DRAFT RECOVERY PLAN
FOR
COLORADO PIKEMINNOW (*Ptychocheilus lucius*)

Photo by J. Ferreira

U.S. Fish and Wildlife Service
Mountain-Prairie Region
Denver, Colorado

August 2022 – Draft Recovery Plan

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Draft Approved_____ **Date**_____

Regional Director, U.S. Fish and Wildlife Service

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This recovery plan and its associated documents can be downloaded from the U.S. Fish and Wildlife Service's website: *https://ecos.fws.gov/ecp/species/3531*.

Technical terms are underlined in their first use and defined in the Glossary at the end of this document.

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I. Introduction

Colorado pikeminnow (*Ptychocheilus lucius*) is a fish in the minnow family (Cyprinidae) that once inhabited warmwater reaches throughout the Colorado River Basin. Colorado pikeminnow was included in the original 1967 List of Endangered Species (32 FR 4001; March 11, 1967) and listed in 1973 as endangered under the Endangered Species Act, as amended (16 U.S.C. 1531 *et seq*; hereafter, Act). In 1994, the U.S. Fish and Wildlife Service (Service) designated critical habitat for Colorado pikeminnow in the Green, upper Colorado, and San Juan subbasins of the upper Colorado River basin (59 FR 13374; March 21, 1994). The Service approved a recovery plan for Colorado pikeminnow in 1991 (Service 1991, entire), which was amended and supplemented with Recovery Goals in 2002 (Service 2002, entire). The most recent 5-year status review (Service 2020, entire) recommended revising the recovery plan based on new information gathered from extensive research completed over the last two decades and an increase in some threats to the species since 2002.

The Service conducted a species status assessment (SSA) for the Colorado pikeminnow and documented our analysis in an SSA report (Service 2022, entire), which is an in-depth, scientific review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain populations over time. In our SSA, we identified individual, population, and species requirements, or needs, and the factors affecting the species' survival. We then evaluated the species' current condition to assess the species' current and future viability in terms of its resiliency, redundancy, and representation (the three Rs). Resiliency is the ability for populations to sustain in the face of stochastic events, or for populations to recover from years with low reproduction or reduced survival, and is associated with population size, growth rate, and the quality and quantity of habitats. Redundancy is the ability for the species to withstand catastrophic events, for which adaptation is unlikely, and is associated with the number and distribution of populations. Representation is the ability of a species to adapt to changes in the environment and is associated with its diversity, whether ecological, genetic, behavioral, or morphological.

This streamlined recovery plan for Colorado pikeminnow is derived from the SSA (Service 2022, entire) and focuses primarily on the elements required under section 4(f)(1)(B) of the Act:

(i) A description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species;

(ii) Objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this section, that the species be removed from the list; and

(iii) Estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal.

In cooperation with our partners, the Service will also prepare a Recovery Implementation Strategy (RIS), which serves as an operational plan for completing the higher-level recovery actions presented in this recovery plan by achieving specific tasks, or activities. The RIS is a

separate document from this recovery plan and can be modified as needed if monitoring reveals that expected results are not being achieved, therefore maximizing flexibility of recovery implementation. The SSA can also be updated as needed to incorporate the latest scientific information. To summarize, there are three documents under our recovery planning and implementation (RPI) process: (1) the SSA, which provides the foundational scientific information to guide recovery planning; (2) the recovery plan (this document), which provides the recovery vision, objective and measurable recovery criteria, site-specific management actions, and estimates of time and cost; and finally (3) the RIS, which is the operational plan of detailed activities associated with the actions identified in the recovery plan that are needed for recovery.

Overview of Status and Life History

The following is a brief overview of the biology, natural history, and current condition of Colorado pikeminnow, per the SSA report (Service 2022, entire). Please refer to the SSA report (Service 2022, entire) for additional discussion, full analysis, and complete literature citations.

Summary of Taxonomy, Life History and Ecology

Colorado pikeminnow is a large, long-lived fish and the largest member of the taxonomic family Cyprinidae native to North America. It is endemic to warmwater reaches of large rivers in the Colorado River basin. Prior to the introduction of nonnative, predatory fish species, Colorado pikeminnow was the apex predator in these reaches and adults are mostly piscivorous. Colorado pikeminnow can grow to a large size, historically greater than 5 feet (1.5 meters) in length and can live over 50 years in the wild. Colorado pikeminnow make long distance migrations (409 miles (mi) [658 kilometers (km)] round trip) to spawn and return to their home range, where they inhabit deep runs, pools, and eddies. Colorado pikeminnow eggs hatch in cobble spawning bars as spring high flows decline, and larvae subsequently emerge and are carried long distances by river flows to low velocity nursery habitats downstream. In these reaches, larvae and juveniles seek low to zero velocity backwaters that provide warm temperatures for growth and abundant macroinvertebrates and small fish prey. Individual Colorado pikeminnow become sexually mature between 7 and 10 years of age and may spawn each year during their lifetime.

Historically, Colorado pikeminnow occurred throughout the Colorado River basin, including the Green, Colorado, and San Juan River subbasins of Wyoming, Colorado, Utah, and New Mexico; downstream through the Colorado River mainstem in Arizona, Nevada, California, and Mexico; and the Gila River subbasin in Arizona and New Mexico (Figure 1). In the lower Colorado River basin (LCRB or 'lower basin') downstream of Glen Canyon Dam, the construction of dams and water projects diverted river flows, fragmented river reaches, reduced peak flows, dewatered some reaches, and channelized the river starting in the early 20th century. As a result of extensive water development, modified hydrology, and reduced habitats, Colorado pikeminnow was extirpated from the LCRB by the 1970s. In the upper Colorado River basin (UCRB or 'upper basin'), including Lake Powell and its tributaries, the construction of large dams and diversions was more dispersed, leaving longer reaches of river available in downstream areas. The remaining UCRB reaches were sufficiently intact to provide habitats that supported Colorado pikeminnow populations in the wild, albeit across a reduced range and in

