FINAL REPORT

ALTERNATIVE STRATEGIES FOR STOCKING COLORADO PIKEMINNOW IN THE SAN JUAN RIVER BASIN

Prepared For:

San Juan River Basin Recovery Implementation Program

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INTRODUCTION AND BACKGROUND

Colorado Pikeminnow (CPM) *Ptychocheilus lucius* is listed as endangered under the Endangered Species Act of 1973. Although historical records of the species in the San Juan River exist, consistent monitoring of the species did not begin until adult and young-of-year CPM were captured during community fish surveys in the late 1980s (SJRIP 2016). In 1992 a recovery program, the San Juan River Basin Recovery Implementation Program (SJRIP), was formed to conserve the population of CPM in the San Juan River while water development proceeded in the basin (SJRIP 2016). The recovery goals for the species in the Upper Colorado River basin were updated and amended in 2002 to include site specific management actions and measurable recovery criteria (USFWS 2002). The current recovery criteria for CPM in the San Juan River basin are:

> Downlist: Over a 5-year period, a target number of 1,000 age-5+ fish (> 300 mm TL) through augmentation and/or natural reproduction.
>
> Delist: Over a 7-year period beyond downlisting, a self-sustaining population exceeding 800 adults (age-7+, > 450 mm TL).

By the mid-1990s it was estimated that the population of CPM in the San Juan River numbered fewer than 100 individuals, and possibly less than 50 (Holden 1999). To increase the population, experimental stocking began in 1996, with a formal augmentation Phase I plan adopted in 2003 and a revised Phase II plan adopted in 2010 (Ryden 2003; SJRIP 2016; Furr 2017). A Phase III plan is currently in development by United States Fish and Wildlife Service (USFWS) New Mexico Fish and Wildlife Conservation Office (S. Davenport, USFWS, personal communication). Since the initiation of the Phase I augmentation plan in 2003, approximately 4.9 million age-0 CPM have been stocked into the San Juan River. Although survival of stocked fish has been low over that time period, the success of recent and ongoing stocking of CPM cannot be overstated. These efforts have directly led to a small population of adult CPM in the San Juan River that has successfully spawned in most years since 2010 (Farrington et al. 2017; Schleicher 2017), with documented post-larval age-0 (young-of-year, YOY) CPM cohorts in 2016, 2017, and 2019 (Barkalow et al. 2020). It is precisely this success that has brought the SJRIP to a point where assessing alternative stocking strategies is warranted.

Augmentation efforts helped to establish a small population of CPM that consistently spawn in the San Juan River, and while this a noteworthy achievement, it is essential that spawning efforts result in CPM that recruit to the adult population. It is therefore imperative that wild fish be distinguishable from hatchery-origin fish stocked into the river to allow for successful management decisions to further recovery efforts working towards a self-sustaining population. Secondarily, it is important to consider the potential effects that stocked fish may have on their wild counterparts through competition for resources and behavioral influences. Given these needs, the SJRIP has undertaken an effort to develop a living document that explores alternatives to current stocking practices. The primary objective of this document is to provide an adaptive management framework to guide and evaluate different stocking strategies for CPM in the San Juan River Basin that allow wild fish to be distinguished from hatchery origin fish and limit their interaction. The stocking alternatives listed herein will be implemented based on the most current augmentation plan or the latest stocking recommendation approved by the SJRIP Biology and Coordination committees (BC,

CC) to determine the number of fish, location(s) to be stocked, and identify specific augmentation objectives.

DESIRED CONDITIONS

The first step in developing management alternatives for stocking CPM in the San Juan River was identifying desired conditions for the population. An adaptive management framework was used to develop a set of four hierarchal desired conditions for the CPM population (Figure 1; Table 1). Desired conditions reflect both resultant conditions following the implementation of management actions and recovery goals for CPM in the San Juan River (USFWS 2002).

Second, conservation actions which will potentially aid in recovery of the CPM population and in obtaining the desired conditions were identified. Finally, quantitative responses to conservation actions, and performance metrics to evaluate those quantitative responses were outlined. All performance metrics outlined for a desired condition would need to be met to evaluate the outcome of a conservation action. Consistent monitoring of performance metrics will allow for accurate assessment of the populations recovery and also help to reduce uncertainties associated with conservation actions. Failure to meet the performance metrics and quantitative measures would indicate that the hypothesized influence of conservation actions on the CPM population in the San Juan River were incorrect. Even if performance metrics or hypothesized outcomes are not met, knowledge gained can be used to develop new conservation actions and performance metrics.

While the successful implementation of multiple conservation actions (e.g., flow recommendations, habitat restoration) are needed to meet the desired conditions, this document focuses solely on population augmentation and its potential management alternatives. The development of desired conditions, quantitative responses, and performance metrics provide the ability to easily explore other conservation actions, and their alternatives, in the future.

The desired conditions are a hierarchical list with the primary and secondary conditions representing the future goals that are being worked towards. While, tertiary and quaternary desired conditions represent the current and past scenarios that were resultant of SJRIP conservation actions to date. The primary desired condition achieves recovery of Colorado Pikeminnow, and should constantly be strived for. In the context of this document, the primary desired condition would be achieved through adaptive augmentation. If the primary desired condition cannot be achieved, then the secondary desired condition would be strived for. Not achieving at least the secondary desired condition would be considered a failure. The four desired conditions, quantitative responses, and performance metrics are listed below.

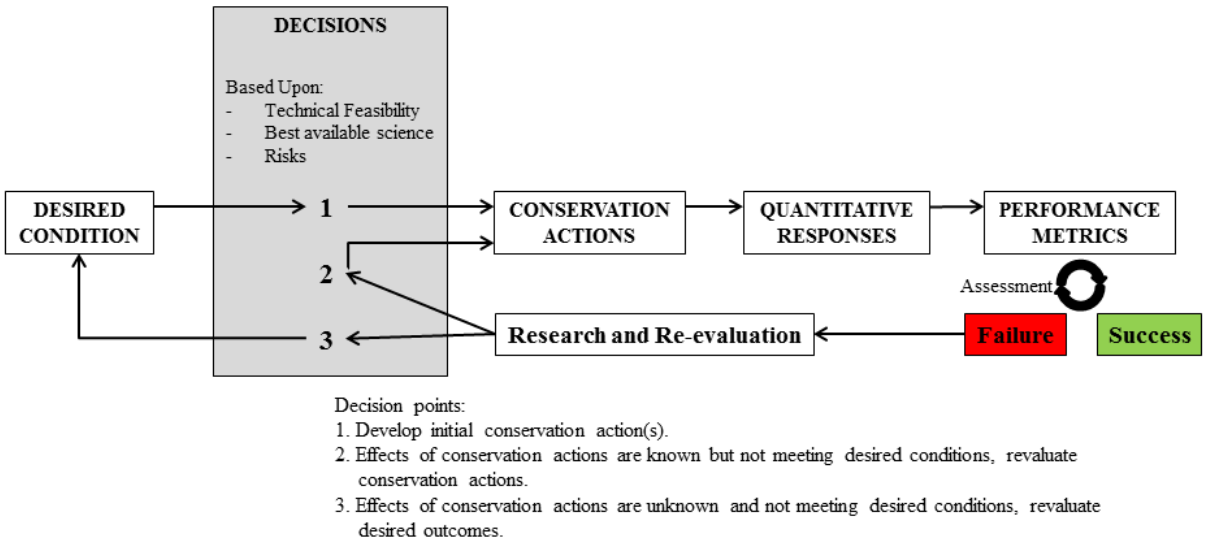

Figure 1. Conceptual model of the adaptive management plan for adaptive augmentation of Colorado Pikeminnow in the San Juan River. Figure adapted from Yellowstone National Park (2010).

