ASSESSMENT OF TAXA OF MANAGEMENT CONCERN IN THE COLORADO RIVER ECOSYSTEM, GLEN AND GRAND CANYONS, ARIZONA, USA: HABITAT NEEDS, AVAILABILITY AND ECOSYSTEM ROLES
DRAFT FINAL REPORT 15 JUNE 2011

EXECUTIVE SUMMARY

Introduction

The loss of native species is one of the three largest human impacts on natural ecosystems. Removal of ecologically important foundation taxa (e.g., dominant trees, abundant prey taxa) or keystone species (e.g., species that influence trophic structure and composition), and the substitution of non-native taxa into those roles in altered habitats, affect structure, composition, function, and resilience, as well as the goods and services provided by those ecosystems. Understanding the distribution and ecological roles of native species that are declining or no longer present in altered environments provides long-term guidance on the stewardship of human-dominated ecosystems.

Here we describe the species known or suspected to be missing or in decline in the Colorado River ecosystem (CRE) in lower Glen Canyon and throughout Grand Canyon on the southern Colorado Plateau (Fig. 1). We provide approaches to understanding restoration potential to the Adaptive Management Work Group (AMWG) in response to its April 2009 motion: "In recognition of GCDAMP [Glen Canyon Dam Adaptive Management Program] goals toward management of the Colorado River through an ecosystem approach, AMWG directs the TWG [Technical Work Group] to establish the Species of Concern Ad Hoc Committee [SMCAHC, (the Committee)] and requests the participation of GCMRC [U.S. Geological Survey Glen Canyon Monitoring and Research Center] in that ad hoc committee, to produce a draft report to be presented to AMWG on or before by May 1, 2011, that contains the following with regard to species of management concern in the CRE: A review of information about an assessment of the status of habitat needs and availability, and ecosystem roles of the species."

The focus of this report is the array of native plant and animal taxa of management concern (TMC) in the CRE. TMC were defined as native CRE species that were: presently or recently federally listed or were recent candidate species; federally or state protected; believed by the Committee to be declining, extirpated, or extinct; or rare endemic taxa or highly isolated populations, as well as those for which too few data are available to assess present status (Appendix A). TMC were selected by the Goal 3 Ad Hoc Committee (the Committee) based on peer-review published and government literature, recommendations from staff and independent experts, and published and unpublished literature (including Grand Canyon Wildlands Council, Inc. 2009).

Methods

The Committee developed the TMC list from diverse information sources, and investigated four restoration prioritization approaches. All approaches involved multiple unweighted criteria, scoring by independent experts and knowledgeable TWG staff, and considerable discussion within the Committee. The Committee considered a suite of 18 issues that influence decisions about population restoration (Table 1). These questions involved the role of the dam in the population decline, conceptual and practical restoration issues (e.g., stock availability), the ease with which restoration could be accomplished, the conservation significance of the action, and the level of stakeholder agreement for restoration. Scoring was

performed by Committee members, expert staff from TWG participating agencies, and independent academic experts, each of whom scored each issue for each taxon with which they were familiar. We used a 0 (no value, low restoration potential) to 4 (high importance, high restoration potential) scoring scale, and variables were not weighted. A total score was calculated for each species based on the total percent possible of non-blank issues scores. Other prioritization approaches involved consideration of policy but less quantification: 1) extirpated taxa; 2) TMC that were endangered, declining, rare, or already included in existing conservation plans; 3) taxa of interest because: a) distribution and status data are insufficient; b) species of individual agency concern, including Tribally important taxa; c) incidentally occurring rare species; d) species known or suspected to be affected by dam operations, which may be increasing; e) species suspected to be declining directly or indirectly due to dam operations; f) federally protected non-native taxa (feral burro). Lastly, we conducted a post-process "reality check" by the Committee to confirm whether information was sufficient to recommend a taxon to the AMWG for further consideration. We also reviewed the trophic status of each TMC in relation to the overall CRE and we discuss restoration requirements and long-term ecosystem management implications of these findings.