decreased numbers. Dams converted sections of rivers to coldwater tailraces, impounded extensive reservoirs with unsuitable habitat for riverine species including Colorado pikeminnow, altered hydrology through reduced spring peaks, and presented barriers to migration. Nonnative sport fishes were also introduced into reservoirs and riverine habitats throughout the entire Colorado River basin, and these nonnative fish compete with and prey upon Colorado pikeminnow. The range of Colorado pikeminnow in the UCRB contracted and populations declined in the Green and upper Colorado River subbasins; the species was functionally extirpated from the San Juan River subbasin in the late 1990s. Those same factors also resulted in earlier extirpation of Colorado pikeminnow from the LCRB. Designated critical habitat in the UCRB is estimated to represent around 29 percent of historical Colorado pikeminnow range (59 FR 13374; March 21, 1994).

Other habitat factors also influence Colorado pikeminnow life history. Colorado pikeminnow inhabit river reaches that historically experienced extremes in both flow and temperature on an annual basis, in addition to high turbidity from sediment inputs as a result of spring snow melt or flash floods. Both adult and nursery habitats, as well as spawning bars, are formed and maintained by high, snowmelt-driven spring flows that redistribute sediment, clean cobble substrates, and maintain channel complexity to provide a diversity of habitats. Base flows the rest of the year maintain these habitats by providing sufficient water depth for movement between reaches. Summer base flows also transport larval Colorado pikeminnow to nursery habitats and determine the quantity and quality of those nursery backwaters. In addition to flows sufficient to create and maintain habitats, Colorado pikeminnow requires relatively warm water temperatures to initiate spawning (greater than 16–18°Celsius [C; 61–64°Fahrenheit (F)]), incubate eggs (18–26°C [64–79°F]), and support larval and juvenile growth (22–30°C [72–86°F]). Because Colorado pikeminnow often migrate to specific spawning sites with clean cobble bars, and adult, juvenile, and larval life stages require different habitat types, Colorado pikeminnow require a variety of connected habitats arranged in a particular longitudinal fashion. In addition, adult Colorado pikeminnow occupy home ranges in reaches of river that provide a forage base comprised of suitable abundance and species of prey fishes. As a result, the extent of connected riverine habitats contributes to basin carrying capacity for Colorado pikeminnow populations.

Summary of Threats

Changes in the flow regime as a result of water development throughout the Colorado River basin led to initial declines in Colorado pikeminnow populations. In some cases, this development created barriers to movement in the form of dams and diversions, which have fragmented river reaches and limited access to historical habitats. Diversions can also entrain fish into water delivery systems and lead to direct mortality. Large dams can alter water temperatures through hypolimnetic releases, creating conditions too cold for Colorado pikeminnow growth and reproduction. Water storage and flow management often reduces spring peaks necessary to create and maintain spawning and nursery habitats needed by Colorado pikeminnow, and also reduces base flows, which can limit Colorado pikeminnow range and reduce habitat availability. Predation and competition from invasive, nonnative fishes reduces survival and recruitment of Colorado pikeminnow in all life stages. Contaminants that impact water quality can reduce reproduction and survival of individuals or lead to population

reductions in the case of large, toxic spills. Lastly, climate change and extended drought reduces streamflow in many river reaches, which strains efforts to manage flows to benefit Colorado pikeminnow (Service 2022, pp. 28–44).

Summary of Current Resiliency

The SSA report (Service 2022, entire) evaluated six "analysis units" throughout the Colorado River Basin based on geographic subbasins delineated by dams and reservoirs: Green River, upper Colorado River, San Juan River, Colorado River in Grand Canyon, Gila River, and lower Colorado River mainstem (Figure 1). Colorado pikeminnow has been extirpated from the three LCRB units (Grand Canyon, Gila River, and lower Colorado River). The three UCRB units are delineated by subbasins and treated as populations. Demographic processes occur independently within each UCRB river subbasin, although individuals do move between the Green and upper Colorado rivers. In these three, extant UCRB subbasins (Green River, Upper Colorado River, and San Juan River), each population currently has a low overall condition for demographic factors (Service 2022, p. 102). In the Green and upper Colorado River subbasins, low adult abundances and declines in adult numbers over the last 15–20 years influenced the low condition of the demographic factors. These population declines were the result of low production of age-0 fish and reduced recruitment. For the San Juan River subbasin, the low overall condition was a result of low reproduction, low adult abundances, and a lack of wild recruitment, despite the adult population increasing due to stocking (Service 2022, pp. 87–100). Currently, populations in all three subbasins demonstrate low resiliency (Figure 1) (Service 2022, pp. 86–102).

Summary of Current Redundancy

Colorado pikeminnow currently inhabits three river subbasins in the UCRB: the Green, upper Colorado, and San Juan (Figure 1). Although individuals move between the Green and upper Colorado Rivers, the San Juan River basin is isolated from the other two subbasins by Lake Powell and a waterfall at its downstream inflow to the reservoir. The population in the Green River subbasin is the largest of the three and inhabits the longest extent of riverine habitat (794 mi [1,278 km]) (Service 2022, pp. 106–107). The upper Colorado River subbasin has supported the second largest population distributed over 296 mi (476 km) of river, and the San Juan River subbasin's population has been increasing through stocking and occupies 216 mi (347 km). Colorado pikeminnow had been stocked into the Salt and Verde rivers in the Gila River subbasin, but survival has been very low. Arizona Game and Fish Department ceased stocking Colorado pikeminnow in 2018, and there are currently no plans to resume (Service 2022, p. 100). Therefore, current redundancy is described by the three extant populations as they are distributed across the river basins in the Green, San Juan, and upper Colorado River subbasins (Figure 1) (Service 2022, p. 122). These three populations occur in over 1,300 mi (2,092 km) of river across the UCRB in several mainstem and tributary reaches.