PRIMARY DESIRED CONDITION

The primary desired condition is characterized by a self-sustaining population which meets the delisting criteria for CPM in the San Juan River basin. The quantitative response for the Primary Desired Condition is that the abundance of wild age-7+ CPM averages 800 or more fish over 7 years.

The performance metrics for the Primary Desired Condition include:

1. Adult (age-7+) population growth rate ≥ 1.0 over a 7 year period.
2. Density of wild YOY CPM averages 0.6 fish/10 m^2 or greater in Reaches 1 – 4 over a 7 year period.
3. Abundance of wild age-7+ CPM averages greater than 5 fish/river mile (RM) over a 7 year period.

SECONDARY DESIRED CONDITION

The secondary desired condition is characterized by a mixed-origin (i.e., hatchery and wild) population which meets the downlisting criteria for CPM in the San Juan River basin. Similar to the primary desired condition, the secondary desired condition would be achieved through adaptive augmentation. The quantitative response for this condition is that the abundance of mixed-origin age-5+ (> 300 mm) CPM averages 1,000 or more fish over 5 years.

The performance metrics for the Secondary Desired Condition include:

1. Population growth rate > 1.0 over a five year period.
2. Adult (age-7+) population growth rate ≥ 1.0 over a 5 year period.
3. Density of wild YOY CPM averages 0.5 fish/10 m^2 or greater in Reaches 1 – 4 over a 7 year period.
4. Abundance of mixed-origin age-5+ CPM averages greater than 6 fish/RM over a 5 year period.

TERTIARY DESIRED CONDITION

The tertiary desired condition is characterized by a mixed-origin population which reproduces every year, however the detection of wild YOY and recruitment is variable and the population is below downlisting criteria. This condition would be achieved by annual augmentation of the CPM population. Based on recent monitoring, this is the current condition of the CPM population in the San Juan River.

The performance metrics for the Tertiary Desired Condition include:

1. Population growth rate > 1.0 over a 10 year period.
2. Larval CPM captured every year.
3. Annual CPM population augmentation.
4. Wild YOY CPM captured 3 out of every 5 years.
5. Abundance of mixed-origin age-5+ CPM averages greater than 1 fish/RM over a 5 year period.

QUATERNARY DESIRED CONDITION

The quaternary desired condition is characterized by a population that has little or no reproduction and abundances of CPM which are well below the downlisting criteria. This condition would be met by annual augmentation of the CPM population. This is the condition which existed in the 1990s and 2000s. Annual augmentation has pushed the population above this condition.

The performance metrics for the Quaternary Desired Condition include:

1. Population growth rate > 1.0 over 10 years.
2. Annual CPM population augmentation.
3. CPUE of age-1+ CPM increasing.

Table 1. Desired conditions, conservation actions, quantitative responses, and performance metrics for Colorado Pikeminnow in the San Juan River above Paiute Farms Waterfall.

Desired Condition	Conservation Actions	Quantitative Response	Performance Metrics
Primary Population is completely self-sustaining, consistent reproduction and recruitment to adults, at levels required for delisting.	Adaptive population augmentation.	Abundance of wild adult (age-7+) CPM averages 800 or more fish over a 7 year period.[1]	● Adult (age-7+) population growth rate ≥ 1.0 over a 7 year period. ● Density of wild YOY CPM averages 0.6 fish/10 m^2 or greater in Reaches 1 – 4 over a 7 year period.[2] ● Abundance of wild age-7+ CPM averages greater than 5 fish/RM over a 7 year period. [3]
Secondary Consistent reproduction and detection of recruitment past larval stage, variable detection of recruitment to adult. Mixed-origin sub-adult and adult CPM present at downlisting levels.	Adaptive population augmentation.	Abundance of mixed-origin age-5+ (> 300 mm) CPM averages 1,000 or more fish over a 5 year period.[1]	● Population growth rate > 1.0 over a 5 year period. ● Density of wild YOY CPM averages 0.5 fish/10 m^2 or greater in Reaches 1 – 4 over a 5 year period.[2] ● Abundance of mixed-origin age-5+ CPM averages greater than 6 fish/RM over a 5 year period.[3]
Tertiary Consistent reproduction, detection of recruitment past larval stage variable, hatchery-origin sub-adult and adult consistently captured.	Yearly population augmentation.	Abundance of mixed-origin age-5+ (> 300 mm) CPM averages 250 or more fish over a 5 year period.	● Population growth rate > 1.0. ● Larval CPM captured every year. ● Stock age-0 CPM every year.[4] ● Wild YOY CPM captured 3 out of 5 years. ● Abundance of hatchery-origin age-5+ CPM averages greater than 1 fish/RM over a 5 year period.[3]
Quaternary Little or no reproduction, low abundances of sub-adult and adult fish.	Yearly population augmentation.	Age-1+ CPM of hatchery-origin fish detectable within the river.	● Population growth rate > 1.0. ● Stock age-0 CPM every year.[4] ● CPUE of age-1+ CPM increasing.

[1]USFWS (2002).

[2]See Appendix A: Calculation of Wild Young-of-year Colorado Pikeminnow Density

[3]Between RM 147.8 and RM 76.4; See Appendix B: Calculation of Age-5+ and Age-7+ Abundances

[4]Furr (2010).

STOCKING ALTERNATIVES

Adaptation of the current Colorado Pikeminnow stocking method is needed because achieving the primary desired conditions requires the establishment of a self-sustaining population of 800 adults. Below we outline the assumptions and uncertainties, associated risks, and the management alternatives for population augmentation of CPM in the San Juan River. The proposed management alternatives are an exhaustive list based on the best available science.

UNCERTAINTIES

Any conservation action has inherent uncertainties. Reducing the uncertainty associated with the below topics is an important component of the adaptive management strategy. Assessment of these uncertainties will inform the success or failure of the management alternative that is implemented. Failure to address the below uncertainties will limit the ability of the SJRIP to assess the efficacy of population augmentation efforts, as well as the achievement of desired conditions. The uncertainties associated with the proposed management alternatives include:

FITNESS OF WILD FISH.—The fitness (i.e., survival and performance) of wild CPM is greater than or equal to the fitness of hatchery-origin CPM.

EFFICACY OF STOCKING (A).—Stocking of age-0 fish is the most efficient hatchery technique for recovery of CPM in the San Juan River.

EFFICACY OF STOCKING (B).—Stocking of age-1 fish is a similarly efficient hatchery technique to stocking age-0 fish for recovery of CPM in the San Juan River.

WILD AND HATCHERY-ORIGIN FISH INTERACTIONS.—The effect of interactions between age-0 wild and hatchery-origin CPM. It is unknown if interactions will result in any deleterious effects on either the wild- or hatchery-origin fish, and, if those interactions will result in population level effects.

RELATIONSHIP BETWEEN SPRING PEAK FLOWS AND CPM SPAWNING.—The April 1st projected available water and the Animas River Basin mean snow water equivalent (SWE) can be used to predict successful reproduction of CPM (Appendix C). Colorado Pikeminnow will successfully spawn and create large age-0 cohorts in years when one or more of the flow recommendations including the 5,000 cfs flow recommendation (21 d at 5,000 cfs) is met or exceeded.

EFFICACY OF HATCHERY ENRICHMENT.— It is assumed that hatchery enrichment techniques, (e.g., prey training, habitat complexity, flow conditioning, etc.) will increase post-stocking survival as a result of increased condition factor, predatory vigor, and behavioral fitness, compared to conventionally raised CPM. While this is based on a number of well-founded concepts this has not been scientifically evaluated within the context of CPM recovery in the San Juan River Basin.

MINIMAL TAG LOSS.—Post-stocking tag loss is known to occur but it is expected to be minimal.

UNDERSTANDING RISK

All potential management actions carry risks. The way in which those risks are understood and perceived by program stakeholders influences the decision making process even when the risks

themselves are sometimes poorly defined or articulated. Our desire is to understand those risks so that they can be mitigated and balanced to the greatest extent possible. A substantial challenge in doing so arises from each individual's perception of how those risk categories are weighted in importance and where they are willing to accept risk. We have attempted to define the various risks associated with CPM augmentation alternatives.

