PETITION TO LIST THE
Sturgeon Chub (*Macrhybopsis gelida*)
and Sicklefin Chub (*Macrhybopsis meeki*)
UNDER THE U.S. ENDANGERED SPECIES ACT

Top: Sturgeon Chub (*Macrhybopsis gelida*). Bottom: Sicklefin Chub (*Macrhybopsis meeki*). Photos © David Ostendorf, used with permission.

Petition Submitted to the U.S. Secretary of the Interior
Acting through the U.S. Fish and Wildlife Service

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INTRODUCTION

WildEarth Guardians (Guardians) respectfully requests that the Secretary of the Interior, acting through the U.S. Fish and Wildlife Service (Service) list the Sturgeon Chub (*Macrhybopsis gelida*) and the Sicklefin Chub (*Macrhybopsis meeki*) as "threatened" or "endangered" under the U.S. Endangered Species Act (ESA) (16 U.S.C. §§ 1531-1544). WildEarth Guardians also requests that the Service designate critical habitat for these species.

Sicklefin and Sturgeon Chub are small fish that inhabit large, free-flowing riverine systems, characterized by swift flows, highly variable flow regimes, braided channels, high turbidity, and sand/fine gravel substrates. Both species are in decline due to severe habitat changes. In particular, the construction and operation of mainstem dams has fragmented the habitat of the Sicklefin and Sturgeon Chub.

ENDANGERED SPECIES ACT AND IMPLEMENTING REGULATIONS

The ESA, 16 U.S.C. §§ 1531-1544, was enacted in 1973 "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such endangered species and threatened species." 16 U.S.C. § 1531(b). The protections of the ESA only apply to species that are listed as endangered or threatened according to the provisions of the statute. The ESA delegates authority to determine whether a species should be listed as endangered or threatened to the Secretary of Interior, who in turn delegated authority to the Director of the U.S. Fish & Wildlife Service. As defined in the ESA, an "endangered" species is one that is "in danger of extinction throughout all or a significant portion of its range." 16 U.S.C. § 1532(6); *see also* 16 U.S.C. § 533(a)(1). A "threatened species" is one that "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." 16 U.S.C. § 1532(20). The Service must evaluate whether a species is threatened or endangered as a result of any of the five listing factors set forth in 16 U.S.C. § 1533(a)(1):

A. The present or threatened destruction, modification, or curtailment of its habitat or range;
B. Overutilization for commercial, recreational, scientific, or educational purposes;
C. Disease or predation;
D. The inadequacy of existing regulatory mechanisms; or
E. Other natural or manmade factors affecting its continued existence.

A taxon need only meet one of the listing criteria outlined in the ESA to qualify for federal listing. 50 C.F.R. § 424.11.

The Service is required to make these listing determinations "solely on the basis of the best scientific and commercial data available to [it] after conducting a review of the status of the species and after taking into account" existing efforts to protect the species without reference to the possible economic or other impacts of such a determination. 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R. § 424.11(b). "The obvious purpose of [this requirement] is to ensure that the ESA not be implemented haphazardly, on the basis of speculation or surmise." *Bennett v. Spear*, 520 U.S. 154, 175 (1997). "Reliance upon the best available scientific data, as opposed to requiring absolute scientific certainty, 'is in keeping with congressional intent' that an agency 'take preventive measures' *before* a species is 'conclusively' headed for extinction." *Ctr. for Biological Diversity v. Lohn*, 296 F. Supp. 2d 1223, 1236 (W. D. Wash. 2003, emphasis in original).

In making a listing determination, the Secretary must give consideration to species which have been "identified as in danger of extinction, or likely to become so within the foreseeable future, by any State agency or by any agency of a foreign nation that is responsible for the conservation of fish or wildlife or plants." 16 U.S.C. § 1533(b)(1)(B)(ii); *see also* 50 C.F.R. § 424.11(e) (the fact that a species has been identified by any State agency as being in danger of extinction may constitute evidence that the species is endangered or threatened). Listing may be done at the initiative of the Secretary or in response to a petition. 16 U.S.C. § 1533(b)(3)(A).

After receiving a petition to list a species, the Secretary is required to determine "whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). Such a finding is termed a "90-day finding." A "positive" 90-day finding leads to a status review and a determination whether the species will be listed, to be completed within twelve months. 16 U.S.C. §1533(b)(3)(B). A "negative" initial finding ends the listing process, and the ESA authorizes judicial review of such a finding. 16 U.S.C. § 1533(b)(3)(C)(ii). The applicable regulations define "substantial information," for purposes of consideration of petitions, as "that amount of information that would lead a reasonable person to believe that the measure proposed in the petition may be warranted." 50 C.F.R. § 424.14(b)(1).

The regulations further specify four factors to guide the Service's consideration on whether a particular listing petition provides "substantial" information:

i. Clearly indicates the administrative measure recommended and gives the scientific and any common name of the species involved;
ii. Contains detailed narrative justification for the recommended measure; describing, based on available information, past and present numbers and distribution of the species involved and any threats faced by the species;
iii. Provides information regarding the status of the species over all or significant portion of its range; and
iv. Is accompanied by appropriate supporting documentation in the form of bibliographic references, reprints of pertinent publications, copies of reports or letters from authorities, and maps.

50 C.F.R. §§ 424.14(b)(2)(i)-(iv).

Both the language of the regulation itself (by setting the "reasonable person" standard for substantial information) and the relevant case law underscore the point that the ESA does not require "conclusive evidence of a high probability of species extinction" in order to support a positive 90-day finding. *Ctr. for Biological Diversity v. Morgenweck*, 351 F. Supp. 2d 1137, 1140 (D. Colo. 2004); *see also Moden v. U.S. Fish & Wildlife Serv.*, 281 F. Supp. 2d 1193, 1203 (D. Or. 2003) (holding that the substantial information standard is defined in "non-stringent terms"). Rather, the courts have held that the ESA contemplates a "lesser standard by which a petitioner must simply show that the substantial information in the Petition demonstrates that listing of the species may be warranted" (Morgenweck, 351 F. Supp. 2d at 1141 (quoting 16 U.S.C. § 1533(b)(3)(A)); *see also Ctr. for Biological Diversity v. Kempthorne*, No. C 06-04186 WHA, 2007 WL 163244, at *3 (N.D. Cal. Jan. 19, 2007) (holding that in issuing negative 90-day findings for two species of salamander, the Service "once again" erroneously applied "a more stringent standard" than that of the reasonable person).

CLASSIFICATION AND NOMENCLATURE

Common name. The common name for *Macrhybopsis gelida* is "Sturgeon Chub." The common name for *Macrhybopsis meeki* is "Sicklefin Chub." This petition refers to both species by their common names. Common names are capitalized throughout the petition under rules developed by the American Fisheries Society committee on names of fishes, but are left unchanged in quotes if the author(s) did not capitalize them.

Taxonomy. The first petitioned species is *Macrhybopsis gelida* (Table 1).

> The species was first described by Girard in 1856 who gave it the name *Gobio gelidus* based on specimens collected in the Milk River, Montana. In 1882, Jordan and Gilbert referred to the species as *Ceratichthys gelidus*, but in 1896 Jordan and Everman consolidated the genus *Ceratichthys* into *Hybopsis*. The sturgeon chub was placed in the subgenus *Macrhybopsis* by Cockerell and Allison in 1909. In 1920, Jordan elevated the subgenus *Macrhybopsis* to generic status and then changed the species name to *gelida* in 1930. Bailey's (1951) merging of several genera of cyprinids into the genus *Hybopsis* included the return of sturgeon chub to the genus *Hybopsis*. Mayden (1989) restored the sturgeon chub to the genus *Macrhybopsis*, and the reclassification has been supported by several workers. The current designation of sturgeon chub is *M. gelida.* (Rahel & Thel, 2004, pp.10-11, *some internal citations omitted; see also* Page et al. 2013, p. 73)

Table 1. Taxonomy of *Macrhybopsis gelida* (Hammerson et al., 2015, p. 1).

Kingdom	Animalia
Phylum	Craniata
Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Macrhybopsis*
Species	*gelida*

The second petitioned species is *Macrhybopsis meeki* (Table 2).

> The sicklefin chub was first collected from the Missouri River near St. Joseph, Missouri, by Jordan and Meek (1885), but was initially misidentified as a sturgeon chub. Type specimens originated from later collections of Jordan and Evermann (1896) made at the same general area of the Missouri River near St. Joseph, Missouri, and were identified as *Hybopsis meeki*. The sicklefin chub was subsequently placed in the genus *Macrhybopsis*. (USFWS, 2001b, p. 3, *some internal citations omitted; see also* Page et al. 2013, p. 73)

Table 2. Taxonomy of *Macrhybopsis meeki* (Hammerson & Dirrigl, 2015, p. 1).

Kingdom	Animalia
Phylum	Craniata
Class	Actinopterygii
Order	Cypriniformes
Family	Cyprinidae
Genus	*Macrhybopsis*
Species	*meeki*

SPECIES DESCRIPTIONS

Sturgeon chub. The Sturgeon Chub is "a slender, streamlined benthic minnow that inhabits main-stem, turbid rivers and resides over sandy and gravel shoals. Generally, their back is light brown with silvery colored sides and belly with the defining characteristic being its long snout that overhangs the mouth, similar to the morphology of sturgeon species, and presence of ridge-like projections on many scales [Figure 1]. Similar to other chub species, maxillary barbels and external taste buds cover the head and body and are used to locate food in highly turbid waters. [They are] benthic insectivores with small eyes that are of little value for locating food. Maximum size has been reported to be 70 mm; however, adults exceeding 100 mm have been captured in the channelized Missouri River" (Steffensen et al., 2014, p. 50, *internal citations omitted; see also* Page & Burr, 2011, p. 210). Juvenile diets are dominated by midge larvae (Starks et al., 2016, p. 1,338). The Sturgeon Chub is a relatively short-lived species with a lifespan of up to four years (USFWS, 2001b, p. 3); however, few live beyond two years (Steffensen et al. 2014, p. 50).

Sturgeon Chub have characteristics considered typical of fish associated with benthic, fast-water environments, including "a narrow streamlined shape, large fins, dorsally positioned eyes, a subterminal mouth, and an arched back and flattened ventral surface. The unique epidermal ridges on the scales of sturgeon chub have been proposed to function as keels. The adaptation of sturgeon chub to high turbidity is evident by their reduced eyes, numerous cutaneous taste buds, and a brain morphology that indicates well developed chemosensory perception" (Rahel & Thel, 2004, p. 11, *internal citations omitted*).

Sicklefin chub. The Sicklefin Chub is a small, obligate large-river minnow that has "evolved specific phenotypic adaptations to the formerly turbid, moderate velocity Missouri River. These included a fusiform body shape, long sickle-shaped pectoral fins, a deeply forked caudal fin, reduced optic brain lobes and eyes, and development of external sensory organs, termed compound taste buds" (Dieterman & Galat, 2005, p. 561). It is usually light green to brown above, often with many dark brown and silver specks, and silver sides (Page & Burr, 2011, p. 210). It is distinguished from the Sturgeon Chub by long, sickle-shaped pectoral fins and the absence of ridge-like projections on its scales (Steffensen et al., 2014, p. 50; Figure 2). Juvenile Sicklefin Chub diets are less specialized than diets of juvenile Sturgeon Chub (Starks et al., 2016, p. 1,341), and comparison of taste bud distribution suggests "*M. gelida* may be able to find prey more effectively in turbid systems, whereas *M. meeki* may be more efficient sorting and concentrating food after it has been ingested" (p. 1,343).

> Maxillary barbels are positioned behind the blunt and slightly overhanging snout. Sicklefin chubs use these barbels and external taste buds to locate food as their eyes are small and of little value in turbid waters. Their diet primarily consists of immature aquatic insects. Maximum size rarely exceeds 95 mm and they have a relatively short life span (< 4 years). (Steffensen et al. 2014, pp. 50-51, *internal citations omitted; see also* Page & Burr, 2011, p. 209-210).

Reproduction. "The sicklefin chub can reach sexual maturity at age 2, with most fish mature by age 3. The fish first become mature at shorter lengths of 70-79 mm (2.8-3.1 inches) in the Missouri River in Montana than the 90-99 mm (3.5-3.9 inches) downstream in Kansas and Missouri… Spawning occurs throughout the summer at water temperatures of 18-28°C (64.4-82.4°F). Multiple stages of eggs in gravid females suggest that the fish spawn multiple times during the summer" (Albers, 2014a, p. 185). Sicklefin Chubs may have a protracted spawning period (Dieterman et al., 2006, p. 125) and may have a high degree of post-spawn mortality (p. 122). The most recent study on Sicklefin Chub reproduction determined that "*Macrhybopsis meeki* hatch dates showed a distinct, bell-shaped curve that started in early June, peaked in mid-July and subsided in mid-August" (Starks et al., 2016, p. 1,341). "[W]hile *M. gelida* and *M. meeki* both require long reaches of unfragmented river, *M. meeki* may be tied to a more specific spawning cue, as suggested by their unimodal peak in hatch dates" (Starks et al., 2016, p. 1,345).

"The sturgeon chub reaches sexual maturity at age 2… Spawning occurs throughout the summer at water temperatures of 18.3-22.7°C (65-72.9°F). Multiple stages of eggs in gravid females suggest that fish spawn multiple times during the summer. Estimates of fecundity range from 2,000 to 5,310 eggs per female" (Albers, 2014b, p. 179). The most recent study on Sturgeon Chub reproduction determined that "*Macrhybopsis gelida* spawned throughout the summer, ranging from early May to late August" (Starks et al., 2016, p. 1,341). "Sturgeon chub exhibit no sexual dimorphism during the breeding season" (Rahel & Thel, 2004, p. 11, *internal citations omitted*).

Both species are "pelagic-spawning cyprinids," small-bodied fish that "produce semi-buoyant, non-adhesive eggs within pelagic zones of large flowing streams" (Perkin et al., 2010, p. 3). These species "produce eggs that achieve semi-buoyancy soon after fertilization, but require water movement to remain in suspension" (Worthington et al., 2014, p. 1). The two species have slightly different specific strategies. The Sturgeon Chub is a pelagophilic broadcast spawner, meaning it reproduces "by releasing non-adhesive, semi-buoyant eggs in open water whereby they are passively transported downstream by the current" (Worthington et al., unpublished data, *internal citations omitted*). The Sicklefin Chub is a lithopelagophilic broadcast spawner, with "a similar reproductive strategy except that the eggs are released over rock or gravel and might be initially adhesive" (Worthington et al., unpublished data, *internal citations omitted*).

Pelagic-spawning cyprinids "represent 25-40% of imperiled species within ecoregions of the Great Plains and have precipitously declined since at least the 1950s when species belonging to this guild dominated vertebrate communities within Great Plains prairie rivers" (Perkin et al., 2010, p. 3, *internal citations omitted*). "A growing body of literature suggests imperilment of pelagic-spawning cyprinid species is a direct consequence of stream fragmentation" (Perkin et al., 2010, p. 11).

The availability of downstream transport (unfragmented river kilometers) is particularly important for the pelagic-spawning reproductive guild because "high mortality rates occur among ichthyoplankton [drifting eggs and larvae] deposited within downstream reservoirs, due to suffocation within anoxic sediments or predation from lacustrine species" (Perkin & Gido, 2011, p 372, *internal citations omitted*).

Pelagic-spawning cyprinids also depend on unobstructed rivers and streams for recolonizing areas as adults:

> Pelagic-spawning cyprinids dispense gametes into pelagic zones of flowing streams. Immediately following spawning, water enters the chorion membrane and fills the perivitelline space of eggs, causing eggs to swell and become semi-buoyant. These semi-buoyant eggs remain suspended within the water column and drift for 24-28 hours before hatching, after which pre-larvae develop as they drift for an additional 2-3 days, presumably becoming displaced great distances (e.g., up to 140 km) downstream from parent localities. Stockpiling of reproductively active adults below barriers suggests migration during reproduction, which provides a mechanism for recolonization of upstream reaches following downstream drift of pre-larva. Stream fragmentation therefore carries the potential to negatively impact the spatial dynamics of pelagic-spawning cyprinids via interruption of dispersal across two planes of space (i.e., in downstream and upstream directions) and time (i.e., during pre-larval and adult life stages). (Perkin et al., 2010, pp. 3-4, *internal citations omitted*)

When the USFWS made its 2001 decision not to list these species, the "reproductive biology of sicklefin and sturgeon chub [was] largely unknown" (USFWS, 2001b, p. 7, *see also* USFWS, 2001a, p. 19,914), including their pelagic-spawning nature. Given that pelagic-spawning cyprinids have precipitously declined, the USFWS should consider the extent to which this life history characteristic imperils the species in their heavily fragmented habitat.

HABITAT REQUIREMENTS

Sturgeon Chub and Sicklefin Chub have similar macrohabitat requirements. Both species "evolved in large, free-flowing riverine systems, characterized by swift flows, highly variable flow regimes, braided channels, high turbidity, and sand/fine gravel substrates" (USFWS, 2001b, p. 4). Because of their reproductive strategy, they require unfragmented stream lengths for sustainable populations. The length of fragment needed is unknown, as "the 'drift distance' required by pelagic-broadcast spawning minnows is undetermined" (Hoagstrom, 2015, p. 4). "[F]ragment length does not guarantee ecological suitability. Extirpations occur in longer fragments, whereas shorter fragments sometimes sustain remnant populations" (Hoagstrom, 2014, p. 450).

There are very few free-flowing rivers or river segments of significant length for Sturgeon and Sicklefin Chub remaining in the Great Plains:

> [O]nly 42 free-flowing rivers longer than 200 km remain in the contiguous 48 states, and only five of these rivers exist in the Great Plains region. Although the Missouri River is not one of them, it does have three reaches that are free-flowing for over 300 km: above Fort Peck Lake, Montana; between Fort Peck Dam and Lake Sakakawea, North Dakota; and

> downstream from Gavins Point Dam, South Dakota. Our analysis of factors influencing sicklefin chub distribution along the Missouri and lower Yellowstone rivers reinforces the importance of retaining existing free-flowing riverine stretches over 300 km long and their associated natural seasonal flow and sediment dynamics. (Dieterman & Galat, 2004, p. 585, *internal citations omitted*)

Turbidity (relative clarity of water) is an important predictor of the presence of both species; both tend to be present in turbid river segments. Clearer water creates disadvantages for these species, as illustrated by their absence in clear water below Garrison Dam:

> Garrison Dam has… increased water clarity in the river. Inflowing suspended sediments settle out behind the dam under reduced current velocities. The habitat models indicate that both chub species inhabit areas with low water clarity, such as in the Yellowstone and Williston segments, as opposed to the clearer waters of the Bismarck segment. More investigations are needed on the exact mechanism resulting in the absence of both chub species in the clearer water. Predation by sight-feeding fishes is one possible cause worth investigating. Regardless of the exact cause, the absence of chubs in all habitats in the Bismarck segment indicates that turbidity is one factor associated with the presence or absence of these species. (Everett et al., 2004, p. 191)

Sicklefin Chub. Though both chub species have similar biological requirements and use similar macrohabitat types, they have some differences in microhabitat use. The Sicklefin Chub "inhabits main-stem, turbid rivers and resides in areas of strong current over sand or gravel shoals" (Steffensen et al., 2014, p. 50). Sicklefin Chub have been collected during studies in Montana, North Dakota, and Missouri at depths from 0.1 to 11.0 meters (m) (0.3 to 36 feet), bottom velocities from 0.14 to 1.06 m/second (0.5 to 3.5 ft/second), and over a variety of substrate types (USFWS, 2001b, p. 4). "While sicklefin chubs have been collected from almost every type of Missouri River habitat type at one time, most fish have been collected in main channel, border channel, and sandbar macrohabitats over sand and fine gravel substrate" (USFWS, 2001b, p. 4). Welker and Scarnecchia (2004, p. 18) found them associated with the main channel, over "sand substrate at depths greater than 3 [meters] and current velocities greater than 0.5 m s^{-1}."

Statistical analysis found four significant habitat variables influencing Sicklefin Chub distribution in the Missouri River: distance to upstream impoundment, flow constancy, mean segment turbidity, and percent of annual flow in August (USFWS, 2001b, p. 4). "Occurrence of sicklefin chub was highest when the river segment was greater than 187 miles (301 km) downstream from a dam; flow constancy was 0.56 or less, indicating an association with river segments having more variable flow regimes; mean summer-early fall turbidity levels were 80 NTUs [Nephelometric Turbidity Units] or greater; and the percent of flow in August was low, less than 10 percent of the total annual flow" (USFWS, 2001b, p. 4; *see also* Dieterman & Galat, 2004).

One model "indicated… sicklefin chubs found most often in main-channel macrohabitats… which tend to have cooler, deeper, faster, more turbid water. Additionally, [the] model indicated that sicklefin chub population densities were highest on warmer, faster and clearer end of temperature, velocity and turbidity ranges, respectively, observed in these flowing habitats" (Wildhaber et al. 2012, p. 1,792, *internal citations omitted*). Another study supports higher velocities associated with chub presence, as well as sand substrate. Welker & Scarnecchia (2004, pp. 18-19) stated that "[h]abitat models predicting either presence or abundance for [sickelfin chub] included percent sand, current velocity, and discharge as significant variables, with an increase in percent sand and current velocity and a decrease in discharge, positively influencing fish presence or abundance." However, Everett et al. (2004, p. 188) indicated that "sicklefin chub presence increased as depth increased, velocity decreased, water clarity decreased and sand became the dominant substrate."

We defer to the most recent work, which states that Sicklefin Chub presence

> is positively correlated with sand, depth, and turbidity and negatively correlated with high late-summer discharge, temperature, gravel, silt, and flow consistency. When the sicklefin chub is present, its abundance is positively correlated with relatively higher temperature and depth and with lower velocity, turbidity, and conductivity. The species is most common over sand substrates in depths >2 m (6.6 feet) with bottom velocities averaging 0.47-0.90 m/second (18.5-35.4 inches/second). Adults prefer faster velocities with a higher percentage of gravel and lower percentage of silt relative to juveniles. Age 0 fish prefer water 0.2-0.5 m deep (7.8-19.7 inches). The species are also most common in river segments with high turbidity (>80 NTU), summer water temperatures of 14-26°C (57-79°F), conductivities of 402-830 μS/cm, and variable annual flows but low, stable flows in late summer. (Albers, 2014a, p. 185)

During a study of four river segments near the confluence of the Yellowstone and Missouri rivers, catch rates for Sicklefin and Sturgeon Chub were highest in the two least altered segments (Welker & Scarnecchia, 2004, p. 20).