Summary of Current Representation

Colorado pikeminnow is limited to three populations in the Upper Colorado River Basin: the Green, upper Colorado, and San Juan River subbasins (Figure 1). Populations in the LCRB were extirpated by the 1970s, and it is not clear to what extent Colorado pikeminnow in the lower

basin may have been unique from extant populations in the upper basin. The Green and upper Colorado River populations are remnant wild populations that represent the genetic and behavioral diversity remaining for wild populations. Genetic analyses have not found evidence of differentiation between these two wild populations, but little research has been conducted using modern techniques. Colorado pikeminnow in the San Juan River subbasin are mainly derived from broodstock developed from fish collected in the Green and Colorado Rivers. As a result, the San Juan River population of Colorado pikeminnow reflects the genetic composition of fish stocked in that system. Although the current distribution of Colorado pikeminnow represents the remnant wild populations in the UCRB, the most recent genetic studies have not found evidence of low diversity or deviation from expected allele frequencies (Service 2022, pp. 123–125). In addition, individuals in these three populations use and make extensive movements between a variety of mainstem and tributary habitats throughout the three subbasins. As a result, maintaining the existing genetic and behavioral diversity found in these populations should allow the species to adapt to changing conditions over time.

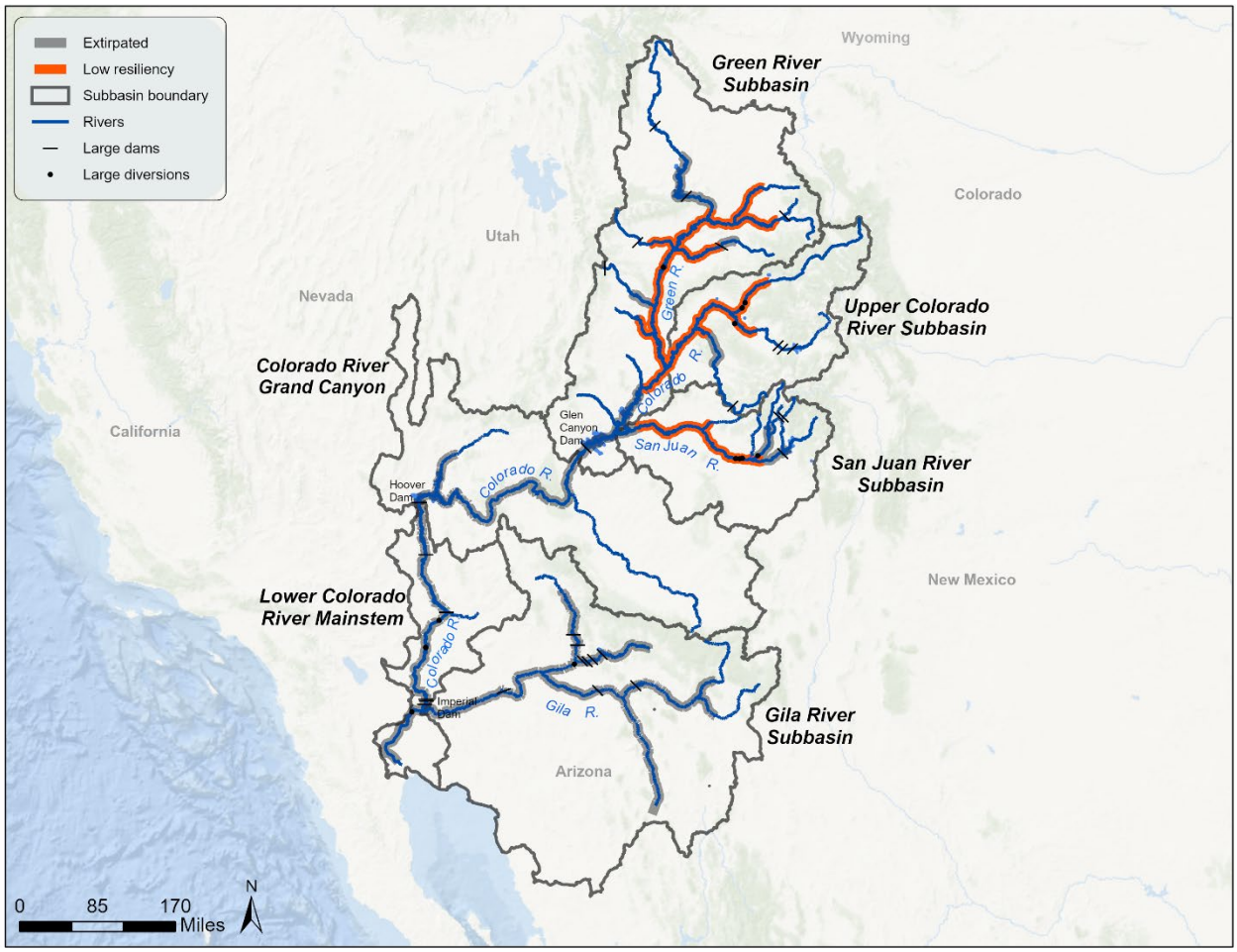

Figure 1. Current conditions of Colorado pikeminnow populations in each subbasin.

Recovery Vision

The recovery vision is the conservation and survival of Colorado pikeminnow. Recovery for Colorado pikeminnow will be signified by at least three populations: two with high resiliency distributed in the Green and upper Colorado River subbasins and one population with at least moderate resiliency in the San Juan River subbasin. These conditions would preserve the current genetic, behavioral, and ecological diversity across suitable habitats within a portion of the species' historical range.

