences for behavior, growth or survival.

Pallid sturgeon implanted in the Mississippi River can be tracked in the Missouri River. Those implanted in the Missouri River can be tracked in the Mississippi River and can be detected by VEMCO passive receiver arrays in limited use for other species in the Lower Missouri River and the Mississippi River. Progress was made on developing a proposed framework for uniform telemetry data collection based upon input from monitoring and research field crews.

Population monitoring offices along the Lower Missouri River have obtained the required telemetry equipment and transmitters. In September and October 2019, the USGS trained Missouri River population assessment crews from the NGPC, MDC and USACE in telemetry fundamentals, surgical implantation, blood sampling, egg biopsy techniques, and data collection. A river sweep of the entire Lower Missouri River was conducted in August when crews could safely access the river to document the number of telemetered sturgeon in the system and assign geographic locations, for subsequent recovery, reproductive assessment, and re-tagging efforts in 2020 (see Section 3.3.5.2).

Going forward, the expansion of more intensive passive receiver networks will provide a more robust, tiered approach to monitoring telemetered fish through seasonal changes in activity and conditions. In the near term, the implementation of more effective passive receiver nodes is more feasible and can be accomplished relatively rapidly in the Upper River than is possible in the Lower River. Passive receivers, in combination with instrumentation of reproductive, adult sturgeon with surgically implanted, archival data storage tags recording temperature and depth for comparison to river gages and data loggers provides a minimal level of continuous data collection on telemetered pallid sturgeon in the Lower Missouri River when high-flow conditions limit manual tracking.

3.4.6 Spawning Habitat Monitoring

Monitoring spawning success is relevant to research and effectiveness monitoring of two potential actions: spawning flows (Upper River BQ1 and Lower River BQ2) and constructed spawning habitat (Lower River BQ5). Preliminary studies at the USGS have developed non-invasive oviduct implantation techniques for spawning indicator tags that are released by female sturgeon during ovulation. Shovelnose sturgeon females implanted with the transmitters in the laboratory retained the oviduct implants until they were artificially induced to ovulate following hormone injections. The microminiature telemetry tags are designed to aid in more precisely defining the timing and location of spawning and egg deposition within constructed or natural spawning habitats.

The Center for Fisheries Aquaculture and Aquatic Sciences at Southern Illinois University Carbondale, in collaboration with the USGS, completed work on the improved genetic techniques for the identification of Acipenseriform unhatched embryos (Kashiwagi et al. 2019). The study (funded by the Western Area Power Authority through the Upper Basin Pallid Sturgeon Workgroup and through the USGS CSRP funded by the USACE) provides the capability to genetically identify sturgeons and paddlefish to species and parent while they are still developing. Genetic identification can be done on unhatched embryos as early as stage 14, which occurs less than 24 hours after spawning. The analyses improve capabilities to monitor spawning in response to habitat conditions, environmental cues, and management actions.

3.4.7 Incorporating Information from Other Sturgeon Species

The primary literature developed by the MRRP has incorporated scientific knowledge from other sturgeon species, especially shovelnose sturgeon, lake sturgeon, and white sturgeon (Kootenai). The primary causes of sturgeon decline and continuing threats to species worldwide are universal—overharvest, fragmentation by dams and impoundments, channelization and other similar large-scale habitat loss, alterations in water flow and quality, and more recently non-native species. The resulting generalized failure of recruitment from spawning through the first year of life is the most common symptom of imperiled populations. Comparisons with other species within the specific context of the Missouri River have structured MRRP hypotheses. For example, hypotheses that support the evidentiary framework for the response of pallid sturgeon in the fragmented Upper Missouri River build upon comparisons of early-life stage stages of other species. Specific scientific questions underpinning the Larval Drift Hypothesis—interstitial hiding or immediate drift, relations of larval developmental milestones with thermal regimes, drift dynamics and larval dispersal distance, and the unlikely survival of larval sturgeon in reservoirs—are all based on comparative understanding of other species.

Missouri River sturgeon research biologists regularly consult with sturgeon biologists throughout the world, review their manuscripts, have our manuscripts reviewed by them, and incorporate diverse understanding of sturgeon through attendance at professional meetings like the American Fisheries Society, World Sturgeon Conservation Society and the North American Sturgeon and Paddlefish Society. The AFS had a sturgeon-specific symposium in 2019, attended by many Program scientists. Program biologists have traveled to Russia and China to gain insights into the global issue of sturgeon decline and propagation. Increased opportunities for international interaction would be welcome. Pallid sturgeon researchers have had numerous requests for interaction from international sturgeon recovery programs, specifically in the areas of large river habitat dynamics, characterization, and mapping; telemetry; and reproductive assessment. More opportunities for increased interaction could provide increased learning and exposure to emerging approaches in monitoring and research. Funding and limitations on international travel often restrict opportunities.

Specific areas of interest for interspecies comparisons include spawning habitat dynamics, larval drift and dispersal, and comparative examination of developmental milestones. Research shows that pallid sturgeon do not appear to spawn on large rock, cobble or gravel bars in the Missouri or Yellowstone River, in contrast to many other species of sturgeon. Pallid sturgeon spawning habitat appears to be far more dynamic than anticipated. The comparative differences among sturgeon species has important consequences for many management actions. Another example includes interstitial hiding, and its importance to downstream dispersal. While this information is not yet published in journal articles, the experimental results showing that pallid free embryos drift immediately after hatch has been presented multiple times and in USGS draft annual reports. This is a specific comparison to white sturgeon (Kootenai) and lake sturgeon that exhibit interstitial hiding and delayed drift. Interspecies differences in drift dynamics have implications for larval retention in rivers with fragmented habitats due to dams and reservoirs, such as the Kootenay, Columbia and Missouri Rivers. An additional specific area is comparative development of eggs, free embryos, and larvae of pallid sturgeon and shovelnose sturgeon, which has been a focus of MRRP research and has been presented multiple times. MRRP scientists have extensive understanding of other species' biology worldwide, but spawning habitat dynamics, interstitial hiding and larval dispersal, comparative early-life stage development, and dietary differences (well-established in the literature) are the specific aspects relevant to pallid sturgeon recovery actions.

There are no specific review papers that compare and contrast the subtleties of life strategies among all sturgeon species. While such a review would be interesting and useful, it is not the best use of Technical Team time, given the need to focus on critical uncertainties related to MRRP decisions on management actions. There is a fair amount of discussion of some comparative sturgeon species in Delonay et al. 2016a and an interesting discussion of species commonalities in Bemis and Kynard (1997). Specific current reviews of the status of scientific knowledge of North American sturgeon species, including pallid sturgeon, were published in the Journal of Ichthyology, Volume 32 (Bruch et al. 2016, Haxton et al. 2016, Hildebrand et al. 2016, Jordan et al. 2016, Kuhajda and Rider (2016), Moser et al. 2016, Phelps et al. (2016), Sulak et al. (2016)). The World Sturgeon Conservation Society and the affiliated North American Sturgeon and Paddlefish Society (NASPS) is a forum for sharing and comparing/contrasting sturgeon species science.

3.5 Model Predictions

Several pallid sturgeon modeling advancements were made in 2019. One-dimensional advection/dispersion (A/D) modeling on the Upper River was improved by integrating concurrent temperature modeling and a new stage-development model linking temperature to the developmental trajectory of sturgeon larvae. These played a central role in alternative investigations of test flows at Fort Peck. The Pallid Sturgeon Integrated Population Model was also used in the Fort Peck EIS to estimate the effects of different alternatives on population growth rates in the Upper River. A number of improvements were made to the population model for the Fort Peck Study, and the model was used extensively to develop PSPAP v. 2.0 as the engine to generate population estimates and distribution parameters.

3.5.1 Improvements to Advection/Dispersion Modeling of Drifting Pallid Sturgeon Free Embryos

A new A/D assessment tool, the Drift and Settling Model (DSM) was developed in 2019 and applied to the Fort Peck EIS. The DSM couples an assessment of temperature-dependent larval development and dispersion to determine the proportion of larvae likely to remain upriver of the Lake Sakakawea headwaters, which are presumed to be lethal to pallid sturgeon larvae due to anoxic conditions at the bed (Guy et al. 2015). The primary model output, retention probability, serves as both a useful benefit metric for the EIS and as a critical input to the Population Model, which assesses the effects of alternatives on the long-term population trends for the Upper River pallid sturgeon demographic unit.

A key difference from earlier A/D modeling (Fischenich et al. 2014; Erwin et al. 2018) is that the DSM couples one-dimensional A/D computations with hourly water temperatures throughout the system calculated with an energy budget using prevailing weather conditions (air temperature, humidity, cloudiness, pressure, solar radiation, and wind speed), water temperatures for the reservoir and tributaries, and release operations. A spawning submodel is applied to determine the likelihood of spawning in a given year based on flow and temperature conditions. A settling submodel is used to determine the distribution of pallid sturgeon larvae at the onset of settling and exogenous feeding. Settling is assumed to occur once thermal exposure thresholds are met using one of two free embryo development models (Braaten 2011; Chojnacki and DeLonay 2019 FSM Presentation - Ontogenesis: Development of Pallid Sturgeon and Shovelnose Sturgeon Free Embryos Reared in the Laboratory).