> In this study, these four cyprinids made up over 65% of the catch, indicating that their status is better in the confluence area than in many portions of the middle and lower Missouri Rivers. Further, even in the confluence area, the density and catch of flathead chub, sicklefin chub, and sturgeon chub in the quasi-natural YRS [Yellowstone River segment] and the BCS [below confluence segment] were higher than in the ACS [above confluence segment], which was the segment most impacted by Fort Peck Dam. For sustainable populations of flathead chub, sicklefin chub, sturgeon chub, and western silvery minnow in the upper Missouri and lower Yellowstone rivers, natural river characteristics, such as a naturally fluctuating hydrograph and a high sediment load, that produce a diversity of habitats and habitat conditions should be preserved and, if possible, improved in altered river segments. Channel modifications, such as bank stabilization and additional irrigation withdrawals, that would alter natural river habitat should be discouraged. (Welker & Scarnecchia, 2004, p. 20)

Sicklefin Chub association with unaltered river segments is supported by the Missouri River Benthic Fishes Study, which was initiated in 1995, ended in 1998, and "produced a baseline against which to evaluate future changes in Missouri River operating criteria" (Wildhaber et al., 2012, p. 1,780). The study determined that Sicklefin Chub were most common in least-altered river zones:

> Sicklefin chubs are found in the Missouri and middle and lower Mississippi rivers inhabiting turbid main channels in high water velocities over sand and fine gravel… Our results indicate that sicklefin chubs were primarily, to almost exclusively, collected in the Yellowstone River, least-altered zone, and upper segments of the inter-reservoir zone directly connected to the Yellowstone River and the lowest segments of the channelized zone in main and secondary flowing channel and tributary mouth macrohabitats with cooler water. (Wildhaber et al., 2012, pp. 1,791-1,792, *internal citations omitted*)

In summary, Sicklefin Chub require relatively unaltered river segments containing turbid mainstem habitats over sand substrates with cool temperatures. There is overlap of Sturgeon and Sicklefin Chub habitat, but Sicklefin Chubs are also found in deeper, faster-flowing water than Sturgeon Chubs (Albers, 2014a, p. 185).

Sturgeon Chub. Though both chub species have similar biological requirements and use similar macrohabitat types, they have some differences in microhabitat use. "[B]oth chubs were present together in only 13.2% of the successful chub sampling sites, which… suggests dissimilarity in the specific habitat selection of the two chubs" (Everett et al., 2004, p. 189). "In contrast to sicklefin chub, which only occur in large river systems, sturgeon chub also inhabit tributaries to the Yellowstone and Missouri Rivers" (USFWS, 2001b, p. 5). "Sturgeon chub… are usually found in main channel and channel border habitats in areas with gravel and/or sand substrate with greatest abundance with fine to medium gravel" (USFWS, 2001b, p. 5). "The species is collected most commonly over sand substrates in depths >2 m (6.6 feet) with bottom velocities averaging 0.5-1.0 m/second (1.6-3.3 feet/second) summer water temperatures of 14-26°C (57-79°F), conductivities of 402-1,105µS/cm, and turbidity of 17-969 NTU" (Albers, 2014b, p. 179). "Sturgeon chubs were more likely to prefer fast flowing, turbid chutes" (Whiteman et al., 2011, p. 106) when compared to Shoal Chubs and several shiner species in the lower Missouri River. "When the sturgeon chub is present, its abundance is positively correlated with relatively higher gravel and conductivity and relatively lower temperature, sand, discharge, velocity, and turbidity" (Albers, 2014b, p. 179).

Most studies indicate that the primary substrate used by Sturgeon Chubs is gravel (USFWS, 2001b, p. 5). "Sicklefin chub, which may sort food items from ingested detritus more effectively, are more commonly associated with sandy substrates whereas sturgeon chub, which appear to have a less efficient sorting but an enhanced food detection mechanism, are more commonly associated with gravel substrates" (Rahel & Thel, 2004, p. 20).

One study concluded that Sturgeon Chub use shallower habitats with faster flows than Sicklefin Chub:

> Sturgeon chubs used shallow habitats (mean depth = 2.5 m), with higher water velocities (mean velocity = 0.89 m/s) and gravel substrate (particle size: 2 mm ≤ 16 mm). In contrast, sicklefin chubs used deeper habitats (mean depth = 6.8 m) with lower water velocities (mean velocity = 0.47 m/s) and sand substrate (particle size: 0.06 mm ≤ 2 mm). (Everett et al., 2004, p. 189)

Other studies agree that Sturgeon Chub use shallow habitat, but indicate that they "inhabit shallower, slower water than the sicklefin chub" (Albers, 2014b, p. 179). We defer to the most recent work.

Wildhaber et al. (2012) found that

> sturgeon chubs were primarily, to almost exclusively, collected in the lower Yellowstone River, least-altered zone, and upper segments of the inter-reservoir zone directly connected to the Yellowstone River in main and secondary flowing channel macrohabitats in shallower, more turbid water over sand. Where collected, sturgeon chub population densities were highest in the lower Yellowstone River and Missouri River least-altered zone in areas with cooler, clearer,

> higher conductivity water over substrate with decreasing proportion of sand. Everett et al. (2004) found sturgeon chubs in shallower, faster, more turbid water whereas Welker and Scarnecchia (2004) found them over sand with actual counts increasing with decreasing flow and turbidity and increasing proportion of gravel. Our model indicated… sturgeon chubs found most often in main-channel macrohabitats, as Everett et al. (2004) and Welker and Scarnecchia (2004) found, which tended to have deeper, faster, more turbid water and greater proportions of sand and gravel. Additionally, our model indicated that sturgeon chub population densities were highest on the finer end of the observed substrate range for mainstem flowing habitats. (p. 1,792, *some internal citations omitted)*

In summary, Sturgeon Chub require relatively unaltered mainstem or tributary habitats with turbid waters, sand or gravel substrates, and cool temperatures. There is overlap of Sturgeon and Sicklefin Chub habitat, but Sturgeon Chubs are also found in shallower, slower-flowing water than Sicklefin Chubs (Albers, 2014b, p. 179).

GEOGRAPHIC DISTRIBUTION: HISTORIC AND CURRENT

Surveys referenced in the 2001 negative finding and status report indicated that both species were more common than was thought previous to 2001. However, since 2001, studies have detected population declines in both species in their remaining range. Below, we discuss the historic and current range of both species in specific rivers and their tributaries.

For the Missouri River, we rely mainly on the data of the Pallid Sturgeon Population Assessment Team (PSPAT), a joint project between the Army Corps of Engineers, the Service, state and federal agencies, and universities. PSPAT developed and implemented a long-term monitoring program to assess the recovery and status of Pallid Sturgeon (*Scaphirynchus albus*, listed as "endangered" under the ESA) in the Missouri River (Pallid Sturgeon Population Assessment Project, or PSPAP) (Oldenburg et al., 2010, p. 1).

> The PSPAP study area encompasses most of the Missouri River from Fort Peck Dam, Montana, at river mile (RM) 1772, downstream to the confluence of the Missouri and Mississippi rivers near St. Louis, Missouri (RM 0). The PSPAT divided the Missouri River into distinct geographic segments and gave state and federal resource management agencies the primary responsibility for monitoring and assessment in one or more segment. The PSPAT designated 12[1] sampling segments on the Missouri River main stem and one on the lower Kansas River to include high-priority management areas for pallid sturgeon (Oldenburg et al., 2010, p. v).

The PSPAP was designed to include assessments for ten other native fish species in the Missouri River, including the Sturgeon and Sicklefin Chubs (Oldenburg et al., 2010, p. 1).[2] References to river segments in this document refer to the PSPAP Missouri River segments and one Kansas River segment, which are delineated as follows, in order of river mile (RM) (Figures 3 and 4):[3]

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[1] There are now 13 segments on the Missouri and one on the Kansas River.
[2] The other monitored species are Shovelnose Sturgeon (*Scaphirhynchus platorynchus*), Blue Sucker (*Cycleptus elongates*), Sauger (*Sander Canadensis),* Speckled Chub (*Machrybopsis aestivalis*), Plains Minnow (*Hybognathus placitus*), Western Silvery Minnow (*H. argyritis*), Brassy Minnow (*H. hankinsoni*), and Sand Shiner (*Notropis stramineus*) (Oldenburg et al., 2010, p. 1).
[3] The source is Oldenburg et al., 2010, p. 3, unless otherwise noted.

1. Fort Peck Dam downstream to the Milk River (RM 1771.5–1760)
2. Milk River downstream to Wolf Point (RM 1760–1701)
3. Wolf Point downstream to the confluence with Yellowstone River (RM 1701–1582)
4. Confluence with the Yellowstone River to the headwaters of Lake Sakakawea (RM 1582–1568)

15. Garrison Dam downstream to the headwaters of Lake Oahe (RM 1386-1270)[4] (Wilson et al. 2013b, p. 4)

5. Fort Randall Dam downstream to the Niobrara River (RM 880–845)
6. Niobrara River downstream to the headwaters of Lewis and Clark Lake (RM 845–825)
7. Gavins Point Dam downstream to Lower Ponca Bend (RM 811–753)
8. Lower Ponca Bend downstream to the Platte River (RM 753–595.5)
9. Platte River downstream to the Kansas River (RM 595.5–367.5)
10. Kansas River downstream to the Grand River (RM 367.5–250)
11. Kansas River from Lawrence, KS, to its mouth (Whiteman et al., 2013, p. 4)

13. Grand River downstream to the Osage River (RM 250–130)[5]
14. Osage River downstream to the confluence with the Mississippi River (RM 130–0)

No similar monitoring program exists for the other rivers in Sturgeon and Sicklefin Chub range and similarly detailed data for both chub species is lacking in those areas.

The Missouri River is divided into the Upper, Middle, and Lower Missouri River basins. The Upper Missouri River basin includes "the main stem Missouri River system and tributaries within the basin from the headwaters in Montana downstream to the Gavins Point Dam (river mile 811) in southeastern South Dakota" (USFWS, 2001b, p. 14). The Middle Missouri River Basin "includes the main stem Missouri River from Gavins Point Dam (river mile 811) in southeastern South Dakota downstream through Iowa and Nebraska to Rulo, Nebraska (river mile 498), near the Nebraska/Kansas State line, and its tributaries" (USFWS, 2001b, p. 25). The Lower Missouri River basin "includes the main stem Missouri River and associated tributaries in Kansas and Missouri, downstream of Rulo, Nebraska (river mile 498), to the mouth of the river (river mile 0) north of St. Louis" (USFWS, 2001b, p. 18).

Sicklefin Chub. "Collection records for sicklefin chub indicate that this species historically occurred in 70 miles of the Lower Yellowstone River, 1,950 miles of the main stem Missouri River, and 1,150 miles of the Mississippi River, below the mouth of the Missouri River" (USFWS, 2001b, p. 37). As of 2001, sicklefin chub occupied "approximately 1,090 miles in the Missouri River drainage or 54 percent of its historic range" (USFWS, 2001b, p. 37; Figure 5). It is "fairly common" in the middle Missouri River and rare elsewhere (Page & Burr, 2011, p. 210), meaning that in the Middle Missouri they "may be found" in their preferred habitat within their range, but are "very unlikely to be found" in their preferred habitat within their range outside the Middle Missouri (p. xii). Page & Burr do not define "Middle Missouri" so it is uncertain if this is the same stretch of river referred to as the Middle Missouri by the USFWS in the 2001 status review.

[4] PSPAT began monitoring this segment in 2012 to detect any entrainment of Pallid Sturgeon (Wilson et al., 2013b, p. ii).
[5] Segment 12 was combined into Segment 13 by the PSPAT in 2005.

Yellowstone River. The Sicklefin Chub historically occurred in at least 70 miles of the Lower Yellowstone River, from the mouth of Thirteen Mile Creek to the confluence of the Missouri River (USFWS, 2001, p. 12).[6] As of 2001, it inhabited the same stretch of river (USFWS, 2001b, p. 12), but is now considered rare everywhere except the middle Missouri (Page & Burr, 2011, p. 210).

Missouri River. The Sicklefin Chub historically occurred in 1,950 miles of the mainstem Missouri River, from the mouth of Cow Creek, Montana, to the confluence of the Mississippi. As of 2001 it occupied 1,015 miles of the Missouri: Cow Creek, Montana to the headwaters of Fort Peck Reservoir; Fort Peck Dam to the headwaters of Lake Sakakawea; and from Gavins Point Dam to the confluence of the Mississippi (USFWS, 2001b, p. 13).

PSPAP data indicate that the Sicklefin Chub is rare or extirpated from several monitored segments of the Missouri River. The PSPAT 2015 Annual Monitoring Report for Segment 1 in Montana states "Throughout ten years of standardized sampling it has become evident that this highly altered stretch of the Missouri River in Segment 1 is detrimental to several native species. Only one pallid sturgeon *Schaphirynchus albus* has been sampled in ten years… Other target species such as sturgeon chub *Macrhybobsis gelida* and sand shiners *Notropis stramineus* have been sampled however with very low numbers, while no sicklefin chub *Macrhybobsis meeki* have ever been documented" (Holte & Hunziker, 2016, p. ii). "The abundance of sicklefin chubs was once again lacking in Segment 2 during the 2015 field season, with the capture of only two specimens," and the population appears to be consistently dominated by adult fish (Hunziker et al., 2016a, p. v). No Sicklefin Chub were captured in Segment 15 in 2012 (Wilson et al., 2013b, pp. ii-iii) or 2013 (Wilson et al., 2014, pp. ii-iii). PSPAT has never captured Sicklefin Chub in the South Dakota segments of the Missouri, Segments 5 and 6 (Pierce et al., 2016, p. 39). The South Dakota Department of Game, Fish, and Parks considers the Sicklefin Chub to be extirpated from the state (Shuman et al., 2005, p. 52).

One Sicklefin Chub was collected in Segment 7 in 2015, the first capture since 2010. In all prior years combined only 17 Sicklefin Chub have been collected in Segment 7 (Loecker et al., 2016, p. 48). Five Sicklefin Chub were captured in 2015 in Segment 8, on the border of Nebraska and Iowa (Huenemann & Steffensen, 2016, p. v). In Segment 9, "[c]urrently, the Sturgeon Chub and Sicklefin Chub population appears to be declining with little to no reproduction and recruitment and are likely a fraction of their historic abundance" (Steffensen & Huenemann, 2016, p. v). Very few Sicklefin Chub have been collected in the Kansas River (Segment 11); only nine have been captured since sampling began (Garner et al., 2014, p. 52). These results indicate that the Sicklefin Chub is declining, rare, or extirpated in the Missouri River in Segment 1, Segment 2, Segment 15, Segments 5 through 9, and the Kansas River.

Mississippi River. The Sicklefin Chub historically occurred in 1,150 miles of the mainstem Mississippi River, from the mouth of the Missouri to the Gulf of Mexico (USFWS, 2001b, p. 12). The USFWS estimates that as of 2001 it was still present in the entire mainstem (USFWS, 2001b, p. 12), but it is now considered rare everywhere except the middle Missouri (Page & Burr, 2011, p. 210). "[H]abitat in the Middle and Lower Mississippi River has been altered by the construction of dike fields, bendway weirs, and other structures designed to maintain the navigation channel. However, due to the lack of data documenting sicklefin chub populations in the Mississippi River the importance of this population and the full extent of impacts are unknown" (USFWS, 2001b, p. 11). Despite this

[6] The exact number of river miles is unclear, as it is listed as 85 river miles on page 12 but later referred to as 70 miles on page 37.

lack of data, the Service concluded in 2001 that "[s]icklefin chub are uncommon and perhaps borderline rare in the Middle Mississippi River. Collections made during the past four field seasons suggest that sicklefin chub numbers are slightly decreasing" (USFWS, 2001b, p. 35).

More recent research supports a declining population of Sicklefin Chub in the Mississippi River. The Sicklefin Chub was the 11^{th} most abundant species captured during trawling studies in the middle Mississippi, and was among the 19 species that constituted only seven percent of the total catch (Jackson, 2002, p. 19). Sicklefin Chub were among the rarest species captured, which the author believes is due to a decline in their population density. "It is the sturgeon chub that is listed as an endangered species in the state of Illinois, but it is the sicklefin chub that appears to be far rarer" (Jackson, 2002, p. 28).

Sturgeon Chub. The Sturgeon Chub also historically inhabited the Yellowstone, Missouri, and Mississippi Rivers, as well as tributaries of the Yellowstone and Missouri rivers:

> Historically, the sturgeon chub occurred throughout 2,100 miles of the main stem Missouri River and 1,150 miles of the main stem Mississippi River. The species also was found in the Yellowstone River in Montana and North Dakota and 30 tributaries to the Yellowstone and Missouri Rivers. The sturgeon chub occurred in portions of four tributaries in Wyoming, nine in Montana, five in North Dakota, six in South Dakota, six in Nebraska, and four in Kansas… Other tributaries that historically provided sturgeon [chub] in two States include the Big Horn, Little Missouri, and Republican Rivers. (USFWS, 2001b, p. 38)

As of 2001, Sturgeon Chub occupied "approximately 1,155 miles or about 55 percent of its former range in the Missouri River. The species also continues to be found in 11 of 30 tributaries to the Yellowstone and Missouri Rivers that were documented as providing sturgeon chub habitat… Field studies… have documented a viable population of sturgeon chub in the Middle Mississippi River and in the Wolf Island area of the Lower Mississippi River" (USFWS, 2001b, p. 38; Figures 6 and 7). They are "fairly common" in the middle Missouri River and rare elsewhere (Page & Burr, 2011, p. 210), meaning that in the Middle Missouri they "may be found" in their preferred habitat within their range, but are "very unlikely to be found" in their preferred habitat within their range outside the Middle Missouri (p. xii). A 2010 study indicated that Sturgeon Chub have been extirpated from a majority (75 percent) of 60 Great Plains stream fragments surveyed (Perkin et al., 2010, p. 11).

Yellowstone River and tributaries. "In Wyoming, the sturgeon chub was collected historically in the North Platte, Big Horn, and Powder River drainages" (USFWS, 2001b, p. 14; Table 3). They have been "[e]xtirpated from the North Platte River drainage. The species has declined recently in the Powder River drainage and is nearly extinct in the [Big Horn] River drainage" (the species has not been documented in the Bighorn River drainage since 2003) (WGFD, 2010, p. IV-3-83). USFWS considered the species extirpated from the Big Horn in 2001 (Table 1). "Currently, sturgeon chub are primarily restricted to the Yellowstone and Powder Rivers of Montana and Wyoming," but they are present in the Powder River at extremely low densities (less than one percent of the total fish assemblage) (WGFD, 2010, p. IV-3-83). This is a change from the 1990s, when streams in the Wyoming plains were dominated by native minnows (Cyprinidae) and suckers (Catostomidae) (Patton et al., 1998, pp. 1,122-1,122) and the population of Sturgeon Chub appeared stable or increasing (Patton et al., 1998, p. 1,124). Sturgeon Chub were once the third most abundant fish in the Powder River mainstem (Senecal et al., 2015, p. 8). Relative abundance of Sturgeon Chub has decreased in the Powder River: "Sturgeon chub made up between 6.2% and 27.4% of the fish sampled in early samples, but decreased to less than 1% (0.02 %) in later samples" (Senecal et al., 2015, p. 6, *internal citations omitted*).

Table 3. Yellowstone River tributaries where Sturgeon Chub were extant or extirpated in 2001 (USFWS, 2001, p. 17).

State	Extant	Extirpated
Wyoming	Powder River	Big Horn River
	Crazy Woman Creek	North Platte River
Montana	Tongue River	Sunday Creek
	Powder River	Big Horn River
	Sears Creek	
	Box Elder Creek	

During a study of four river segments near the confluence of the Yellowstone and Missouri rivers, the highest relative abundance and greatest number of Sturgeon Chub were found in the Yellowstone River segment (Welker & Scarnecchia, 2004, p. 14)

During a study of seven river systems in the Missouri River drainage, "Sturgeon chubs had a restricted distribution and were only sampled from five reaches in the Powder River" (Quist & Hubert, 2004, p. 732).

Missouri River and tributaries. As of 2001, Sturgeon Chub occupied "approximately 1,155 miles or about 55 percent of its former range in the Missouri River"(USFWS, 2001b, p. 38). PSPAP data indicate that the Sturgeon Chub is rare or extirpated from several monitored segments of the Missouri River. Sturgeon Chub have been extirpated from 18 tributaries of the Missouri (Table 4).

PSPAT found no Sturgeon Chubs in Montana in Segment 1 during sampling in 2015 (Holte & Hunziker, 2016, p. 13). Only one Sturgeon Chub has ever been collected in Segment 1 in 10 years of sampling (Holte & Hunziker, 2016, p. 13). A total of 15 sturgeon chubs were captured in Segment 2 in 2015, and the population appears to be consistently dominated by adult fish (Hunziker et al., 2016a, p. v). No Sturgeon Chubs were captured in Segment 15 in 2012 (Wilson et al., 2013b, pp. ii-iii) or 2013 (Wilson et al., 2014, pp. ii-iii). Only two Sturgeon Chubs have ever been captured in Segment 5 (in 2012) since monitoring began in 2003, and no Sturgeon Chubs have been captured in Segment 6 on the South Dakota/Nebraska border (Pierce et al., 2016, p. 39). No Sturgeon Chub were captured in 2015 on the South Dakota/Nebraska border in Segment 7, and only four have ever been captured in this reach since monitoring began (Loecker et al., 2016, p. 45). Thirteen Sturgeon Chub were collected from Segment 8 in 2015 (Huenemann & Steffensen, 2016, p. 51). In Segment 9, "[c]urrently, the Sturgeon Chub and Sicklefin Chub population appears to be declining with little to no reproduction and recruitment and are likely a fraction of their historic abundance" (Steffensen & Huenemann, 2016, p. v). No Sturgeon Chub have been captured in the Kansas River (Segment 11) from 2006 to 2013 (Garner et al., 2014, p. iii). Sturgeon Chub appear to be declining, rare, or extirpated in Segment 1, Segment 2, Segment 15, Segments 5 through 9, and the Kansas River (Segment 11).