Results

Extirpated Taxa: At least 14, and as many as 23 animal species that formerly bred in the CRE have been extirpated, with only two of those prior extirpations occurring prior to the closure of Glen Canyon Dam in 1963 (Table 2; Appendix A). TMC known to have been extirpated include: 4 fish (Colorado pikeminnow – *Ptychocheilus lucius*, razorback sucker – *Xyrauchen texanus*, and bonytail and roundtail chub – *Gila elegans* and *G. robusta*, respectively), 2 amphibians (*Lithobates pipiens* and *L*. nr. *yavapaiensis*), zebra-tailed lizard, 4 birds (breeding southwestern willow flycatcher – *Empidonax trailii extimus*; western yellow-billed cuckoo - *Coccyzus americanus occidentalis*, Gambel's quail - *Callipepla gambelii*, and California condor - *Gymnogyps californianus*, which was reintroduced outside the CRE in 1996); and 3 mammals (badger – *Taxodea taxa*; the likely extinct southwestern river otter – *Lutra canadensis Sonora*; and gray wolf, *Canis lupus youngi* which was extirpated from northern Arizona by 1945). The status of several apparently rare herpetofauna (e.g., regal ring-necked snake – *Diadophis punctatus regalis*, western threadsnake – *Leptotyphlops humilis*, other snakes), as well as numerous rare plant and invertebrate taxa, remains unknown.

Endangered or Previously Listed TMC: A total of 18 taxa (21.2 percent) are presently or recently have been federally or state-protected, or are of specific importance to Tribes, either through the ESA, through separate federal legislation, or through state or Tribal recognition. Among these 18 taxa are at least 10 extant endangered species in the CRE, including: 1 terrestrial gastropod , 1 fish species, 4 bird species, and several incidentally-occurring listed bird taxa.

Non-listed Extirpated, Declining, and At-risk TMC: Extirpated or at-risk species that are not federally listed make up the majority of those on the list in the CRE in post-dam time. A total of 46 (54 percent) of the TMC had restoration potential scores $\geq$50, suggesting that they may warrant management attention or at least monitoring. However, the quality of status and distribution data on at least 52 (61 percent) of the TMC was inadequate to determine

management needs or options, including rare invertebrate, herpetofaunal (especially amphibians and snakes), rodent, and migratory bird and bat taxa.

Non-Native Species: Although the focus of this report is on native TMC, we note the presence of several hundred non-native taxa (particularly plants, fish, several invertebrates, and several bird taxa) that occur in the river corridor, interact with native species in complex fashions, and play important ecological roles in the CRE. A more comprehensive ecosystem-based understanding of the role of non-native species is warranted.

Dispersal Limitations: Glen Canyon Dam may play a long-term role in CRE diversity through interruption of passive downstream or upstream propagule distribution. Prior to 1963, "waif" plant and animal species were transported via hydrochory or gravity into the CRE, becoming established, but often being too rare or physiologically stressed to reproduce successfully. Many unlisted but rare taxa identified in this analysis were downstream-dispersed waif species, known only from a few collections in the post-dam CRE. Upstream colonization via animal or wind transport is generally slower than downstream or gravity-based waifing recruitment, but both dispersal processes are important long-term diversity in the CRE (Stevens and Waring 1987; Stevens and Polhemus 2008; Stevens and Bailowitz 2009). Glen Canyon Dam likely has limited the dispersal of waif taxa propagules (e.g., Shafroth et al. 2002), potentially reducing long-term CRE biodiversity.

Trophic Status of TMC: We analyzed the trophic status of extirpated and at-risk TMC among the array of narrow and wide reaches of the CRE (Schmidt and Graf 1990), demonstrating that the presently monitoring focus on 3 TMC (i.e., humpback chub – *Gila cypha*, Kanab ambersnail – *Oxyloma haydeni kanabensis*, and southwestern willow flycatcher) occupy lower and middle trophic positions. While those focal species are administratively important, they may not provide adequate "umbrella" protection for most other CRE TMC and important ecological processes. Therefore, the usefulness of these 3 endangered taxa for understanding and managing the full array of ecosystem dynamics is limited (Stevens et al. 2001). Two groups of terrestrial CRE species in particular have not received sufficient monitoring or conceptual attention: top riparian predators, and rare or endemic taxa, including insects. Additional monitoring data are needed on such species to develop a more thoroughly linked aquatic-terrestrial conceptual ecosystem model for the CRE, and such an effort is likely to better serve long-term CRE management and the AMP.