The new modeling scheme provides considerable improvements over previous drift modeling when evaluating management options, mainly due to its explicit modeling and consideration of temperature. Details of the DSM and its application to the Fort Peck EIS, experimental design for test flows, monitoring schemes, and potentially to near-real-time decisions is provided in the documentation currently under review for the purposes of USACE planning model certification (Fischenich 2019). As noted in Section 3.3.6 , the Fort Peck DEIS used 1930 to 2012 as the period of record, but the DSM and population models were also applied to the 2019 conditions and the results were compared with preliminary findings of the 2019 Drift Experiment.

3.5.2 Applications of the Pallid Sturgeon Integrated Population Model

The MRRP Pallid Sturgeon Integrated Population Model serves as the framework to integrate understanding from effectiveness monitoring, focused research, and the PSPAP. By incorporating links between parameter values and actions, it can also provide a predictive understanding of population-level responses and uncertainties associated with management actions. The population model can be used to make the population projections, viability analyses, and evaluation of new information needed to support MRRP decisions. The model was used extensively to develop PSPAP v. 2.0 as the engine to generate population estimates and distribution parameters. Steady progress has been made on model implementation since 2015, with significant advancements in 2019. The population model can be run as a spatially explicit individual-based model or as a deterministic, age-structured demographic model.

3.5.2.1 Model Updates

Population model updates in 2019 centered on the needs for comparing Fort Peck flow alternatives. While some advances to the (stochastic) individual-based population model have occurred throughout 2019 as part of continued model development, the main focus has been on improvements to the deterministic, age-structured demographic population model needed to provide analyses of management actions. Documentation for this model is currently under review for the purposes of USACE planning model certification (Reynolds and Colvin 2019).

The demographic population model structure remains the same as in 2018; however, spawning has been expanded to account for location (Upper Missouri River below Fort Peck Dam versus Yellowstone River). Model parameter values have also been updated using PSPAP data and estimates in the literature. Additionally, the demographic model has been coupled with a spawning model and the DSM (Section 3.5.1) for the purposes of analyzing Fort Peck alternative flows (Figure 3-21).

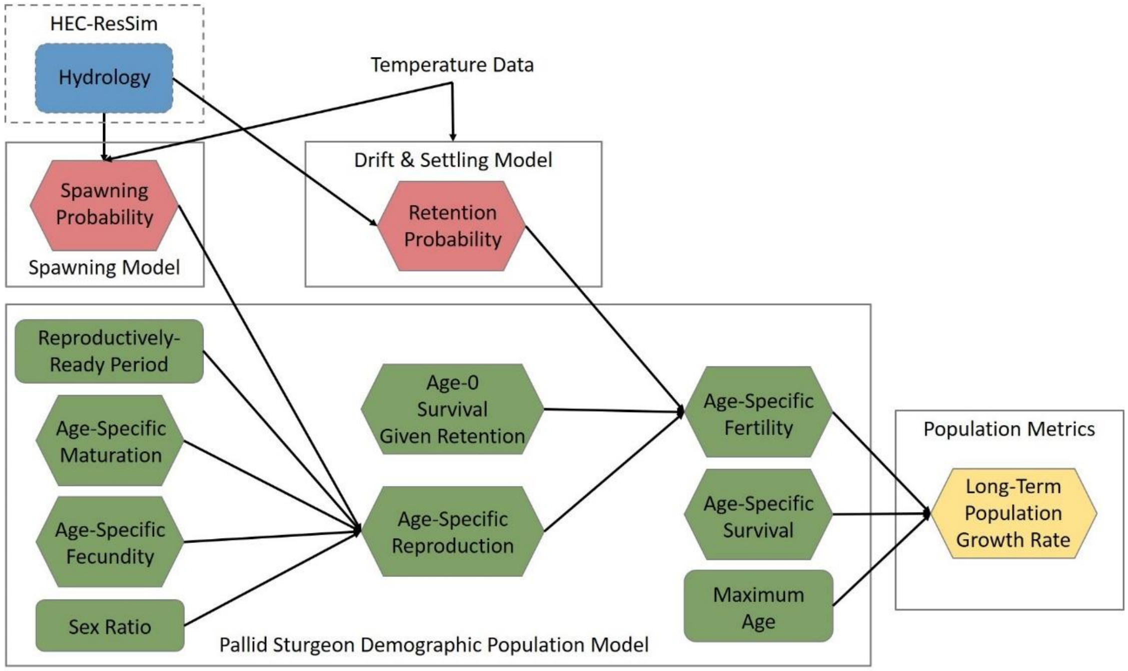

Figure 3-21. A graphical representation of the framework utilized in modeling the long-term pallid sturgeon population growth rate with respect to the various management alternatives. Colors represent outputs from an established external model (blue), outputs from newly developed models (red) which are population model inputs, parameters (green), and output (yellow). Individual models are represented as labeled boxes containing rates (hexagons) and other types of values (rounded boxes).

3.5.2.2 Application to Fort Peck and Upper Missouri

Alterative flows from Fort Peck Dam were modeled to estimate joint spawning and retention probabilities (provided by the spawning model and the DSM, respectively). This information then served as inputs to the deterministic, age-structured demographic population model (Figure 3-21). For each year and alternative flow scenario, the long-term population growth rate was computed given the predicted spawning and retention inputs. The long-term population growth rate represents the expected growth rate of a population that consistently experiences the given flow and temperature conditions, and is used as a metric for comparing flow alternatives within a particular year.

In addition to providing a metric for comparing Fort Peck flow alternatives, the pallid sturgeon demographic model was used to perform sensitivity analyses and to better understand regions of parameter space that lead to population growth. Sensitivity analyses revealed that the long-term population growth rate is especially sensitive to age-0 survival given retention in the free-flowing Missouri River, which is highly uncertain. Added knowledge regarding this parameter will improve the model's ability to project pallid sturgeon population dynamics, as well as to understand regions of viability (e.g., scenarios that lead to population growth). The long-term population growth rate is also sensitive to the maximum age of a reproductive female, indicating the need to better understand the lifespan of females, as well as the contribution of older females to the population.

Model analyses assume that current spawning on the Yellowstone River results in 100% free-embryo drift into the headwaters of Lake Sakakawea, which is presumed fatal due to anoxic water (Guy et al.

2015) or other factors. Passage at Intake Diversion Dam will create opportunities for increased drift distance. By expanding the model to account for the potential of recruitment stemming from spawning on the Yellowstone River, the demographic population model can further be used to evaluate the relative effects of Fort Peck flow alternatives, as well as the fate of the Upper River pallid sturgeon demographic unit in this broader context. Reliable hydrodynamic, water temperature, and drift and development models of the Yellowstone River are necessary precursors to meaningful population modeling on that system; these do not yet exist, as described in Section 3.3.4 . The population model could also be expanded to incorporate sensitivity analyses related to management actions that alter turbidity. Because work on the Fort Peck models is ongoing at this time, the best source for model results will be the Fort Peck DEIS, which is expected to be released near the end of May 2020.

3.5.2.3 Application to Lower Missouri

While model updates and applications have focused on the Upper Missouri River, the learning and model developments that have taken place are applicable to future population modeling of the Lower Missouri River. For example, instead of considering age-0 survival conditional on drift into (or not into) Lake Sakakawea, a Lower River model may consider age-0 survival conditional on drift into (or not into) an IRC. This past year's work on Upper River modeling has laid the foundations for building and analyzing a model that can inform Lower Missouri River questions. It has not yet been decided what modeling should be the primary focus after modeling efforts are completed for the Fort Peck DEIS.

3.6 Progress in Learning and State of the Science

Progress in implementing research actions at Levels 1 and 2 is described in detail in the Appendix. A summary of the progress is presented in this section, organized by river reach and Big Question. The Big Questions were developed as a communication tool to group management hypotheses (from the EA, Jacobson, et al. 2016a) that require similar scientific approaches (Fischenich et al. 2018b). How Big Questions relate to management actions and decision making is discussed in detail in the SAMP.

As illustrated in Figure 53 of the SAMP, each of the Big Questions, hypotheses, and research studies at Levels 1 and 2 directly relate to critical uncertainties associated with management decisions on whether / how to implement potential management actions or the effectiveness of actions that have already been implemented. Each research effort at Levels 1 and 2 is part of an integrated science program that provides relevant information directly or indirectly to management decisions and is an essential part of the MRRP AM cycle.

A variety of science efforts are underway to address priorities among the 21 working hypotheses developed in the EA. Scientific approaches to evaluating the hypotheses can be broken down into a sequence of steps, first asking if a process is limiting to the population, then developing functional relationships to quantify how the process relates to vital rates related to survival, and then developing management actions that alter those rates to increase survival and population growth. However, as indicated in the SAMP (Fischenich et al. 2018b), science components are being undertaken in a parallel approach, rather than being addressed sequentially. As a result, the progress reported in this section includes learning about multiple hypotheses. The parallel approach compresses the timeframe for developing decision-relevant information, but carries the risk that some investigations may later be determined unnecessary. A challenge for the adaptive management process is to develop analytics and criteria for recognizing when a hypothesis can be rejected and related management actions discontinued or altered. Section 3.1.4 of the Appendix provides a summary of the current status of evaluations of each of the hypotheses presented in the EA, as well as additional hypotheses for fish condition (Lower River BQ7).