Table 4. Missouri River Tributaries where Sturgeon Chub were extant or extirpated in 2001 (USFWS, 2001b, p. 17).

State	Extant	Extirpated
Montana	Redwater River	Milk River
		Teton River
North Dakota		Little Missouri River
		Box Elder Creek
		Beaver Creek
		Green River
		Heart River
South Dakota	White River*	Grand River
	Little White River*	Little Missouri River
	Bear in the Lodge Creek	
	Cheyenne River	
Nebraska	Platte River	Niobrara River
		Republican River
		Loup River
		Elkhorn River
		Bazile Creek
Kansas		Smoky Hill River
		Kansas River
		Wakarusa River
		Republican River

*Dr. George Cunningham sampled these tributaries in 2015. Sturgeon Chub used to be present in large numbers in both but now there are very few (G. Cunningham, pers. comm., July 7, 2016)

Mississippi River. The Sturgeon Chub historically inhabited 1,150 miles of the main stem Mississippi River, from the mouth of the Missouri to the Gulf of Mexico. As of 2001, based on four years of data, Sturgeon Chub were uncommon, but not rare in the Middle Mississippi, and their numbers were steady to slightly increasing (USFWS, 2001b, p. 35). "[H]abitat in the Middle and Lower Mississippi River has been altered by the construction of dike fields, bendway weirs, and other structures designed to maintain the navigation channel. However, due to the lack of data documenting [sturgeon] chub populations in the Mississippi River the importance of this population and the full extent of impacts are unknown" (USFWS, 2001b, p. 14). Currently, viable populations exist in the middle Mississippi River and the Wolf Island area of the lower Mississippi River (Hammerson et al., 2015, p. 2). The Sturgeon Chub was the 5th most abundant species captured during trawling studies, but were among the 19 species that constituted only seven percent of the total catch (Jackson, 2002, p. 19).

DETECTION PROBABILITY

"Historically, seines of various lengths were used to sample cyprinid populations in shallow water habitat. Since 1994, researchers have found that benthic trawling is a more effective method of collecting sicklefin and sturgeon chub, particularly in water depths over 1 meter" (USFWS, 2001b, p. 8).

PSPAP sampling of the Missouri River took place during two distinct seasons, fish community season and sturgeon season:

> The sturgeon season was defined as the period when water temperatures were below 12.7°C (55°F) in the fall, until 30 June. While water temperatures were below 12.7°C, experimental gill nets were used and above this temperature, otter trawls are generally utilized… The fish community season begins on July 1 and continued until water temperatures drop below 12.7°C. Four gears are used during the fish community season: 1.0" trammel nets, trot lines, otter trawls, and mini-fyke nets. (Steffensen & Huenemann, 2013, pp. 1-2)

Small-bodied fish including *M. gelida* and *M. meeki* are generally not captured in the large mesh of gill or trammel nets (Schloesser et al., 2012, p. 215). Otter trawls (a type of benthic trawl) yielded varying detection probabilities for these species depending on external factors (Figure 8). "Small-bodied fish models strongly supported river segment as the best descriptor of detection probabilities… Habitat was the second ranked candidate model for… *M. meeki*, and year was second for *M. gelida*. However, the differences in QAIC and AIC between the segment model and the next best candidate model was >20 for all small-bodied fishes, indicating little support for other candidate models… Detection probabilities of… *M. meeki* increased in downstream segments to nearly 0.50 in Segments 13 and 14. *M. gelida* detection probabilities were similar among Segments 9, 10, 13, and 14 (mean p=0.14), but lower in Segment 8 (p=0.02)" (Schloesser et al., 2012, p. 219).

POPULATION STATUS AND TRENDS

Yellowstone River and tributaries. In Wyoming, Sturgeon Chub are found in the Yellowstone River and two tributaries: the Powder River and Crazy Woman Creek. Sturgeon Chub have been extirpated from two other Yellowstone River tributaries: the Big Horn River and the North Platte River (USFWS, 2001b, p. 17). Studies indicate a declining population of Sturgeon Chub in Wyoming:

> The fish community at the Wyoming border has changed significantly over the past three decades, and continues to lose sensitive species and biological integrity. For example, sturgeon chubs have significantly declined or are now absent in the study reach from the Wyoming Border to Moorhead Bridge and potentially further downstream. Patton et al. (1998) found sturgeon chubs at half of eight sites sampled in the Wyoming portions of the Powder River near Montana. Confluence Consulting (2004) found two sturgeon chubs in 2002 at only one Wyoming site close to the Montana border, and three years later MTNHP and the USGS (2005) did not capture a single sturgeon chub within 40 miles of the Wyoming border despite combined sampling of 6 stream reaches. The rarity of the sturgeon chub in this reach is alarming for a river that has provided substantial habitat for this species in the past. (Stagliano, 2012, p. 17, *some internal citations omitted*).

The Yellowstone River is a relatively undisturbed river that used to provide substantial habitat for the Sturgeon Chub; however, the species appears to be declining precipitously.

Missouri River and tributaries. Sturgeon and Sicklefin Chub are considered decreasing in the Missouri River (Galat et al., 2005, p. 287) and Galat et al.'s review "substantiates consistent population declines throughout much of the main channel Missouri River" (2005, p. 275)

Between 2006 and 2008 there was no trend in abundance in the upper sampling area (segments 1-4, from Fort Peck Dam, Montana, to the headwaters of Lake Sakakawea, North Dakota), but there was a significant negative trend for both species in the lower sampling area (Segments 5-10, 13, and 14, the region from Fort Randall Dam, South Dakota, to the confluence with the Mississippi River):

> A total of 2,754 sturgeon chubs and 972 sicklefin chubs were randomly sampled in the upper monitoring area from 2006 through 2008, and no significant trends in relative abundance were found across the years. A total of 328 sturgeon chubs, 1,182 sicklefin chubs, and 2,884 shoal chubs were randomly sampled in the lower monitoring area from 2006 through 2008 and significant negative trends were found for all three species. It is possible that the observed decline in the relative abundance of *Macrhybopsis* spp. is related to the increased relative abundance of pallid sturgeon in the lower monitoring area, because pallid sturgeon are known to prey on sturgeon and sicklefin chubs. Furthermore, there was a trend of increased relative abundance with increasing downstream distance from dams for all three *Macrhybopsis* spp., suggesting a correlation between the relative abundance of *Macrhybopsis* spp. and river segments with more natural, large-river conditions (e.g., increased turbidity and discharge fluctuations). (Oldenburg et al., 2010, p. vii)

We examine these trends by state and river segment below.

Montana. A study seining 120 sample sites in Montana returned one Sturgeon Chub and no Sicklefin Chub (Wuellner et al., 2013, p. 1,501), though it is not stated how many sample sites were in Sturgeon Chub or Sicklefin Chub historic range. The Sturgeon Chub was one of the rarest natives species identified in the study (Wuellner et al., 2013, p. 1,503).

Powder River Basin. "The Powder River is a vast drainage representing one of the last undammed, large prairie rivers in the United States… The Powder River aquatic ecosystem supports many elements of a fully functioning, biologically diverse system, including 25 native fish species (19 in Montana) and numerous species of rare invertebrates (Stagliano, 2012, p. 1, *internal citations omitted*). In six surveyed sites in the Middle Powder River Watershed in Montana, "fish numbers and diversity were significantly lower (about 1/4 as many individuals) in 2011 than in 2005… The Sturgeon Chub, a Montana species of concern previously common in this reach, was not collected in 2011 and only at one downstream site in 2005, indicating a sustained decline or absence in this reach" (Stagliano, 2012, p. iii, *see also* Stagliano, 2006). "In addition, two common taxa collected in 1975, lake and sturgeon chubs, which were absent from the 2005 and 2011 samples, were not observed in 2011. Moreover, sturgeon chubs have not been collected within 30 miles of this site in the past five years" (Stagliano, 2012, p. 12). Sturgeon Chub were once the third most abundant fish in the Powder River mainstem (Senecal et al., 2015, p. 8). Relative abundance of Sturgeon Chub has decreased in the Powder River: "Sturgeon chub made up between 6.2% and 27.4% of the fish sampled in early samples, but decreased to less than 1% (0.02 %) in later samples" (Senecal et al., 2015, p. 6, *internal citations omitted*). "Given its short life span and long drifting distance, sturgeon chub is likely the Powder River species most sensitive to changes in flow regime and habitat alteration and fragmentation" (Senecal et al., 2015, p. 9).

Despite offering relatively undisturbed habitat, the Powder River Basin has experienced a decline in relative abundance of Sturgeon Chub. The reason for this decline is unclear.

Above Fort Peck Dam. Sturgeon Chub were the second-most common species collected in a study area above Fort Peck Dam in 2000 (Gardner, 2000, p. 5), but they appear to be decreasing. Pallid Sturgeon Recovery-Priority Management Area (RPMA) 1 is between the mouth of the Marias River to the headwaters of Fort Peck Reservoir. "In the last two years [2012 and 2013], despite excellent sampling conditions of fairly low flow, CPUE of sicklefin chub has been at record low levels. Sturgeon chub catch has also been low for such excellent sampling conditions. Pallid sturgeon numbers have been steadily increasing in RPMA 1. The favorite prey items of juvenile pallid sturgeon appear to be sicklefin and sturgeon chub. The reduction in CPUE of these chubs is a concern if it represents a real decline" (UBPSW, 2014, p. 96, *internal citations omitted*).

Though there is little recent information available about this relatively undisturbed area of the Missouri River, what information does exist appears to indicate decreasing populations of both Sicklefin and Sturgeon Chub, potentially due to increased predation.

Segment 1. Segment 1 is "the most highly altered area of the Missouri River downstream of Fort Peck Dam within Montana" (Haddix et al., 2013a, p. ii). It has been sampled each year from 2006 to 2015. "Throughout ten years of standardized sampling it has become evident that this highly altered stretch of the Missouri River in Segment 1 is detrimental to several native species. Only one pallid sturgeon *Schaphirynchus albus* has been sampled in ten years… Other target species such as sturgeon chub *Macrhybobsis gelida* and sand shiners *Notropis stramineus* have been sampled however with very low numbers, while no sicklefin chub *Macrhybobsis meeki* have ever been documented" (Holte & Hunziker, 2016, p. ii).

> This reach of the Missouri River is characterized by an unnatural hydrograph, thermograph, sediment dynamics, and fish community due to the influence of Fort Peck Dam, which was constructed in 1940… Regulated hypolimnetic water releases from Fort Peck Reservoir have changed a once turbid sandy bottom stretch of river into a cold clear cobble dominated river. Fort Peck Reservoir has substantially reduced suspended sediment loads in the river below Fort Peck Dam when compared to its natural state. Peaks in the hydrograph are related to power production and barge traffic downstream, instead of natural spring runoff and precipitation events. Many species native to this stretch of river such as the pallid sturgeon, sicklefin chub and sturgeon chub find the cold clear water unsuitable and are now common only farther downstream where tributaries have warmed and muddied the waters of the Missouri. Fish much more suited for this cold clear water such as rainbow trout *Oncorhynchus mykiss*, brown trout *Salmo trutta* and Chinook salmon *Oncorhynchus tshawytscha* have been stocked on and off from 1950 to 1990. Other nonnative species such as largemouth bass *Micropterus salmoides*, northern pike *Esox lucius*, walleye *Sander vitreus*, and yellow perch *Perca flavescens* have been stocked in the dredge cuts to increase angling opportunities. It is believed that many of these sight-feeding piscivores have out competed the native fishes in this stretch of river. In summary, this unique stretch of river is now vastly different from the once braided and shifting channels of the "Big Muddy" before Fort Peck Dam. (Haddix et al., 2013a, p. 4, *internal citations omitted*)

Numerous non-natives inhabit Segment 1:

> [D]uring the past six years of sampling, a total of 10 non-native species have been found in segment 1 including, common carp *Cyprinus carpio*, rainbow trout *Onchorhyncus mykiss*, brown

> trout *Salmo trutta*, lake trout *Salvelinus namaycush,* lake whitefish *Coregonus clupeaformis*, ciscoe *C. artedi,* spottail shiner *Notropis hudsonius*, smallmouth bass *Micropterus dolomieu*, and yellow perch *Perca flavescens.* (Haddix et al., 2013a, p. 25)

Many of these predatory fish were entrained below the dam in 2011, potentially impacting native cyprinid populations:

> With the spill that occurred over the Fort Peck Dam Spillway in 2011 a lot of predatory game fish such as walleye and northern pike were entrained into the Missouri River downstream of the Dam. This increase in predator abundance was observed in FWP's annual gill netting of the Missouri River Dredge Cuts. This increase in predators could be one reason why we did not observe higher numbers of native cyprinids, since predation was likely high. (Haddix et al., 2013a, p. 26)

Segment 1 is highly altered, populated by non-native fish, and does not appear to be suitable habitat for Sicklefin and Sturgeon Chub. There has been no detectable population trend in this segment, because no population has been detected since sampling began. This is likely due to the impacts of Fort Peck Dam, including lowered temperature and turbidity and an altered hydrograph. It may also be due to an increase in predation.

Segment 2. Nine Sicklefin Chubs were collected in the lower twelve miles of Segment 2 in 2012 (Hunziker et al., 2013, p. 47). The population in Segment 2 is dominated by adult fish (Hunziker et al., 2013, p. 47). "Relative density of sickelfin chubs remains very low in Segment 2, most likely due to the highly altered habitat associated with downstream of Fort Peck Dam. In contrast, sicklefin chubs are much more common in the lower stretches of Segment 3 of the Missouri River" (Hunziker et al., 2013, p. 47).

Sturgeon Chub were slightly more common, but their population is also dominated by adult fish:

> A total of 48 sturgeon chubs *Macrhybopsis gelida* were sampled in Segment 2 during 2012, which was an increase from 2011 (N=21) and nearly identical to 2010 (N=47). With a reported combined season CPUE of 0.08 fish/100m, catch rates have remained reasonably comparable since 2009… All but the smallest sturgeon chub (30 mm) captured were greater than 70 mm in TL, indicating that Segment 2 continues to be dominated by an adult class of fish. (Hunziker et al., 2013, p. iv)

The apparent lack of reproduction in this segment is likely due to habitat alteration from Fort Peck Dam:

> Segment 2… is impacted by the presence and operations of Fort Peck Dam. Fort Peck Dam inhibits the natural spring pulses and distributes that water more evenly throughout the remainder of the year. Fort Peck Dam draws its water for power production from the hypolimnetic regions of Fort Peck reservoir, which are significantly colder during the summer months and warmer during the winter months, when compared to the Missouri River above the reservoir. Fort Peck Reservoir traps the sediment loads of the Missouri River and therefore releases sediment free water to the Missouri River. This sediment free high-energy water scours the river of fine sediments and has reduced the amount of sand bars within the river. (Hunziker et al., 2013, p. 3, *internal citations omitted*)

The domination of adult fish continued in 2015:

> A total of 15 sturgeon chubs were captured in Segment 2 in 2015… The sturgeon chubs observed during the 2015 field season in Segment 2 averaged 84 mm in total length, which is identical to the past three field seasons. This reoccurring phenomenon indicates that the population of sturgeon chubs in Segment 2 continues to be dominated by adult fish. The abundance of sicklefin chubs was once again lacking in Segment 2 during the 2015 field season, with the capture of only two specimens... Low capture rates continue to cause otter trawl CPUE to hover barely above 0 fish/100m. With both individuals being of larger size, 90 and 102 mm, respectively, what few sicklefin chubs are observed continue to support the pattern of an adult-only population of sicklefin chubs residing in Segment 2 of the Missouri River. (Hunziker et al., 2016a, p. v)

Segment 2 is highly altered and does not appear to provide much habitat for Sicklefin and Sturgeon Chub; populations appear stable but at very low relative densities. The segment does not appear to support reproduction, as the small sample size of both species has been dominated by adult fish. This is likely due to the impacts of Fort Peck Dam, including lowered temperature and turbidity and an altered hydrograph.

Segment 3. "The 2015 sampling year marked the 10th consecutive field season for Pallid Sturgeon Population Assessment crews in Segment 3 of the Missouri River in Montana." (Hunziker et al., 2016b, p. ii). Segment 3 is further from the influence of Fort Peck Dam and thus exhibits characteristics more favorable to native cyprinids:

> In this large section, the river has completely transitioned from a cold clear cobble substrate river in segment 2 to a warm turbid prairie river, more similar to its natural characteristics. The aggrading streambed of segment 3 is flanked by stream deposited sediment of the Fort Union Formation. This stretch of river is slightly less flow regulated than upstream segments due to the tributaries and runoff events. There are five major tributaries that influence this section of river, which include the Milk River, Redwater River, Poplar River, Big Muddy Creek, and Prairie Elk Creek. These sediment packed tributaries flush their warmer turbid waters into the Missouri River increasing flows and suspended sediment, which in turn enables sandbar and island formation. Turbidities in this stretch of river are greater than that of segment 2 and discharge constantly changes with precipitation events and tributary discharge. The species composition of this stretch of river is vastly different from the uppermost segment just below Fort Peck Dam. The non-native fish stocked for recreation are much less prevalent and the prevalence of native, non-sport fish is increased. This stretch of ever-changing river is diverse with over 36 species of fish, many of which are benthic specialists, exhibiting streamlined bodies and well-developed chemosensory organs for surviving the sometimes high flows and ever-turbid waters. This stretch of river can be highly dynamic and is more reminiscent of what the Missouri River looked like before it became one of the most regulated and impounded rivers in the United States. However, due to the extremely low spring and summer flows that we've experienced in the past three years due to the operations of Fort Peck Dam, habitat formation is not occurring as it might have during the high runoff years of the 1990's. (Haddix et al., 2013b, p. 4, *internal citations omitted*)

“Although the high waters of 2011 influence the distribution of pallid sturgeon within Segments 2 and 3, we did not see increases in many of the target cyprinids. Sand shiners, western silvery minnows, sturgeon chub and sicklefin chub abundance did not appreciably increase in 2012 when compared to prior sampling years” (Haddix et al., 2013b, p. 69). Good water years improve populations of predaceous fish, which may make it harder for native cyprinids to bounce back even in good conditions:

> While the same good water years that produced sauger and shovelnose sturgeon and likely led to higher survival and growth of hatchery reared pallid sturgeon, likely had a positive effect on native cyprinid populations. However, while native cyprinids only live for a short few years, sauger and sturgeon are longer lived and may make it harder for cyprinid populations to bounce back after years of poor water conditions. The fact that we haven’t seen any bump in native cyprinid numbers after the 2011 water year may provide evidence of heavy predation of native cyprinids by predators. (Haddix et al., 2013b, p. v)

The relative abundance of Sturgeon Chub has decreased in this segment since 2006, along with other native cyprinids:

> The relative abundance of many native cyprinids such as sturgeon chub *Macrhybopsis gelida*, sicklefin chub *M. meeki*, sand shiner *Notropis stramineus* and western silvery minnows *Hybognathus argyritis* have been being monitored by the combination of otter trawls and mini fyke nets. The relative abundance of all these species have either decreased in recent years or have remained at very low detection levels. For instance, sturgeon chub CPUE using the otter trawl was at a seven year high in 2006 with more than 0.6 fish/100 m trawled. Since 2006 otter trawl CPUE has decreased to 0.21 fish/100 m, in 2012. (Haddix et al., 2013b, p. iv).

The most recent data from 2015 did not reveal a trend in the population:

> A total of 157 sturgeon chubs… were observed in Segment 3 in 2015... Catch per unit effort for sturgeon chub in Segment 3 in 2015 was recorded as follows; 0.11 fish/100m during sturgeon season, 0.18 fish/100m during fish community season, and 0.14 fish/100m for combined seasons. All three different catch rate metrics have remained comparable since 2009. (Hunziker et al., 2016b, p. 46)

A variety of age classes of Sturgeon Chub were present in this segment:

> The sturgeon chubs observed during the 2015 field season in Segment 3 averaged 63 mm in total length; with a range of 29 mm to 109 mm. The observed average length and range, especially when compared to Segment 2, continues to indicate that Segment 3 is suitable habitat for a variety of age classes of sturgeon chubs. (Hunziker et al., 2016b, p. v)

Sicklefin Chub numbers fluctuated dramatically over the two sampling seasons in 2012, going from an all-time high CPUE to the second lowest on record:

> During 2012 a total of 111 sicklefin chubs were collected within Segment 3… Although more sicklefin chubs were collected during 2012 than during 2011, the overall CPUE for

> both seasons combined was less in 2012. Sicklefin chub CPUE for both seasons combined was estimated at 0.10 fish/100 m, slightly down from 2011, which had an estimate of 0.13 fish/100 m. Although overall CPUE was similar to prior years, the CPUE of sicklefin chubs was at a seven year high during the sturgeon season with an estimate of 0.15 fish/100 m. Sicklefin chub CPUE then declined to 0.05 fish/100 m during the fish community season, which was the second lowest over the seven years of sampling. (Haddix et al., 2013b, p. 46)

The most recent data for 2015 suggests a fluctuating population that reached a high in 2015:

> Sampling events during 2015 in Segment 3 resulted in the capture of 204 sicklefin chubs… Sicklefin chub CPUE for 2015 within Segment 3 was reported as follows; 0.12 fish/100m during sturgeon season, 0.24 fish/100m during fish community season, and a combined season CPUE of 0.18 fish/100m, which was an all time high. Despite CPUEs being highly comparable the past two field seasons, there appears to be an every-other-year type pattern of elevated CPUE observed across all three metrics of measuring CPUE. (Hunziker et al., 2016b, p. 46)

Smaller age classes of Sicklefin Chub were rare in this segment:

> The sicklefin chubs during 2015 in Segment 3 averaged 85 mm in total length, with a range of 35 mm to 115 mm. Although the observed range appears to have a multitude of size classes, the majority (99.5%) were greater than 60 mm TL, indicating that the smaller age classes either reside in areas we don't sample, or are rearing in habitats further downstream. (Hunziker et al., 2016b, p. v)

Segment 3 supports a healthier population of Sicklefin and Sturgeon Chub than Segment 2, as it is less altered. Sturgeon chub declined between 2006 and 2009, and remained relatively stable from 2009 to 2015. Segment 3 supports a variety of age classes, indicating it is suitable habitat for Sturgeon Chub reproduction. Sicklefin Chub populations fluctuated dramatically in this segment but appear to have reached a high in relative abundance in 2015. It is unclear whether this segment supports Sicklefin Chub reproduction.