TMC Restoration

Restoration of TMC must be consistent with NPS and other managing agencies reintroduction policies, but heretofore has been regarded as a tertiary priority, behind improving the population health of one federally listed fish species (humpback chub), and sediment management. Thus, questions of whether, how and when to restore other at-risk or extirpated endangered or non-listed species remain unaddressed. Unfortunately, major information gaps exist with regards to understanding the distribution and present status of many TMC in the CRE. Such information and discussion may play an important role in the planning and implementation of population reintroduction and restoration actions. We describe and discuss issues associated with reintroduction of extirpated CRE TMC, including: a) development of the administrative context; b) compiling relevant information, stock assessment, and prioritization, c) plan

development, d) multi-agency compliance, e) implementation, potentially with multiple stocking efforts, and f) integration of monitoring and feedback information.

Discussion

Ecosystem management requires adequate understanding of the ecological role and potential for restoration of extant TMC as well as extirpated species and processes. Understanding the feasibility and advisability of restoration of extirpated species is coordinated through Goal 3 of the AMWG mission, and also by the wildlife managing agency stakeholders, most notably the NPS, FWS, and AGFD, and several Native American Tribes. Filling information gaps about missing or declining species is needed to more fully inform the Secretary of the Interior about Glen Canyon Dam impacts, as well as providing information for the compliance requirements of AMWG cooperating agencies needed to undertake reintroduction efforts. Through its multi-stakeholder structure, AMWG is uniquely poised to recommend to the Secretary of the Interior the technical, interagency, and societal information needs and processes through which to achieve the purposes of AMWG's Goal 3. There is at present no commitment for the AMP to fund TMC restoration efforts, as such activities may be the specific purview of the resource managing agencies. Nonetheless, the AMWG can play an important multi-agency advisory role to the Secretary in evaluating TMC restoration priorities and potential in the CRE. In addition, the AMP may benefit from monitoring information about reintroduced or translocated TMC, as well as in public outreach. We provide previously uncompiled background information on missing and at-risk species, and summarize approaches to assess TMC prioritization potential. We offer this information as guidance to the AMWG, recognizing that the diverse views among AMWG stakeholders as to the AMP's responsibilities require further discussion about roles and responsibilities for CRE management.

Two administrative issues emerged from this analysis that previously have not been discussed by the AMWG. First, many TMC were recognized in the CRE that may warrant management or monitoring attention, either by the AMWG and/or by other managing agencies. A total of 47 (54 percent) of the 85 TMC considered here had potential restoration scores $\geq$ 50 percent (Table 2; Appendix A). Also, many species with scores <50 percent lacked critical information on distribution, habitat use, or population status. Abundant opportunity exists to improve the quality of basic information on TMC in the CRE.

Second, AMWG monitoring recommendations currently focus primarily on humpback chub, as well as flow and sediment transport, with less attention on Kanab ambersnail and southwestern willow flycatcher. However, at least 5 species (1 plant, 1 lizard, and 3 non-listed fish) scored higher than humpback chub in our analyses. Concern for Goodding's willow arose due to its CRE-wide demise in the post-dam river corridor. Concern for the 3 non-listed CRE fish arose from the desire of the Committee to prevent those species from becoming federally endangered. The zebra-tailed lizard scored above HBC because its population restoration would be inexpensive and easily accomplished. AMWG may choose to engage in further discussion of the restoration potential of these and other TMC, and we hope that the information provided here contributes to those discussions and to improved stewardship of the CRE.