BIOLOGICAL RISK—The risk that implementing a management action will result in slower progress towards recovery for biological reasons. Three scenarios are likely to result in realization of this risk; 1) The program anticipates recruitment of a cohort of wild spawned CPM to age-1 and therefore does not produce hatchery fish to stock in the river but the recruitment of wild fish fails thereby resulting in a missing cohort for that year, 2) The program incorrectly anticipates a wild cohort will not be present in the river, produces CPM in the hatchery for stocking, and then stocks hatchery CPM on top of a wild cohort of CPM, 3) Stocking age-1 CPM results in lower returns (survival to subsequent age class) than what has been observed for age-0 stocked fish. Scenario 1 is problematic if stocking does not occur for several years in a row, resulting in a large gap of age classes in the population. However, only two years in a row of stocking could be missed before the selected stocking alternative would be determined to be incorrect and reevaluated. Scenario 2 is only problematic if the hatchery fish cannot be reliably marked and thereby differentiated from wild CPM when encountered later or if hatchery fish are found to have a negative effect on wild fish, which is a substantial uncertainty. Lastly, Scenario 3 is problematic if the program opts to stock age-1 Colorado Pikeminnow in the anticipation of similar or increased survival and instead effectively weakens the forthcoming age classes.

FISCAL RISK—The risk that the program will invest fiscal resources in production of CPM in the hatchery but later decide not to utilize those fish, thereby negating that fiscal investment. Any losses associated with a fiscal risk are usually a matter of degree. That is, only in a scenario where the fish cannot be utilized in any manner that benefits recovery would the loss be total. If the fish are used in an alternate, albeit less effective manner, to benefit recovery the fiscal loss would be partial.

OPPORTUNITY RISK—The risk that a management action will take resources away from an alternate action that ultimately would have been more beneficial. This risk shares similarities with financial risk but is different in that it is broader in scope. In our case, an example of opportunity risk would be producing fish at the hatchery that ultimately are not needed when the personnel and fiscal resources could have been utilized for habitat improvement, research, or other projects. This scenario also demonstrates the opportunity risk for the hatchery where space to rear fish is often limited and valuable.

SOCIO-POLITICAL RISK—The risk that a management action has negative or unintended outcomes, or outcomes that are perceived as such, to the degree that external forces dictate changes in the decision making process regardless of whether it is warranted or not. The program includes stakeholders and decision makers who are not as familiar with all of the biological complexity as those on the technical committees. Some decisions, no matter their biological justification, may simply be unacceptable because of their actual or perceived outcomes. As an example, it has often been said that producing CPM at the hatchery only to later destroy them because wild fish are

present in the river, will be politically unacceptable. Further, the concern exists that even proposing such an approach might be politically perilous. It is extremely difficult to quantify or predict political risk especially given the fact that something may be acceptable in one place in time but not another.

MANAGEMENT ALTERNATIVES

The development of management alternatives to a conservation action is a central component of adaptive management. Currently, augmentation of CPM is conducted under the Phase II Plan which recommends the stocking of approximately 400,000 age-0 CPM every year from 2010 to 2020 (Furr 2010). The efficacy of calcein marking stocked age-0 CPM was recently assessed as a method to distinguish them from wild fish in the river. Results from that study found that the calcein mark was correctly identified 80% of the time after 300 days in fish held in a laboratory setting, however, the mark was not reliably detected in fish held in an outdoor pond settings (Gilbert et al. 2019). While a better quantification of how light exposure differs between field and experimental settings may further our understanding of the utility of calcein marking as a means to distinguish hatchery and wild age-1 fish, it remains unreliable and therefore insufficient. Unless a novel technique to distinguish between hatchery-origin and wild fish in the river is implemented, continued stocking of age-0 CPM when a wild cohort is present in the river will prevent the SJRIP's ability to track recruitment of wild fish to adults. Furthermore, experimental evaluation of hatchery enrichment will be more efficient if stocked CPM are individually marked. Consequently, the SJRIP BC recommended and subsequently CC recently voted to suspend stocking of 400,000 age-0 CPM in favor of stocking 12,000 PIT-tagged age-1 CPM annually (BC February Meeting Summary 2020, CC May Meeting Summary, 2020).

Presented below are six management alternatives, including the uncertainties and quantitative measurements of success associated with those alternatives. It is expected that the current standardized annual larval, young-of-year (i.e., small-bodied fishes), sub-adult/adult monitoring, and demographic monitoring can be used to assess whether or not these performance metrics are met. Regardless of the management alternative selected, it is recommended that management alternative be conducted for a five year period before its success is evaluated and potentially a different alternative is implemented.

ALTERNATIVE 1.—Unmarked age-0 Colorado Pikeminnow would be stocked annually. This option is analogous to a "no action" or continuation of the current conservation actions outlined in the Phase II Augmentation Plan.

Reasoning

During the Phase I Colorado Pikeminnow Augmentation Plan (2003 – 2009), approximately 2.2 million age-0 Colorado Pikeminnow were stocked into the San Juan River, with an additional 2.7 million stocked from 2010 – 2016 under the Phase II Augmentation Plan (Furr 2010, 2017). Stocking of age-0 fish into the San Juan River has resulted in an adult population which has reproduced most years since 2010 (Farrington et al. 2017; Schleicher 2017) with recruitment of wild YOY CPM documented in 2016, 2017, and 2019 (Barkalow et al. 2020). A novel method to distinguish wild and hatchery-origin CPM would need to be developed to allow for wild fish to be tracked to adult recruits.

Uncertainties

1. Efficacy of Stocking (A).

2. Wild and Hatchery-origin Fish Interactions.

Measurement of Success

- Over a five year period, the abundance of age-2+ CPM in the San Juan River will statistically increase as measured by the SJRIP's Demographic (2019 – 2021) and Community (2022-2023) Monitoring programs.
- Wild YOY cohorts will be produced three out of every five years,
- Wild CPM can be distinguished from hatchery-origin fish and tracked to adults.

ALTERNATIVE 2.—The April 1st projected available water in Navajo Reservoir and the mean SWE in the Animas River basin will be used to determine if unmarked age-0 CPM are produced and subsequently stocked in the San Juan River (Appendix C). The number of fish and location(s) to be stocked will follow the guidelines of the most current augmentation plan and be implemented in annual scopes-of-work (SOWs).

Reasoning

Recent genetics work to evaluate the N_b of CPM (an estimate of the number of fish that successfully spawn) has indicated varying levels of adult contribution to larval production (Diver and Wilson 2018). Subsequent analysis by Durst (USFWS, unpublished data) indicates that when the 5,000 cfs flow recommendation (21 d at 5,000 cfs) is met, the number of spawning CPM is higher than years when it is not. If the April 1st projected available water for Navajo Reservoir is predicted to be large enough to meet or exceed the 5,000 cfs flow recommendation or the Animas River basin has a mean SWE of 22 or greater as determined by snow telemetry (SNOTEL) gauges, age-0 CPM would not be produced by the hatchery or stocked that year. Otherwise, unmarked age-0 CPM would be produced and subsequently stocked in the San Juan River in accordance with the guidelines provided in the most current augmentation plan and be implemented in annual SOWs.

Uncertainties

1. Relationship between Spring Peak Flows and CPM Spawning.
2. Wild and Hatchery-origin Fish Interactions.
3. Fitness of Wild Fish.

Measurement of Success

- The predicted relationship between spring peak flows and CPM spawning will be correct 4 out of 5 years (80% prediction success).
- Successful spawning by CPM will produce densities of wild age-0 CPM in Reaches 2 – 4 greater than 0.1 fish/10 m^2.
- The abundance of age-2+ CPM in the river will statistically increase over five years as measured by Demographic and Community Sampling.
- Survival of wild age-1, age-2, and age-3 fish is statistically higher than survival of hatchery-origin CPM of these age classes (i.e., wild fish have greater fitness).