Wyoming. See "Yellowstone River and Tributaries," and "Powder River Basin," above.

North Dakota.

Segment 4. Segment 4 is just above Lake Sakakawea, a reservoir formed by the operation of Garrison Dam, and thus is impacted by the level of the reservoir:

> The amount of riverine habitat available for sampling in segment 4 is entirely dependent on reservoir levels. For example, in 2005 through 2008 the river reached below rivermile 1535. At full pool, the reservoir will extend as far up as rivermile 1574 as it did in 2010; however, the normal reach of river is around rivermile 1550. Although the Yellowstone River is not part of the segment, it does provide a significant amount of influence on this reach of the Missouri River. Seasonal flows, sediment load and natural temperature fluctuations provide a semblance of the historic conditions that existed prior to development of the Missouri under Pick Sloan plan. (Wilson et al., 2013a, p. 4)

"During the 2015 sampling year, 226 sturgeon chub were sampled with the otter trawl which was less than last year (N = 426)… Otter trawl CPUE of sturgeon chub during the fish community [season] was the fifth highest in eleven years of sampling" (Wilson & Sandness, 2016, p. 42).

Sicklefin Chub relative abundance has been decreasing for several years in Segement 4 as of 2012: "[CPUE] of sicklefin chub in the otter trawl during 2012 fish community season was the lowest in eight years of sampling. The decrease in relative abundance of sicklefin chub started in 2009" (Wilson et al., 2013a, p. 44). As of 2015, CPUE "of sicklefin chub in the otter trawl during the sturgeon season continues to remain low since 2010. The decrease in relative abundance of sicklefin chub started in 2010 and continued through 2014, although in 2015 there was an increase during fish community season" (Wilson & Sandness, 2016, p. 45).

Researchers were concerned by the trends in both chub populations:

> A couple of trends we are concerned with [are] the decline in sturgeon and sicklefin chub numbers in segment 4. Prior to 2012, catch per unit effort of sturgeon chubs in the otter trawl have been declining from a high in 2007 to a low in 2011. Overall numbers of sturgeon chub collected decreased from a high of 741 in 2007 to a low of 158 in 2011. In 2012, we saw an increase in both CPUE of sturgeon chub and the overall number sampled (N = 467). Catch per unit effort of sturgeon in the otter trawl in 2012 was the third highest in eight years of sampling. The number of sicklefin chub captured in the otter trawl in 2012 was the second fewest in eight years of sampling (N = 111). In 2011, only 94 sicklefin chubs were collected with the otter trawl. Four hundred thirty six sicklefin chub were captured during 2010 which was fewer than in 2009 (N = 685) but more than 2008 (N = 306), 2007 (N = 379), 2006 (N = 227) and 2005 (N = 330). Catch per unit effort of sicklefin chub has been declining since 2009. In 2012, CPUE of sicklefin chubs in the otter trawl during fish community season was the lowest in eight years of sampling. (Wilson et al., 2013a, p. 67)

The Upper Basin Pallid Sturgeon Workgroup noted a decline in both chub species in Segment 4: "There has been a steady decline in both the numbers and catch per unit effort of sicklefin and sturgeon chub with the otter trawl since 2009. We are not sure if this decline is related to the increased number of pallid sturgeon in the river or the increase in other predators such as sauger" (UBPSW, 2014, p. 113).

Segment 4 is relatively unaltered, though impacted by the level of the Reservoir at Lake Sakakawea, and supports populations of both Sicklefin and Sturgeon Chub, but both species appear to be declining, potentially due to increases in predation.

Segment 15. "Segment 15 of the Missouri River is a highly altered segment because of the influence of Garrison Dam, a hypolimnetic withdrawal structure. Water temperature at the USGS Bismarck gauging station ranged from 0 to 19.4 °C with an average of 14 °C. Turbidity ranged from 3 to 58 NTU with an average of 15.8 NTU" (Wilson et al., 2014, p. 35). No Sicklefin or Sturgeon Chubs were captured in Segment 15 in 2012 (Wilson et al., 2013b, pp. ii-iii) or 2013 (Wilson et al., 2014, pp. ii-iii), the only two years data is readily available.

Segment 15 is highly altered and does not appear to support Sicklefin or Sturgeon Chub populations, likely due to low turbidity.

South Dakota, Nebraska-Iowa border, and Kansas-Missouri border. Sturgeon Chub are missing from several previously occupied sites in South Dakota:

> In South Dakota, the sturgeon chub is missing from the Grand River, upper Missouri River valley, and Little Missouri River drainages, which it formerly occupied. The species is still present in the lower Missouri River valley below Gavins Point Dam, the mainstem White River, and the mainstem Cheyenne River" (Hoagstrom et al., 2006, p. 184, *internal citations omitted*).

The Sturgeon Chub was considered declining (Hoagstrom et al., 2006, p. 184) or extirpated (Shuman et al., 2005, p. 52) in South Dakota by 2006 and "may be more adversely affected by dewatering than [western silvery minnow and plains minnow] because it depends on swift-water habitats. For example, the combined effects of drought and habitat fragmentation by a reservoir could have led to the extinction of sturgeon chub from the Little Missouri River" (Hoagstrom et al., 2006, p. 184). The species may have disappeared from the Little Missouri River well before 2006; Dr. George Cunningham sampled the Little Missouri River in 1995 and found no sturgeon chub at that time, likely due to the use of water for and impacts of oil and gas exploration (G. Cunningham, pers. comm., July 7, 2016). After the advent of fracking in the Little Missouri, it is unlikely that many fish are present in the river (G. Cunningham, pers. comm., July 7, 2016).

The Sicklefin Chub is considered declining in South Dakota (Hoagstrom et al., 2006, p. 185):

> In South Dakota, the sicklefin chub is missing from the upper Missouri River valley drainage where it was previously present. The species is still present in the lower Missouri River valley drainage below Gavins Point Dam. Given that the sicklefin chub is restricted to only the largest rivers of the Missouri River drainage, it is likely that major modifications to these rivers, primarily dams and reservoirs, have caused the decline of this species. Remaining populations of sicklefin chub are largest where rivers are least modified. (Hoagstrom et al., 2006, p. 185, *internal citations omitted*)

"[T]he entire Missouri River along Nebraska's border has been negatively affected by river alternation and management decisions which resulted in a negative response by the native fish community" (Steffensen et al., 2014, p. 63). Mainstem dams, channelization, and other water operations have altered species composition and abundance in the Missouri River along the Nebraska border:

> The dominant species are still native species (i.e., Emerald Shiner *Notropis atherinoides,* Red Shiner *Cyprinella lutrensis,* River Shiner *N. blennius* and Spotfin Shiner *C. spiloptera*) but represent a sight feeding generalists guild which are able to take advantage of these altered conditions. The long term impact of this shift in species composition on the Missouri River ecosystem is currently unknown. (Steffensen et al., 2014, p. 64, *internal citations omitted*)

Sturgeon and Sicklefin Chubs are both negatively affected by channelization:

> [Sturgeon and Sicklefin Chubs] are found in very low numbers in the channelized sections of the Missouri River in Nebraska and are rare in the unchannelized sections. Nebraska is located within the species' central distribution; however, population levels are much higher in the upper Missouri River and slightly higher in the Missouri River downstream of Nebraska. These chub species appear to be highly impacted by the changes and ongoing management of the river. Due to their low population levels in Nebraska and the known role they play in the life history of Pallid Sturgeon, we recommend the continued listing of Sturgeon Chubs as an endangered species and listing Sicklefin Chubs as endangered species in Nebraska" (Steffensen et al., 2014, p. 63)

Segments 5 & 6. Segments 5 & 6 in South Dakota are assessed together by PSPAT. These two segments are located between Fort Randall Dam and the headwaters of Lewis and Clark Lake, formed by the operation of Gavins Point Dam.

> Segment 5… encompass[es] the riverine section downstream of Fort Randall Dam to the Niobrara River confluence. In this segment, water temperatures are depressed by hypolimnetic discharges from Fort Randall Dam and turbidity is low. Segment 6… encompass[es] the riverine section downstream of the confluence of the Missouri and Niobrara rivers to the headwaters of Lewis and Clark Lake. This segment has higher water temperature and turbidity due to inflows from the Niobrara River and includes the large braided delta formed in the former headwaters of Lewis and Clark Lake. (Shuman et al., 2013, pp. 20-21)

No Sicklefin Chub have been captured in South Dakota in Segments 5 or 6 since monitoring began in 2003 (Pierce et al., 2016, p. 39), "suggesting that [this] chub species [is] either extirpated or at such a low abundance that we were unable to detect them" (Shuman et al., 2013, p. 104). "Only two Sturgeon Chub have been collected in Segments 5 and 6 during 13 years of sampling. Both specimens were collected with otter trawl during 2012 in Segment 5" (Pierce et al., 2016, p. 39). "The lack of Sturgeon Chub… and Sicklefin Chub in Segments 5 and 6 is likely due to low abundance or extirpation rather than an inability to catch them because these species are consistently captured with standard PSPAP gears in other reaches of the Missouri River" (Pierce et al., 2016, p. 64).

These segments are highly altered and do not appear to support healthy populations of Sicklefin or Sturgeon Chub, likely due to impacts from Fort Randall Dam including lowered temperature and turbidity.

Segment 7. Segment 7 is downstream of Gavins Point Dam, and the dam has had significant impacts on the river:

> This reach of the river was isolated from upstream reaches when Gavins Point Dam was closed in 1955. Controlled releases from Gavins Point continue to influence the morphology and ecology of Segment 7 today. The U.S. Army Corps of Engineers uses the dam to provide stable releases to downstream areas, thus allowing for reliable navigation and water supplies. The dam blocks natural sediment transport causing incision and decreased turbidity. These facts, combined with an altered hydrograph, have created conditions that are quite different from the pre-dam era. (Stukel et al., 2013, p. 4)

Very few Sicklefin or Sturgeon Chubs have ever been captured in this reach. "No sturgeon chubs were captured in 2015. Only four have been captured since monitoring began in 2005 with the last specimen being sampled in 2009" (Loecker et al., 2016, p. 45). "One sicklefin chub measuring 114 mm was captured in 2015… Our last capture of this species occurred in SY 2010. Prior to this year, only 17 sicklefin chubs have been captured (all of them in otter trawls)" (Loecker et al., 2016, p. 48).

> [L]ow catch numbers may be partially attributable to the difficulty associated with trawling in such a challenging environment. Sand waves, cobble, and constant woody snags may decrease trawl efficiency. It is also possible that the effects of Gavins Point Dam have reduced chub numbers. Reduced turbidity may make these fish more vulnerable to sight-feeding predators. Hydrograph or thermal modification could have also altered habitat and food availability. (Stukel et al., 2013, p. 80, *internal citations omitted*)

The impacts of the flood of 2011 are still being felt in this reach:

> The Missouri River flood of 2011 caused many changes in habitat that were still evident in 2015. One of these changes was an increase in backwater habitats. Our sampling has shown that many fish species utilize these backwater areas throughout their life cycle. The flood also created many new large sandbars in some areas while scouring and deepening the main channel in other areas. It appears the fish community is still adjusting to the changes brought on by the flood of 2011. (Loecker et al., 2016, p. 78)

This segment is highly altered and does not appear to support healthy populations of Sicklefin or Sturgeon Chub, likely due to decreased turbidity, increased predation, and an altered hydrograph.

Segment 8. "Sampling efforts in Segment 8 are limited to few macro and mesohabitats due to simplification of the river by channelization" (Huenemann & Steffensen, 2013, p. 11). Both sicklefin and sturgeon chubs appear to be low in abundance in this reach:

> *Macrhybopsis* species collected in 2012 for Segment 8 resulted in low abundance. No sturgeon chub or sicklefin chub were sampled in 2012 and only five shoal chubs. Catch rates is Segment 8 are generally low with only 34 *Macrhybopsis* collected in standard sampling in 2010 and 31 in 2009. Shoal chubs, sturgeon chubs, and sicklefin chubs have all been collected in Segment 8; however, annual capture frequencies have been low since sampling began in 2005. Although, it is difficult to make accurate comparisons between years due to low sample sizes, it appears that *Macrhybopsis* species are declining through time. (Huenemann & Steffensen, 2013, p. 75, *internal citations omitted*)

Low abundance of *Macrhybopsis* species continued in 2015: "Forty one shoal chubs, nine sturgeon chubs, and four sicklefin chubs were all sampled in otter trawls, plus four shoal chubs and one sicklefin chub were captured in mini fyke nets in 2015. Overall, *Macrhybopsis* species are rarely collected in Segment 8" (Huenemann & Steffensen, 2016, p. v). "Overall, only 71 sicklefin chubs have been collected in Segment 8 since sampling began 2005" (Huenemann & Steffensen, 2016, p. 53). CPUE increased, however: "Catch rates for [sicklefin chubs in] otter trawls in 2015 (CPUE = 0.01 fish / 100 m trawled, ±2SE = 0.01) were the highest since 2010" (Huenemann & Steffensen, 2016, p. 53) and "…2015 catch rate [of sturgeon chub] (CPUE = 0.036 fish / 100 m trawled, ±2SE = 0.028) [were] the highest since sampling began in 2005" (Huenemann & Steffensen, 2016, p. 51).

Despite a slight increase in CPUE in 2015, populations of both species remain very small in this reach and, at least as of 2012, appeared to be declining.

Segment 9. **"**Segment 9 is the longest segment (227.5 miles) in the project and consists of 80 bends" (Steffensen & Huenemann, 2013, p. 4). "Sampling efforts in Segment 9 were limited to a few macro and mesohabitats by simplification of the river due to channelization." (Steffensen & Huenemann, 2013, p. 11)

"Catch rates for Macrhybopsis species peaked from 2004 to 2006 but has significantly declined over the past 10 years... Currently, the Sturgeon Chub and Sicklefin Chub population appears to be declining with little to no reproduction and recruitment and are likely a fraction of their historic abundance" (Steffensen & Huenemann, 2016, p. v). Catch rates are explained in more detail below:

> During 2015, 16 Sturgeon Chubs were captured with the standard otter trawl. Catch per unit effort for otter trawls were similar during the sturgeon season (CPUE = 0.07 fish per 100 m trawled; F = 3.65, df = 1, P = 0.0570) and the fish community season (CPUE = 0.02). This resulted in an overall CPUE of 0.04 for both seasons. Catch per unit effort during the sturgeon season was lower compared to the long-term mean (CPUE = 0.09), as was the CPUE during the fish community season (long-term mean CPUE = 0.09). Annual catch rates for both seasons combined were significantly different than the long term mean (t = 10.59, P < 0.0001). Pairwise comparison showed the 2015 catch rates were significantly lower than 2005 (t = 5.38, P < 0.0001) and 2006 (t = 3.64, P = 0.0167) and similar to all other years. (Steffensen & Huenemann, 2016, p. 53)

> During 2015, 54 Sicklefin Chubs were captured with the standard otter trawl and four with the standard mini-fyke net. Catch per unit effort for otter trawls were similar during the sturgeon season (CPUE = 0.09 fish per 100 m trawl) and the fish community season (CPUE = 0.19; F = 1.43, df = 1, P = 0.2335; Figure 21). This resulted in an overall CPUE of 0.14 for both seasons. Catch per unit effort during the sturgeon season was lower than the long-term mean (CPUE = 0.11); whereas, CPUE during the fish community season was higher compared to the long-term mean (CPUE = 0.14). The annual catch rates across both seasons varied significantly (F = 2.85, df = 12, P = 0.0007) but the pairwise comparisons showed the 2015 catch rates were similar to all previous years. (Steffensen & Huenemann, 2016, p. 56)

Sicklefin and Sturgeon Chub populations have been declining in this segment since 2006, likely due to the channelization of the river. The segment does not appear to support reproduction.

Kansas. There is little evidence that either species sustains reproductively viable populations in Kansas (Haslouer et al., 2005, p. 44). Haslouer et al. (2005) indicate that the Sturgeon Chub should be upgraded from state threatened to state endangered in Kansas, and that the species is extirpated or nearly so. "This species formerly occurred in the lower Smokey Hill and Kansas river, but none has been taken from these rivers in the last 25 years"(Haslouer et al., 2005, p. 36, *internal citations omitted)*. Haslouer et al. (2005, p. 33) recommend the retention of state endangered status for the Sicklefin Chub.

Segment 11. This segment of the Kansas River is partly channelized:

> The Kansas River below the Weir is channelized through the industrial area of Kansas City to the confluence, though no channel is maintained for navigation traffic. River banks are lined with revetment along the outside and inside bends of the River. Structures in this segment are few, but include very small wing dikes in some areas. There are various large boulder areas, refuse concrete slabs, junk cars, degraded areas with undercut banks, natural islands, and side chute habitats… In the upper sampling area, the River is mostly unchannelized. The five mile area just upstream of the Weir is mostly pooled, still water and the portion of the River above the pooled area consists of a few (10-15) randomly placed dikes and banks are revetted in areas. Otherwise, most of this area is braided, characterized by a shallow and shifting channel. (Whiteman et al., 2013, p. 5)

Machrybopsis species are generally rare in this reach: "Shoal chub (N = 11), silver chub (n = 9), and sicklefin chub (N = 1) were the only *Macrhybopsis spp.* captured in segment 11 during the 201[3] season**.** This is only the fifth year (2006, 2008, 2010, 2012, and 2013) since sampling began that sicklefin chub have been sampled in the Kansas River… No sturgeon chub have been captured in segment 11" (Garner et al., 2014, p. ii-iii). "Sicklefin chub were only sampled previously in Segment 11 during the 2006 (N = 1), 2008 (N = 2), 2010 (N = 1), and 2012 (N = 4) sampling years" (Garner et al., 2014, p. 52).

Segment 11 does not appear to support Sturgeon Chub and supports very low numbers of Sicklefin Chub, likely due to channelization and pollution (and possible instream sand dredging, see discussion of threats, below).

Missouri.

Segment 10. Segment 10 is highly altered but still contains chub habitat:

> Within segment 10, the USACE maintains a nine foot deep river channel for navigation traffic, bank revetment along the outside bends of the river, and has constructed various dike structures to create a self-cleaning navigation channel. Structures in this segment included kicker dikes, L-dikes, wing dikes, and rootless dikes. Some of these dikes have been notched or otherwise modified to increase habitat diversity, widen the channel, and prevent channel bed aggrading. There are few islands and side-channels in this segment, but expansive sand bars exist in some areas and are often exposed depending on river stage. (Niswonger et al., 2013, pp. 4-5)

Catch rates for these species do not show a detectable pattern in this segment, and tend to fluctuate with year and water level:

> Catch rate for *Macrhybopsis* spp. is variable across the sample years, showing no discernable pattern. CPUE for all three of the target species, sturgeon, sicklefin, and shoal chub, have been relatively higher in 2012 and 2013 than in previous year… CPUE for sicklefin for both season's combined were higher in 2013 than any other sample year, at 0.913 fish/ 100 m. Over both seasons, the highest catch rate for the most infrequently-captured *Macrhybopsis* species, sturgeon chub, was highest in 2012, at 0.172 fish/ 100, but second highest in 2013 at a close rate (0.141 fish/ 100 m). Very low catch rates were recorded in 2011 for the all three *Macrhybopsis* spp. However, the low catch rates may not be indicative of the population in

> 2011. During this sample years, there was sustained high water during most of the summer months during which we could not perform our standard sampling. In 2011, most (57%) of our sampling was performed in October, with only no effort in August, and only 6% in September. In the past years of sampling, most (52%) of our *Macrhybopsis* spp. have been captured during August and September. Therefore, if more sampling would have been during these two months, we may have captured more of these species. (Niswonger & Winders, 2014, p. 94)

Sturgeon Chub were the rarest *Macrhybopsis* species in this reach in 2012: "A total of 41 sturgeon chub was captured using standard gears in segment 10 during the 2012 sampling year. This was an increase from previous years (N=12, 31, 11 and 6 in 2008-2011, respectively)" (Niswonger et al., 2013, p. 45). Sicklefin chub were less rare: "A total of 109 sicklefin chub was captured in segment 10 during the 2012 season. Most (108) of the sicklefin chub were captured with standard otter trawl sampling. One sicklefin chub was captured with a trot line" (Niswonger et al., 2013, p. 48). "[2012] was the first year since 2009 that young-of-year sicklefin chub (less than 40 mm) have been been sampled" (Niswonger et al., 2013, p. 48).

Reproduction of sturgeon chub appears to be more consistent in recent years:

> A total of 31 sturgeon chub was captured using standard gears in segment 10 during the 2013 sampling year. This was a decrease from 2012 (N = 41), but an increase from previous years (N = 12, 31, 11 and 6 in 2008 – 2011, respectively). Most (N = 30) sturgeon chub were collected in standard otter trawl samples. One was captured in a mini-fyke net. Total lengths ranged from 17 to 88 mm in 2013. We captured six young-of-year (YOY) sturgeon chub (< 30 mm) in 2013, and eight YOY in 2012. In all previous years, from 2005 through 2011, we only caught eight total YOY sturgeon chub. (Niswonger & Winders, 2014, p. 63)

Sturgeon chub catch rate in otter trawls during the 2013 season was 0.913 fish/100 m (Niswonger & Winders, 2014, p. iii)

Sicklefin chub also appeared to be reproducing in 2013:

> A total of 146 sicklefin chub was captured in segment 10 during the 2013 season. Most (145) of the sicklefin chub were captured with standard otter trawl sampling. Most of these were captured in fish community season (91%), than during sturgeon season (9%). One sicklefin chub was captured with a mini-fyke net. The amount of sicklefin chub that have been captured over the last eight years of sampling has ranged from nine individuals captured (2011) to 146 (2013). The size range of sicklefin chub captured in 2013 was 15 to 96 mm. In 2013, along with 2102, were the only two years since 2009 that young-of-year sicklefin chub (less than 40 mm) have been been sampled. CPUE during 2013 was higher than any other year, at 0.913 fish/ 100 m (Figure 20). Mean CPUE in 2012 was 0.497 fish/ 100 m, which was no different than most other years. However, mean CPUE with otter trawls for the 2008 (0.178 fish/ 100 m) and 2011 season (0.041 fish/ 100 m) were lower than all other years. (Niswonger & Winders, 2014, p. 66)

Segment 10 appears to support a reproducing population of both species. There is no discernable population trend.