INTRODUCTION

Impacts of Native Species Loss on Ecosystems

The loss of native species is one of the three largest human impacts on natural ecosystems. Removal of ecologically important foundation taxa (e.g., dominant trees, abundant prey taxa) or keystone species (e.g., taxa that strongly influence trophic structure and composition), and the substitution of non-native taxa into those roles in altered habitats affect the structure, composition, function, and resilience, as well as the goods and services provided by those ecosystems. Understanding the distribution and ecological roles of native species that are declining or no longer present in regulated rivers, such as the Colorado River ecosystem (CRE) in lower Glen Canyon and throughout Grand Canyon on the southern Colorado Plateau, is fraught with uncertainties because: 1) information on the natural condition of those populations and the ecosystem in general often is limited, and 2) novel arrays of environmental gradients and trophic linkages arise in anthropogenically altered ecosystems, affecting native species population dynamics, as well as ecosystem processes and functions. Accounting for missing or declining species and the ecological processes that characterized the natural ecosystem is fundamental to adaptive management (Walters et al. 2000). Failure to account for missing species, coupled with continued species loss, means that iterative planning and stewardship efforts result in stepwise degradation of ecosystem integrity. Understanding the extent of species loss and restoration potential allows ecosystem stewards to define and manage for desired future ecosystem conditions (Schmidt et al. 1998, Myers et al. 2007).

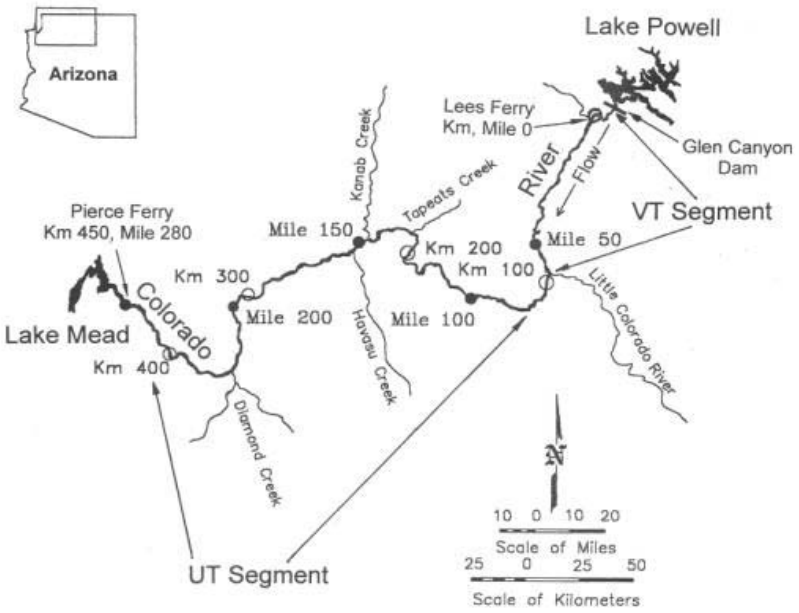


Figure 1: Map of the Colorado River ecosystem between Glen Canyon Dam and Lake Mead, Arizona. Turbidity segments: VT – variably turbid, UT – usually turbid.

Species Loss in the Grand Canyon Region

As has occurred in many of the nation's great landscape parks, a substantial number of native taxa have been extirpated or appear to be at risk in the CRE (Minckley 1991, Newmark 1995, Stevens et al. 2001, Stevens and Gold 2003). Much ecological research has been devoted to the study of reduced or dwindling populations of currently endangered species in the CRE, particularly the big river fishes, and specifically humpback chub (HBC; *Gila cypha*; Minckley 1991; Valdez and Ryel, 1995, 1997; Marsh and Douglas 1997; Stone and Gorman 1999; Gloss et al. 2005; Coggins 2008; Coggins and Walters 2009; Andersen et al. 2010; Yard et al. 2011), as well as one landsnail (Kanab ambersnail – KAS, *Oxyloma haydeni kanabensis*; Spamer and Bogan 1994; Meretsky et al. 2000) and one bird species (southwestern willow flycatcher – SWFL, *Empidonax trailii extimus*; summarized in Paxton et al. 2007). Federal listing prompted ecological research on other formerly listed CRE taxa, including bald eagle (*Haliaeetus leucocephalus;* Brown et al. 1989, 1998; Brown and Stevens 1997) and peregrine falcon (*Falco peregrinus anatum*; Brown et al. 1992; Stevens et al. 2009). However, the ecological roles and distributions of other endangered species that occur incidentally in or near the river corridor (e.g., California condor - *Gymnogyps californicus*; Mexican spotted owl - *Strix occidentalis lucida*), as well as non-listed endemic, declining, or extirpated species, is less well known.