3.6.1 Upper River

3.6.1.1 BQ1 Spawning Cues: Can spring pulsed flows from Fort Peck synchronize reproductive pallid sturgeon, increase chances of reproduction and recruitment?

Work related to BQ1 in 2019 focused on advancing the Fort Peck AM framework and assessing the potential biological benefits and HC impacts of alternative flows (see Section 3.3.5). This work included consideration of flows required for attracting, retaining, aggregating, and spawning of adults, as well as the dispersal of embryos. Though 2019 had very high flows below Fort Peck, it wasn't feasible to test pallid responses to these flows (Pat Braaten, USGS, Pers. Comm., November 25, 2019). The known spawn-candidate females had already been pulled out of the river for the drift/dispersal study. In addition, spillway releases were not consistent with tentatively-planned Level 2 releases from Fort Peck (2019 FSM, Long & Fischenich - Overview of Fort Peck modeling efforts including retention modeling and effects of temperature; slide 36).

Recent and previous telemetry studies indicate that pallid sturgeon will migrate in response to flow pulses when they are reproductive (in both the Missouri and Yellowstone Rivers), consistent with BQ1, hypothesis H2. However, pallid sturgeon appear to spawn repeatedly at Fairview, MT (RM 6.5 on the Yellowstone River), even during years with high Missouri River flow such as 2018 and 2019. Some tagged female sturgeon conduct long migrations up and down both the Yellowstone and Upper Missouri Rivers prior to spawning at Fairview (Pat Braaten, USGS, Pers. Comm., November 2019), which highlights the interconnectedness of habitat conditions in both systems. These system linkages (and consequently flow releases from Fort Peck) may become even more important to consider if passage at Intake Diversion Dam proves successful (see Section 3.3.3). The relative importance of flow, temperature, turbidity, available habitat, and social-behavioral interactions and connectedness of both systems remain somewhat unknown (see insights under BQ3, however).

Tracking spawning pallid sturgeon with telemetry is an intensive but necessary effort for understanding the effectiveness of Fort Peck flows in improving pallid sturgeon movement, aggregation, reproduction, and recruitment. In 2019, significant efforts were completed to improve the design of telemetry technologies in the Upper Missouri River (see Section 3.4.5).

3.6.1.2 BQ2 Food and Forage: Can naturalization of the flow regime from Fort Peck contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?

No new information directly related to Upper River BQ2 was presented in 2019. While not a primary focus of research in 2019, information on pallid sturgeon growth rates and river carrying capacity (explored under the Rangewide Stocking and Augmentation Plan, see Section 3.3.1) could potentially raise the priority of this big question in the future. Population monitoring in the Upper Missouri can detect survivors of the 2019 drift experiment, providing an opportunity to assess the availability of food and forage for any age-0 sturgeon that reached the exogenously feeding stage.

3.6.1.3 BQ3 Temperature Control: Can water-temperature manipulations at Fort Peck contribute significantly to an increased chance of reproduction and recruitment?

As part of the Fort Peck EIS (discussed in Section 3.3.6), a new model was developed to integrate A/D modeling results with predicted hourly water temperatures for the Missouri River from Fort Peck dam to Lake Sakakawea under different reservoir operations and weather/climate conditions. The new model (see Section 3.5.1) incorporates the effects of temperature on embryo development during the drift phase to determine the position at settling, improving estimates of retention and survival. This model was informed by hourly measurements of air temperature, pressure, humidity, cloud cover, solar radiation and wind speed since 1960, and water temperatures for the tributaries and Fort Peck Reservoir collected over the POR (2019 FSM, Long & Fischenich - Overview of Fort Peck modeling efforts including retention modeling and effects of temperature), past studies of embryo development (Braaten et al. 2012), and information from 2019 laboratory experiments on how the development of pallid sturgeon embryos varies with temperature (2019 FSM, Chojnacki - Pallid developmental series; Section 3.4.2). Mrnak (2019) found that larvae reared at warmer temperatures transitioned faster from drifting to settling than if reared at cooler temperatures. This research, as well as the work by Erwin et al. (2018; Section 3.6.1.5), emphasize the importance of temperature in affecting developmental time to the exogenously feeding stage and therefore retention in the Upper Missouri River above Lake Sakakawea. A synthesis of existing information by Erwin et al. (2018) suggests that reoperation of reservoirs to alter the flow regime may provide limited benefits due to lower advection rates.

Operations that include spillway releases of warm surface waters from Fort Peck Reservoir alter thermal regime and may accelerate rates of ontogenetic development for larvae, thus promoting the potential for retention and recruitment to the broader population. The effects of spillway releases at Fort Peck Dam on Missouri River temperatures and larval dispersal have been evaluated as part of the Fort Peck EIS. Conditions during 2019 were not favorable for evaluating whether warm water released over the spillway would significantly affect adult pallid sturgeon movement, aggregation and spawning because known spawn-candidate females had been pulled out of the river for the drift / dispersal study (Patrick Braaten, Pers. Comm., Nov. 25, 2019).

3.6.1.4 BQ4 Sediment Augmentation: Can sediment bypass at Fort Peck contribute significantly to an increased chance of reproduction and recruitment?

No significant new information was acquired on turbidity in 2019. Analyses completed as part of the Fort Peck population modeling demonstrated that population growth rate is quite sensitive to age-0 survival, which could improve if turbidity were to reduce predation rates on drifting embryos (see Section 3.5). The expert panel contributing to the Fort Peck Framework (USACE and USFWS 2018*)* noted that turbidity may affect both reproduction and survival in the Upper Missouri River, and is potentially an important part of the Fort Peck AM Plan, along with flow and temperature. The group noted that, while sediment bypass is likely infeasible, small-scale augmentation of fine sediment below Fort Peck dam during the spawn and drift might be feasible. The DSM used for the Fort Peck A/D and temperature analyses can also simulate turbidity, though more in-river monitoring of turbidity would be desirable for model calibration and validation, as turbidity is not currently being measured in the Upper Missouri.

3.6.1.5 BQ5 Drift Dynamics: Can combinations of flow manipulation from Fort Peck, a drawdown of Lake Sakakawea, and pallid sturgeon passage at Intake Dam on the Yellowstone River increase the probability of successful dispersal of free embryos and retention of exogenously feeding larvae?

Considerable progress on BQ5 was made in 2019. Over fifty scientists and field crew members were involved in the design and implementation of a drift and dispersal experiment in July 2019 (2019 FSM Presentation by Pat Braaten: 2019 Pallid Sturgeon Drift and Dispersal Experiment in the Upper Missouri: Initial Results and Progress). As described at the 2019 FSM, this Level 1 experiment involved the release of 772,000 1-day post-hatch (1-dph) embryos and 201,000 5-dph embryos at RM 1700, just downstream from Wolf Point, MT in the Upper Missouri River, and monitoring their drift down to RM 1550 upstream from Williston, ND in Lake Sakakawea. While the data are still being analyzed and the genetic analyses are incomplete, preliminary results suggest that: 1) the drift was well quantified at most sites; 2) the 5-

dph embryos moved more slowly than the 1-dph embryos; 3) dispersal velocity decreased as embryos moved downstream; 4) a relatively small number of experimental free embryos were entrained in low-velocity habitats; and 5) some free embryos transitioned from drifting to settling on benthic habitats. Tracking the fish used in this experiment will be helpful for determining the potential of 1-dph and 5-dph fish to survive to age-1 in the Upper Missouri.

Work by the USGS relevant to BQ5 (FSM presentation by Erwin et al. UMOR Drift and Dispersal Modeling) has involved a multi-pronged approach. Multi-dimensional hydrodynamic models were constructed with high-resolution topography for the zone of the 2019 drift experiment, and are being tested with biological field data from the 2019 drift study as well as being informed by flume studies. This work is intended to improve 3-D particle tracking models and 1-D advection-dispersion models. Better tools will improve our ability to evaluate and quantify free-embryo drift, dispersal, interception, and retention. While applied to the Upper Missouri, the basic understanding of processes and developed tools are transferable to the Yellowstone and Lower Missouri Rivers, and relevant to such actions as Intake and IRCs. The flume studies demonstrated differences in behavior depending upon fish age (e.g., 1-5 dph fish move at a rate close to the velocity of the flow and are distributed throughout the water column, whereas 11-14 dph fish move more slowly than the velocity of the flow and are more benthically oriented). Ongoing work will involve comparing model simulations with 2019 larval data, refining the particle tracking and A/D models, and collaborating with scientists working on the Fort Peck modeling (Section 3.5). The DSM and the Demographic Population Model can help address questions related to BQ5 by applying parametric calibrations derived from the drift study to assess a wide range of conditions.

3.6.1.6 BQ6 Population Augmentation. Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked pallid sturgeon?

The results of periodic updates to survival estimates, population modeling, and genetic analyses have demonstrated that annual stocking activities contribute to an increase in effective population size, which is progress towards recovery. Revised guidance documents for the CPSP released in 2019 provide a framework for annual reporting and evaluation. Garrison Dam NFH is continuing research on the impacts of diet on larval survival as they transition from yolk sac to exogenous feeding. This work is anticipated to address (in part) Pallid Sturgeon CPSP research priorities. Miles City State Fish Hatchery in Montana is not currently stocking due to problems with fin curl but is conducting experiments to evaluate methods and operations in order to prevent fin curl. This information will inform CPSP activities when complete.