Segment 13. Segment 13, like most of the Missouri River, is highly altered. However, restoration efforts have created habitat for both chub species:

> Over the last two decades, the [Corps of Engineers] has undertaken efforts to restore lost and degraded habitats by notching dikes, creating "pilot channels" on the floodplain and by controlled spring releases from upstream dams to imitate portions of the natural hydrograph. In recent years, much emphasis has been given to these dike modification projects and many of the existing dikes in this reach of river have been altered. Notches are now deeper and wider, following modifications [initiated] in 2003 and can divert water to promote erosion-deposition processes. Dike types vary in design but, in general, outside bends contain L-shaped dikes pointing downstream while dikes on the inside bend are more perpendicular to water flow, projecting straight into the channel and slightly downstream. Subsequent habitats that exist behind modified dikes vary widely and can provide habitat and refuge for fish and other aquatic species. In its current condition, the river vaguely resembles the one explored by Lewis and Clark, though some remnant historical habitat types still exist at different water stages.

This segment had one of the two highest populations of both chub species in 2012:

> Catch per unit effort for sturgeon chub, sicklefin chub and shoal chub collected in otter trawls during the fish community season was the highest on record, with most of these fish being consistent with the size of age-0. However, CPUE for these same species during the sturgeon season was very low. Catch rates for *Macrhybopsis* spp. chub have experienced large annual variations since 2003. (Wrasse et al., 2013, p. iii).

The majority of Sturgeon and Sicklefin Chub were captured during the fish community season. "No sturgeon chub were captured in otter trawls during the 2012 sturgeon season; however, 77 sturgeon chub were collected during the fish community season resulting in a CPUE that was more than three times greater than any other year" (Wrasse et al., 2013, p. 57). "Only three sicklefin chub were captured with otter trawls during the sturgeon season; however 634 sicklefin chub were captured during the fish community season resulting in a CPUE that was more than three times greater than any other year " (Wrasse et al., 2013, p. 60). These numbers suggest that this reach supports a viable, reproducing population:

> The high abundances of small sturgeon, sicklefin, and shoal chub collected late in the 2012 season suggested that conditions were suitable for successful reproduction and survival of chubs. Age-0 *Macrhybopsis* chubs need low velocity refuges for successful recruitment (Ridenour et al. 2009). The low flows of 2012 created many shallow, slow velocity habitats which may have aided reproduction and/or survival of small chubs. Anecdotal observations suggest there is currently an increased amount of exposed gravel substrate which could also benefit sturgeon chubs which are known to inhabit gravel substrates. (Wrasse et al., 2013, p. 85)

However, the populations of both species have declined in the most recent sampling year, potentially due to high summer flows limiting low velocity habitats:

> Relative abundances of *Macrhybopsis* chubs declined in 2015 following three consecutive years of relatively high relative abundances. While the mechanisms driving *Macrhybopsis* populations in the Missouri River are not fully understood, we have noted relative high catch rates of age-0 size chubs during years of low summer flows, and conversely, lower catch rates during years of high summer flows. Chubs need relatively slow velocity habitat to recruit, but these slow velocity habitats are limited during high flows in Segment 13. (Wrasse, 2016, p. iii)
>
> We captured a total of 14 Sturgeon Chub in 2015 compared with 225 in 2014. Sturgeon Chub otter trawl CPUE (0.046 fish/100m) in 2015 declined by 92% from 2014. From 2012-2014 Sturgeon Chub CPUEs were above the long-term monitoring average; however, the 2015 CPUE was similar to pre-2012 levels. (Wrasse, 2016, p. 54)
>
> A total of 135 Sicklefin Chub were collected. Sicklefin Chub CPUE (0.95 fish/100m) for otter trawl during the 2015 sturgeon season was similar to 2014. However, CPUE decreased to 0.18 fish/100m during the fish community season – an 87% decrease from 2014. (Wrasse, 2016, p. 57)

Segment 13 supports a reproducing population of both species, though both declined in 2015 after three years of relatively high abundance.

Segment 14. Segement 14 had the greatest abundance of Sicklefin and Sturgeon Chub in 2012, and the population appears to be reproducing.

> We collected 122 sturgeon chubs (105 with standard gears) in Segment 14 during 2012. All sturgeon chubs were captured during the fish community season using otter trawls (121) or mini-fyke nets (1). Mean sturgeon chub CPUE during the fish community season was 0.50 fish/100 m ± 0.17, the highest catch rate since the beginning of the fish community monitoring program in 2003. Sturgeon chubs ranged in length from 26 to 93 mm TL. Fifteen sturgeon chubs were collected in Segment 14 that were consistent with age-0 size fish (< 40 mm TL). Only two sturgeon chubs > 80 mm TL were collected during 2012, indicating that the majority of sturgeon chubs captured in Segment 14 were likely between the ages of 1 and 4. (Meyer et al., 2013, p. 56, *internal citations omitted*).
>
> We collected 1,433 sicklefin chubs (1,376 with standard gears) in Segment 14 during 2012. All sicklefin chubs were captured during the fish community season using otter trawls (1,431) or mini-fyke nets (2). Mean sicklefin chub CPUE during the fish community season was 6.89 fish/100 m ± 2.53, the highest catch rate since the beginning of the monitoring program in 2003, and 84.5% greater than CPUE in 2004 (second highest CPUE on record; Figure 20). Sicklefin chubs ranged in length from 20 to 86 mm TL (Figure 21). We collected 159 sicklefin chubs in Segment 14 that were consistent with age-0 size fish (< 30 mm TL). No sicklefin chubs > 90 mm TL were collected during 2012, indicating that the majority of sicklefin chubs (89%) captured in Segment 14 were likely between the ages of 1 and 3. (Meyer et al., 2013, p. 59, *internal citations omitted*)

The most recent sampling data indicates a decline from 2014 for both species:

> We collected 30 Sturgeon Chub during standard sampling in Segment 14; all from otter trawls. Mean Sturgeon Chub CPUE from otter trawls during sturgeon season and fish community season was 0.14 fish/100m ± 0.09 and 0.11 fish/100 m ± 0.08, respectively. Overall, CPUE in 2015 continues to be at or above the 13-year mean of 0.04 fish/100m ± 0.03 (sturgeon season), 0.11 fish/100m ± 0.07 (fish community season); however, catch rates are notably lower than in 2014. (Herman & Wrasse 2016, p. 57)
>
> We collected 213 Sicklefin Chub with standard gears in Segment 14 during 2015... Mean Sicklefin Chub otter trawl CPUE during the sturgeon season (0.77 fish/100 m ± 0.32) was the higher than the 13-year average (0.29 fish/100 ± 0.19) but lower than effort in 2014 (0.89 fish/100 m ± 0.43). Mean otter trawl CPUE during the fish community season (0.80 fish/100 m ± 0.35) and both seasons combined (0.79 fish/ 100m ±0.27) were the third highest since 2013; however, a marked decline from 2014 was observed (Herman & Wrasse 2016, p. 60)

Segment 14 supports a reproducing population of both species, though both declined in 2015.

Mississippi River and tributaries. As of 2001, based on four years of data, Sturgeon Chub were uncommon, but not rare in the Middle Mississippi, and their numbers were steady to slightly increasing (USFWS, 2001b, p. 35). "[H]abitat in the Middle and Lower Mississippi River has been altered by the construction of dike fields, bendway weirs, and other structures designed to maintain the navigation channel. However, due to the lack of data documenting [sturgeon] chub populations in the Mississippi River the importance of this population and the full extent of impacts are unknown" (USFWS, 2001b, p. 14). Currently, viable populations exist in the middle Mississippi River and the Wolf Island area of the lower Mississippi River (Hammerson et al., 2015, p. 2). The Sturgeon Chub was the fifth most abundant species captured during trawling studies, but was among the 19 species that constituted only seven percent of the total catch (Jackson, 2002, p. 19).

As of 2001, "due to the lack of data documenting sicklefin chub populations in the Mississippi River the importance of this population and the full extent of impacts are unknown" (USFWS, 2001b, p. 11). Despite this lack of data, the Service concluded in 2001 that "[s]icklefin chub are uncommon and perhaps borderline rare in the Middle Mississippi River. Collections made during the past four field seasons suggest that sicklefin chub numbers are slightly decreasing" (USFWS, 2001b, p. 35).

More recent research supports a declining population of Sicklefin Chub in the Mississippi River. The Sicklefin Chub was the eleventh most abundant species captured during trawling studies in the middle Mississippi, and was among the 19 species that constituted only seven percent of the total catch (Jackson, 2002, p. 19). Sicklefin Chub were among the rarest species captured, which the author believes is due to a decline in their population density. "It is the sturgeon chub that is listed as an endangered species in the state of Illinois, but it is the sicklefin chub that appears to be far rarer" (Jackson, 2002, p. 28).

The Upper Mississippi River Restoration Program's Long Term Resource Monitoring Program (LTRMP) monitors one site in historic Sicklefin and Sturgeon Chub range on the Mississippi; the Open River sampling site, located between Grand Tower and the confluence of the Ohio River (Figure 9). Annual monitoring conducted by the Open River Field Station found rare occurrences of Sicklefin Chub and almost no Sturgeon Chub. Sicklefin Chub were collected at this site in 1991 (2) (Gutreuter et al., 1998), 1992 (37) (Gutreuter et al., 1997a), 1995 (1) (Gutreuter et al., 1997b), 1997

(6) (Burkhardt et al., 1998), 1998 (2) (Burkhardt et al., 2000), and 2015 (CPUE 0.46) (USGS, 2016), but not at any other time (Bartels et al., 2004a; Bartels et al., 2004b; Bartels et al., 2006a; Bartels et al., 2006b; Bartels et al., 2007; Bartels et al., 2008; Burkhardt et al., 1997; Burkhardt et al., 2001; Burkhardt et al., 2004a; Burkhardt et al., 2004b; Gutreuter et al., 1997a, Gutreuter et al., 1997b; USGS, 2016).

One Sturgeon Chub was captured at the Open River sampling site in 2003 (Bartels et al., 2004b, Table 3.5), but no others have been collected by the LTRMP (Bartels et al., 2004a; Bartels et al., 2004b; Bartels et al., 2006a; Bartels et al., 2006b; Bartels et al., 2007, Bartels et al., 2008; ; Burkhardt et al., 1997; Burkhardt et al., 2000; Burkhardt et al., 2001; Burkhardt et al., 2004a; Burkhardt et al., 2004b; Gutreuter et al., 1997a; Gutreuter et al., 1997b; Gutreuter et al., 1997c, Gutreuter et al., 1997d; Gutreuter et al., 1998; USGS, 2016).

There is little recent information about Sicklefin and Sturgeon Chub population trends in the Mississippi River, but the little information that does exist appears to indicate rare or declining populations.

Summary. The 2001 finding states that both species "comprise a significant portion of the Missouri River fish community above Fort Peck Reservoir in Montana, in the Yellowstone/Missouri River confluence area in Montana and North Dakota, and in the Lower Missouri River in Missouri" and that both species have viable populations in the Middle Mississippi River and in the Wolf Island area of the Lower Mississippi River (USFWS, 2001a, p. 19,912). These ostensible population strongholds are fragmented and dwindling, and have an uncertain future.

Above Fort Peck Reservoir, there have not been many recent studies on Sicklefin and Sturgeon Chub populations. What little information exists points to declines in 2012 and 2013 (UBPSW, 2014, p. 96).

In the Yellowstone/Missouri River confluence areas, catch rates for the Sicklefin and Sturgeon Chub were highest in the least altered segments studied (Welker & Scarnecchia, 2004, p. 20), suggesting that the species are associated with rare unaltered river segments. In Segment 4, the closest PSPAP segment to the confluence,"[t]here has been a steady decline in both the numbers and catch per unit effort of sicklefin and sturgeon chub with the otter trawl since 2009" (UBPSW, 2014, p. 11). In relation to the confluence, fish numbers in the Middle Powder River Watershed have declined, and the rarity of Sturgeon Chub in the Powder River Basin was deemed "alarming" (Stagliano, 2012, p. 17).

Of the Missouri River segments studied by the PSPAP, it appears that only Segments 3, 10, 13, and 14 in the Lower Missouri River support healthy, reproducing populations of Sicklefin and Sturgeon Chub (though it is unclear if Segment 3 supports Sicklefin Chub reproduction). Even in the segments with the healthiest populations-—Segments 10, 13, and 14—a significant negative population trend was detected between 2006 and 2008 (Oldenburg et al., 2010, p. vii). In all other segments, populations are extirpated, declining, rare, and/or dominated by adult fish (*see discussions of individual segments, above*).

Sicklefin Chub were among the rarest species captured in the Middle Mississippi, and appear to be decreasing. A sampling site in historic Sturgeon Chub range on the Mississippi has captured only one Sturgeon Chub since 1991. No other information is available to indicate whether or not the Mississippi River populations are still viable.

IDENTIFIED THREATS TO THE PETITIONED SPECIES: CRITERIA FOR LISTING

The Service must evaluate whether a species is "threatened" or "endangered" as a result of any of the five listing factors set forth in 16 U.S.C. § 1533(a)(1):

> A. The present or threatened destruction, modification, or curtailment of its habitat or range;
> B. Overutilization for commercial, recreational, scientific, or educational purposes;
> C. Disease or predation;
> D. The inadequacy of existing regulatory mechanisms; or
> E. Other natural or manmade factors affecting its continued existence.

"More than 20 percent of the world's 10,000 freshwater species have become extinct, threatened or endangered in recent decades" (Wong et al., 2007, p. 5, *internal citations omitted).* Ricciardi and Rasmussen (1999, p. 1,221) predict a future extinction rate of ~4 percent per decade for freshwater fishes, mollusks, crayfish, and amphibians, and a 2.4 percent future extinction rate for freshwater fishes. Almost 40 percent of North American fishes are currently imperiled; of those that were considered imperiled in 1989, most (89 percent) are currently in the same or worse conservation condition (Jelks et al., 2008, p. 372). The loss of biodiversity in freshwater ecosystems is attributed to anthropogenic disturbances including changes in land use, climate change, nitrogen deposition (Sala et al., 2000, p. 1,772) introduction of nonnative species, habitat degradation, and introduction of diseases and parasites (Jelks et al., 2008, p. 382). Conservation relies on refugia:

> Ultimate conservation of global biological diversity partly relies on viable refuges nested within human-dominated landscapes. This is particularly evident for aquatic biota of river systems in semi-arid, arid, or heavily populated regions where water development for human use results in appropriation of water supplies, fragmentation and degradation of natural habitats, alteration of natural processes, and invasion of non-native species. (Hoagstrom et al, 2011, p. 28, *internal citations omitted*)

Sicklefin and Sturgeon Chub are threatened in particular by channel changes, dispersal barriers, and water withdrawal/drought (Hoagstrom et al., 2006, p. 202). In Wyoming, "[h]abitat degradation (e.g., dewatering, loss of connectivity) and introduced species pose the most serious threats to [the sturgeon chubs'] persistence" (WGFD, 2010, p. IV-3-83).

(Factor A) The Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Habitat fragmentation. Habitat fragmentation is one of the most serious threats to freshwater fish of the Great Plains. "Human disturbances have impacted endemic fishes of the plains by degrading characteristic habitats (dewatering, fragmentation, geomorphic and flow regime degradation, non-native introductions, pollution) and restricting dispersal (fragmentation)" (Hoagstrom et al., 2011, p. 28).

Pelagic-spawning cyprinids, in particular, are vulnerable to habitat fragmentation. "Pelagic-spawning cyprinid communities inhabiting fragmented streams throughout the Great Plains represent a disappearing guild of fishes," and a "growing body of literature suggests imperilment of pelagic-spawning cyprinid species is a direct consequence of stream fragmentation" (Perkin et al., 2010, p. 11; *see also* Wilde & Urbanczyck, 2013). Models of stream fragments revealed that fragmentation explained the majority of variation associated with Great Plains pelagic-spawning cyprinid declines (Perkin et al., 2010, p. 11) and that river fragment length explained 71 percent of cumulative extirpations among these species (Wilde & Urbanczyck, 2013, p. 445).

The Missouri River has changed dramatically in the last two centuries. "The predevelopment Missouri River exhibited a braided, sandbar, and island filled channel that had continually shifting banks due to sediment erosion and deposition. Overbank floods were common, turbidity was high, and enormous quantities of sediment were transported to the Mississippi River" (Galat et al., 2005, p. 254). This is quite different from current conditions:

> The present-day lower Missouri River hardly resembles the river that Lewis and Clark explored over 200 years ago. In its natural setting, river banks caved readily during floods. Shallow sandbars were numerous during normal flows and often split into many smaller channels with sand in between, and through the intricate process of channel migration and bank sloughing, side-channel chutes and cutoff lakes were numerous. However, dramatic changes have occurred along most of the Missouri River. The Missouri River Bank Stabilization and Navigation Project (BSNP) and Pick Sloan Project included seven different acts of legislation that has brought about the damming and channelization of the Missouri River since the early 1900s. The BSNP is multi-purpose with primary objectives being flood control, bank stabilization, navigation, hydroelectric generation, and land reclamation along the lower third of the Missouri River. These various acts have resulted in 67% of the river's length being impounded or channelized at an estimated cost of 6.1 billion dollars (Whiteman et al., 2011, p. 100, *internal citations omitted*)

Large portions of the river have been converted by impoundments and channelization:

> Thirteen hundred km of the lower Missouri River has now permanently accreted to terrestrial habitat. The channelized Missouri River (e.g., below the lowermost reservoir near Yankton, SD, USA) has lost nearly all of the sandbars, sloughs, chutes, backwaters, and cutoff lakes. A large loss of available fish habitat has resulted from these changes. The Missouri River has had 1.6 million ha of its ecosystem switched to agriculture or inundated with reservoir waters. This has changed the fish diversity in portions of the Missouri River. (Whiteman et al., 2011, p. 106, *internal citations omitted*)
>
> Collectively, basin and channel-floodplain development have transformed nearly one-third of the Missouri River's lotic habitat into lentic reservoirs. Longitudinal and lateral connectivity has been fragmented, sediment transport and turbidity below reservoirs drastically reduced, and channel geomorphology altered through bed and bank degradation. (Galat et al., 2005, p. 254).
>
> The Missouri River… has been heavily modified and fragmented to fit the needs of human civilization. The physical effects of these anthropogenic alterations have reduced the total

surface area of the Missouri River by over 67%, the total river length by at least 204 km and eliminated over 178 million ha of river channel, erosion zone, floodplain grass and timber and tributary valley lands. In concert with river alteration, populations of sicklefin chub *Macrhybopsis meeki* and *M. gelida* have been extirpated from over half of the river's length, and their numbers continue to decline. (Starks et al., 2016, p. 1,336, *internal citations omitted*)

Impoundments and the resulting habitat transformations fragment native pelagic-spawning cyprinid habitat. The availability of downstream transport (unfragmented river kilometers) is important for the pelagic-spawning reproductive guild because "high mortality rates occur among ichthyoplankton [drifting eggs and larvae] deposited within downstream reservoirs, due to suffocation within anoxic sediments or predation from lacustrine species" (Perkin & Gido, 2011, p 372, *internal citations omitted*).

> Fragmented longitudinal connectivity threatens spawning success among [pelagic-broadcast spawning] species as evidenced by lack of recruits during periods of isolated pool formation, despite evidence that spawning occurs within isolated pools. Furthermore, fragmented longitudinal connectivity threatens ichthyoplankton survival by washing drifting individuals into downstream reservoirs where they eventually settle and suffocate within sediments. (Worthington et al., unpublished data, *internal citations omitted*)

Pelagic-spawning cyprinids also depend on unobstructed rivers and streams for recolonizing areas as adults:

> Pelagic-spawning cyprinids dispense gametes into pelagic zones of flowing streams. Immediately following spawning, water enters the chorion membrane and fills the perivitelline space of eggs, causing eggs to swell and become semi-buoyant. These semi-buoyant eggs remain suspended within the water column and drift for 24-28 hours before hatching, after which pre-larvae develop as they drift for an additional 2-3 days, presumably becoming displaced great distances (e.g., up to 140 km) downstream from parent localities. Stockpiling of reproductively active adults below barriers suggests migration during reproduction, which provides a mechanism for recolonization of upstream reaches following downstream drift of pre-larva. Stream fragmentation therefore carries the potential to negatively impact the spatial dynamics of pelagic-spawning cyprinids via interruption of dispersal across two planes of space (i.e., in downstream and upstream directions) and time (i.e., during pre-larval and adult life stages). (Perkin et al., 2010, pp. 3-4, *internal citations omitted*)

A study of four cyprinids, including the Sturgeon Chub, found that impoundments decreased native cyprinid populations both upstream and downstream:

> Reaches without any large impoundments in their watershed had a high percentage of fine substrate, high catch rates of turbid-river cyprinids, few exotic piscivores, and little gravel or large rocky substrate. Reaches with a downstream impoundment (i.e., within 200 km) had habitat characteristics similar to those without impoundments but had few turbid-river cyprinids and many exotic piscivores. Reaches with an upstream impoundment (i.e., within 200 km) had little fine substrate, a high percentage of large rocky substrate, few turbid-river cyprinids, and many exotic piscivores. Our results suggest that impoundments have had a substantial influence on the distribution and abundance of cyprinid species adapted to

> hydrologically dynamic, turbid prairie streams and that conserving these species is dependent on maintaining natural flow and sediment transport regimes and on reducing habitat suitability for exotic piscivores. (Quist & Hubert, 2004, p. 727)
>
> Several factors increase extinction risk in shorter reaches: (i) more direct impacts of dams lessen habitat suitability and retentive capacity; (ii) retentive capacity is less due to fragment length; (iii) less habitat in shorter frag- ments supports smaller populations more susceptible to flux-related extinction; and (iv) nonnative species are more prevalent near impoundments. (Hoagstrom, 2015, p. 4, *internal citations omitted*)

Reconnecting fragmented river reaches may be the most important conservation action we can take for river fauna: "Neither natural flow regimes nor habitat restoration efforts are likely to result in long-term recovery of pelagophils without also restoring connectivity between fragmented river reaches. It is becoming increasingly apparent that solutions to river fragmentation and regulation need to be conceptualized and implemented at the catchment scale" (Dudley & Platania, 2007, p. 2,084, *internal citations omitted*).