Umbrella species are those that, when conserved, provide protection to co-occurring taxa, habitats, or ecosystems. While often a useful effort, meta-analyses of this process suggested that focal species selection required careful assessment of the ecological roles of many species (Branton and Richardson 2010). Importantly, federally endangered ("listed") taxa may not necessarily serve as adequate umbrella taxa (Roberge and Angelstam 2004), particularly in complex landscapes. Ozaki et al. (2006) reported that northern goshawk (*Accipiter gentilis*), a wide-ranging predator that facultatively adapts to anthropogenically altered landscapes, did not provide adequate protection for associated species and habitats.

Although HBC is used as a focal species for CRE management, but adults are relatively low-vagility fish that and almost exclusively spawn in the lower Little Colorado River, a spring-fed tributary in Grand Canyon. Therefore, HBC may not well represent the ecosystem requirements of more highly migratory fish species, such as razorback sucker (RBS; *Xyrauchen texanus*) or Colorado pikeminnow (CPM; *Pychocheilus lucius*), both of which have been extirpated, or terrestrial species (e.g., KAS or SWFL; Stevens et al. 2001). A broader examination of the status of taxa of management concern (TMC) in the CRE can provide insight into improved stream-riparian ecosystem restoration options, consideration by the Glen Canyon Dam Adaptive Management Program (AMP), and provide support to the National Park Service (NPS) and other resource managers working to fulfill responsibilities, such as that of the NPS to "… strive to understand, maintain, restore, and protect the inherent integrity of the natural resources, processes, systems, and values of parks … (U.S. National Park Service 2006:36).

Ecosystem Roles of Extirpated or Declining Taxa

Extirpated and declining taxa, both federally listed or not, may have had important ecosystem roles, and the loss of those species may greatly compromise ecosystem function (Soulé et al. 2005; Myers et al. 2007). Because of the important role of keystone (ecologically strongly interacting species) on ecosystem function, and because the legal framework may not have kept up with advances in ecosystem and conservation ecology, Soulé et al. (2005) recommend that natural resource managers…"adhere to a doctrine of 'best conservation practices based on the best science,' applying a more rigorous standard for the management of

relatively interactive species than may be mandated by older statutes and effected by current practice and convention." In addition, little scientific attention has been paid to the distribution and conservation of rare and endemic taxa, in Grand Canyon and elsewhere, particularly invertebrates, for which few population status or life history data exist. The continued health of those populations may be jeopardized by uninformed or insensitive land management practices. For example, Stevens and Polhemus (2008) reported that 52.6% of 89 aquatic Heteroptera species in the Grand Canyon region were found at 3 or fewer sites, and that more than 25% were found only at single localities, primarily springs. Springs in the vicinity of Grand Canyon are widely recognized as being threatened by regional groundwater pumping. External threats to the regional aquifers around Grand Canyon may affect discharge of springs and therefore the habitats of many springs-requiring species. Groundwater pumping may threaten the flow of Blue Springs in the lower Little Colorado River, a springs complex that provides essential flow for spawning humpback chub. Therefore, management of both species and habitats in a regional context may be needed to maintain and restore species and ecosystem health.