Recovery Strategy

The recovery strategy describes the path needed to achieve the recovery vision. The Service measures species viability in terms of resiliency, redundancy, and representation, as described in the SSA report (Service 2022, entire). Through the recovery vision, recovery criteria, and recovery actions outlined in this recovery plan, we attempt to conserve representation and improve resiliency and redundancy of Colorado pikeminnow.

We consider Colorado pikeminnow populations resilient when they are sufficiently large to endure stochastic environmental change. Achieving such population sizes and vital rates is reliant on the quantity, quality, and distribution of riverine habitats supported by flow management. Due to the long lifespan of individuals, Colorado pikeminnow populations also require demographic processes be sufficient to replace adults over extended timeframes. Specifically, large populations of Colorado pikeminnow alone may not adequately represent resiliency in the absence of adequate reproduction and recruitment, since adults may live many years without new individuals recruiting to replace them. As a result, the recovery criteria listed below are designed to evaluate both current resiliency for adult populations in each subbasin, as well as the likelihood for populations to persist into the future based on trends in reproduction and recruitment.

Currently, all three subbasins have low resiliency (Service 2022, p. 102), so the recovery strategy for Colorado pikeminnow is to implement recovery actions and activities to improve the resiliency of populations in the Green and upper Colorado River subbasins from low resiliency to high resiliency, and from low resiliency to moderate resiliency in the San Juan River subbasin, as described in the SSA report (Service 2022, pp. 83–85). Once these populations' conditions are improved, additional recovery actions and the achievement of two threats-based criteria will ensure the species needs are met to maintain at least three populations with moderate to high resiliency. Four demographic recovery criteria and two threat-reduction recovery criteria are described below to objectively measure progress toward achieving the recovery vision.

The four demographic recovery criteria are described at a subbasin scale, recognizing all mainstem and tributary habitats contribute to recovery. Tributaries, in addition to mainstem reaches, will be important to achieve demographic criteria. Providing a variety of habitats and resources throughout each subbasin will be necessary to reach the degree of resiliency needed for recovery. As mentioned previously, the life history needs of Colorado pikeminnow individuals change as they grow from age-0 juveniles to mature adults. Tributaries can provide spawning, feeding, and home range resources needed to fulfill these life history requirements. Increasing the distribution of these resources in different locations can increase the likelihood that a needed

habitat feature is available when environmental conditions limit resources in another location. Finally, a larger network of quality habitats can support higher abundances by increasing the carrying capacity within a particular subbasin. It also reduces the chance that a catastrophic event (e.g. debris flow from wildfire burn scars) will affect the entire population, since individuals should be spread across a larger area or have access to suitable reaches.

Achieving recovery for Colorado pikeminnow will require stabilizing populations that have been declining and then increasing adult abundances in all three extant populations (Green River, Upper Colorado River, San Juan River). To support and improve adult abundance in these populations, flow management actions should continue or be improved to meet the species' needs, particularly for spawning and survival of juvenile fish. Recovery actions to provide and maintain access across Colorado pikeminnow current range will allow adults to access specific habitats needed to establish home ranges, forage, and spawn. The negative effects of nonnative fish to all life stages of Colorado pikeminnow need to be reduced to increase survival and recruitment, which will likely require developing new methods to deal with invasive fish species. Finally, a captive broodstock, or broodstocks, should be developed to conserve the genetic diversity of extant wild populations. This last action is intended to not only provide a genetic refuge should wild populations decline, but a broodstock can also be used to augment or restore populations where necessary.

As Colorado pikeminnow populations stabilize, the second suite of actions will assist in improving conditions, supporting increased adult abundances, and improving demographic processes. These include actions that maintain the forage base and habitats to support all life stages of Colorado pikeminnow, protecting water quality, expanding access to habitats necessary to achieve resilient populations, operating dams to provide suitable water temperatures, and reducing risks associated with resident nonnative species or those with the potential to be introduced. Second priority actions listed above further reduce threats to the species and improve conditions to support populations at resilient levels indicated in the recovery criteria.

The recovery vision addresses the needs of Colorado pikeminnow by identifying three subbasins with resilient populations that represent the species' existing genetic diversity. This vision also provides redundancy by maintaining, at a minimum, the three populations in the UCRB subbasins. The lack of specific recovery criteria for LCRB habitats does not minimize the importance of conservation actions or the pursuit of opportunities to establish populations in the LCRB. Rather, uncertainties around the potential for establishing Colorado pikeminnow and the demographic response in LRCB habitats preclude the ability to develop objective and measurable criteria for these areas. As conditions change, additional areas within the species' historical range should be evaluated for their recovery potential. For example, experts have identified potential habitat in Grand Canyon that may support Colorado pikeminnow (Service 2022, pp. 103–119; Dibble *et al.* 2022, entire). Should habitat conditions and recovery potential improve, any Colorado pikeminnow in the LCRB or other reaches will be included in future SSAs and considered during 5-year status reviews. Although the LCRB is not described in the recovery vision and criteria, this does not negate the importance of conservation efforts that might occur there in the future. Populations established in the LCRB would benefit Colorado pikeminnow redundancy by adding to existing populations in the three UCRB subbasins, thereby improving the viability of the species.