ALTERNATIVE 3.—Unmarked age-0 Colorado Pikeminnow will be produced annually, the decision to stock those fish will be determined based on the number of wild YOY CPM captured in September during

annual small-bodied fishes monitoring. The number of fish and location(s) to be stocked will follow the guidelines of the most current augmentation plan and be implemented in annual SOWs.

Reasoning

As discussed in the Recovery Goals for Colorado Pikeminnow (USFWS 2002), delisting of the species requires a self-sustaining population. Documenting recruitment of wild fish to adults is therefore paramount to demonstrating recovery of the species in the San Juan River. If no stocking occurs when wild age-0 YOY CPM are present in the river, then origin of fish from a particular year class will be known with certainty, even if a novel technique to distinguish between hatchery-origin and wild CPM is lacking. Stocking of hatchery-origin fish would not occur if density of YOY CPM in Reaches 2 – 4 is greater than 0.6 fish/10 m^2; Flannelmouth Sucker *Catostomus latipinnis* and Bluehead Sucker *Catostomus discobolus* YOY densities rarely exceed 0.6 fish/10m^2 (Appendix A). Not stocking age-0 CPM would require a contingency plan for the disposition of those fish (see Un-stocked Fish Disposition discussion below).

Uncertainties

1. Fitness of Wild Fish.
2. Efficacy of Stocking (A).
3. Wild and Hatchery-origin Fish Interactions.

Measurement of Success

- The abundance of age-2+ CPM in the river will increase over the 5 years as measured by Demographic Monitoring and Community Sampling.
- Survival of wild age-1, age-2, and age-3 CPM is higher than survival of hatchery-origin fish of these age classes.

ALTERNATIVE 4.—The April 1st projected available water in Navajo Reservoir and the mean snow water equivalent (SWE) in the Animas River basin will be used to determine whether or not unmarked age-0 CPM are produced (Appendix C). The decision to stock those fish will then be determined by the number of wild YOY CPM captured in September during annual small-bodied fishes monitoring. The number of fish and location(s) to be stocked will follow the guidelines of the most current augmentation plan and be implemented in annual SOWs.

Reasoning

This alternative is a combination of management alternatives 2 and 3. The decision to produce fish every year would be based on the April 1st projected available water in Navajo Reservoir and the mean snow water equivalent (SWE) in the Animas River basin. If the April 1st projected available water for Navajo Reservoir is predicted to be large enough to meet or exceed the 5,000 cfs flow recommendation or the Animas River basin has a mean SWE of 22 or greater as determined by snow telemetry (SNOTEL) gauges, age-0 CPM would not be produced or stocked that year. Otherwise, age-0 CPM would be produced. The decision to stock any produced fish in November would then be dependent on the number of wild YOY CPM captured during small-bodied fishes monitoring. If density of YOY CPM in Reaches 2 – 4 is greater than 0.6 fish/10 m^2, then the produced fish would not be stocked. If fish

are not stocked, a contingency plan for the disposition of fish not stocked is required (see Disposition of Un-stocked Fish discussion below).

Uncertainties

1. Fitness of Wild Fish.
2. Efficacy of Stocking (A).
3. Relationship between Spring Peak Flows and CPM Spawning.

Measurement of Success

- The predicted relationship between spring peak flows and CPM spawning will be correct 4 out of 5 years (80% prediction success).
- Spawning by CPM will produce densities of wild YOY CPM in Reaches 2 – 4 greater than 0.1 fish/10 m^2.
- The abundance of age-2+ CPM in the river will increase over the 5 years as measured by Demographic Monitoring and Community Sampling.
- Survival of wild age-1, age-2, and age-3 fish is higher than survival of hatchery fish of these age classes.

ALTERNATIVE 5.—Stock only age-1 PIT-tagged CPM.

Reasoning

Holding hatchery-origin CPM until they are large enough to be PIT-tagged before stocking will increase the ability to differentiate them from wild fish while still maintaining annual stockings. However, some tag loss is expected and will prevent the identification of origin for some portion of the population as fish age. Hatchery produced CPM could be held in a passively or actively managed pond and provided hatchery enrichment (e.g. prey training). All fish would be PIT-tagged before being stocked to allow accurate distinction between wild spawned and hatchery produced fish as well as permit evaluation of post stocking survival and hatchery enrichment.

Assumptions and Uncertainties

1. Fitness of Wild Fish.
2. Efficacy of Stocking (B).
3. Wild and Hatchery-origin Fish Interactions.
4. Efficacy of Hatchery Enrichment.
5. Minimal Tag Loss.

Measurement of Success

- PIT-tagged age-1+ CPM will be stocked every year in accordance with the most current augmentation plan or approved stocking alternative and be implemented in annual SOWs.
- Survival from age-1 to age-2 of CPM stocked at age-0 and age-1 are statistically similar, resulting in similar numbers of stocked age-2 fish in the river.
- The abundance of age-2+ CPM in the river will increase over the 5 years as measured by Demographic Monitoring and Community Sampling.
- Wild CPM can be distinguished from hatchery-origin fish and tracked to adults.

ALTERNATIVE 6.—Stocking of CPM in the San Juan River is ceased until such a time that it is determined that stocking needs to be reinitiated.

Reasoning

Recent collection of wild YOY CPM in 2016, 2017, and 2019 indicates that the population may have increased above some threshold where recruitment past the larval stage is at a level which can be detected using current sampling methods. Continued increases in the adult population would most likely result in increased recruitment of wild fish past the larval stage, and eventual recruitment to adults. Ceasing augmentation would allow for the assessment of wild fish survival and the ability of the population to be self-sustaining. Augmentation would have to be resumed if the population failed to continue producing wild cohorts or the population began declining.

Assumptions and Uncertainties

1. Fitness of Wild Fish.

Measurement of Success

- Density of wild YOY CPM in Reaches 2 – 4 is greater than 0.1 fish/10 m^2.
- The abundance of age-2+ CPM in the river will increase over the 5 years as measured by Demographic Monitoring and Community Sampling.
- Survival of wild age-1, age-2, and age-3 is higher than survival of hatchery-origin fish of these age classes (i.e., wild fish have greater fitness).

DISPOSITION CONTINGENCIES FOR UN-STOCKED FISH

A major component of Alternatives 3 and 4 is the disposition of fish produced in the hatchery but not recommended for augmentation. For either of these management alternatives to be implemented, a plan for unused hatchery fish must be in place. Six potential contingencies for disposition of those fish are listed below in no particular order. The SJRIP Biology and Coordination committees will determine which contingency to pursue if disposition of un-stocked fish is required. Further, all stocking of CPM will either occur in locations outlined by the most current augmentation plan and be implemented in annual SOWs or in a location that is recommended by the BC and subsequently approved by the CC.

Disposition Contingencies:

- Stock fish below the waterfall in the San Juan Arm of Lake Powell.
- Stock fish in tributaries outside of currently occupied areas.
- Holdover fish in an actively managed pond(s) until they are large enough to be PIT tagged.
- Holdover fish in a passively managed pond(s) until they are large enough to be PIT tagged.
    - Holdover could occur at a hatchery or in a net pen in Lake Powell
- Give age-0 fish to another recovery program to support their augmentation efforts.
- Destroy fish.

RECOMMENDATION

Implementation of a management action involves balancing the risks and uncertainties associated with an alternative, while ensuring that the recommendation moves the CPM population in the San Juan River towards the Primary Desired Condition in a timely manner. Based on the information above, Management Alternative 5 is being recommended for implementation over a five-year period as the management plan for stocking CPM in the San Juan River Basin. This alternative will maintain annual population augmentations of CPM, while also increasing the probability of accurate identification of wild produced and hatchery-origin CPM. The first stocking of age-1 Colorado Pikeminnow will occur in 2021 and continue every subsequent year. All available age-1 CPM will be stocked in accordance with the guidelines outlined in the most current augmentation plan and be implemented in annual SOWs.