Channelization. Channelization and simplification of rivers can change the various components of a river flow regime, including rate of flow which affects the transport speed and distance of ichthyoplankton. "For pelagic-broadcast spawning cyprinids, increased habitat complexity may reduce downstream transport distance of ichthyoplankton… [S]lower transport rates in reaches with wider and more braided channel morphology would allow more time for developing eggs and larva to reach their free-swimming stage" (Worthington et al., 2014, p. 6). Altering the natural flow regime and reducing the geomorphic complexity of river habitats potentially increases the length of unfragmented river habitat required for ichthyoplankton to mature (Worthington et al., 2014, p. 7).

Dams. Dams alter key ecological attributes of a natural flow regime, including sediment dynamics and timing and extent of flows (*see, e.g.,* Bunn & Arthington, 2002; Ligon et al., 1995; Poff et al., 2007; Power et al., 1996). Dams therefore fundamentally change the ecosystem integrity of river systems.

Dam construction is one of the major causes of river fragmentation and is leading to declines in freshwater diversity:

> Construction and operation of dams and reservoirs for flood control, hydroelectric power generation, and irrigation have led to global declines in the abundance and diversity of freshwater fauna. Dams and reservoirs block natural migration routes of many freshwater fishes and increase the likelihood of extirpation or extinction by fragmenting populations. Numerous obligate freshwater fish species may be particularly affected by river regulation because their eggs and larvae (propagules) drift passively downstream with the water current. Drifting propagules require a specific developmental time to become free-swimming individuals capable of seeking nursery habitats. However, river fragmentation and regulation have reduced the available time that propagules can drift prior to being swept into unsuitable downstream environments such as reservoirs or irrigation networks. (Dudley & Platania, 2007, p. 2,074, *internal citations omitted*)

Even small diversion dams impact pelagic-spawning cyprinids. Perkin et al. (2014) stated that "[a]ll pelagic-spawning and pelagic substrate-spawning fishes included in this study have experienced range reductions caused by fragmentation throughout the Great Plains, but the results presented here extend the known effects of fragmentation beyond mostly large structures to include even small diversion dams" (p. 12, *internal citations omitted*). "Although documented occurrences indicate that fishes belonging to these guilds once occupied the now fragmented upstream portions of [the Arkansas and Ninnescah] rivers, small dams have apparently truncated longitudinal distributions" (Perkin et al., 2014, p. 12, *internal citations omitted*).

Yellowstone River. The Lower Yellowstone Project, begun in 1905, included the construction of the Intake Diversion Dam (also known as Yellowstone River Diversion Dam), a wood and stone diversion dam that spans the Yellowstone River and is submerged under water year-round. The Intake Diversion Dam is located approximately 70 miles upstream from the confluence of the Yellowstone and Missouri Rivers near Glendive, Montana.

In order to improve fish passage for Pallid Sturgeon and other native fish, the U.S. Army Corps of Engineers is planning to construct a concrete weir and a fish bypass channel. The Corps asserts that this project is likely to improve conditions for Pallid Sturgeon, but the degree of improvement will not be known until the project is completed (USDOI & USACE, 2015, p. ES-5). And the assertion that it will improve conditions is contested (*see* Hunter, 2015). It is also unknown if, or how much, the project will improve connectivity for populations of Sturgeon and Sicklefin Chub in the Yellowstone and Missouri rivers.

Missouri River. The distribution and abundance of both Sicklefin and Sturgeon Chub decreased following the construction of six main stem Missouri River dams (Everett et al., 2004, p. 183). These dams, as well as agricultural and urban development, have resulted in significant habitat changes along most of the Missouri River, including alterations of the natural flow of the river, altered river temperatures, and decreases in turbidity. Many portions of the Missouri River now consist of a single, narrow, deep channel with swiftly flowing water. Additionally, the reservoirs above each dam serve as sediment sinks, limiting the downstream movement of sediment and reducing turbidity (Everett et al., 2004, p. 184). "After completion of the six main-stem dams on the middle Missouri River, suspended-sediment concentrations on the lower Missouri River declined by as much as 80 percent; average annual sediment load transported to the Mississippi River declined by at least 60 percent" (Alexander et al., 2012, p. 20, *internal citations omitted*).

Mississippi River. Work to channelize the Mississippi River has been ongoing since 1927, and at the time of the Status Review the work was about 66 percent complete, with 111 miles of stone dikes, 169 miles of rock revetment, and 16 miles of bendway weirs constructed to narrow the channel for navigation (USFWS, 2001b, p. 44).

Currently, the middle (from St. Louis, Mo., to the confluence with the Ohio River) and lower (from the confluence with the Ohio River to the Gulf of Mexico) sections of the Mississippi River are not impounded by any main-channel dams (Alexander et al., 2012, p. 11). "Fish that inhabit swift-current habitats in the unimpounded lower Mississippi River have not declined as much as in the upper Mississippi River" (Alexander et al., 2012, p. 31, *internal citations omitted*).

Altered hydrology. Habitat fragmentation interacts with altered hydrology to threaten fish species. "Reproductive success for pelagic-broadcast spawning cyprinids is thought to be intrinsically linked to flow availability and magnitude. Spawning may take place at any point during the extended reproductive period, with an increase in reproduction in response to high flow events. However, reproductive success is thought to be non-existent during period of no flow" (Worthington et al., 2013, p. 1, *internal citations omitted*). "Members of th[e] 'pelagic-broadcast spawning' reproductive guild decline in association with fragmentation of riverscapes, reduced discharge magnitude, and especially when both factors are combined" (Perkin et al, 2015, p. 74, *internal citations omitted*).

Using a Principle Components Analysis including fragment length, discharge magnitude, and percentage of days without flow, researchers discovered that "predicted species richness declined… from 18 species in fragments with extreme negative PC1 scores (longer and wetter fragments) to eight among fragments with extreme positive PC1 scores (shorter and drier fragments). Similarly, the proportion of pelagic-spawning fishes declined… while the proportion of benthic-spawning fishes increased… resulting in a shift in dominance from pelagic- to benthic-spawning fishes moving positively along PC1" (Perkin et al., 2015, pp. 80-81). "Among extensively dewatered habitats, the fishes most sensitive to fragmentation did not persist despite greater longitudinal lengths because these same guilds were also most sensitive to the effects of stream desiccation" (Perkin et al., 2015, p. 83).

Restoring the natural hydrograph is listed among important actions that need to be taken to prevent fish extinctions in the Missouri River:

> The history of changes in the fish communities up and down the Missouri River has resulted from the complex interactions between natural and human factors. However, the richness of the Missouri River's native fish populations remains relatively intact despite these assaults; no native fish have yet been extirpated although the pallid sturgeon is on the Federal list of endangered species. Nevertheless, the widespread and long history of human intervention has contributed to declines of about 25 percent of the species. Partly as a result of these declines, the National Research Council (2002) has suggested that the degradation of the Missouri River ecosystem will continue unless the part of the hydrologic and geomorphic processes that sustained the preregulation Missouri River and flood-plain ecosystem is restored. Otherwise, the Missouri River ecosystem will face the prospect of extinction of species. These processes include flood pulses that emulate the natural hydrograph and cut-and-fill alluviation associated with river meandering. (Alexander et al., 2012, p. 32, *some internal citations omitted*)

Water depletion. Water diversion for municipal, agricultural, and energy related industrial uses within the Missouri River basin impacts Sicklefin and Sturgeon Chub populations and habitats (USFWS, 2001b, p. 45).

> Great Plains stream fishes are highly adapted to harsh conditions and can migrate to areas of permanent water, reproduce quickly, or withstand poor water quality in isolated pools. Nevertheless, water withdrawals in a number of semiarid regions, including the Great Plains, have exacerbated stream drying and eliminated many spring refugia, while impoundments have restricted the movement of fishes and further fragmented populations. These alterations to prairie streams have had profound effects on the otherwise tolerant fish

> communities. Perhaps the most heavily affected guild of fishes consists of the large-river minnows that release semi-buoyant eggs during turbid storm events (e.g., *Hybognathus, Macrhybopsis,* and several *Notropis* spp.). This is regrettable, because these fishes have historically defined Great Plains river vertebrate communities. (Dodds et al., 2004, p. 214, *internal citations omitted*)

The 2001 Status Report identified "areas of concern" for water depletion in the Upper Missouri River and Lower Yellowstone River basin in Montana and North Dakota, and the Platte River in Nebraska (USFWS, 2001b, p. 45). "Much of the flow of the Platte River has been depleted and other water development projects have been proposed or are under construction in the Colorado and Wyoming portions of the basin. The Lower Platte River has experienced substantial depletion of flows during high runoff periods over the past century" (USFWS, 2001b, p. 45).

"The Lower Yellowstone River and Missouri River upstream and downstream of the confluence of these two rivers, collectively known as the Mon-Dak irrigation frontier, are subject to considerable water depletion projects for irrigation purposes" (USFWS, 2001b, p. 45). This is one of the areas mentioned as a population stronghold for both chub species (*see above*).

The 2001 Status Report identified a Montana plan that would "require an unquantified amount of water depletions from the Yellowstone and Missouri Rivers and their tributaries" (USFWS, 2001b, p. 46) in order to meet the goal of increasing irrigation in eastern Montana by 500,000 ac by 2005. As of 2003, "more than 18,000 acres of land [had] been put into irrigated crop production," and additional projects were pending (Brewster, 2003, p. 3).

Water depletion appears to interact with river fragmentation to "rachet down" fish populations, particularly pelagic-spawning fishes. "[I]nteractions between fragmentation and drying are hypothesized as operating as an ecological ratchet mechanism in which forward movement toward pelagic-spawning fish extirpation occurs during desiccation, and reciprocated reverse movement toward recolonization following return of flows is blocked by fragmentation" (Perkin et al., 2014, p. 1). This hypothesis is supported by the decline of three pelagic-spawning species following droughts in fragemented riverscapes:

> [F]ollowing fragmentation and consequently dewatering, the effects of drought became increasingly effective at causing declines among pelagic-spawning fishes even in the largest of the remaining stream fragments, as illustrated here on at least three occasions. First, the drought cycle of 2001-2003 caused punctuated decline, but not extirpation, of plains minnow and peppered chub in the Arkansas River. Second, following the 2001-2003 drought cycle, occurrences of both species remained low until the next drought cycle of 2005-2007, during which plains minnow occurrence declined to zero. Third, during the drought cycle of 2010-2013, the probability of occurrence for peppered chub closely followed the pattern of plains minnow during the previous drought cycle, including declining to zero occurrence. (Perkin et al, 2014, p. 12)

"[F]uture drought combined with effects of past and ongoing disturbance could result in rapid, widespread losses of endemic fish populations" in the Great Plains (Hoagstrom et al., 2011, p. 28, *internal citations omitted*). "As slowing ratcheting will become increasingly challenging under the expected warmer and drier climatic conditions of the future, implementing sustainable water management approaches aimed at conserving freshwater resources is crucial" (Perkin et al., 2014, p. 14, *internal citations omitted*). "Water management is challenging in its own right, so unless planning explicitly includes measures to preserve or restore endemic fish refuges and lower extinction debts, extinction risk will likely increase and extinctions will likely continue" (Hoagstrom et al., 2011, pp. 30-31, *internal citations omitted*).

Energy development. "The Powder River Basin in Wyoming and Montana is currently undergoing one of the world's largest coalbed natural gas (CBNG) developments, with about 12,000 wells in place in 2003, 14,200 in 2005, and up to 70,000 projected over the next 20 to 30 years" (Stagliano, 2012, p. 1). Discharge of coalbead methane effluent water has changed the flow regime in the Powder River, likely to the detriment of native fish:

> Decreasing occurrences of zero flow days, despite reduced precipitation regimes, may be linked to direct discharge of coalbed methane effluent water to the Powder River watershed in Wyoming. Periods of low or no flow, in addition to high flow periods, are integral in shaping and maintaining native fish assemblages in unfragmented prairie river systems. Alterations to stream habitat, and the timing and intensity of extreme flow events may make the Powder River system more hospitable to nonnative species. (Senecal et al., 2015, p. 10, *internal citations omitted*)

Development of coalbed methane mining (CBM) threatens prairie streams and rivers in the Powder River Basin of northeastern Wyoming and south-central Montana (Freilich, 2004). In 2004, federal and state agencies were in the process of permitting more than 100,000 new CBM wells in the Powder River Basin (Freilich, 2004). These permits would encompass an area larger than Connecticut and Massachusetts combined (Freilich, 2004). "These wells will, using even the most conservative estimates, release many trillions of cubic meters of produced water [similar to the polluted water produced by fracking] to the surface," impacting the Powder, Little Powder, Belle Fourche, and Cheyenne rivers by increasing flows and disrupting the intermittent nature of flows (Freilich, 2004). "Coalbed natural gas (CBNG) development has the potential to influence species in Great Plains streams due to increases in salinity, alkalinity, magnesium, and sulphate" (Worthington et al., unpublished data, *internal citations omitted*).

Oil spills are on the rise in North Dakota (Sontag & Gebeloff, 2014, p. 4). In July 2011, approximately 42,000 gallons of oil spilled into the Yellowstone River upstream of Billings, Montana (EPA, 2011, p. 2). In January 2015, approximately 30,000 gallons of crude oil spilled into the Yellowstone River upstream of Glendive, Montana (MDEQ, 2015).

Brine, a product of hydraulic facturing with high salinity and possibly containing fracking fluids and petroleum, has spilled into Sicklefin and Sturgeon Chub habitat. A pipeline near Williston, North Dakota, spilled three million gallons of brine in 2015 in a leak that reached the Missouri; the largest saltwater spill in the state's history (*see* Jacobson, 2015).

Pollution. PSPAP Segment 11, on the Kansas River, flows through a highly industrialized portion of the Kansas City metropolitan area (Whiteman et al., 2013, p. 82). "High concentrations of nitrogen and phosphorus have been documented in water quality studies on the Kansas River and poor water quality associated with urban environments may be the cause of low numbers or absence of many native benthic fishes" (Whiteman et al., 2013, p. 82).

Instream sand dredging. Sand and gravel mining in the Kansas River impact riverine habitat. Dredge sites resemble reservoirs (deep water, low velocity), and contained more generalist and lentic species, "which has been indicated as sign of habitat degradation in large rivers" (Paukert et al., 2008, p. 630, *internal citations omitted*). Sicklefin and Sturgeon Chub have not been documented in the Kansas River for 20 years or more (Paukert et al., 2008, p. 631). "Although the loss of these fishes cannot be directly linked to dredging, these fishes typically prefer the swift currents of large rivers. Therefore, creation of low-velocity habitats at dredged sites may not be suitable for large-river fishes, and efforts to reintroduce these fishes to provide suitable habitat could be hampered by these low-velocity habitats" (Paukert et al., 2008, p. 631, *internal citations omitted*).

(Factor C) Disease or Predation

The Walleye (*Stizostedium vitreum*), White Bass (*Morone chrysops*), Skipjack Herring (*Alosa chrysochloris*), and Northern Pike (*Esox lucius*) are all piscivorous fish that either have been introduced to the Missouri River and its tributaries or have become much greater in abundance in response to changed river conditions (USFWS, 2001b, p. 47). Given the diminishing populations of Sicklefin and Sturgeon Chub, predation by non-native fish and increased predation by native fish could take a heavy toll on both species.

Non-native predators. Introduction of non-native piscivorous fishes adapted to modified habitat conditions and decreased turbidities may contribute to the vulnerability of the Sicklefin and Sturgeon Chub to predation (USFWS, 2001b, p. 47), as "[a]lterations that stabilize habitat also allow for the establishment of nonnative fish predators and competitors" (Quist & Hubert, 2004, p. 728). In the Missouri River drainage in Wyoming, a study suggests that "the abundance of turbid-river cyprinids… was related to substrate composition and the abundance of exotic piscivores, all of which were associated with the presence and location of large, main-stem impoundments in the watershed" (Quist & Hubert, 2004, p. 734). In that same study, "reaches upstream from impoundments generally had the same number of exotic piscivores as reaches downstream from reservoirs despite differences in habitat. The most common piscivores were smallmouth bass, green sunfish, and rock bass, which have been shown to be important predators on native fishes in the Great Plains" (Quist & Hubert, 2004, p. 740).

Increases in predation by native fish. Sicklefin and Sturgeon Chub have been identified as major prey sources for a number of native fishes including Sauger (*Stizostedion canadense*), Pallid Sturgeon (*Scaphirhynchus albus*), and Channel Catfish (*Ictalurus punctatus*) (USFWS, 2001b, p. 47). Sicklefin and Sturgeon Chub are important prey species for juvenile Pallid Sturgeon:

> Sicklefin chub and sturgeon chub, two species that have been negatively affected by anthropogenic habitat alterations in many areas of the Missouri River, were the primary prey of juvenile pallid sturgeon in one of the least-altered sections of the Missouri River. Reduced availability of these prey in the upper Missouri River may reduce survival, growth, and maturation rates in hatchery-reared juvenile pallid sturgeon. Thus, the use of sicklefin chub and sturgeon chub by juvenile pallid sturgeon as a food resource indicates that recovery and management of native cyprinids in the upper Missouri River is an important step to the long-term recovery of pallid sturgeon. (Gerrity et al., 2006, p. 607).

In areas with populations of Pallid Sturgeon, Sicklefin and Sturgeon Chub appear to be decreasing, for example above Fort Peck Dam: "In the last two years [2012 and 2013], despite excellent sampling conditions of fairly low flow, CPUE of sicklefin chub has been at record low levels. Sturgeon chub catch has also been low for such excellent sampling conditions. Pallid sturgeon numbers have been steadily increasing in RPMA 1. The favorite prey items of juvenile pallid sturgeon appear to be sicklefin and sturgeon chub. The reduction in CPUE of these chubs is a concern if it represents a real decline" (UBPSW, 2014, p. 96, *internal citations omitted*).

Changes in turbidity and flow regimes may make Sicklefin and Sturgeon Chub more vulnerable to predation by native fish. Sedimentation is significantly diminished or non-existent in rivers below existing dams. Clearer waters increase visibility of Sicklefin and Sturgeon Chub and could increase predation upon them. The Annual Report for Segments 5 & 6 noted that "[p]redation could… explain the low abundance or lack of presence of [Sicklefin and Sturgeon Chub] chub species" (Shuman et al., 2013, p. 105). Below Gavins Point Dam, "[r]educed turbidity may make [Sicklefin and Sturgeon Chub] more vulnerable to sight-feeding predators" (Stukel et al., 2013, p. 80, *internal citations omitted*).

In Segment 1, predatory fish were entrained below Fort Peck Dam in 2011, potentially impacting native cyprinid populations:

> With the spill that occurred over the Fort Peck Dam Spillway in 2011 a lot of predatory game fish such as walleye and northern pike were entrained into the Missouri River downstream of the Dam. This increase in predator abundance was observed in FWP's annual gill netting of the Missouri River Dredge Cuts. This increase in predators could be one reason why we did not observe higher numbers of native cyprinids, since predation was likely high. (Haddix et al., 2013, p. 26)

In Segment 3, high water years did not lead to higher cyprinid populations, likely because of an increase in predation:

> While the same good water years that produced sauger and shovelnose sturgeon and likely led to higher survival and growth of hatchery reared pallid sturgeon, likely had a positive effect on native cyprinid populations. However, while native cyprinids only live for a short few years, sauger and sturgeon are longer lived and may make it harder for cyprinid populations to bounce back after years of poor water conditions. The fact that we haven't seen any bump in native cyprinid numbers after the 2011 water year may provide evidence of heavy predation of native cyprinids by predators. (Haddix et al., 2013b, p. v)

The Upper Basin Pallid Sturgeon Workgroup noted a decline in both chub species in Segment 4, hypothesizing that it might be related to an increase in predation: "There has been a steady decline in both the numbers and catch per unit effort of sicklefin and sturgeon chub with the otter trawl since 2009. We are not sure if this decline is related to the increase number of pallid sturgeon in the river or the increase in other predators such as sauger" (UBPSW, 2014, p. 113).

The potential impact of native predators on Sicklefin and Sturgeon Chub highlights the need to preserve adequate habitat in order to maintain balance between predator and prey.

(Factor D) The Inadequacy of Existing Regulatory Mechanisms

Non-regulatory rankings. The American Fisheries Society's Endangered Species Committee considers both the Sicklefin and Sturgeon Chub "vulnerable," meaning they are taxons "in imminent danger of becoming threatened throughout all or a significant portion of [their] range" (Jelks et al., 2008, p. 390). The status of the Sturgeon Chub has remained the same since 1989, while the status of the Sicklefin Chub has improved. Both are considered vulnerable due to habitat destruction or degradation (Jelks et al., 2008, p. 390). This designation carries no legal weight but supports our conclusion that the species are imperiled.

Conservation projects: 2001 to the present. In its 2001 finding, the Service emphasized the promise of two planned conservation measures in deciding not to list the Sicklefin and Sturgeon Chub. The first was the Missouri River Bank Stabilization and Navigation Project fish and wildlife mitigation plan, authorized in 1986. The plan called for the acquisition of land and rehabilitation of aquatic habitats. The Service conceded that the impacts of the wildlife mitigation plan to Sicklefin and Sturgeon Chub were unknown. As the Service stated in its finding, "[b]ased on the conceptual plans that have been developed, State and Federal agencies anticipate the rehabilitation of aquatic and terrestrial habitats will benefit fish and wildlife resources, including the sicklefin and sturgeon chub." Thus, the expected conservation benefits were only "anticipated" at the time of the decision.