3.6.2 Lower River

3.6.2.1 BQ1 Spawning Cues: Can spring pulsed flows synchronize reproductive pallid sturgeon, increase chances of reproduction and recruitment?

BQ1 will be informed by 9 years of opportunistic evaluation of pallid sturgeon responses to background flow pulses (see Section 3.3.4). High flow conditions in 2018 and 2019 demonstrated that existing hydrologic variation in the Lower Missouri River is likely to provide opportunities for learning about pallid sturgeon behavioral responses. In 2019, however, flow conditions were too high and would not allow safe access for field crews to track movement and spawning of pallid sturgeon through telemetry monitoring.

Given the value of information and necessity of tracking movement of spawning pallid sturgeon to understand responses to flow, significant work was undertaken in 2019 to improve the integration, detectability, and flexibility of the telemetry system to serve information needs for the Lower Missouri River (see Section 3.4.5). Although 2019 did not provide an opportunity to track the movement of spawning pallid sturgeon, a telemetry survey of the Lower Missouri River was undertaken later in the year to enumerate and assess the reproductive status of pallid sturgeon with active transmitters. As many as 65 tagged fish will be available for tracking in 2020. Seven female pallid sturgeon were identified and expected to be in reproductive condition in 2020.

3.6.2.2 BQ2 Temperature Control: Can water-temperature manipulations at Fort Randall and/or Gavins Point contribute significantly to an increased chance of reproduction and recruitment?

No new information directly related to Lower BQ 2 was developed in 2019. Decisions on temperature manipulations at Fort Randall and/or Gavins Point, while currently a low priority, could benefit from investigations conducted for the Fort Peck EIS (Section 3.3.6), as well as Level 1 research on temperature-development relationships (Section 3.4.2), and temperature effects on the movement, spawning, and migration of reproductively ready adults. Water temperature is less of an issue at Gavins Point Dam than at Fort Peck Dam for two reasons: distance / time for development is not such a constraint to age-0 survival for the Lower Missouri River as it is for the Upper Missouri River, and major tributaries (e.g., the James and Big Sioux Rivers) mitigate the effects of cold hypolimnetic releases from Gavins Point Dam.

3.6.2.3 BQ3 Food and Forage: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?

Research and monitoring results suggest that the current definition for foraging habitat (depth = 1-3 m; velocity = 0.5 to 0.7 m/s) had little influence on age-0 sturgeon prey consumption (Gemeinhardt et al. 2019) and may be too restrictive (2019 FSM Presentation by Nate Gosch and Jerrod Hall: Foraging Habitat Definition). Age-0 sturgeon are found across wider ranges of depth and velocity than are embodied in existing criteria and the ranges vary with the size class of age-0 fish. Analyses have shown that very few undifferentiated age-0 sturgeon (mostly shovelnose or hybrids) have empty stomachs and little evidence exists for biologically significant differences in growth from year to year of age-0 sturgeon in the Lower River (Gemeinhardt et al. 2019; 2019 FSM Presentation by Nate Gosch and Jerrod Hall: Assessing Age-0 Sturgeon Food Limitation). The latter finding was notable because food-producing habitat in the Lower River for 2019 exceeded what would be produced by IRC habitat because of the high floodplain connectivity. Both of these lines of evidence suggest that food availability is not a limiting factor for age-0 sturgeon. In an additional IRC study, the USGS mapped topography and bedforms to evaluate habitats in a bend of ecological interest in the Lower Missouri River (dubbed 'old reliable') and the response of this bend to an extreme flow event (2019 FSM Presentation by E. Bullinger: Connectivity and Larval Fish Transport During an Extreme Event). Although fewer age-0 sturgeon were present at 'old reliable' than anticipated (2019 FSM Lower River Presentation: Bonneau et al. IRC Monitoring and Concurrent Related Activities), the study provided detailed understanding of bedform evolution during flood events and a proof-of-concept for how advanced habitat assessment can be paired with trawling to improve understanding of occupancy and habitat selection.

3.6.2.4 BQ4 Drift Dynamics: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to decreased direct mortality and increased interception of free embryos into supporting habitats?

Research was conducted during 2019 over the course of a large flood event to map how bedform distribution and dynamics could influence ecological potential, specific to interception and retention, in the Lower Missouri River (2019 FSM Presentation by C.M. Elliott: Bedform distribution, dynamics, and ecological potential during a flood event in a large channelized river). Other relevant studies completed by the USGS are described above under BQ3.

3.6.2.5 BQ5 Spawning Habitat: Can channel reconfiguration and spawning substrate construction increase probability of survival of eggs through fertilization, incubation, and hatch?

A key unknown is whether the sequence leading to the production of free embryos (spawning, fertilization, incubation, and hatch) is limited by the quantity or quality of habitat and whether the resultant numbers of free embryos recruits are reasonable given the number of spawning adults. Hence, hypotheses related to spawning habitat continue to have currency, albeit perhaps not with the urgency indicated by expert opinion in the EA (Jacobson et al. 2016a). Surveys of actual spawning habitats and demonstration project habitats confirm that such habitats are subject to erosional and deposition dynamics. Work by Elliott et al. (2020) shows that habitat used by pallid sturgeon for spawning is more common and widespread in the present-day channelized Lower Missouri River relative to the sparse and dispersed coarse substrates available prior to channelization. Laboratory studies show a surprising resilience of eggs and free embryos to abrasion and burial by sand. An experimental design presented in Appendix E3 of the SAMP would determine whether tagged, reproductively ready adults preferentially choose to spawn at constructed spawning habitats over other locations. The pallid sturgeon simulation model, together with particle tracking and advection-dispersion models described under BQ4, may be helpful in determining the optimal location of constructed spawning habitat. Understanding the spawning habitats currently utilized in the Yellowstone River, and in the Lower Missouri River, and determining whether they are functioning properly, will contribute to designs of habitat rehabilitation projects.

3.6.2.6 BQ6 Population Augmentation: Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked pallid sturgeon?

Periodic updates to survival estimates, population modeling, and genetic analyses have demonstrated that annual stocking activities contribute to an increase in effective population size, and progress towards sub-objective 2 of the MRRP. The 2018 AMCR identified concerns about decreases in recapture rates and survival rates of hatchery-origin pallid sturgeon. The condition of hatchery fish was considered as one of several possible reasons for these declines. In response to this and other concerns raised over fish condition, the USFWS, Federal and State hatcheries, and the Pallid Sturgeon Propagation Committee co-developed recommendations for standardized fish health assessment and the development of fish condition metrics. This information is referenced in the revised CPSP documents and is being implemented basin-wide. Annual evaluation and reporting based on the new CPSP Evaluation Plan (USFWS 2019) will guide documentation, reporting and adaptive use of information to improve the effectiveness of augmentation and address these concerns.

3.6.2.7 BQ7 Fish Condition: Are there combinations of management actions (flow alteration, channel re-configuration, population augmentation, water quality management, or management of other fish species) that could improve the condition of pallid sturgeon within key segments of the Lower Missouri River, resulting in population stability or growth?

Lower River BQ7 incorporates multiple hypotheses (Fischenich et al. 2018b) and these hypotheses fall into three categories that relate declining adult condition to pallid sturgeon health (disease, contaminants), ecosystem productivity (including primary, secondary productivity, competition), and diminished habitat quantity or quality (increased energetic demands). As noted by Randall et al. (2017), the existing data are insufficient to indicate a specific cause or solution, and it is possible that multiple causes apply. In 2019, Montana State University started an investigation of the ecological mechanisms underlying the occurrence of emaciated pallid sturgeon in the Lower Missouri River and will develop research, monitoring, and evaluation program for stream-side health and condition assessment. In addition to training field crews and purchasing equipment, Montana State worked with NGPC, MDC, and USACE field crews to collect blood samples and perform Fatmeter measurements on 23 adult pallid sturgeon. The USFWS worked with Montana State to develop a non-invasive contaminant sampling protocol with tissue biopsies beginning in 2020. Following the development and approval of a transport protocol, adult pallid sturgeon were transported from Gavins Point NFH to Bozeman Fish Technology Center for work to start in late 2019. Extensive data mining and analyses have also begun, using the National Pallid Sturgeon Database to answer the following questions:

- What is the minimum condition threshold for survival?
- What ranges of fish condition are associated with healthy fish, and how do they vary by season, gender, and spawning activity?
- Is there a sudden shift in growth, reproduction, or condition that can be associated with temporal, spatial, or other tracked variables for individual fish?
- Is there evidence of family or year class influencing performance or condition?

Results will be shared during the 2020 Fall Science Meeting. Section 3.2.5 summarizes trends in predicted weights of pallid sturgeon, a key indicator of fish condition as described in Randall et al. (2017). Over the two regions and six length categories, the only statistically significant changes since 2018 were in the Lower Missouri, and include a decrease in predicted weights for the 200 mm length category and an increase in predicted weights for the 1200 mm length category.