Annual monitoring efforts will be used to assess the efficacy of the recommended alternative during the five year implementation. The success of this management alternative will be evaluated by the SJRIP Biology and Coordination committees in 5 years (2025). Following the review, any divergence from or any change to the approved alternative would require a recommendation by the SJRIP BC and subsequent approval by the CC. Given that annual monitoring efforts provide insight into potential failings of the implemented alternative, changes could be implemented prior to five years if deemed necessary by the BC and CC. The reasoning, uncertainties, and measurements of success for the recommend management alternative are listed below.

Reasoning

Holding hatchery-origin CPM until they are large enough to be PIT-tagged before stocking will increase the ability to differentiate them from wild fish while still maintaining annual stockings. However, some tag loss is expected and will prevent the identification of origin for some portion of the population as fish age. Hatchery produced CPM could be held in a passively or actively managed pond and provided hatchery enrichment (e.g. prey training). All fish would be PIT-tagged before being stocked to allow accurate distinction between wild spawned and hatchery produced fish as well as permit evaluation of post stocking survival and hatchery enrichment.

Assumptions and Uncertainties

1. Fitness of Wild Fish.
2. Efficacy of Stocking (B).
3. Wild and Hatchery-origin Fish Interactions.
4. Efficacy of Hatchery Enrichment.
5. Minimal Tag Loss.

Measurement of Success

- PIT-tagged age-1+ CPM will be stocked every year in accordance with the most current augmentation plan or approved stocking alternative and be implemented in annual SOWs.
- Survival from age-1 to age-2 of CPM stocked at age-0 and age-1 are statistically similar, resulting in similar numbers of stocked age-2 fish in the river.
- The abundance of age-2+ CPM in the river will increase over the 5 years as measured by Demographic Monitoring and Community Sampling.
- Wild CPM can be distinguished from hatchery-origin fish and tracked to adults.

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APPENDIX A: CALCULATION OF WILD YOUNG-OF-YEAR COLORADO PIKEMINNOW DENSITY

The ability to estimate the abundance of wild young-of-year (YOY) Colorado Pikeminnow (CPM) is required for the San Juan River Basin Recovery Implementation Program to assess the reproductive output needed to support a self-sustaining population of CPM in the San Juan River. Recent analysis of the 2016 cohort estimated a potential abundance of 1,155 – 54,805 wild YOY CPM in the river depending on their distribution, capture probability, and percentage of near zero and zero velocity habitats sampled (Zeigler and Ruhl 2017). Although this analysis provided context to this wild cohort's importance, uncertainties in the model, specifically with capture probabilities, required the development of a new model. To facilitate comparisons of abundances in the Upper Basin, the potential density (fish/10 m^2) of YOY CPM in the San Juan River was used to predict total abundance of YOY and adult (age-7+) CPM. We used three steps to develop an estimate of YOY densities for the Desired Conditions and Management Alternatives Measures of Success: (1) predicting YOY CPM abundances, (2) using the YOY CPM abundances to project the future number of CPM adults, and (3), estimating the potential number of captures during autumn small-bodied fishes (SBF) monitoring based on YOY abundances.

The amount of available habitat and an expected range of densities were used to estimate the total abundance of YOY CPM in the river. Young-of-year CPM have only been captured in Reaches 2 – 4, so only the available area (m^2) of habitats in Reaches 1 – 4 were considered. It was assumed that if fish were present in Reach 2, they would also be present in Reach 1. The area of available habitats in Reaches 1 – 4 averaged 378,045 m^2 (range: 212,855 – 593,599 m^2) from 2002 to 2007 (Figure A1) (Bliesner et al. 2009). River-wide habitat mapping was discontinued after 2007, so newer data is not available for this analysis. Long-term (1979 – 2012) density of YOY CPM in the lower Green River averaged 1.47 fish/10 m^2 and 0.51 fish/10 m^2 in the middle Green River (Bestgen and Hill 2016). A range of densities (0.10 – 1.50 fish/10 m^2) that was similar to those observed in the Green River were then used to predict the total abundance of YOY CPM expected to be present in Reaches 1 – 4 during autumn, assuming an even distribution of fish throughout these reaches. Predicted abundances of YOY CPM present in the river would range from 3,780 to 56,707 fish (Figure A2). For comparison, the 2003–2017 estimated densities of YOY commonly encountered suckers (Flannelmouth Sucker *Catostomus latipinnis* and Bluehead Sucker *Catostomus discobolus*) in the San Juan River ranged between 0.02 and 0.63 fish/10 m^2 (Figure A3).

The number of adult (age-7+) CPM was estimated from the abundance of YOY present in the river, age-specific survival estimates of CPM in the Green River assuming a single-phase population trajectory (Miller 2018), and a maximum age of 15 (i.e., no fish survive past age 15). Young-of-year abundance estimates were assumed to be an average through time. Estimated adult abundance ranged from 143 to 2,143 fish (Figure A2). A mean YOY CPM density of 0.1 fish/10 m^2 over time would result in a population with 143 adults, similar to current adult estimates for the San Juan River population. Increasing the YOY CPM density to 0.60 fish/10 m^2 would increase the adult population to 857 fish, slightly above the Recovery Goals for delisting.

The number of YOY expected to be captured during autumn SBF monitoring was estimated using the total abundance of YOY CPM and the potential amount of available habitat sampled during monitoring. The amount of near zero and zero velocity habitat sampled during SBF monitoring was obtained for Reaches 1 – 4 from the monitoring program's long-term database. The percentage of available habitat sampled during monitoring from 2003 – 2007 was calculated using the total available habitat area (m^2). The mean percentage of habitat sampled over those years was 0.7% (range: 0.3 – 1.6%).

A range from 0.25 – 2.50% of sampled area was then used to predict the number of YOY captured in the river based on their total abundance in Reaches 1 – 4. The number of captures was also adjusted by assuming that only 57.8% (RM 130 – 52.8) of Reaches 1 – 4 will be sampled any given year. Depending on the total YOY CPM abundance and the percentage of habitat sampled, the expected number of catches during SBF monitoring would range from 6 – 832 fish (Figure A4.; Table A1). The range between 11 and 333 YOY CPM is the more likely as the average amount of habitat sampled is usually 1% of that available.

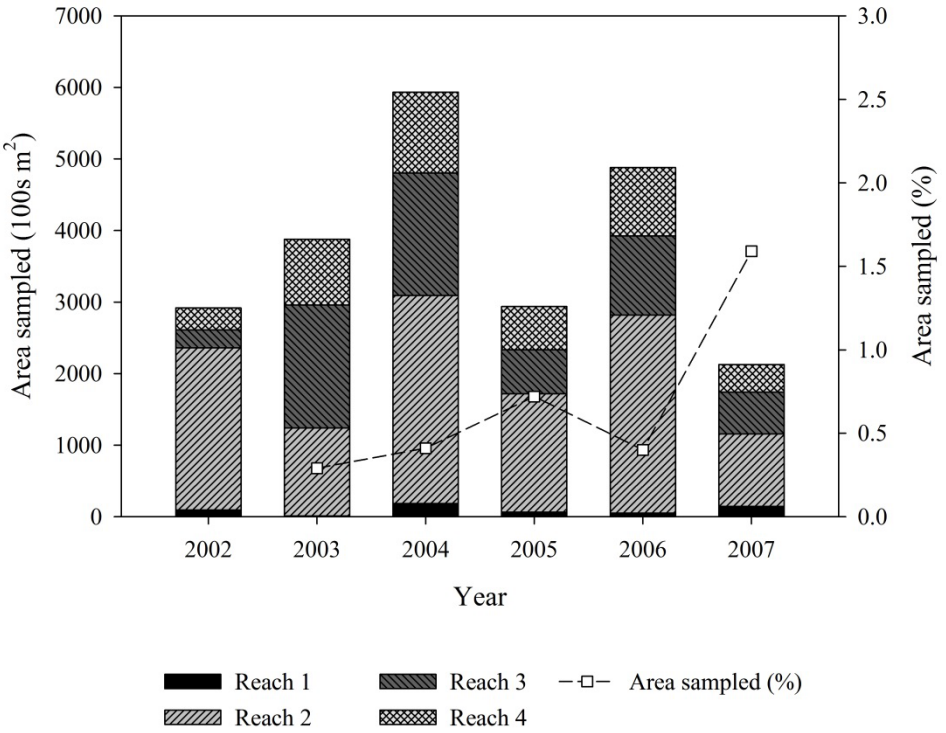

Figure A1. The area (100s m2) of available zero and near zero velocity habitat in Reaches 1 – 4 of the San Juan River from 2002 – 2007, and the amount of the available habitat area sampled (%) during small-bodied fishes monitoring from 2003 – 2007.