It appears that the installed mitigation chutes, backwaters, chevrons, etc., provided only short-term, limited benefits to the chub species (G. Cunningham, pers. comm., July 7, 2016). In some places, stakeholder concerns have caused delays or halts in Corps projects:

> Unfortunately, large scale habitat restoration projects often create complex socioeconomic and ecological issues because of the potential effect on a diverse group of stakeholders. Varying stakeholder interests often create conflicts for decision makers, resulting in slowed or halted projects. For example, the Missouri Clean Water Commission expressed concern during the 2007 Jameson Island chute construction project over potential effects of sediment discharge from SWH restoration sites on Missouri River water quality as sediment discharges often exceed 500,000 metric tons per project. Concerns mainly focused on potential localized effects of sediment discharges on Missouri River nutrient concentrations as well as potential downstream effects on the Gulf of Mexico hypoxic zone. Those opposing SWH projects also contended that sediment discharges during habitat construction violated state and federal water pollution control laws. Subsequently, the USACE ceased construction on the Jameson project, halted all habitat creation efforts in the state of Missouri and requested independent guidance from the National Research Council (NRC) on Missouri River sediment management and the potential effects of SWH projects, both locally and downstream to the Gulf of Mexico. (Gosch et al., 2013, p. 250, *internal citations omitted*)

A Freedom of Information Act submitted to the U.S. Fish and Wildlife Service did not produce any responsive documents demonstrating specific benefits to the Sicklefin or Sturgeon Chub from the mitigation plan.

The second was a Biological Opinion (BiOp) issued by the Service on the Corps of Engineers' Operation of the Missouri River Main Stem System, the related operation of the Kansas River Tributary Reservoirs, and the Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Projects. According to the 2001 "not warranted" finding, "[i]mplementation of the identified conservation measures are expected to have a significant beneficial effect on sicklefin and sturgeon chub through habitat restoration and creation projects, improved water temperature regimes, and flow modifications designed to mimic the natural hydrograph" (USFWS, 2001a, p. 19,914). At the time of the finding, the Corps of Engineers was "seeking public input on the Implementation Plan for the Reasonable and Prudent Alternative identified in the Biological Opinion" (USFWS, 2001a, p. 19,914). Thus, the benefits of the BiOp to the Sicklefin and Sturgeon Chub were speculative at the time of the finding.

The benefits are still speculative. Habitat restoration in the BiOp is focused on creating shallow water habitat (SWH) for the Pallid Sturgeon, defined as "areas where water depth is greater than 0 (zero) but less than 5 feet (0-1.5m) and current velocity is less than 2 feet/second (0.6 meters/second) (USACE, 2015, p. 61). "The existing BiOp concludes that the restoration of 12,035 acres to 19,565 acres (20 to 30 acres per mile) of SWH is needed," and the goal is to complete restoration of this amount of SWH by 2024 (USACE, 2015, p. 62).

SWH may overlap partially with Sicklefin and Sturgeon Chub habitat requirements, but appears to trend shallower:

> Sturgeon chubs used shallow habitats (mean depth = 2.5 m), with higher water velocities (mean velocity = 0.89 m/s) and gravel substrate (particle size: 2 mm ≤ 16 mm). In contrast, sicklefin chubs used deeper habitats (mean depth = 6.8 m) with lower water velocities (mean velocity = 0.47 m/s) and sand substrate (particle size: 0.06 mm ≤ 2 mm). (Everett et al., 2004, p. 189)

Pallid Sturgeon often co-occur with Sicklefin and Sturgeon Chub, as the chubs are common prey species for the sturgeon; however, it is unclear to what extent their habitats overlap and to what degree habitat restoration focused on Pallid Sturgeon will benefit either chub species, as this issue is not mentioned in the BiOp (*see* USFWS, 2003).

In 2011, the Missouri River experienced record floods. "The significant peak flow duration and volume of the 2011 Missouri River flood event exceeds all other events in the recorded gage history of the river. The excess energy acting on the river floodplain and projects within this environment were unprecedented. Most projects have altered habitat compared to pre-flood conditions" (USACE & USFWS, 2013, p. 10). Deposition and erosion impacted numerous project sites (USACE & USFWS, 2013, p. 11), potentially cancelling out any benefits to the species.

A Freedom of Information Act submitted to the U.S. Fish and Wildlife Service did not produce any responsive documents demonstrating specific benefits to the Sicklefin or Sturgeon Chub from the BiOp.

The Yellowstone Intake Dam Modification Project, intended to improve fish passage for Pallid Sturgeon and other native fish, was initiated after the 2001 listing decision. The Corps asserts that this project is likely to improve conditions for pallid sturgeon, but the degree of improvement will not be known until the project is completed (USDOI & USACE, 2015, p. ES-5). And the assertion that it will improve conditions is contested (*see* Hunter, 2015). It is also unknown if, or how much, the project will improve connectivity for populations of Sicklefin and Sturgeon Chub in the Yellowstone and Missouri rivers.

It is difficult to evaluate the effects of most Missouri River restoration projects:

> Unfortunately, Missouri River rehabilitation efforts have seldom included explicit ecologically based objectives and performance measures. They are often site specific and driven by political realities rather than recovery of ecological processes. Equally important, they generally lack adequate pre- and postproject appraisals to evaluate progress towards restoration objectives and their outcomes. The result is that the "learning-by-doing" feedback loop essential to adaptive management is often missing. Other river and native fish restoration programs have experienced mixed success for similar reasons. Management agencies are encouraged to adopt a more holistic perspective for their activities to benefit the biological integrity of the Missouri River hydrosystem, rather than the single species approach emphasized by endangered species recovery plans. The National Research Council (2003) recently recommended that the Corps of Engineers adopt a set of principles and guidelines for successful restoration programs. We urge Missouri River restorationists to consider these in their project planning, execution, and evaluation. A well-designed, performance-based, restoration program should include relevant stakeholders and treat habitat rehabilitation and flow reregulation as an adaptive management experiment. (Galat et al. 2005, p. 277, *some internal citations omitted*)

State. The Sturgeon Chub is unofficially classified in Wyoming as a "species of concern" and is considered under the State's Mitigation Policy and for planning purposes. Both species are considered "species of special concern" in Montana (USFWS, 2001b, p. 48). The Missouri Department of Conservation considers both the Sturgeon Chub and Sicklefin Chub rare (USFWS, 2001b, p. 48). In South Dakota, the Sicklefin and Sturgeon Chub are state listed as "threatened." However, the South Dakota Department of Game, Fish, and Parks believes the Sicklefin Chub may be extirpated from the State (USFWS, 2001b, p. 48). In Nebraska, the Sturgeon Chub is listed as "endangered."[7]

Both chubs receive legal protection in the State of Kansas where they are state listed as "threatened" and "endangered," respectively (USFWS, 2001b, p. 48). Take of either species is prohibited and provisions allow for habitat protection and designation of critical habitat (USFWS, 2001b, p. 48). The Sturgeon Chub is state listed as "endangered" in Illinois, which prohibits take and provides some habitat protection (USFWS, 2001b, p. 48). Kentucky has restrictions on collections of both chubs and Tennessee prohibits the take or possession of either chub or the knowing destruction of habitats (USFWS, 2001b, p. 48). "In light of the low numbers of sturgeon chub and sicklefin chub in these States, the effectiveness of the various regulations is difficult to assess" (USFWS, 2001b, p. 49). Continued low numbers and/or declining population trends in both species throughout most of their range indicate that state-level protections have not been sufficient to protect these species.

The Sicklefin and Sturgeon Chub receive no legal protection in Wyoming, Montana, North Dakota, Iowa, Missouri, or Louisiana (USFWS, 2001b, p. 48). Missouri contains the most successful populations of both species, and these successfully reproducing populations should be protected in order to safeguard them. Montana contains some of the last unfragmented chub habitat above Fort

[7] http://rarespecies.nebraska.gov/species/

Peck Dam, but the population appears to be in decline and is without state protections. Unprotected Wyoming and Montana populations in the Yellowstone and Powder River appear to be in decline as well.

(Factor E) Other Natural or Man-made Factors Affecting its Continued Existence

North American freshwater fauna are disproportionately imperiled. "It is striking to note that the projected mean future extinction rate for freshwater fauna is about five times greater than the rate for terrestrial fauna and three times the rate for coastal marine mammals" (Ricciardi & Rasmussen, 1999, p. 1,221). "Given that 40 of 1061 North American freshwater fish have become extinct in this century, the modern regional rate (in the recent past) is equivalent to one extinction every 2600 species-years, which is 1000 times higher than the background rate" (Ricciardi & Rasmussen, 1999, p. 1,222). Freshwater ecosystems and their inhabitants are vulnerable to a myriad of impacts:

> Freshwater ecosystems show substantial impacts from land use, biotic exchange, and climate. Land use is expected to have especially large effects because humans live disproportionately near waterways and extensively modify riparian zones even in terrestrial biomes that otherwise are sparsely populated. This leads to many changes within the waterways, including increased inputs of nutrients, sediments, and contaminants. In addition, humans use waterways as transportation corridors, sewage disposal sites, and water sources, so that much of Earth's accessible freshwaters are already coopted by humans. Biotic exchange, in particular, is relatively more important for aquatic (especially lakes) than for terrestrial ecosystems because of both extensive intentional (for example, fish stocking) and unintentional (for example, ballast water releases) releases of organisms. Carbon dioxide and nitrogen deposition generally had less impact on lakes and streams than on terrestrial ecosystems, but acidic deposition (partly attributable to nitrogen deposition) and its interactions with climate change, land use, and stratospheric ozone depletion are large—especially for boreal lakes. Recent analyses suggest that, as a result of all these impacts, global freshwater biodiversity is declining at far greater rates than is true for even the most affected terrestrial ecosystems. (Sala et al., 2000, p. 1,772)

Biological vulnerability. Fish in the "pelagic-spawning cyprinid" (pelagophilic) reproductive guild, like the Sicklefin and Sturgeon Chub, have massively declined due to habitat alterations from impoundments, diversion dams, and stream dewatering (Perkin & Gido, 2011, p. 371). Sturgeon Chub were extirpated from the majority (75 percent) of stream fragments studied by Perkin & Gido (2011, p. 375), which appears to be a direct consequence of stream fragmentation on this reproductive guild. The greatest challenge associated with the conservation of pelagic-spawning cyprinids is allowing the transport of ichthyoplankton through reservoirs in fragmented river systems; there are no known initiatives addressing this challenge (Perkin & Gido, 2011, p 381).

Pelagophilic fishes persist in longer stream reaches, but these stream reaches lose their value as refuges if they dry 0.10 percent of the time:

> Mechanisms driving the decline of small-bodied pelagophilic fishes include disrupted spawning cues, reduced survival of drifting progeny, insufficient habitat complexity for recruitment processes, and truncated availability and connectivity of wetted refuge habitats. These findings have shifted management focus toward early life stages that are most

> sensitive to environmental alterations, and work considering longitudinal habitat connectivity and heterogeneity suggests natal dispersal via drift is critical for population persistence. We found that greater longitudinal habitat connectivity predicted increased probability of occurrence for small-bodied pelagophilic fishes; however, this relationship did not hold for stream fragments that dried .10% of the time. (Perkin et al., 2015, p. 85, *internal citations omitted*)

Small, isolated populations. The Service has previously recognized that small population size and small, isolated populations increases the likelihood of extinction.[8] For example, in reference to the Sisi snail (*Ostodes strigatus*), the Service noted that "[e]ven if the threats responsible for the decline of this species were controlled, the persistence of existing populations is hampered by the small number of extant populations and the small geographic range of the known populations." Heightened risk of extinction is "inherent in low numbers," a basic tenet that has been a cornerstone of conservation biology (Caughley 1994, p. 216). Small, isolated populations such as those of the Sicklefin and Sturgeon Chub are particularly vulnerable to: 1) demographic fluctuations, 2) environmental fluctuation in resource or habitat availability, predation, competitive interactions and catastrophes, 3) reduction in cooperative interactions and subsequent decline in fertility and survival, 4) inbreeding depression reducing reproductive fitness, and 5) loss of genetic diversity reducing the ability to evolve and cope with environmental change (Traill et al., 2010, p. 29).

The Service, in their final rule listing the streaked horned lark and Taylor's checkerspot butterfly, considered both species at risk due to small population size or small, isolated populations (USFWS, 2013a, p. 61,489).

> Populations that are small, fragmented, or isolated by habitat loss or modification of naturally patchy habitat, and other human-related factors, are more vulnerable to extirpation by natural, randomly occurring events, to cumulative effects, and to genetic effects that plague small populations, collectively known as small population effects. These effects can include genetic drift (loss of recessive alleles), founder effects (over time, an increasing percentage of the population inheriting a narrow range of traits), and genetic bottlenecks leading to increasingly lower genetic diversity, with consequent negative effects on evolutionary potential. (USFWS, 2013a, p. 61,488)

The Service found similar threats when listing the Florida bonneted bat:

> In general, isolation, whether caused by geographic distance, ecological factors, or reproductive strategy, will likely prevent the influx of new genetic material and can result in low diversity, which may impact viability and fecundity. Distance between subpopulations or colonies, the small sizes of colonies, and the general low number of bats may make recolonization unlikely if any site is extirpated. Isolation of habitat can prevent recolonization from other sites and potentially result in extinction. The probability of extinction increases with decreasing habitat availability. Although changes in the environment may cause populations to fluctuate naturally, small and low-density populations

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[8] For examples, see candidate assessment forms for *Ostodes strigatus* (Sisi snail, June 2013), *Porzana tabuensis* (spotless crake, June 2013), *Vagrans egistina* (Mariana wandering butterfly, June 2013), *Gallicolumba stairi* (friendly ground-dove, June 2013), and *Hyla wrightorum* (Arizona treefrog, April 2013) (Available at http://ecos.fws.gov/tess_public/pub/SpeciesReport.do?listingType=C&mapstatus=1)

> are more likely to fluctuate below a minimum viable population (i.e., the minimum or threshold number of individuals needed in a population to persist in a viable state for a given interval). If populations become fragmented, genetic diversity will be lost as smaller populations become more isolated. (USFWS, 2013b, p. 61,037, *internal citations omitted*)

"Sicklefin and sturgeon chub populations on the Missouri River basin may be effectively isolated by the Missouri River main stem dams" (USFWS, 2001b, p. 39). Because of damming and channelization along the Yellowstone, Missouri, and Mississippi Rivers, sicklefin and sturgeon chub have small, isolated populations and fragmented habitat, and thus are at risk of extinction. Below Gavins Point Dam, both species could be considered one population; however from that point upstream, populations are isolated and fragmented, making gene flow virtually impossible (G. Cunningham, pers. comm., July 7, 2016).

Climate change. "By 2030, several GCMs (general circulation models) project that the Great Plains could be on average 2±4°C warmer in winter and 2±3°C warmer in summer. GCMs also project a less productive growing season as a result of less precipitation" (Covich et al. 1997, p. 1,010 *internal citations omitted*). Small streams and shallow water habitats are expected to become less hospitable to native fish species:

> During late summer in the Great Plains, many shallow water habitats are already at extremely high temperatures and low flows, yet native fishes are adapted to these conditions. Any additional increases in water temperatures, lowering of water levels or increases in salinity are likely to be highly detrimental to most native fish species. (Covich et al. 1997, p. 1,014, *internal citations omitted*).

It is uncertain how climate change will impact mainstem rivers, but "[i]n a warmer, drier climate the increased cultural demand for diverting surface and ground water resources could eliminate some shallow water habitats" (Covich et al. 1997, p. 1,015). A study of northwestern rivers shows that they have already begun to trend warmer. For sites including the Missouri River in Montana, a "cooling trend was apparent during the spring and warming trends during other seasons, with warming rates highest during the summer" (Isaak et al., 2012, p. 509). "Significant warming during many seasons of the year has more than offset a spring cooling trend in recent decades to cause a net temperature increase that generally tracks regional air temperature increases. As a result, this study adds to the growing list that documents warming of the Earth's rivers and streams " (Isaak et al., 2012, p. 511, *internal citations omitted*).

> A growing number of studies predict substantial disruptions to aquatic ecosystems from climate change within the northwest U.S. and more broadly. The trends in river and stream temperatures we document, in combination with increasing evidence of thermal constraints on some populations, suggest these predictions are being realized. Although most species have persisted through greater climatic perturbations in past millennia, modern climate change is happening especially rapidly, at the end of an already warm period, and is being imposed on populations that are often already depressed and fragmented from a century of intense human development. To minimize the losses of biodiversity that could occur in the next half century, much needs to be learned in a relatively short period of time about changing stream and river thermal regimes and aquatic ecological responses (Isaak et al., 2012, p. 515, *internal citations omitted*)

Changing temperature regimes will impact native fish:

> Thermal regimes in river and stream ecosystems are fundamentally important to fish and other aquatic organisms because most are ectotherms with physiologic processes directly controlled by temperatures of the ambient environment. As a result, temperature strongly dictates the distribution and abundance of individual species across many spatial and temporal scales. As anthropogenic climate change progresses and the Earth's temperatures warm this century, aquatic communities in rivers and streams will have to shift to track thermally suitable habitat, but could encounter difficulties in linear stream networks that are often heavily fragmented by water resource development (Isaak et al., 2012, p. 500, *internal citations omitted*)

Dams and fragmentation will increase the impacts of climate change:

> Elevated atmospheric CO_2 will impact the spatial and temporal availability of water on and beneath the earth's surface. Changes in water availability in the Great Plains will be particularly critical because water availability is limited and taxed by both natural ecosystems and managed production… The Missouri River basin is at risk in reference to water resources and climate change because (1) annual demand for water is large relative to annual supply, (2) more than 25 percent of total energy production is from hydropower, and (3) the basin ground water supply is susceptible to overdraft (Hotchkiss et al., 2000, p. 375, *internal citations omitted*)

Climate change is expected to effect dammed rivers, like the Missouri, more than it would impact undammed rivers."[W]ithin 50 years, river basins that are impacted by dams or by extensive development will experience greater changes in discharge and water stress than unimpacted, free-flowing rivers" (Palmer et al., 2008, p. 88). These changes will have impacts on both biodiversity and human society:

> Changes brought on by urbanization, excessive water withdrawals, or climate shifts that occur rapidly and lead to flows outside the natural range of variability will have important consequences for river ecosystems and the people who depend on them. Native riverine biodiversity and productivity may decline, water quality for human consumption may be compromised, and in some regions, the risk of flooding, with concomitant damage to property and people, may increase. (Palmer et al., 2008, p. 81, *internal citations omitted*).

Cumulative threats. The Service should consider whether the array of aforementioned threats intersect and act synergistically, therefore increasing the likelihood of extinction or endangerment of the Sicklefin and Sturgeon Chub in the foreseeable future. For example, limited viable populations are exacerbated by predation, which may prevent the species from recovering in the areas in which they still exist. Habitat fragmentation interacts with both altered hydrology and water depletion to threaten pelagic-spawning fish species in ways that are not fully understood:

> At present, extinction risk, extinction debt, and restoration potential are poorly understood in most river fragments on the plains. All life stages [of pelagic-broadcast spawning minnow] are vulnerable and it is unknown which succumb to impacts that cause extinction. For

> instance, unnatural flow-regimes and channelization diminish propagule retention, but also reduce habitat suitability, and can disrupt dispersal. Streamflow intermittence precludes recruitment, but also decimates adults. If vulnerable life stages and critical habitat features can be identified, future conservation and restoration efforts could be more focused. (Hoagstrom, 2014, p. 450, *internal citations omitted*)

Fragmentation from dams, sediment capture in impoundments, drought and water depletion, and channelization all interact and cause declines in pelagic-spawning fish:

> Dams act as dispersal barriers that fragment metapopulations. Base-flow depletion and drought eliminate shallow, fluvial habitats used by adults, which also fragments metapopulations. Flood and sediment capture within impoundments create ecological discontinuities and establish narrow and confined river channels over long distances. Mechanical channelization also creates confined river channels. Confined channels of all kinds slow the diffusive spread of adult populations, decrease propagule retention and eliminate juvenile-adult habitat, especially at high flow. Further, these processes interact strongly and are collectively linked to declines of pelagic-broadcast spawning minnows. (Hoagstrom & Turner, 2015, p. 290, *internal citations omitted*)

Dams will interact with the impacts of climate change to decrease the resilience of river ecosystems. "[D]ue to changes in discharge and water stress [resulting from climate change], the area of large river basins in need of reactive or proactive management interventions will be much higher for basins impacted by dams than for basins with free-flowing rivers" (Palmer et al., 2008, p. 85).

Climate change, combined with human population growth, will lead to higher levels of water withdrawal. "Increasing water demand related to economic and population growth may dominate the effects of climate change on overall available water for many rivers and this will be exacerbated in dam-impacted basins" (Palmer et al., 2008, p. 85, *internal citations omitted*).

> If major shifts in precipitation occur in the Great Plains as a result of global climate change, the additional competition for water resources could result in further degradation or elimination of freshwater habitats… Future climate changes are likely to be coupled with the additional cumulative effects of intensive land use and may accelerate the affects on biotic communities and associated ecosystem processes. (Covich et al., 1997, p. 994, *internal citations omitted*)

> Future climate change might negatively affect [pelagic broadcast spawning (PBS)] species as their thermal tolerances are close to maximum summer temperatures. Temperature also alters habitat use, swimming speed, and parasite susceptibility. Climate change may act synergistically with other anthropogenic stressors, e.g., reduced base-flows in the spawning season and contaminants, to further impact PBS and other Great Plains species. (Worthington et al., unpublished data, *internal citations omitted*)

These are just examples of intersecting threats facing the Sicklefin and Sturgeon Chub.