Hypothesis HFC6 under Lower BQ7 concerns diminished fish health related to contaminant exposure. A basin-wide assessment of contaminants potentially affecting pallid sturgeon was completed in March 2019 (Webb et al. 2019); excerpts of the Executive Summary of this report are in Section 3.6.2.7 of the Appendix.

3.7 Summary of Progress towards Species and Learning Objectives, and Questions for Discussions of the Strategic Plan

Table 3-5 summarizes the progress made on various components of the MRRP relative to requirements in the 2018 BiOp, and possible strategic questions to be discussed at the AM Workshop in March 2020. The example questions are meant to stimulate discussions that are relevant to revising the Strategic Plan.

Table 3-5. Tabulation of progress and strategic implications for program components.

Program Component	Progress Towards Species and Learning Objectives	2018 BiOp Requirements	Examples of Strategic Questions for the AM Workshop
Status and Trends; Population Monitoring	PSPAP v. 2.0 (Section 3.2) will provide a solid foundation of population monitoring data going forward, including absolute estimates of population abundance for comparison to MRRP sub-objective 2. All three elements of PSPAP v. 2.0 (trawling for age-0 fish, mark-recapture, telemetry) are expected to be implemented in the Missouri River by the end of 2020 and trawling for age-0 pallid sturgeon is planned for the middle Mississippi River in the spring of 2020. About 8% of the fish captured between 2003 and 2015 in the Lower Missouri were determined to be "presumptive wild origin", though it isn't known if these fish originated in the Missouri or Mississippi Rivers. Fish weights continue to recover in the Lower River (see Appendix, Section 3.2.1.6). Lack of wild pallid sturgeon below 800 mm in size likely reflects multiple factors: low reproduction, high mortality of early life stages, low catchability of smaller size categories, hybridization with shovelnose sturgeon, and transport of drifting free embryos or larvae into inhospitable habitats or into the Mississippi River, (see Section 3.1.2). There is no evidence of natural recruitment to age-1 in the Upper Missouri.	As described in Section 1.5.2 and Table 1-6, the development of PSPAP v. 2.0 will provide the information required for calculation of various metrics related to incidental take, as described in Section 17.1 of the 2018 BiOp (USFWS 2018), and other requirements for pallid sturgeon population monitoring (e.g., Section 4.3.1 in the 2018 BiOp).	• Are there ways to further optimize PSPAP v. 2.0 to reduce costs? • Would a rotating panel approach be appropriate (i.e., only sampling some segments in each year)? • What are the implications of any proposed changes to PSPAP v. 2.0 for the precision of population estimates, the ability to assess the responses of adult fish to flow changes, and effectiveness monitoring of other actions? • How critical is it to determine the origin of wild fish that are caught in the Lower Missouri River? How can this best be accomplished? • Is it worth acquiring additional genetics information and doing further analyses to determine N_e, the effective population size, of the Upper and Lower River populations, in addition to estimates of N, absolute abundance (see Section 0 and Section 3.2.1.2.1 of the Appendix)?
Effectiveness Monitoring and Evidentiary Framework	Appendices to the SAMP were completed in 2018, focused on the following actions: IRCs (Appendix E1), rehabilitation of Shallow Water Habitat (SWH) into IRCs (Appendix E2), Level 2 spawning habitat construction in the Lower River (Appendix E3), Level 2 spawning flows at Gavins Point (Appendix E4) and the bypass channel at Intake Dam on the Yellowstone River (Appendix E5). Work on the Fort Peck EIS (Section 3.3.6) as well as other Level 1 research (Sections 3.4 and 3.6.1) has led to the development of hydrodynamic and population modeling tools that could be used in the detailed design of Level 2 flow experiments at Fort Peck. The continued development of an evidentiary framework and associated performance criteria will also help in the detailed design of effectiveness monitoring for various actions.	The effectiveness monitoring designs in Appendix E provide the foundation for evaluation of various Level 2 actions. Such monitoring evaluations are emphasized in various parts of the 2018 BiOp (e.g., Sections 1.7, 4.3.2, 4.3.3, 6.1, 17.1). Permits are required for all monitoring.	• What are the next priorities for effectiveness monitoring, given the timetable for various actions (including stocking and augmentation)? • Will all of the components of PSPAP v. 2.0 that are required for effectiveness monitoring (Table E.3 in Appendix E of SAMP) be in place when required? • Do possible changes to PSPAP v. 2.0 affect the ability to do effectiveness monitoring?

Program Component	Progress Towards Species and Learning Objectives	2018 BiOp Requirements	Examples of Strategic Questions for the AM Workshop
Stocking and Augmentation	The 2019 release of the Guidance and Planning Document for CPSP provides valuable direction on this essential Level 4 action (Section 3.3.1 . The genetic diversity of stocked fish continues to slowly increase in both the Upper and Lower River (Section 0). Reduced growth and survival rates of some recent year classes of stocked fish remain a concern (USACE 2017).	Progress on stocking and augmentation is consistent with Section 4.3.1 of the 2018 BiOp, which emphasizes the importance of propagation and augmentation for preventing extinction.	• What requirements for effectiveness monitoring have emerged from the CPSP Evaluation Plan? • Are these requirements fully captured by PSPAP v. 2.0? • Would changes to PSPAP v. 2.0 (i.e., lessening the frequency of some monitoring) affect the ability to evaluate growth and survival rates of stocked fish?
IRCs	Due to Congressional direction prohibiting construction until reporting requirements identified in WRDA 2018 were fulfilled, no IRC sites were constructed in 2019, the second year of delayed implementation, extending the timeline for full evaluation from 8 years to 10 years (Section 3.3.2). Scientists made good progress at completing Level 1 research (Sections 3.4 and 3.6), implementing physical and biological effectiveness monitoring (described in Appendix E1 of the SAMP), and test-driving analytical methods. Recent Level 1 research confirms the preliminary results in 2018 suggesting potential revisions to the criteria used to define foraging habitat, shows similarities between shovelnose and pallid sturgeon habitat use and diets and indicates that age-0 fish (almost entirely shovelnose sturgeon) do not appear to be food-limited. Work is underway by USACE and the USFWS to define what types of decisions can be supported by evidence from age-0 fish (almost entirely shovelnose sturgeon) versus those decisions which require either evidence from pallid sturgeon, or proof that shovelnose are appropriate surrogates.	Construction of IRCs and associated effectiveness monitoring is consistent with Section 1.6.5 of the 2018 BiOp, and Table 42 of the SAMP, developed jointly by the USACE and the USFWS.	• What are the implications for the Strategic Plan of not implementing construction of IRCs in either 2018 or 2019 (e.g., does this mean that funds are available to be allocated to other priorities?) • What types of research could evaluate evidence of the effects of IRCs on survival of pallid sturgeon to age-1 and beyond (e.g., if there were sufficient hatchery sources of exogenously feeding larvae, conducting some release experiments similar to those performed in the Upper Missouri)? • How could such research be done in a way that does not confound the IRC staircase design? • What population monitoring would be required in the mid-Mississippi to track survival rates of released hatchery larvae?

Program Component	Progress Towards Species and Learning Objectives	2018 BiOp Requirements	Examples of Strategic Questions for the AM Workshop
Flow management at Gavins Point and Fort Peck	Good progress at implementing telemetry in both the Upper and Lower River (Section 3.4.5), so as to both implement PSPAP v. 2.0 and track adult pallid sturgeon responses to flow variation, though flows were too high in 2019 to allow crews to safely do this work. Considerable progress was made on flow management in the Upper River (Section 3.6.1), through development of the Fort Peck draft EIS, the 2019 drift study, and associated Level 1 research (e.g., a better understanding of the effects of temperature on embryo development in shovelnose and pallid sturgeon; development of hydrodynamic and biological models).	Progress on evaluating the effects of flows on spawning is consistent with discussions of spawning cues in Sections 1.6.3, 1.7, 4.3.2 and 17.1 of the 2018 BiOp, and Table 42 of the SAMP, developed jointly by the USACE and USFWS.	• Given the progress that's been made in 2019 on Fort Peck flows, what are the most critical research, monitoring and modeling activities for the Upper River during the next three years? • Are these activities in the Strategic Plan or do they need to be added? If added, what can be dropped? • Will the new telemetry effort enable monitoring of pallid sturgeon responses to high flows in the Lower River? • Are there sufficient numbers of tagged and reproductively ready adult fish to evaluate flow effects in both the Upper and Lower Missouri (e.g., 7 tagged female fish are expected to be reproductively ready in the Lower Missouri in 2020)?
Passage at Intake Dam on the Yellowstone River	Construction of the bypass channel at Intake Dam began in July 2019 and the project (including construction of the replacement weir) is expected to be completed no later than 2023 (Section 3.3.4). Tracking of 12 translocated and telemetered fish occurred in 2019, and translocation will be maintained for the duration of construction.	Progress being made is consistent with Section 18 of the 2018 BiOp (Conservation Recommendations), which recommends continuing to pursue completion of fish passage at Intake Dam on the Yellowstone River.	• Does the Strategic Plan have in place the necessary funds to conduct effectiveness monitoring of the bypass at Intake Dam (as described in Appendix E5 of the SAMP)? • How will the ROD for the Fort Peck EIS take into account the ongoing learning on the Yellowstone?
Spawning habitat	No spawning habitat projects were planned or constructed in the 2019 reporting year. Level 1 research showed that past spawning events used habitats that are prevalent in the channelized Lower Missouri River (Section 3.3.3). Other research has advanced the ability to use tags to determine where and when spawning and egg deposition occurs (Section 3.4.6). The next step for this management action is to discuss with the USFWS whether spawning habitat construction remains a priority given evidence of successful reproduction in the Lower Missouri River. If construction is to proceed in the next few years, then researchers and engineers will need to be engaged in determining where and how spawning habitat should be constructed.	Construction of spawning habitat is consistent with Section 1.6.4 of the 2018 BiOp, and Table 42 of the SAMP, developed jointly by the USACE and USFWS.	• What are the trade-offs in constructing spawning habitat given observed reproduction in the Lower River and does information exist to develop designs that limit hybridization risks? • Are there sufficient numbers of tagged and reproductively ready adult fish to evaluate the effects of spawning habitat construction (see Appendix E3 of SAMP)? • Are protocols for physical assessments of spawning habitat sufficient and are resources available to carry out the assessments?