II. Recovery Criteria

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the Act are no longer necessary and a species may be delisted. Delisting is the removal of a species from the Federal Lists of Endangered and Threatened Wildlife and Plants (Lists). Downlisting is the reclassification of a species from an endangered species to a threatened species. The term "endangered species" means any species (species, subspecies, or Distinct Population Segment) that is in danger of extinction throughout all or a significant portion of its range. The term "threatened species" means any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Revisions to the Lists, including delisting or downlisting a species, must reflect determinations made in accordance with sections 4(a)(1) and 4(b) of the Act. Section 4(a)(1) requires that the Secretary determine whether a species is an endangered species or threatened species (or not) because of threats to the species. Section 4(b) of the Act requires that the determination be made "solely on the basis of the best scientific and commercial data available." Thus, while recovery plans provide important guidance on methods of minimizing threats to listed species and measurable objectives against which to measure progress towards recovery, they are guidance and not regulatory documents. Recovery criteria help indicate when we would anticipate that an analysis of a species' status under section 4(a)(1) would result in a determination that the species is no longer an endangered species or a threatened species. A decision to revise the status of, or remove a species from the Lists, however, is ultimately based on an analysis of the best scientific and commercial data then available, regardless of whether that information differs from the recovery plan. When changing the status of a species, we first propose the action in the *Federal Register* to seek public comment, followed by a final decision announced in the *Federal Register*. The following recovery criteria are based on information compiled in the SSA report (Service 2022, entire), and other input provided by scientific experts.

The following recovery criteria, when met collectively, would indicate that Colorado pikeminnow may be considered for reclassification to threatened (downlisting) or may no longer need the protections of the Act (delisting):

Recovery Criteria 1 – Population Stability

> **Criterion 1 for Downlisting:** Wild and stocked adult abundances are stable or increasing over a consecutive 15-year period in the Green, upper Colorado, and San Juan River subbasins. Adult abundances will be measured using standardized estimation techniques.
>
> **Criterion 1 for Delisting:** Wild adult abundances are stable or increasing over a consecutive 15-year period in the Green, upper Colorado, and San Juan River subbasins. Adult abundances will be measured using standardized estimation techniques.

Justification for Criteria 1:

The long lifespan of Colorado pikeminnow necessitates evaluating populations' stability over timescales relevant to the species life history. To confidently capture potential changes in demographic processes, 15 years was selected for this criterion because it is based on the generation time of a female Colorado pikeminnow, who mature more slowly than males. Population stability, as measured by trends in adult abundances, may be supported by management through the addition of stocked fish into the population, which adds specificity when evaluating adult population sizes under Recovery Criteria 2, below. To meet delisting criteria, stable or increasing trends in adult populations would need to be the result of wild fish abundance patterns. This recognizes the need for populations to be self-sufficient to be considered resilient. Stocked fish that survive to adult size are included in the downlisting criterion since stabilizing or increasing population sizes would reduce the threat of immediate extinction. The 15-year time scale allows for short term fluctuations in demographic processes due to environmental variation inherent to the Colorado River basin but assesses trends over periods relevant to the species' life history. A resilient population would be expected to recover from short-term declines and evaluating trends over a longer time interval should capture that population response.

A 15-year timeframe is based on generation time, using the formula in Valdez (2018, p. 37). This formula takes into consideration the age at reproductive maturity and annual adult survival. It represents the average time for a population to increase by a factor equal to the net reproductive rate and should therefore be a sufficient amount of time to detect changes in populations. In this case, we used 10 years as the age when females reproduce (Osmundson 2006, pp. 1569–1579) and an average annual survival of 0.8 for adults (Bestgen *et al.* 2005, p. 31; Osmundson and White 2009, p. 62; Bestgen *et al.* 2010, p. 35).

Recovery Criteria 2 – Population Size

Adult abundance thresholds are met over a consecutive 10-year period, as described in Table 1 for down- and de-listing.

Table 1. Adult Colorado pikeminnow abundances for each subbasin necessary to achieve Recovery Criteria 2 for both downlisting and delisting. (≥ is "greater than or equal to")

Population	Adult Abundance over a consecutive 10-year period	
	Recovery Criteria 2: Downlisting	**Recovery Criteria 2: Delisting**
Green River Subbasin	≥ 2,600 adults	≥ 3,100 adults
Upper Colorado River Subbasin	≥ 500 adults	≥ 760 adults
San Juan River Subbasin	≥ 250 adults	≥ 250 adults

Justification for Criteria 2

Adult Colorado pikeminnow abundances represent the reproductive potential for the species over long time scales, and because of the species' long lifespan, adult populations serve as indicators whether life history requirements are being met. In addition, long term monitoring for adult abundances in the Green and upper Colorado River subbasins provide data on population sizes in the recent past (1990s–2000s) when demographic processes appeared adequate to support resiliency. At a minimum, adult populations determine the species' ability to recover from stochastic events, since larger populations can better withstand unfavorable conditions. Finally, adults contribute to reproduction which replaces individuals lost from stochastic events. Stocked fish that survive to adult size may be included in achieving these criteria, and Criteria 3 and 4 (below) account for other life stages that contribute to the long-term viability of the species.

The timeframe of 10 consecutive years for adult abundance criteria is based on the age at which females reach sexual maturity (Osmundson 2006, pp. 1569–1579). This period of time would indicate adult abundances have been sustained long enough for young individuals to enter the adult population and contribute to reproductive success at a rate sufficient to replace adults as they die.

Due to differences in available habitat and extent of suitable river reaches, adult abundances are presented for each subbasin. For the Green and upper Colorado River subbasins, adult abundances for delisting criteria are based on population sizes observed in the 1990s and early 2000s, and adult numbers exceeded this criterion in those years when reproduction and recruitment appeared to be occurring at levels that supported resilient populations (Bestgen *et al.* 2007, entire; Osmundson and White 2017, entire; Bestgen *et al.* 2018, entire). San Juan River subbasin abundance criteria are based on estimated carrying capacity from bioenergetics modeling in currently available habitat (Miller and Lamarra 2006, entire; Miller 2014, pp. 58–59).