> Traits such as ecological specialization and low population density act synergistically to elevate extinction risk above that expected from their additive contributions, because rarity

> itself imparts higher risk and specialization reduces the capacity of a species to adapt to habitat loss by shifting range or changing diet. Similarly, interactions between environmental factors and intrinsic characteristics make large-bodied, long-generation and low-fecundity species particularly predisposed to anthropogenic threats given their lower replacement rates. (Brook et al., 2008, p. 455, *internal citations omitted*)
>
> [O]nly by treating extinction as a synergistic process will predictions of risk for most species approximate reality, and conservation efforts therefore be effective. However challenging it is, policy to mitigate biodiversity loss must accept the need to manage multiple threatening processes simultaneously over longer terms. Habitat preservation, restoring degraded landscapes, maintaining or creating connectivity, avoiding overharvest, reducing fire risk and cutting carbon emissions have to be planned in unison. Otherwise, conservation actions which only tackle individual threats risk becoming half-measures which end in failure, due to uncontrolled cascading effects. (Brook et al., 2008, p. 459, *internal citations omitted*)

CONCLUSION AND REQUESTED DESIGNATION

WildEarth Guardians hereby petitions the U.S. Fish and Wildlife Service under the Department of Interior to list the Sicklefin Chub (*Macrhybopsis meeki)* and Sturgeon Chub (*Macrhybopsis gelida*) as "endangered" or "threatened" species under the Endangered Species Act. Listing is warranted, given the rarity of this species and ongoing threats. The Sicklefin and Sturgeon Chub are threatened by at least four of the five listing factors under the ESA: A) the present or threatened destruction, modification, or curtailment of its habitat or range; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; and E) other natural or manmade factors affecting its continued existence.

WildEarth Guardians also requests that critical habitat be designated for the Sicklefin and Sturgeon Chub in occupied and unoccupied suitable habitat concurrent with final ESA listing. Designating critical habitat for these species will support their recovery and protect areas crucial to long-term survival of Sicklefin and Sturgeon Chub populations.

FIGURES

Figure 1. Sturgeon Chub (Steffensen et al., 2014, p. 50, *image © Joseph R. Tomelleri*).

Figure 2. Sicklefin Chub (Steffensen et al., 2014, p. 51, *image © Joseph R. Tomelleri*).

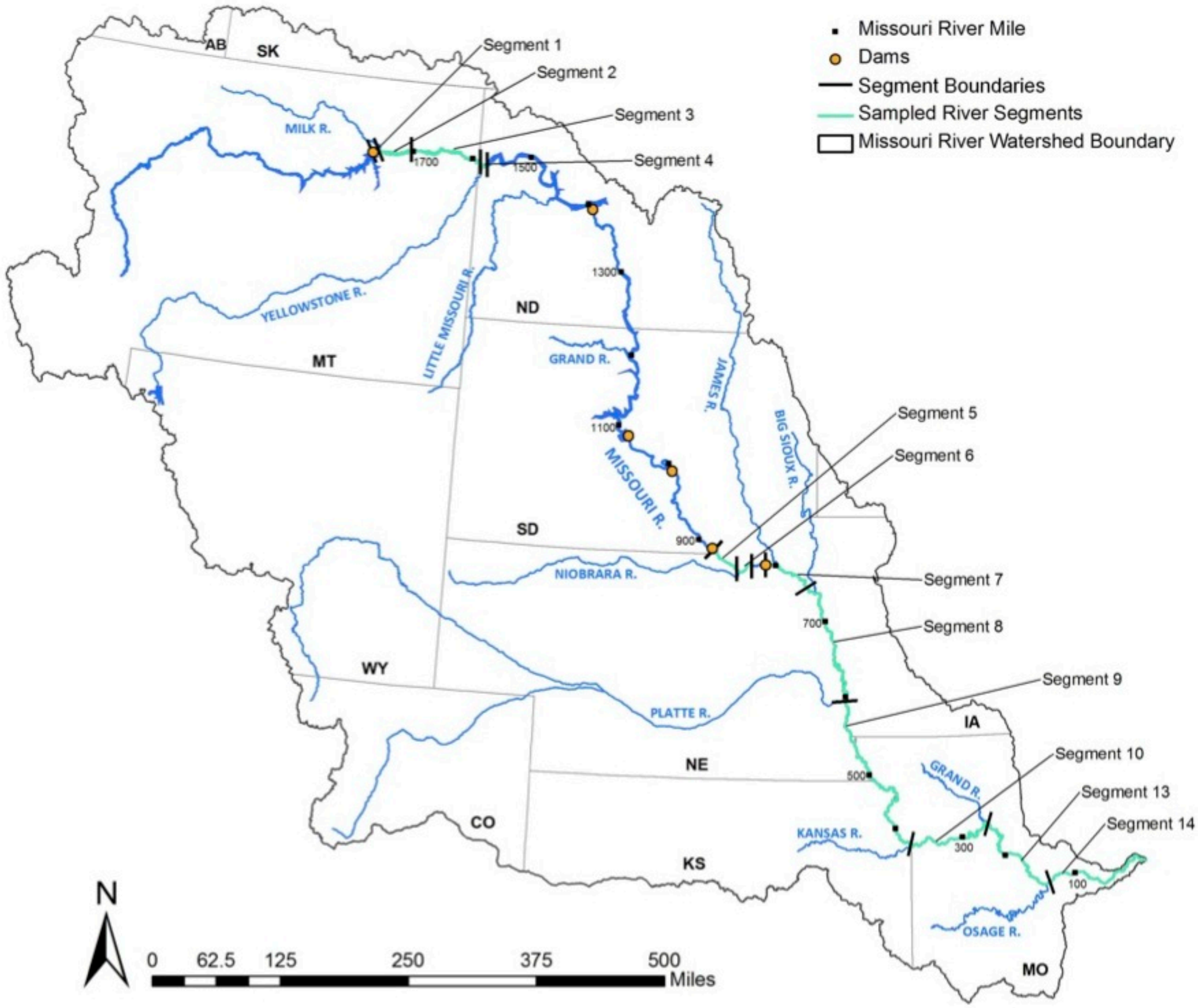

Figure 3. Map of the Pallid Sturgeon Population Assessment Project study area, delineating the Missouri River segments. Segment 11 is not shown but encompasses the Kansas River from Lawrence, KS, to its mouth. Segment 15 is not shown but is located in North Dakota (*see* Figure 4, below)

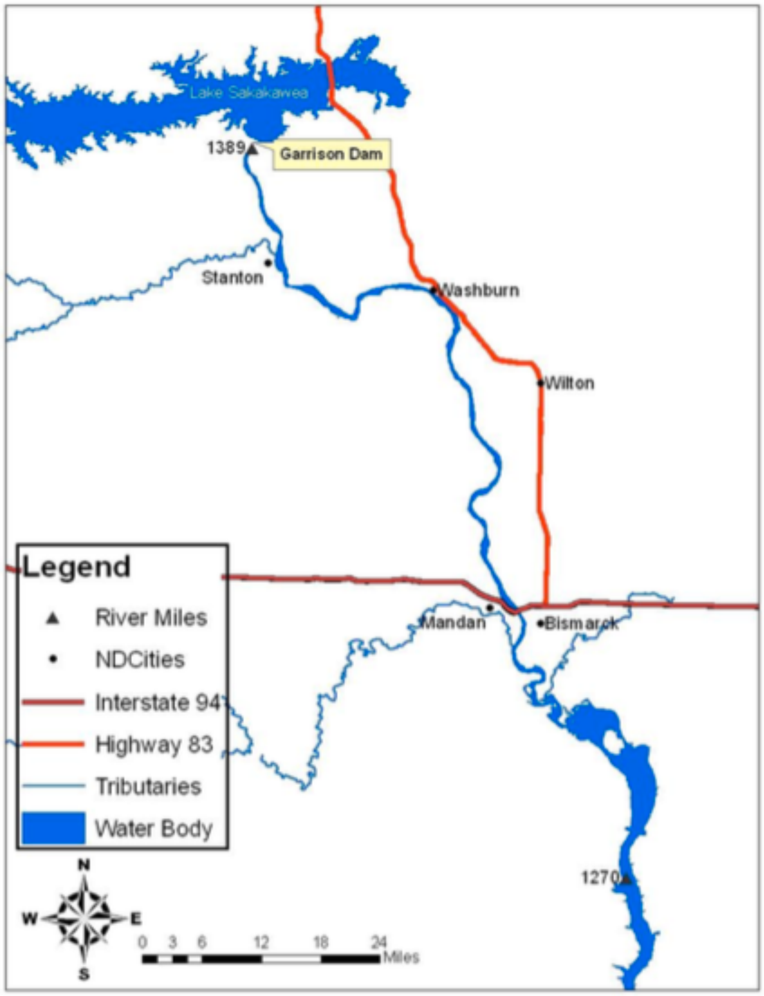

Figure 4. Map of Segment 15 of the Missouri River (Wilson et al., 2013b, p. 5).

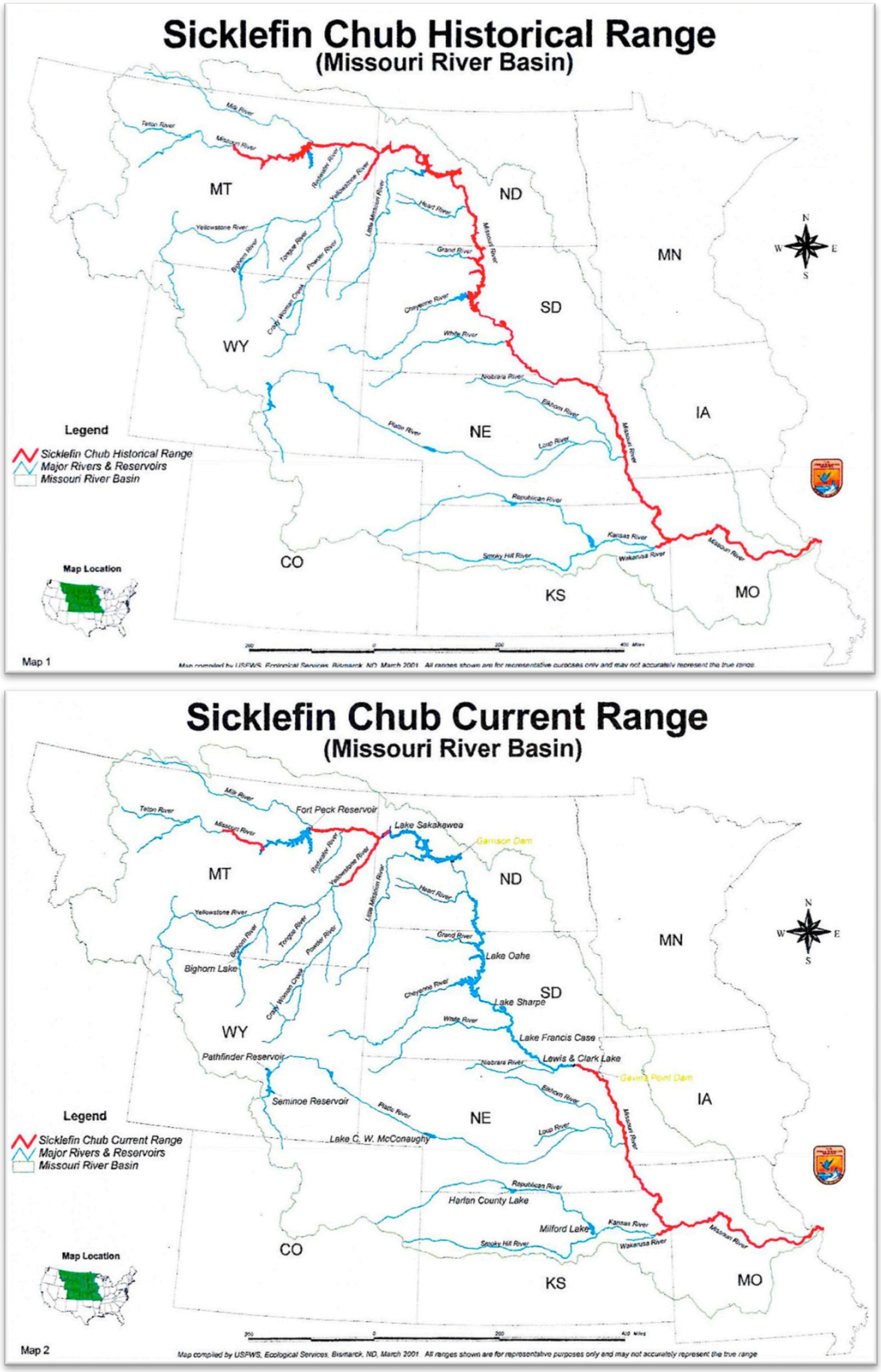

Figure 5. Maps of historic and current (as of 2001) Sicklefin Chub range in the Missouri River basin (FOIA response from USFWS received 9/12/14)

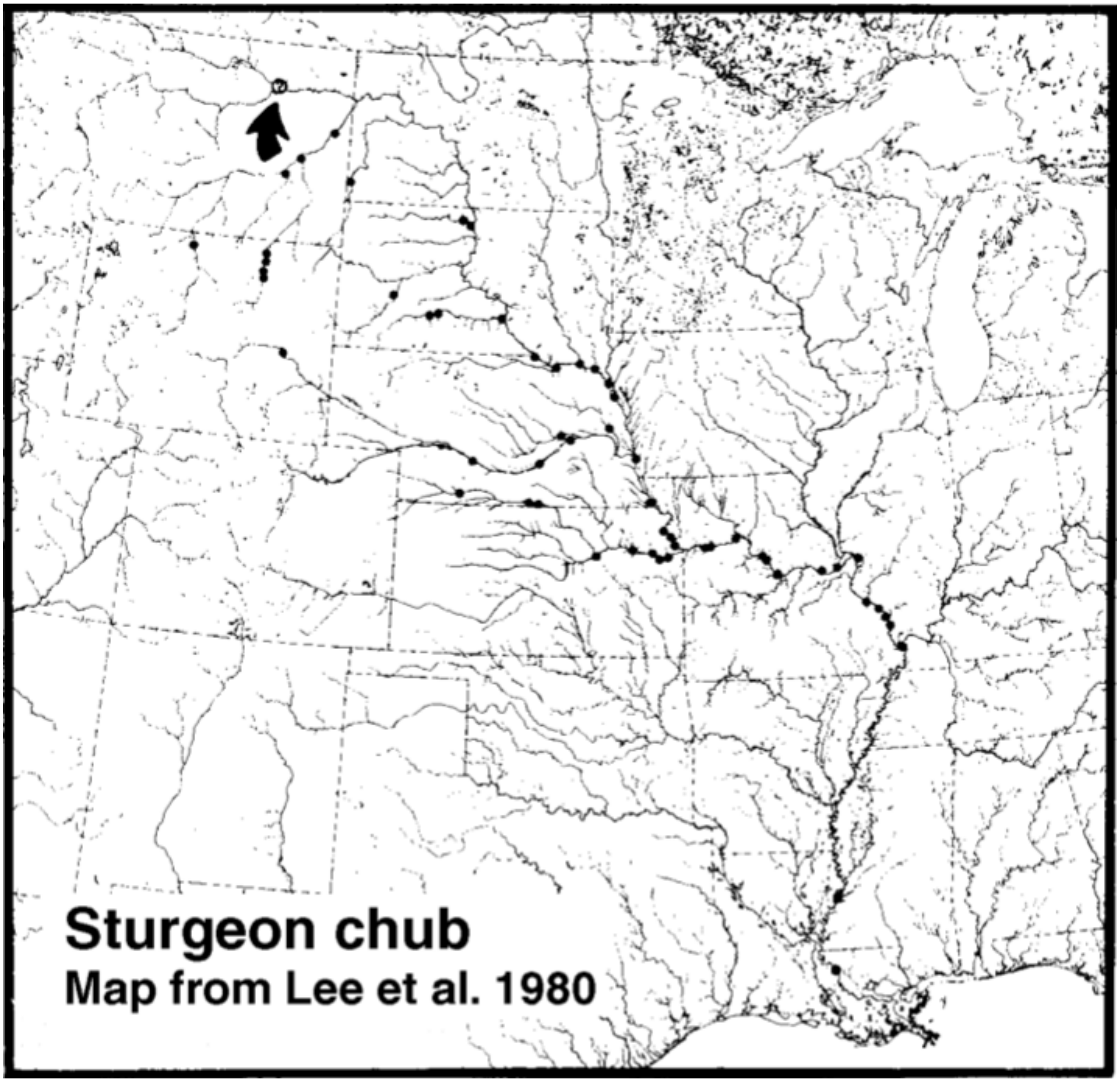

Figure 6. Historic occurrence of Sturgeon Chub in the United States; in the main stem of the Yellowstone, Missouri, and Mississippi rivers in the central U.S. and in a number of tributaries of the Yellowstone and Missouri rivers (Rahel & Thel, 2004, p. 12).

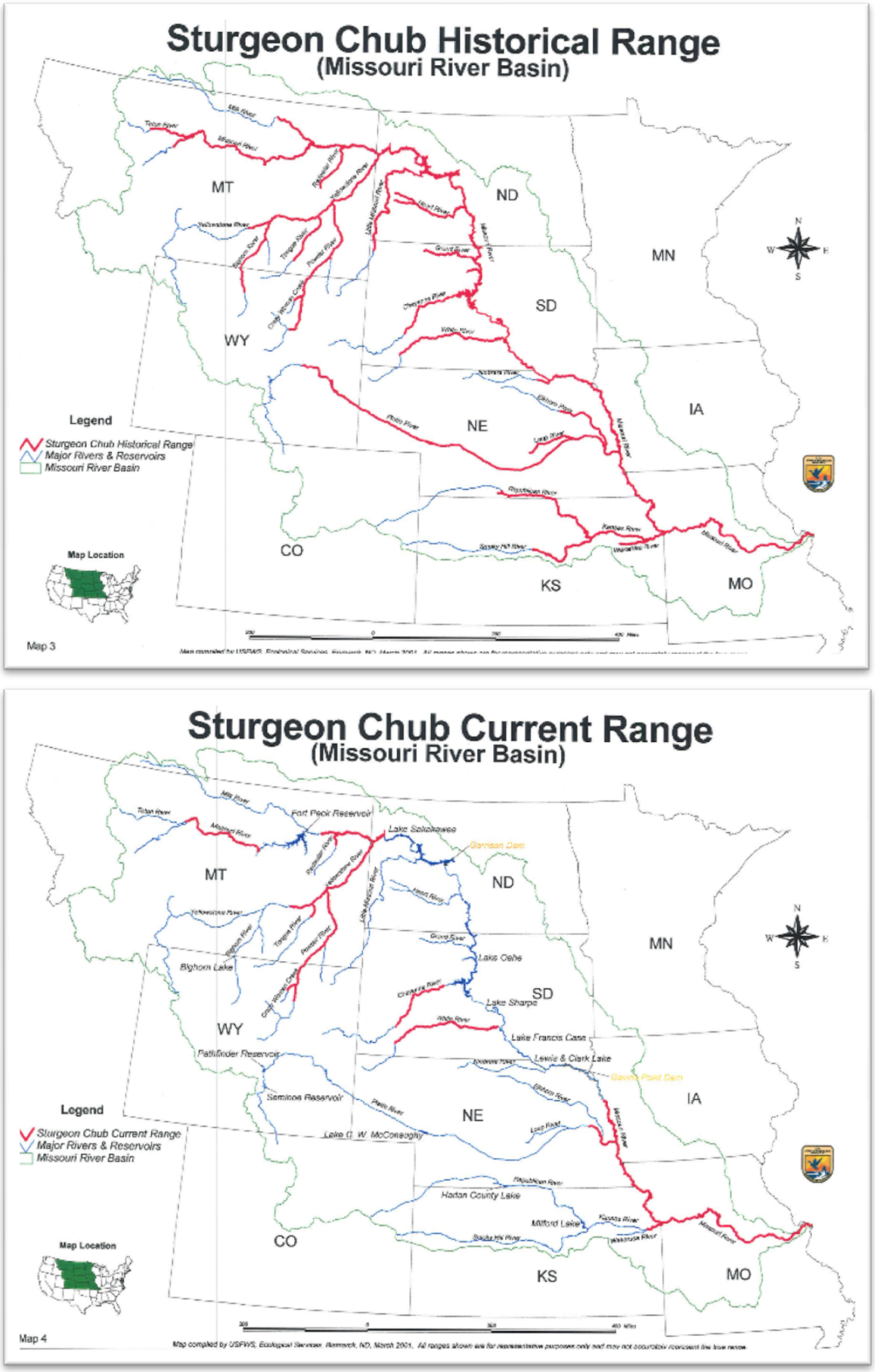

Figure 7. Maps of historic and current (as of 2001) Sturgeon Chub range in the Missouri River basin (FOIA response from USFWS received 9/12/14)

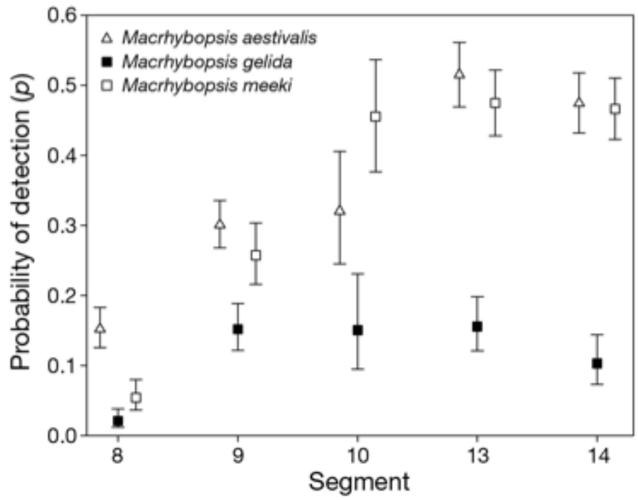

Figure 8. Probability of detection (p) estimates by river segment for *Macrhybopsis aestivalis*, *M. gelida*, and *M. meeki* caught in otter trawls. Estimates and 95 percent confidence intervals are shown for Segments 8 (rkm 1212 to 958), 9 (rkm 958 to 591), 10 (rkm 591 to 402), 13 (rkm 402 to 209), and 14 (rkm 209 to 0) in the Lower Missouri River (Schloesser et al., 2012, p. 221).

Figure 9. The Open River sampling site on the Mississippi River from Grand Tower to the Ohio River (Source: USGS, 2016: www.umesc.usgs.gov/rivers/upper_mississippi/reach_3/sel_a_pool_r3.html)

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