4 Human Considerations

4.1 Introduction

The overriding MRRP strategic priority related to human considerations (HCs) remains the availability of sites for habitat construction. This concern has eased since 2018 with respect to ESH for birds as a result of natural sandbar formation. For pallid sturgeon IRCs, progress has been made in outlining proposed candidate sites for the coming few years. Beyond this horizon, however, site identification for IRCs may prove problematic and proactive discussions with tribes and stakeholders may be required.

As noted in Section 1, the 2018/19 water year was the second wettest on record. These high flows affected the implementation of several of the MRRP's actions. Plans for the construction of ESH in the Garrison reach were canceled, and other management actions for birds were either canceled or scaled-back.

Plans to construct IRCs for pallid sturgeon were suspended due to a moratorium on construction until the report required by Section 1226 of AWIA was submitted to Congress. This report was submitted on March 18, 2020 (USACE 2019a).

Nevertheless, despite the lack of MRRP actions undertaken in 2019 with the capacity to significantly affect HCs, concerns remain about the potential for impacts to HCs from ongoing actions, primarily those potentially related to previous years' construction of IRC habitat for pallid sturgeon.

HCs are integral to the ongoing planning and assessment of the Fort Peck Dam Test Release – Draft Environmental Impact Statement. In 2019, the HC Work Group was involved in a number of engagements and discussions with the USACE regarding this initiative.

4.2 HC Activities Related to the Design and Implementation of Actions for Piping Plover

4.2.1 Overview

Stakeholders have expressed concerns that MRRP actions for Piping Plover and Least Tern that have the potential for affecting HCs include sandbar habitat construction, flow management to reduce inundation of nests and chicks, sandbar augmentation, vegetation management, predation management, and human restriction measures.

4.2.2 Sandbar Construction

As discussed in Section 2.3 , ESH construction was suspended because modeling and field observations suggested ESH was created by high flows in 2018 and 2019, obviating the need for construction. Planning activities around siting mechanical bird habitat construction in 2019 were limited to confirmatory modeling and projections. The need to create more by mechanical means will be deferred until conditions indicate otherwise, at which point new sites will need to be identified that reflect the state of habitat and conditions on the river at that time.

MRRIC Recommendation 32 to the USACE, regarding MRRP 2019 Spring Strategic Plan and Science and Adaptive Management Plan Implementation (MRRIC 2019, USACE 2019), made a number of related points:

- It supported USACE plans (SP 2.3.2 and 3.3.3) to engage with the Bird Team / Bird Work Group for early exploration into expanding the planning, engineering, and design (PED) work for piping plover habitat creation.
- It recommended a conceptual planning step that would identify and evaluate the opportunities and tradeoffs associated with a wide variety of management actions for enhancing quality and quantity of existing habitat (e.g., island shaping and augmentation, top dressing, vegetation control, etc.) as well as through new habitat construction.
- It recommended that the opportunities and tradeoffs identified in the PED phase be considered by the USACE when assessing the need for mechanical ESH construction.

The USACE developed a conceptual planning framework in response to this recommendation. Ultimately, the Bird Work Group requested an indefinite deferral of work on this recommendation and instead requested a comprehensive review of all SAMP actions for the birds. No further work has been completed on this recommendation.

4.2.3 Flow Management to Reduce Inundation of Nests and Chicks

No flow management activities were undertaken in 2019 to retain sandbar habitat and reduce nest inundation (Section 2.3).

4.2.4 Sandbar Augmentation and Modification

Modifications and augmentation to existing sandbars were not implemented in 2019.

4.2.5 Vegetation Management

The USACE typically conducts vegetation removal activities to maintain ESH for the tern and plover, including herbicide application (aerial and ground-based), vegetation clearing and prescribed burns (see Section 2.3.3). However, in 2019 the USACE conducted no vegetation removal in either the Northern or Southern Regions because any vegetation that would be treated was submerged due to high stage flows. No herbicide spraying or controlled burning was undertaken specifically for the MRRP in 2019.

To assess possible water quality impacts from herbicide spraying to ESH restoration sites, water quality monitoring is conducted in the Northern Region. Although spraying did not occur in 2019, water quality monitoring was still conducted.

Further, in 2019, two Supplemental EAs concerning Emergent Sandbar Habitat Complex Restoration in the Missouri River, North Dakota (USACE 2019b) and Nebraska/South Dakota (USACE 2019c) found that related actions, including the application of pre and/or post-emergent herbicides and other vegetation removal activities such as cutting, mulching, disking, mowing, raking, burning, and removing vegetation, had no significant impacts on HCs.

4.2.6 Predation Management

No predation management actions occurred in 2019.

4.2.7 Human Restriction Measures

Signs prohibiting human entry into tern and plover nesting areas were posted in all river segments in 2019. Postings appeared in a total of approximately 68 sandbars/shoreline areas: 19 sites in the Northern Region (Lake Sakakawea, the Garrison segment, Lake Oahe, and Lake Sharpe) and 49 sites in the Southern Region, including the Fort Randall, Lewis & Clark Lake, and Gavins Point segments. Violations (people entering restricted areas despite the signs restricting access) were common on all river segments, and 5 plover nests and 17 least tern nests were destroyed as a result.

The MRRMP-EIS states that impacts on recreation from human restriction measures are short-term and adverse for some types of visitors (USACE 2018e).

4.3 HC Activities Related to the Design and Implementation of Pallid Sturgeon Actions

4.3.1 Overview

Stakeholders have expressed concerns that MRRP actions for pallid sturgeon that have the potential to affect HCs include channel reconfigurations to create IRC habitats, construction of spawning habitat, Intake Dam Bypass and the use of flows to influence sturgeon attraction, holding, spawning and drift.

In addition, 2019 saw discussions regarding legacy MRRP SWH projects in the Lower Missouri River (e.g. side-channel chutes). Flooding in 2019 caused flanking of several of the flow-control structures within these chutes, raising stakeholder concerns regarding potential impacts to navigation and flood risk management. To assess the need for rehabilitation, the USACE evaluated MRRP-related chutes and notches during the flood to understand the effects of these projects on flows and stage and the potential subsequent impacts of those effects on other authorized purposes. This work is ongoing.

4.3.2 Channel Reconfigurations for IRCs

Physically, channel reconfigurations for IRCs involve the rearrangement of stone on the inside of a bend, typically to create a widened notch as illustrated in Figure 4-1:

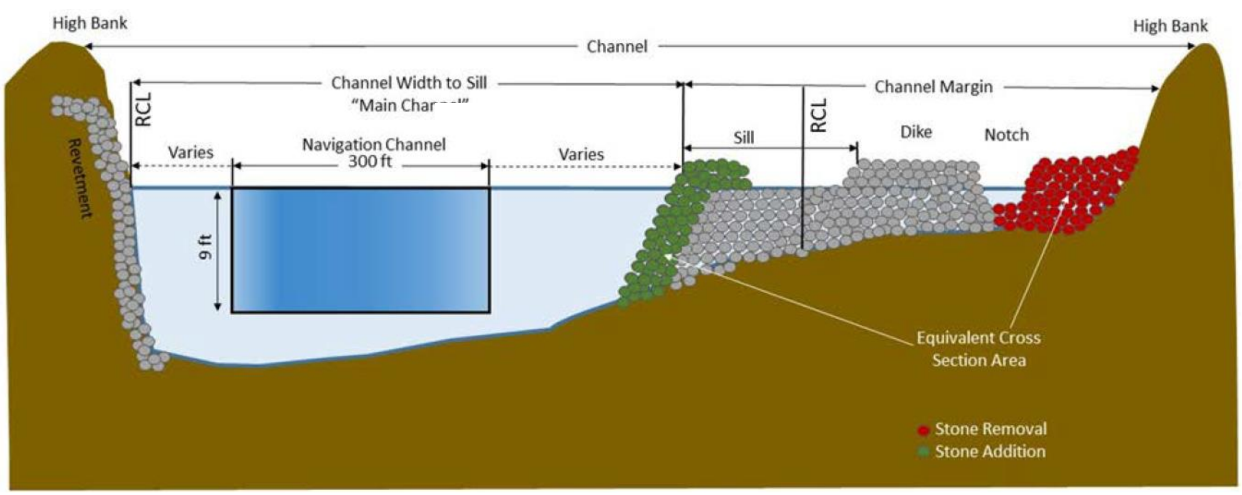

Figure 4-1. Illustration of the configuration of the inside of a channel bend showing positioning of stone before and after modifications for IRC construction.