Species Translocations and Reintroductions in the Grand Canyon Region

The establishment and translocation of native and non-native species has a lengthy history in the CRE. Federal management of the North Rim early in the 20th Century involved widespread elimination of upland predators, actions that may have had large impacts on ecosystem structure (Rasmussen 1941). Exotic plants in the CRE include tamarisk (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia*), and more than 75 other species (Stevens and Ayers 2002). Numerous aquatic invertebrate taxa were released by the AGFD into the tailwaters of Glen Canyon Dam in the mid-late 1960's to improve the aquatic foodbase (Stone and Queenan, 1967; Stone and Rathbun 1968, 1969). Endangered Kanab ambersnail were successfully introduced into upper Royal Arch Creek in Grand Canyon in 1998 by AGFD and the NPS to develop a refuge population if dam operations negatively affect natural snail habitat at Vaseys Paradise Spring in the CRE (Spamer and Bogan 1994; Sorensen 2005). Introduced fish include common carp (*Cyprinus carpio*) and catfish (Ictaluridae), which already were the most abundant fish in the lower Colorado River by the turn of the Twentieth Century (Grinnell 1914). Rainbow (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) were released by the NPS shortly after the establishment of Grand Canyon National Park, and 17 other non-native fish species also have become established. Rainbow trout became an important recreational resource in Glen Canyon following closure of the dam in 1963, but trout piscivory may threaten native fish (Yard et al. 2011). The NPS, FWS, and AGFD have translocated HBC into previously unoccupied habitat in the Little Colorado River, upstream from a barrier falls (U.S. Fish and Wildlife Service 2010), and into Shinumo Creek. Non-native burros (*Equus asinus*) were widely introduced by early prospectors, and were removed from Grand Canyon National Park and most of the CRE in the early 1980s. Semi-native terrestrial vertebrate introductions include: wild turkey (*Meleagris gallopavo*; Brown et al. 1987), bighorn sheep (*Ovis canadensis nelsoni*) in upper Grand Canyon. Restoration of endangered California condor (*Gymnogyps californianus*) generally has been successful (Southwest Condor Release Team 2007); however, Meretsky et al. (2000a) question whether reintroduction can be successful because of condor susceptibility to lead poisoning, an issue that has lead to a proposed ban on lead shot. Grand Canyon supports the largest breeding population of previously federally listed peregrine falcons (*Falco peregrinus anatum*) of any land management area in the lower 48 states as a result of pesticide control and reintroduction efforts elsewhere in the Colorado River basin in the early 1980's (Brown et al. 1992; Stevens et

al. 2009). Louisiana river otters (*Lontra canadensis lataxina*.) were translocated into the upper Colorado River and Verde River drainage in Arizona, restoring their contribution to ecosystem function (GCWC 2005). Clearly, much of the CRE has been affected by these introductions and translocations.

Adaptive Management Goal 3

The Adaptive Management Work Group (AMWG) approved the following motion at its April 2009 meeting:

> *In recognition of GCDAMP [Glen Canyon Dam Adaptive Management Program] goals toward management of the Colorado River through an ecosystem approach, AMWG directs the TWG [Technical Work Group] to establish the Species of Concern Ad Hoc Committee (SMCAHC) and requests the participation of GCMRC [U.S. Geological Survey Glen Canyon Monitoring and Research Center] in that ad hoc committee, to produce a draft report to be presented to AMWG on or before by May 1, 2011, that contains the following with regard to species of management concern in the CRE: A review of information about an assessment of the status of habitat needs and availability, and ecosystem roles of the species.*

This directive requires a more complete review of information on the distribution, status, ecological role(s) than has heretofore existed, as well as development and testing potential methods to prioritize the reintroduction potential of extirpated and at-risk TMC to better understand and manage the CRE as an ecosystem.

Here we present a list of the native CRE TMC, including extirpated, endangered, declining, or those for which insufficient data exist to determine current population status. We describe the distribution, habitat requirements, ecological role(s), status, and the quality of information available on those species. We integrate selected taxa into a conceptual trophic diagram of the CRE, discuss the advantages and challenges associated with developing a more complete understanding of their status, and present approaches for prioritizing the reintroduction potential of extirpated, endangered, or declining species.. We briefly review the compliance requirements of participating agencies in relation to reintroduction efforts. We provide this information to assist in the adaptive management process for the CRE move towards a more comprehensive ecosystem management perspective.