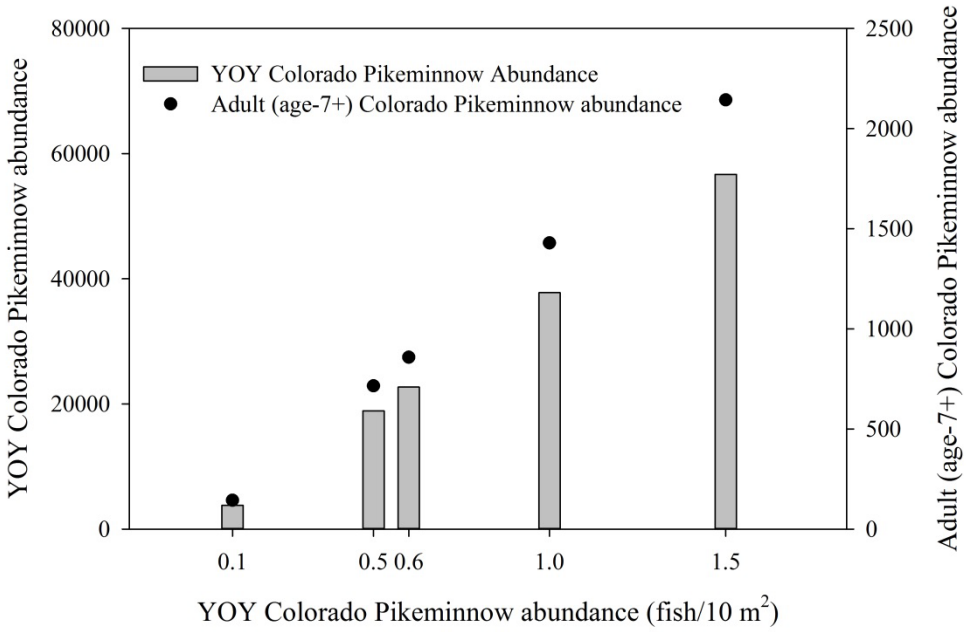

Figure A2. The predicted abundance of young-of-year (YOY; grey bars) and adult (age-7+, black circles) Colorado Pikeminnow in Reaches 1 – 4 of the San Juan River based on different densities (fish/10 m^2) of YOY fish.

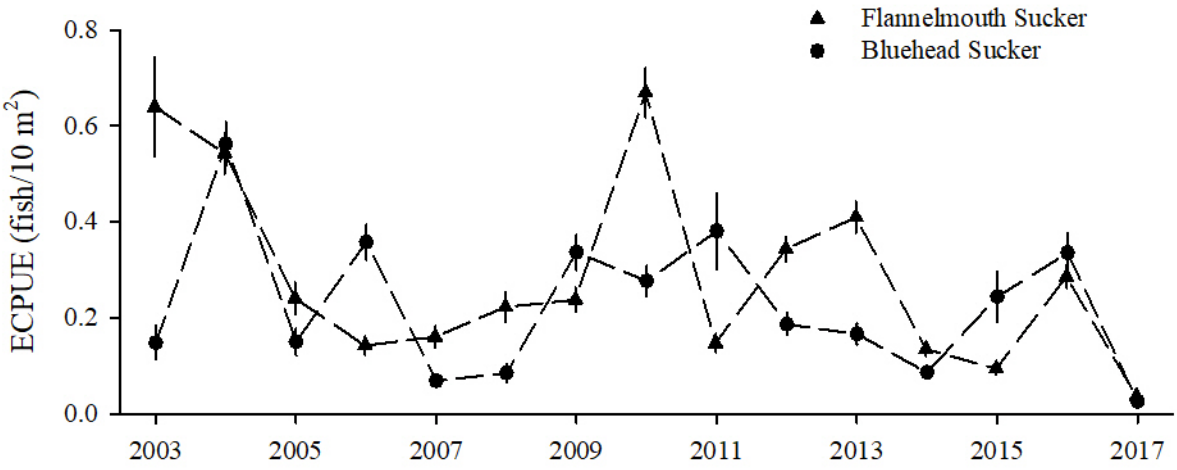

Figure A3. The estimated density of young-of-year Flannelmouth Sucker (triangles) and Bluehead Sucker (circles) in Reaches 3–6 of the San Juan River from 2003 to 2017.

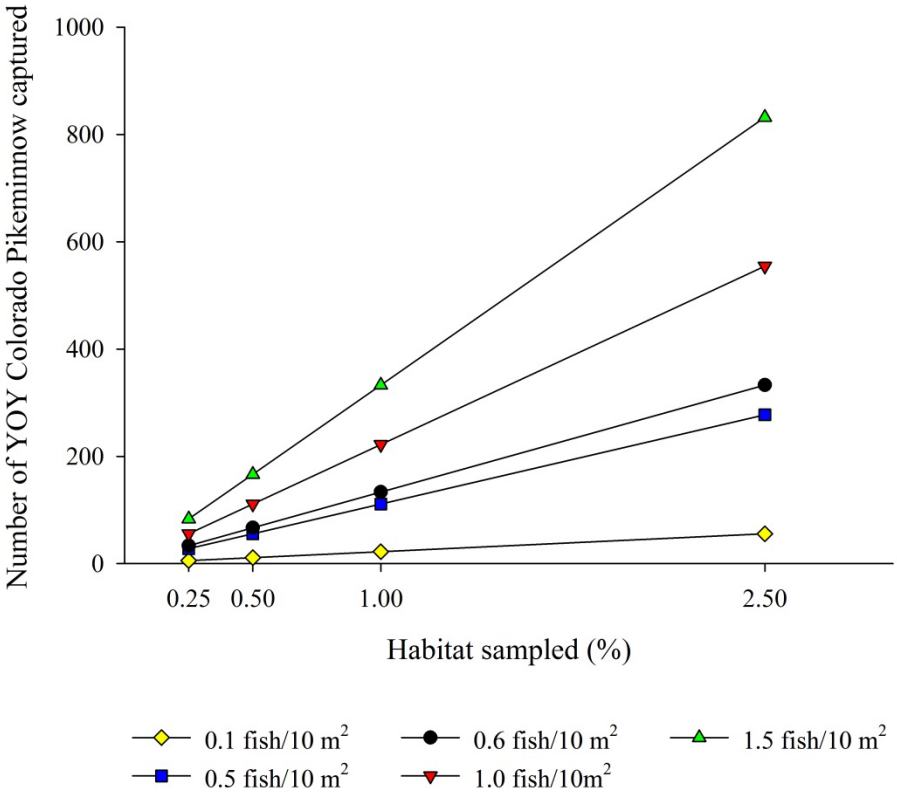

Figure A4. The expected number of young-of-year (YOY) Colorado Pikeminnow to be captured during small-bodied fishes monitoring in Reaches 2 – 4 (TM 130 – 52.8) based on the density of YOY Colorado Pikeminnow in the river and the available habitat sampled (%).