Interception and rearing complex sites were not constructed in 2019 due to a moratorium on construction to allow time to submit the WRDA report to Congress outlining the IRC construction process. Significant engagement with stakeholders regarding the preparation of this document has occurred.

As noted in Section 3.3.2 , twelve IRC treatment sites and twelve control sites are still required. Eight of the 12 sites have been identified, with the remaining four to be determined pending additional consultation with stakeholders.

The potential impacts of IRCs in general on Human Considerations were analyzed at a programmatic level during the MRRP-EIS (USACE 2018). Further details on the potential for IRCs to affect HCs and the measures taken by USACE to avoid and to monitor potential impacts to HCs are discussed in detail in the IRC Report to Congress on March 18, 2020 (USACE 2019a). Because no IRCs were constructed in 2019, there is no need to reiterate these here.

Four meetings occurred between USACE and stakeholders in 2019 on this issue.

- On 29 March, in Kansas City, MO, the USACE met with representatives of Inland Rivers, Ports, and Terminals and various MOR navigators to discuss IRC-related Missouri River navigation issues.
- On July 16, the USACE met with the Osage Nation in Pawhuska to discuss IRC project locations, designs, and cultural concerns regarding construction.
- On 19 August, the USACE met in St Louis, MO with the Coalition to Protect the Missouri River to discuss IRCs.
- On 27 September, the USACE met in Jefferson City, MO with the Coalition to Protect the Missouri River to discuss MRRP dike notches and chutes.

Nevertheless, concerns regarding the potential for impacts to HCs from IRCs, particularly with respect to navigation, continue to be expressed by stakeholders. USACE will continue outreach to stakeholders to ensure that a full and mutually-informed dialog occurs.

4.3.2.1 IRC Monitoring

Existing and future IRC projects have a physical monitoring component to detect changes in channel geomorphology that are either beneficial or could become problematic for navigation or other interests.

A detailed description of physical monitoring for IRCs is presented in Appendix 3.1

In summary, physical monitoring of areas before (since 2013) and after the construction of two IRCs are shown in Table 4-1. Monitoring occurs through bathymetry surveys (which map the elevation of the riverbed) and Acoustic Doppler Current Profiling studies (ADCP, a tool used to measure velocities) to create an overall map of the river bed and velocities and how these things change over time. Multi-dimensional hydrodynamic and particle tracking models are for each site are updated with the monitored data and applied to a range of flows (beyond those at the time of the survey) to evaluate effects of the action on velocities, water surface elevations, interception potential, and habitat distributions (depth/velocity/substrate combinations). Model outputs are in turn used to consider potential impacts to navigation and other potentially affected HCs.

Table 4-1. Summary of Physical Monitoring Studies Undertaken to Date at Two IRC Sites.

	Searcys Data RM178.4-180.3 Boonville Gage				Moberly (Baltimore) RM 296.6-299.6 Waverly gage			
	Bathymetry		ADCP		Bathymetry		ADCP	
	Date	*Discharge*	*Date*	*Discharge*	*Date*	*Discharge*	*Date*	*Discharge*
2013	9-Aug	63,700	--	--	8-Sep	*41,700*	--	--
2015	26-Aug	68,000	26-Aug	68,000	Oct 9-15	53,000	Oct 9-15	53,000
	20-Oct	50,300	8-Oct	57,400			18-Sep	53,600
2016	--	--	25-May	110,000	June 9-13	117,000	June 9-13	117,000
	--	--	25-Aug	55,700				
2017	8-Jun	93,700	8-Jun	93,700	1-Jun	113,000	1-Jun	113,000
					1-Sep	61,500		
2018	30-May	77,700	31-May	77,500	24-Aug	110,000	6-Sep	139,000
	2-Aug	90,800			6-Sep	139,000		
	24-Aug	110,000						
	17-Oct	178,000						
2019	7-May	161,000	29-Aug	174,000	14-May	175,000	25-Sep	157,000
	8-May	166,000	30-Aug	176,000	26-Sep	153,000		
	29-Aug	174,000						
	13-Dec	115,000						
2020	15-Jan	94,600	--	--	--	--	--	--

Appendix 3.1 Physical Evaluation presents detailed physical and HC monitoring findings regarding changes in:

- Before and after data on navigation channel width and depth
- Channel width encroachment
- Channel velocities (including direction)
- Water surface elevation

Due to a limited number of data sets for post-construction and because there have been high flows since construction, it is too early to draw conclusions about differences between the pre-and post-construction states. There are some (possibly transient) differences in river channel widths and depths in individual cases, but no evidence to suggest that the navigation channel has been compromised.

In one case, sediment movement during the high flow events of the past two years has created temporary deposits of sediment in particular sections of the river, potentially including (but not limited to) those adjacent to IRCs. In December 2019 at the Searcys bend IRC, a temporary bed shift created a shoal that reduced the navigation channel width to 315'. This occurred outside of the navigation season and a month later had dissipated. The USACE plans to further liaise with navigators to ensure that perceived navigation concerns are communicated and addressed effectively, particularly in the vicinity of IRC projects.

Existing shallow water habitat projects continue to be monitored as well. For example, discharge rates in existing chutes are periodically measured to ensure the chutes are not capturing excessive amounts of flow from the main channel which could affect navigation and other interests. If the percent of river flow into a chute exceeds 15% at normal navigation flow, steps are taken to reduce the flow into the chute. Additional low-water monitoring will be conducted in early 2020 to assess any damages sustained to the structures from the 2019 flood.

4.3.3 Construction of Spawning Habitat

No spawning habitat construction or planning occurred in 2019.

4.3.4 Intake Bypass Construction

In response to questions from the HC Work Group, an update on the construction progress of this project is included here.

On March 15, 2019, the Court of Federal Claims issued an oral decision in favor of the government regarding the post-award protest for this project. The Omaha District issued notice to proceed to the contractor on March 25, 2019, and the contractor mobilized in mid-late April 2019.

The in-water work restriction remained in place until July 1, 2019. The USACE also worked with the Bureau of Reclamation and the contractor to avoid access to Joe's Island until July 8, 2019, to accommodate paddle fishing season through the July 4th weekend.

The contractor deployed about 60 employees on site during the summer of 2019 and maintained about 20 employees on site at the end of 2019. While USACE staff availability at the start of the project was affected by flooding throughout the Missouri River basin, the Omaha District hired one project engineer who is on site full-time and the Portland District provided structural and geotechnical engineering support on site during the summer. The Bureau of Reclamation also provided an on-site Quality Assurance Review for the 2019 construction season.

The need to realign the weir was identified in September 2019 and the USACE prepared a contract modification to shift the weir location. The Environmental Review Team met on-site on Nov 5, 2019 with representatives from USACE, the Bureau of Reclamation, the Lower Yellowstone Irrigation District, and several other state and Federal agencies. The largest concern noted during this meeting was the existing material placed in the river for the causeway and the need to ensure it was removed before high water in the spring. The material was successfully removed in December 2019.

USACE, the Bureau of Reclamation, and the contractor held a partnering meeting on Dec 3, 2019. The USACE and the primary contractor discussed roles and responsibilities for QC and QA, dispute resolution, safety, and upcoming modifications.

The construction of the by-pass channel and new weir is anticipated to be completed no later than the end of 2023.

4.3.5 Fort Peck Flows

In the January 19, 2018 amendment to the October 30, 2017 Biological Assessment for the Operation of the Missouri River Mainstem Reservoir System, the Operation and Maintenance of the Bank Stabilization and Navigation Project, the Operation of the Kansas River Reservoir System, and the Implementation of the MRRMP (USACE 2017), the USACE proposed, among other things, to work with the USFWS and the MRRIC to “review previous information and information generated since the EA to formulate test flow releases from Fort Peck Dam and an adaptive management framework for their implementation."

This commitment was relied upon by the USFWS in its 2018 BiOp finding that the USACE's proposed action is "not likely to jeopardize" pallid sturgeon (USACE 2018).

In 2018, the USACE developed an Adaptive Management Framework for Fort Peck (USACE and USFWS 2018). The associated NEPA process involving the evaluation of potential impacts of HCs was initiated in early 2019. The EIS will document the formulation and evaluation of test-flow alternatives from Fort Peck Dam intended to benefit pallid sturgeon.

The EIS scoping period extended through March 26, 2019. Public comments were invited to assist in identifying the scope of potentially affected environmental, social, and economic issues relevant to the proposed Federal action and determining reasonable alternatives to be considered in the EIS. A list of engagements in 2019 pertaining to this initiative includes:

- 19-20 Feb 2019: Scoping Meetings (public and tribal)
- 7 Mar 2019: Hydropower Analysis Discussion
- 30 May 2019: Hydropower Analysis Discussion
- 25 Jul 2019: Site visit with irrigators
- 26 Jul 2019: Missouri River Conservation District Council Meeting
- 15 Aug 2019: Hydropower Analysis Discussion
- 21 Aug 2019: Meeting with Ft Peck Tribe
- 10 Oct 2019: Hydropower Analysis Discussion
- 30 Oct 2019: Irrigation Analysis Discussion

Key discussion points to date include the adequacy of the USACE's irrigation intake inventory for the purposes of this exercise (an issue that the USACE is currently reviewing), and the nature of particular flow specifications and their potential impacts on hydropower.