In the Green River subbasin, the downlisting criterion was developed from estimates of the minimum viable population (MVP) size (Service 2002, pp. 18–22). A minimum viable population identifies an abundance where a population should be viable or resilient and considers both environmental stochasticity and genetic diversity. Based on this concept, the MVP abundance of ≥2,600 adults was established for downlisting. In addition, since Colorado pikeminnow move between the upper Colorado and Green River populations, adult abundances in these two subbasins contribute to the viability of both populations. For the upper Colorado River subbasin, the downlisting criterion is based on observed adult abundances that have resulted from low recruitment rates in prior years. In this subbasin, the adult abundance from 1992 to 2010 averaged over 600 adults (Osmundson and White 2014, entire). When adult abundances were estimated to be less than 500 fish, it was believed to be the result of poor recruitment and years of low reproduction (Elverud *et al.* 2020, p. 30). Based on these data, the downlisting criterion of 500 adults for the upper Colorado River subbasin is based on adult abundance that would be expected to result from sufficient demographic processes to maintain the population, namely reproduction and recruitment. The downlisting criterion of 250 adults for the San Juan River subbasin is based on reaching the threshold for a "moderate" condition in adult abundance (Service 2022, p. 85) and reflects uncertainty in the size of population that

might be expected in that subbasin. The down- and de-listing criterion for the San Juan River subbasin is the same due to this uncertainty. The criterion represents an adult abundance below the carrying capacity, but much improved compared to recent estimates and is expected to reflect improvements in other demographic processes in the absence of stocking (Miller 2018, pp. 37–38). Finally, Colorado pikeminnow in the San Juan River subbasin are largely derived from broodstocks collected in the upper Colorado and Green River subbasins. The San Juan River population contributes to redundancy and maintains the species in a portion of its historical range.

Recovery Criteria 3 – Recruitment to Sexual Maturity

> **Criterion 3 for Downlisting:** Wild recruitment to sexual maturity equals or exceeds annual adult mortality over 10 consecutive years in the Green, upper Colorado, and San Juan River basins.
>
> **Criterion 3 for Delisting:** Wild recruitment to sexual maturity equals or exceeds annual adult mortality over 15 consecutive years in the Green, upper Colorado River, and San Juan River basins.

Justification for Criteria 3

These criteria for down and delisting recognize the importance of documenting recruitment to the adult life stage to confidently assess resiliency of populations. Again, because of Colorado pikeminnow's long lifespan, adult abundances alone may not reflect whether demographic processes are sufficient to maintain populations into the future. The 10- and 15-year time scales for this criterion reflect the age at which females reach maturity (see Recovery Criteria 2, above) and the generation time described for Recovery Criteria 1, above. Longer time scales also allow for short term fluctuations in demographic processes due to environmental variation but assess trends over periods relevant to the species' life history.

Recovery Criteria 4 – Reproductive Success

Mean density of wild age-0 juveniles collected in autumn standardized sampling meets thresholds described in Table 2 over a consecutive 10-year period in the Green, upper Colorado, and San Juan River basins.

Table 2. Age-0 Colorado pikeminnow densities for each subbasin to meet recovery criterion 4.

River Subbasin	Downlisting and Delisting Criteria
Green River subbasin	≥5 age-0 per 100m^2 habitat
Upper Colorado River subbasin	≥3.3 age-0 per 100m^2 habitat
San Juan River subbasin	≥1.4 age-0 per 100m^2 habitat

Justification for Criteria 4

Reproductive success, as measured by densities of age-0 fish collected in autumn, is believed to be a significant factor in recent declines or low abundance of Colorado pikeminnow populations. Despite displaying high adult abundances in the Green and upper Colorado River subbasins around the year 2000, Colorado pikeminnow populations in those two subbasins declined in response to low recruitment of age-0 fishes (Osmundson and White 2017, pp. 141–144; Bestgen *et al*. 2018, pp. 71–74). Low adult abundances and the need for augmentation in the San Juan River subbasin are believed to be the result of inadequate recruitment of fish produced in the wild (Miller 2018, pp. 15–16).

The specific criteria thresholds for each subbasin were derived from long-term monitoring studies or models developed to predict adult abundances. For the Green River subbasin, age-0 densities were derived from long-term mean densities in Bestgen and Hill (2016, entire) and analyses used in population models by Miller (2018, pp. 10–11). These densities represent the combined product of reproduction and recruitment in the first growing season after spawning and appear to be levels of reproduction needed to maintain or increase adult abundances over longer periods. Similar methods were used to derive long-term mean densities for Colorado pikeminnow in the upper Colorado River subbasin to inform PVA models (McAbee 2017, entire; Valdez *et al*. 2017, pp. 1–6; Miller 2018, pp. 13–14), and these densities help establish measurable indicators of reproduction and recruitment that should support adult abundances through time. For the San Juan River subbasin, age-0 densities were derived from models (Zeigler *et al*. 2021, pp. 15–19). These models used PVA projections from the Green River (Miller 2018, p. 10–12) to estimate the relationship between age-0 abundances and future adult population sizes. The models then predicted the density of age-0 fish captured based on their overall abundance in the river, availability of habitats, and sampling design. From these relationships, the models predicted that age-0 densities would need to be ≥1.4 age-0 fish per 100 m^2 to maintain or exceed an abundance of 250 adults.

Recovery Criterion 5 – Threats-based (Delisting)

Regulatory mechanisms or conservation plans are in place that include stakeholder commitments to management actions that support Colorado pikeminnow populations beyond delisting in the Colorado, Green, and San Juan subbasins. Commitments should include management actions such as controlling nonnative fishes, operating fish passages and entrainment reduction facilities,

and maintaining a genetic refuge. Plans or management actions should be revised and updated based on the best available science.