Table A1. The expected number of young-of-year (YOY) Colorado Pikeminnow captured during San Juan River autumn small-bodied fishes monitoring in Reaches 2 – 4 (RM 130 – 52.8) based on the density (fish/10 m^2) of YOY Colorado Pikeminnow present in the river and the percentage of available habitat sampled in this section of river. The abundance of YOY and adult (age-7+) fish based on the mean YOY density through time is given for clarity.

			Available habitat sampled (%)			
			0.25	0.5	1.0	2.5
YOY Density (fish/10 m^2)	YOY Abundance	Adult Abundance	Expected number of YOY captures			
0.1	3,780	143	6	11	22	55
0.5	18,902	714	28	55	111	277
0.6	22,683	857	33	67	133	333
1.0	37,805	1,429	55	111	222	555
1.5	56,707	2,143	83	166	333	832

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APPENDIX B: CALCULATION OF AGE-5+ AND AGE-7+ COLORADO PIKEMINNOW ABUNDANCES

New Demographics Monitoring will provide the ability of the SJRIP to estimate age-specific abundances of Colorado Pikeminnow. This information will provide a better understanding of the population in the San Juan River, and also provide a better ability to assess the population's movement towards a specific desired condition. Although monitoring will only be conducted from Shiprock, NM (RM 147.8) downstream to Sand Island, UT (RM 76.4), estimates of abundance per RM should permit estimation of river-wide abundance (RM 180 – 0). Based on the amount of the river the species can occupy (180 RMs), an estimate of 6 or more age-5+ fish per RM would result in a total abundance of 1,080 age-5+ fish and 5 or more age-7+ fish per RM would result in 900 age-7+ fish river-wide. Although these numbers are slightly higher than the required Quantitative Responses (Table 1), abundances of CPM are higher in the section of river that will be sampled so slightly lower abundances in areas above and below the sampling reach should result in actual numbers closer to the Quantitative Responses.

APPENDIX C: FORCASTING HIGH FLOWS IN A LARGE TRIBUTARY TO THE SAN JUAN RIVER USING SNOW WATER EQUIVALENT.

The timing and magnitude of the San Juan River's spring flows are managed through releases from Navajo Dam to meet flow targets set forth by the San Juan River Basin Recovery Implementation Program that were identified as critical for the maintenance of biotic and abiotic factors that promote recovery of endangered fishes (Holden 1999; SJRRIP 2018). In an effort to meet flow targets and mimic a natural hydrograph, spring releases from Navajo Dam are timed to synchronize with peak runoff conditions in the Animas River. The Animas River is a large and relatively unregulated tributary to the San Juan River and annually the Animas River contributes a significant proportion of the water in the San Juan River and often exceeds the San Juan River's spring discharge. In the absence of a spring release from Navajo Reservoir, the Animas River determines the hydrograph of the San Juan River.

Given the importance of the Animas River in determining spring runoff conditions in the San Juan River, a method to assess the Animas River's spring runoff potential is necessary when considering flow based stocking alternatives for Colorado Pikeminnow (CPM).The flow based stocking alternatives were initiated by recent genetics work of CPM (Diver and Wilson 2018) and subsequent analysis by Durst (USFWS, unpublished data) that demonstrated when the 5,000 cfs flow target is met the number of spawning CPM is higher than years when it is not met, which gives rise for the necessity of accurately anticipating spring runoff conditions. The decision to not produce CPM is both significant and time sensitive; as April 1st is the no-cost deadline for U.S. Fish and Wildlife Southwestern Native Aquatic Resources and Recovery Center to halt CPM production. The need for including a method to assess the Animas River's spring runoff is especially compelling considering years like 2019. In 2019, the April 1st projected spring releases from Navajo Dam were not to exceed 5 days at 5,000 cfs, yet with some releases from Navajo Reservoir, the Animas River contributed enough water that all of the San Juan River flow recommendations were met (USBR 2019; Figure C1).

In 2019, the Animas River basin mean snow water equivalent (SWE), assessed from 3 snow telemetry (SNOTEL) gauges (Red Mountain Pass, Molas Lake, and Stump Lakes), on April 1st (30.1) was the third highest in 30 years (Figure C1). As a result of the 2019 record high SWE in the Animas River basin, runoff conditions in concert with a coordinated maintenance release from Navajo Reservoir resulted in the San Juan River meeting all identified flow targets for the first time since 2005.

Using the mean April 1st SWE in the Animas River Basin is a streamlined but proficient way to estimate the potential for high volume and sustained discharge contributed to the San Juan River during spring runoff on an annual basis. When the thirty year (1990–2019) mean April 1st SWE in the Animas River basin is above the average (20.6) the majority (85%; 1993, 1994, 1997, 2005, 2008, 2019) of years experienced sustained high volume discharge during spring runoff (Figure C2). While the relationship between SWE in the Animas River Basin doesn't always reflect the resultant spring flows (e.g., 2015 and 2017) there has never been a year when a mean SWE of 22 or greater didn't result in the San Juan River meeting or exceeding the 21 days at 5,000 cfs flow target (Figure C1).

Here we propose using both the US Bureau of Reclamation April flow predictions and the April 1st mean SWE in the Animas River basin as ways to elect to initiate or halt CPM production for stocking as outlined in the stocking plan. Given the importance of meeting CPM stocking goals set forth in the proposed adaptive management stocking plan, it is prudent to assess the potential for failure, defined by two scenarios. In the first scenario, the decision is made to not produce CPM, but flows never reach the 5,000 cfs target and a wild CPM cohort is not produced. Alternately, the decision to produce CPM is

made erroneously based on discharge projections and hatchery produced CPM are stocked on top of a wild cohort. Luckily, this can be assessed by implementing the proposed amendments retrospectively visualizing the results (Table C1). Had the proposed hydrologically cued amendments been in place, CPM production and consequently stocking would have occurred in 7 out of 10 years. In all of the 7 years where CPM would be produced and stocked, the SJR did not meet the 5,000 cfs flow target, and wild post-larval young-of-the-year (YOY) CPM were not captured during annual fall monitoring. In the three years (2016, 2017, and 2019) when the decision would have resulted in CPM not being produced, the 5,000 cfs flow target was met and YOY CPM were captured during annual fall monitoring in all three years (Table C1).