To assist MRRIC participants in engaging in the Draft EIS (DEIS) process, during some of the engagements listed above the USACE continued to share and discuss draft findings and materials. These included, for example, the provision of an online tool called HydroViz, which allows MRRIC participants to explore USACE modelling outputs that detail how system flows and stages might change under the different DEIS alternatives (illustrated in Figure 4-2).

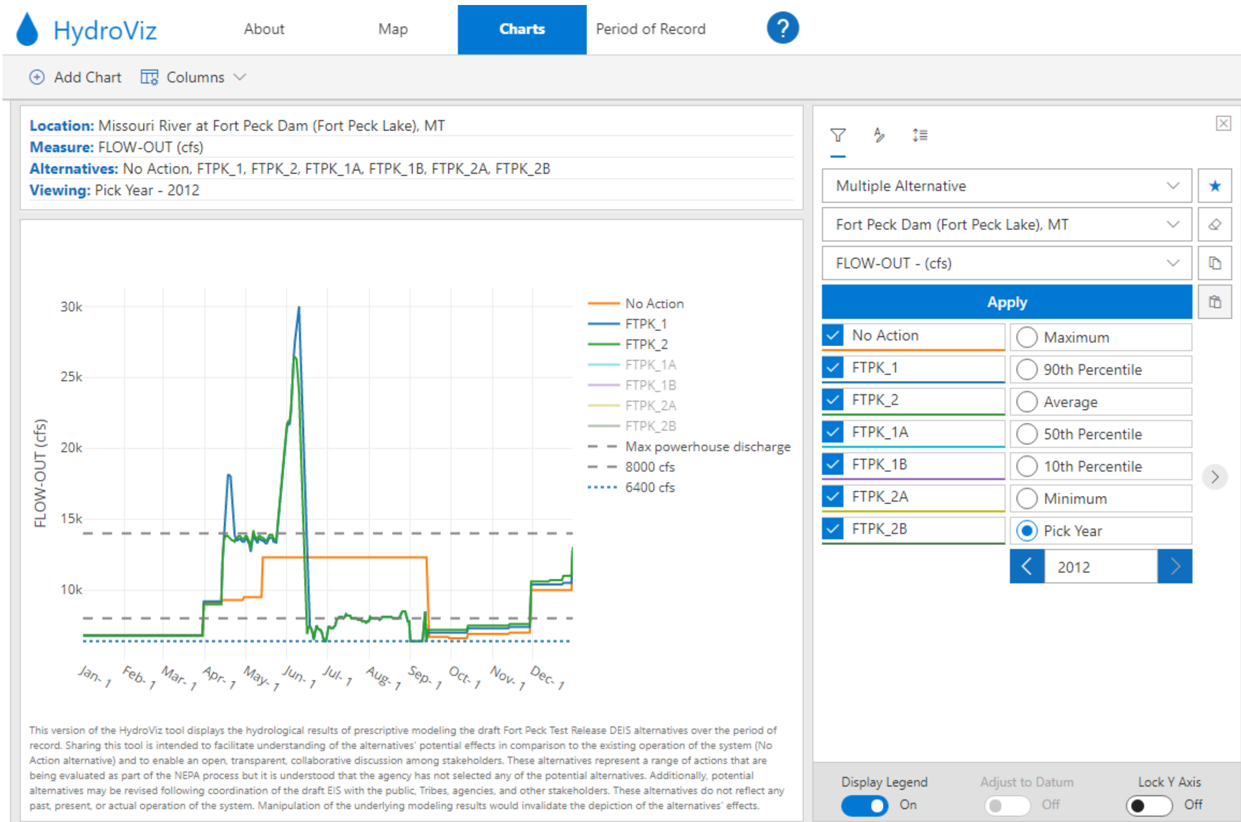

Figure 4-2. Example screen shot from HydroViz, which allows participants to explore how system flows and stages might change under the different DEIS alternatives.

MRRIC participants were also shown preliminary socioeconomic findings for each of the DEIS alternatives for a number of areas including:

- Recreation
- Flood Risk Management
- Irrigation
- Cultural Resources
- Hydropower
- Thermal Power
- Water Supply

During discussions of this draft material, an unanticipated behavior in one of the models was observed, and the USACE made a decision to remodel the alternatives. This caused an extension of the deadline of the EIS to spring of 2021, as shown in Figure 4-3, which indicates the state of the development of the DEIS as of April 2020. It is anticipated that a Draft Report for Public Review will be available in May 2020. Tribal and public engagements will continue through 2021.

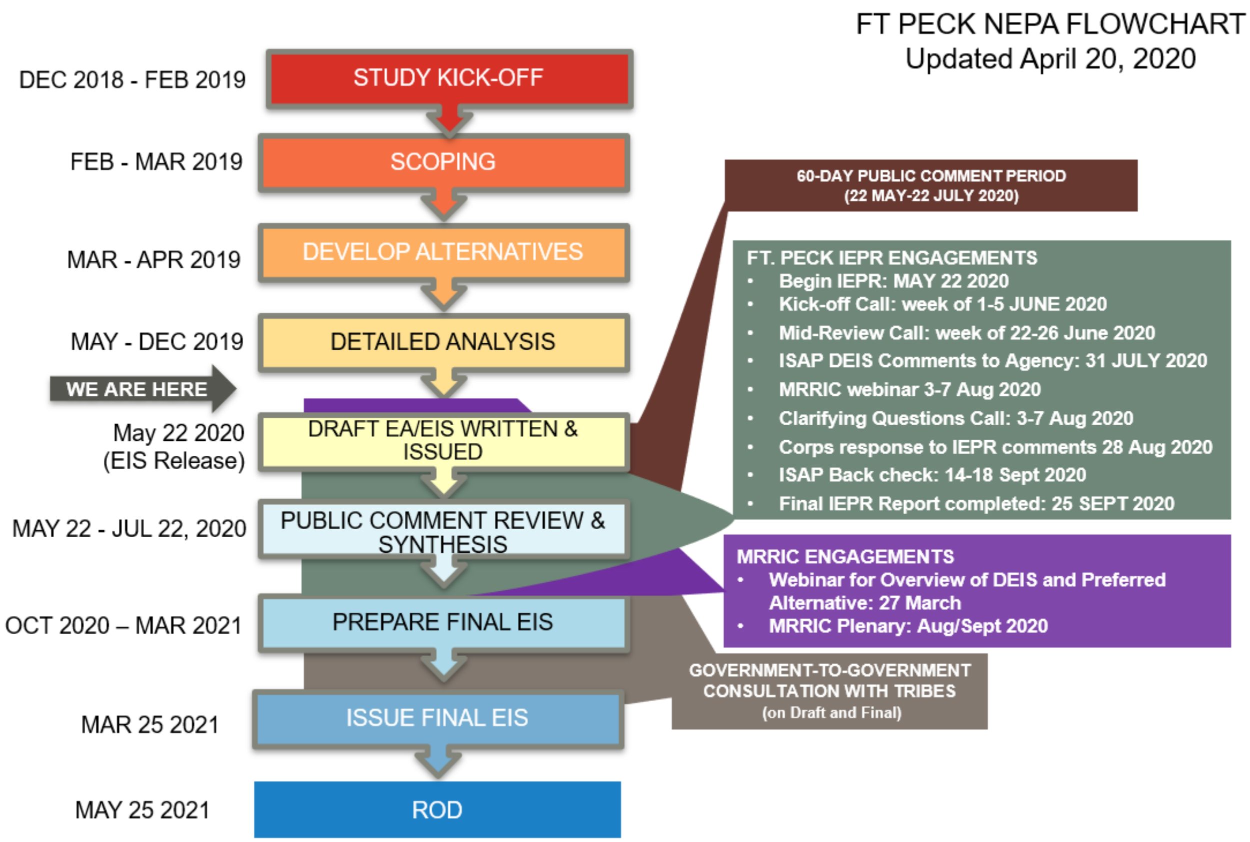

Figure 4-3. Fort Peck EIS schedule as revised in November 2019.

4.3.6 Lower River Spawning Flows

Under circumstances described in the SAMP (Fischenich et. al 2018), a requirement for spawning cue flows (and appropriate scope) may emerge from the outcome of Level 1 and Level 2 monitoring and modeling studies following year 9 of plan implementation. Should a spawning cue flow be required after year nine, HC concerns will be addressed through appropriate NEPA mechanisms. During 2019, no specific flow or planning action was undertaken on this issue.

Science activities continued to assess the effects of natural flows on Pallid Sturgeon movement, aggregation and reproduction in both the Upper and Lower Missouri (see Section 3.3.5).

4.4 Other Notable Engagements and Outcomes

The USACE and USFWS responses to MRRIC Recommendations and a summary of MRRP-related engagements are included in Appendix 1.

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