Justification for Criterion 5

Current actions to support recovery of Colorado pikeminnow are coordinated by the two recovery programs in the Upper Colorado River Basin and the San Juan River Basin. These programs were created to address the need for basin-wide recovery actions, thus meeting the requirements of the Act and associated regulatory documents. Certain management actions may need to continue in order to maintain conditions that support the species, even potentially following a delisting. Stakeholders will need to determine which entities will be responsible for management actions into the future through conservation agreements or other regulatory documents before delisting could occur. For example, without ongoing management, nonnative fishes will likely continue to pose a threat to Colorado pikeminnow at all life stages. Similarly, fish passages will be needed to maintain access to reaches of river that support adult abundance or habitats necessary to complete Colorado pikeminnow life history. Finally, it is recommended that a broodstock be maintained to serve as a genetic refuge in case of a catastrophic event. The demographic criteria indicate recovery could be considered if three populations meet the thresholds listed. With only three populations, and the potential for genetic differences to exist between the Green and upper Colorado River lineages, maintaining a genetic refuge will contribute to preserving diversity of the extant populations and provide redundancy in case of a catastrophic reduction in populations size.

Recovery Criterion 6 – Threats-based (Delisting)

Flow management plans are in place that include stakeholder commitments to provide flows that support current populations of Colorado pikeminnow beyond delisting in the Colorado, Green, and San Juan basins. Commitments should include legally protecting flows in Colorado pikeminnow designated critical habitat in accordance with tribal, state, and federal laws. Commitments should also include providing flows that support the species in the Colorado, Green, Gunnison, San Juan, White[1], and Yampa Rivers and revising flow recommendations when appropriate and based on the best available science.

Justification for Criterion 6

As described above, peak and base flows are critical components of river habitats necessary for Colorado pikeminnow to complete its life cycle. In addition, the alteration of stream flows as a result of water development is specified as a factor contributing to the listing of Colorado pikeminnow (Service 2020, p. 17). The recovery programs and applicable Records of Decision (RODs) coordinate flow management throughout the current range of Colorado pikeminnow to support recovery. In the absence of recovery program coordination or regulatory compliance for the Act, it is unclear how flows will be provided to support Colorado pikeminnow populations. It will be necessary to provide certainty that adequate flows will be provided in the future to support Colorado pikeminnow populations, and that those flows will be conveyed through needed reaches.

[1] Current flow recommendations are interim.

III. Prioritized Recovery Actions

The following is a list of prioritized actions, including site-specific management actions, that when fully implemented are expected to result in recovery of Colorado pikeminnow. Priority 1 actions are based on currently available information that suggests those actions must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future. Priority 2 actions are those that must be taken to prevent a significant decline in population size or habitat quality or some other significant negative impact. The assignment of priorities does not imply that some recovery actions are of low importance but recognizes that lower priority items may be deferred while higher priority items are being implemented. Please refer to Table 3 for a clear association among recovery actions and the threats addressed by these actions. The RIS will contain the specific tasks required to implement these recovery actions.

In developing recovery actions for Colorado pikeminnow, several broad themes emerged that applied to most, if not all, of the actions listed below. There are still uncertainties in the level of action and the species' response to actions, so research needs to be conducted to refine the needs of Colorado pikeminnow in each subbasin. The best available science from this research should be used to guide and implement recovery actions and management practices. In addition, recovery actions should be periodically evaluated and revised based on the response of Colorado pikeminnow populations. Finally, although demographic criteria have been developed for populations at a subbasin scale, we recognize the need to implement recovery actions in important tributaries as well as mainstem reaches. It is likely Colorado pikeminnow will need a variety of habitats available throughout each subbasin to achieve the degree of resiliency needed for recovery. These recovery actions will improve the ability of Colorado pikeminnow to withstand catastrophic events and long-term environmental change.

Priority 1 Actions

1. Manage river flows in all subbasins to include both inter- and intra-annual variability that approximates the natural hydrograph and supports Colorado pikeminnow life history. This action provides an ecologically based suite of flows throughout the year and between years. For example, spring peak flows should clean spawning substrates, maintain channel complexity, create nursery habitats, provide access to floodplains, and promote movements to spawning areas. Base flows should support fish movement, maintain food web productivity, transport larvae, and maintain nursery habitats.

2. Operate and maintain fish passage facilities in all subbasins to facilitate Colorado pikeminnow movement. This action provides habitat access across the species' current range that allows for use suitable to fulfill life history requirements.

3. Control nonnative fish populations that reduce Colorado pikeminnow abundance and survival, particularly in the Colorado and Green River subbasins. This action improves Colorado pikeminnow recruitment and survival by reducing predation and competition from problematic nonnative species. Successful implementation of this action will minimally involve determining the level of invasive species reductions needed to improve Colorado pikeminnow demographics, developing new strategies and methods,

and implementing additional or novel methods to suppress or eradicate nonnative fishes at a landscape scale.

4. Develop captive broodstock(s) from wild fish to maintain existing genetic diversity of populations in the Colorado and Green River subbasins. This action protects the extant genetic and life history lineages. Broodstock(s) should serve as a genetic refuge and provide offspring for augmentation programs where needed. If determined necessary to meet demographic recovery criteria, this action should include production, rearing, and stocking sufficient numbers of Colorado pikeminnow to meet stocking goals and augmentation plans.

Priority 2 Actions

5. Conserve, or improve, native fish communities to provide a forage base for all life stages of Colorado pikeminnow in all subbasins. This action supports growth and survival of Colorado pikeminnow. Supporting native fish communities may include controlling nonnative fish to reduce impacts to native fish species and augmenting or reintroducing native fish species where necessary, in addition to implementing flow management described for Colorado pikeminnow.

6. Create and maintain habitats for Colorado pikeminnow using mechanical restoration methods or flow management actions in all subbasins. This action provides necessary habitats through a variety of mechanisms, including if climate change causes natural hydrologic conditions to become insufficient to perform habitat maintenance functions. Flow management activities under this action might differ from those intended to directly benefit Colorado pikeminnow populations, such as flows to reverse negative effects of vegetative encroachment or to transport sediment.

7. Develop partnerships to improve land management practices that may reduce water quality via runoff of contaminants or spills in all subbasins. This action protects stream water quality.