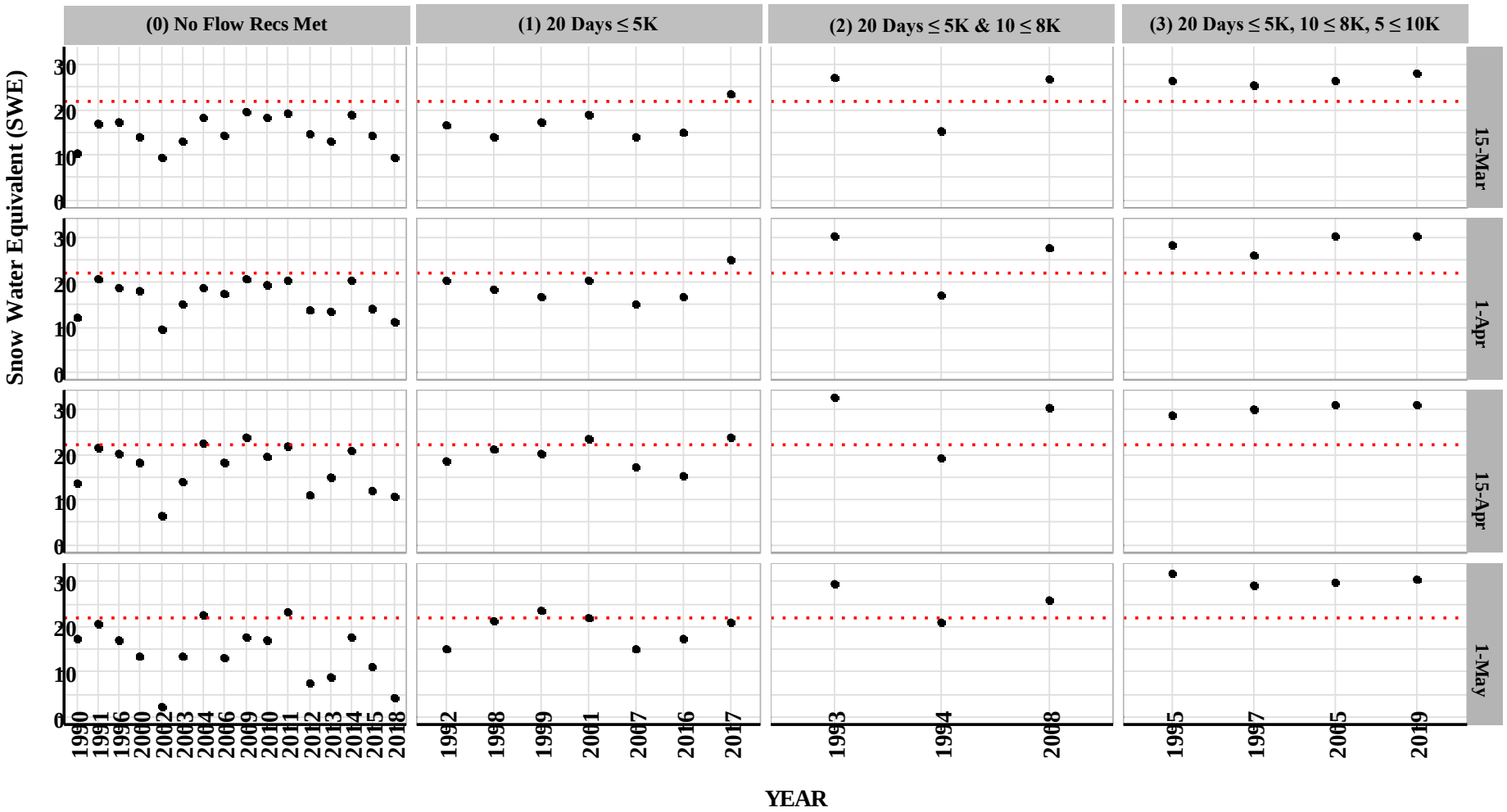

Figure C1. The mean snow water equivalent (SWE) from three SNOTEL gages (Red Mountain Pass (713), Molas Lake (632), Stump Lakes (797) as it changes through time (March 15, April 01, April 15, and May 01) in years 1990–2019. The dotted red line is set at the proposed cutoff (mean SWE of 22). Vertical panels (0,1,2,3) are arranged by years when one of four flow conditions was met: (0) 21 days ≥ 5,000 cfs was not met, (1) 21 days ≥ 5,000 cfs was met, (2) 21 days ≥ 5,000 cfs and 10 days at 8,000 cfs, and (3) 21 days ≥ 5,000 cfs, 10 days at 8,000 cfs, and 5 days at 10,000 cfs. Flow conditions were assessed from USGS Gage 09371010 San Juan River at Four Corners, CO.

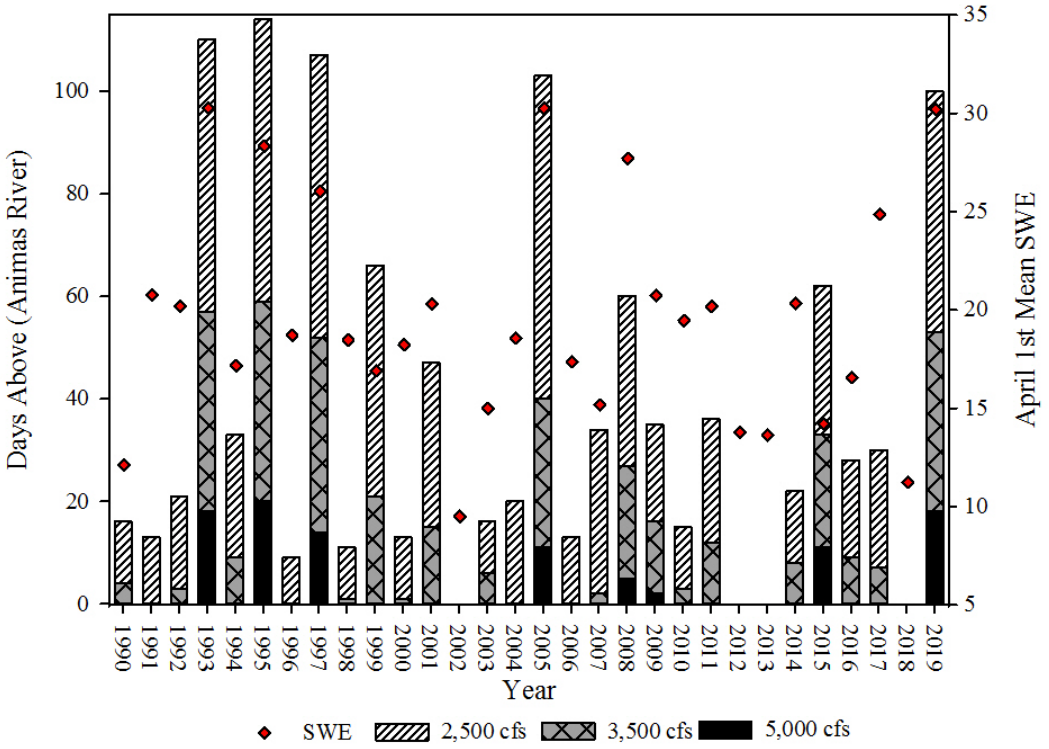

Figure C2. The Animas River at Farmington (USGS 09364500) days above 2,500 cfs, 3,500 cfs and 5,00cfs between April 1 and July 31 and mean April 1st snow water equivalent (SWE) from three SNOTEL gages (Red Mountain Pass (713), Molas Lake (632), Stump Lakes (797).

Table C1. A retrospective analysis (2010–2019) of projected April 1st flows from Navajo Dam or Animas River Basin snow water equivalent (SWE) to influence the decision to produce and consequently stock Colorado Pikeminnow in the San Juan River. Young of year (YOY) Colorado Pikeminnow presence/absence from Small Bodied Fishes Monitoring and Larval Colorado Pikeminnow estimated densities (provided by American Southwest Ichthyological Researchers) are presented for increased clarity. San Juan River flows were assessed at USGS Gage 09371010 (San Juan River at Four Corners, CO).

YEAR	April 1 Projected Navajo Dam releases	Animas River Basin SWE ≥ 22	San Juan River at 4Corners Number of Days at CFS ≥5,000	≥8,000	≥10,000	CPM Stocked?	Larval CPM *E*(X)	YOY CPM Present?
2010	No spring release	NO	0	0	0	YES	*0.08*	NO
2011	7 days at 5,000	NO	12	7	0	YES	*0.73*	NO
2012	7 days at 5,000	NO	6	0	0	YES	*0*	NO
2013	No spring release	NO	0	0	0	YES	*0.41*	NO
2014	No spring release	NO	0	0	0	YES	*8.65*	NO
2015	No spring release	NO	14	0	0	YES	*0.43*	NO
2016	31 days at 5,000	NO	32	4	0	**NO**	*11.96*	**YES**
2017	31 days at 5,000	**YES**	46	4	0	**NO**	*3.87*	**YES**
2018	No spring release	NO	0	0	0	YES	*1.29*	NO
2019	5 days at 5,000	**YES**	25	10	5	**NO**	NA	**YES**

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