8. Operate dams to provide appropriate release water temperatures to meet life history requirements, specifically from Flaming Gorge Dam, Navajo Dam, and the Aspinall Unit. This action should be continued at Flaming Gorge Dam or enacted where feasible at the other locations if water temperatures are a limitation in achieving demographic recovery criteria.

9. Expand Colorado pikeminnow access into the greatest feasible extent of historically occupied range. This action increases the species' resiliency, redundancy, and representation, recognizing that Colorado pikeminnow is currently limited to a small portion of its former range. Implementation of this action might include exploring opportunities to reintroduce the species, constructing additional passage or improvement projects, or modifying existing structures where access is a limitation to achieving demographic recovery criteria. Warmer stream temperatures from climate change and future management actions could lead to improved habitats outside the current distribution for Colorado pikeminnow. Periodic assessments should be conducted to

determine the suitability of additional reaches to contribute to recovery of the species, particularly in the LCRB.

10. Prevent escapement of invasive fishes from source populations by constructing exclusion facilities, replacing invasive species in reservoirs with compatible sport fisheries, and eliminating sources where possible. This action reduces threats posed by the expansion of nonnative species into current range of Colorado pikeminnow.

11. Reduce illicit and unintentional movements of all invasive taxa that could become established in Colorado pikeminnow current range by conducting outreach, enacting regulations where needed, and enforcing regulations. This action reduces the risks posed by the introduction or establishment of additional invasive species.

Table 3. Factors affecting the survival of Colorado pikeminnow (Service 2020, pp. 16–18) and associated recovery actions and criteria.

Listing Factors under the Act	Threats Description	Recovery Actions	Recovery Criteria
Factor A- *The present or threatened destruction, modification, or curtailment of its habitat or range*	Habitat degradation and fragmentation due to water development	1, 2, 6, 8, 9	1, 2, 3, 4, 5, 6
Factor C- *Disease or predation*	Predation	3, 10,11	3, 4, 5
Factor E- *Other natural or manmade factors affecting its continued existence*	Small population size and extirpation in some basins	4	1, 2
	Climate change	1, 2, 6, 8	5, 6
	Contaminants	7	2, 3, 4
	Reduced forage base	5	2, 5, 6

IV. Estimated Time and Costs to Achieve Recovery

We summarized the estimated time and costs to achieve recovery of Colorado pikeminnow (Table 4). The values are derived from projected time and costs for actions similar to those described as recovery actions above and do not account for possible future inflation. These estimates will be described more specifically in the activities to be developed collaboratively in the Recovery Implementation Strategy (RIS). While this plan and the associated estimates are based on actions needed to recover Colorado pikeminnow specifically, most of the actions will also provide benefits to other listed and native fishes of the Colorado River basin. We estimate that the full implementation of these actions would improve the status of Colorado pikeminnow and could be completed approximately 15 years following the adoption of this plan. We note that the recovery program may change over time, or the timeframe estimated to implement the recovery actions to achieve recovery of the species may take longer than expected. Many of the recovery actions described in this plan address threats to the species and will need to continue beyond delisting so that these threats do not reverse progress made in recovering the species.

Finally, Federal, State, non-governmental organizations (NGOs), and local stakeholders direct a suite of additional activities that, while not specifically directed at Colorado pikeminnow, further contribute to recovery of the species. These activities are not part of the estimated costs and may include efforts such as improving water quality, managing water supplies and timing of flows, protecting water rights, and restoring ecosystem functions.

Table 4. Estimated time and costs of recovery actions for the recovery of Colorado pikeminnow.

Costs ($1,000s) and Time Frames (Years)					
Recovery Action	**Action Summary**	**Implementation Timeframe**			
		Years 1–5	**Years 6–10**	**Years 11–15**	**Total**
1	Manage flows	10,930	10,930	10,930	32,790
2	Operate and maintain fish passages	25,250	10,650	10,650	46,550
3	Control nonnative fishes	11,420	11,420	11,420	34,260
4	Develop and maintain broodstock	4,735	4,735	4,735	14,205
5	Conserve or improve forage base	3,690	3,690	3,690	11,070
6	Create and maintain habitats	2,165	4,340	2,165	8,670
7	Protect stream water quality	250	250	250	750
8	Operate dams for appropriate temperatures	200	0	0	200
9	Expand range	7,728	7,728	7,728	23,185
10	Prevent escapement of nonnative fishes	5,165	1,165	1,165	7,495
11	Prevent introductions of new invasive species	215	215	215	645
Total		**71,748**	**55,123**	**52,948**	**179,820**

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VI. Glossary

Term	Definition
Catastrophic	The outcome of a wide-ranging event that may result in the loss of one or more populations.
Extirpated	The local extinction of a species, where it ceases to exist in a particular area but continues to exist elsewhere.
Hypolimnetic	Originating from a layer of water in a thermally stratified lake or reservoir. The hypolimnion layer is deeper in the water, does not circulate, and maintains colder temperatures.
Piscivorous	A description for an animal that primarily or exclusively feeds on fish.
Redundancy	The number of populations or sites necessary to endure catastrophic losses (Shaffer and Stein 2000, pp. 308–10).
Representation	The genetic diversity necessary to conserve long-term adaptive capability (Shaffer and Stein 2000, pp. 307–308).
Resiliency	The size of populations necessary to endure random environmental variation (Shaffer and Stein 2000, pp. 308–310).
Species viability	A species' ability to sustain populations in the wild beyond the end of a specified time period, assessed in terms of its resilience, redundancy, and representation (Service 2016).
Stochastic	Random or non-deterministic events. Can also refer to natural changes in genetic composition of a population, unpredictable fluctuation in environmental conditions, or variation in population demographics (Service 2016).
Turbidity	A measure of a liquid’s clarity as a result of suspended particles.
Viability	See “Species Viability” above

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