METHODS

Study Area

The CRE under the purview of the AMWG extends from the forebay of Lake Powell and Glen Canyon Dam in Glen Canyon National Recreation Area (GLCA) and for a total distance of 447 km downstream through Grand Canyon National Park (GRCA) to the boundary of Lake Mead National Recreation Area at about Colorado River Mile (RM) 278 (Fig. 1). The CRE includes the river and shorelines within the 100-yr flood stage, the lower portions of selected tributaries, and the lower 15 km of the Little Colorado River. River mile (RM) from Lees Ferry is traditionally used to designate location in the CRE, with mileage measured for both upstream (negative) and downstream (positive) distance. The side of the river is designated looking downstream (right=R or left=L).

The CRE is managed under several administrative processes. The National Park Service (NPS) manages natural and cultural resources of 2 NPS unit (Grand Canyon National Park and Glen Canyon National Recreation Area), pursuant to Grand Canyon National Park enabling legislation (1919), Glen Canyon National Recreation Area enabling legislation (1972), the NPS Organic Act (1916), and subsequent legislation including the 1992 Grand Canyon Protection Act, and in accord with: the U.S. Fish and Wildlife Service (FWS) and the Endangered Species Act of 1973 (ESA) and the Fish and Wildlife Coordination Act (FWCA); the Arizona Department of Water Resources and the Arizona Game and Fish Department (AGFD) administrative water, fish and wildlife policies and regulations; and those of six actively participating Native America Tribes. Glen Canyon Dam management is achieved though Secretarial advisement by the Bureau of Reclamation's Adaptive Management Work Group (AMWG)—a Federal Advisory Committee composed of representatives from the major stakeholder groups (Stevens and Gold 2003, Melis and Lovich 2005), and by the Colorado River Annual Operating Plan (AOP) group. The Secretary of the Interior is the Water Master of the Colorado River and integrates recommendations from both AMWG and the AOP group. Goal 3 of the Glen Canyon Dam Adaptive Management Program (AMP) is to "Restore populations of extirpated species, as feasible and advisable." The AMWG developed the above-quoted motion to provide relevant information as a comprehensive first step towards achieving Goal 3.

Information Sources

The focus of this document is the array of native plant and animal taxa of management concern (TMC) in the CRE. TMC were defined as native CRE species (but including federally protected non-native feral ass, *Equus asinus*) that were: presently or recently federally listed or were recent candidate species; Arizona state listed; federally protected; believed by the Committee to be declining, extirpated, or extinct; or rare endemic taxa or highly isolated populations, as well as those for which too few data are available to assess present status (Appendix A). TMC were selected by the Goal 3 Ad Hoc Committee (the Committee) based on peer-review published and government literature, and recommendations from staff and independent experts, as well as the published and unpublished literature, including a regional conservation area plan developed by Grand Canyon Wildlands Council, Inc. (2009).

Restoration Scoring and Prioritization

The Committee developed the TMC list from diverse information sources, and investigated four restoration prioritization approaches. First, the Committee considered a suite of 18 issues that influence decisions about population restoration (Table 1). These questions involved the role of the dam in the population decline, conceptual and practical restoration issues (e.g., stock availability), the ease with which restoration could be accomplished, the conservation significance of the action, and the level of stakeholder agreement for restoration. Scoring was performed by Committee members, expert staff from TWG participating agencies, and independent academic experts, each of whom scored each issue for each taxon with which they were familiar. We used a 0 (no value, low restoration potential) to 4 (high importance, high restoration potential) scoring scale, and variables were not weighted. A total score was calculated for each species based on the total percent possible of non-blank issues scores. The level of stakeholder agreement was not sufficiently well-understood by the collaborators, so that criterion was excluded from the scoring analysis. Other prioritization approaches involved consideration of policy issues, including whether the TMC: 1) had been extirpated; 2) were endangered,

Table 1: Issues related to restoration potential of species of management concern in the CRE. Each issue was scored on a 0 to 4 scale by each expert within a taxon, where information was deemed sufficient. The total score was the percent of possible scores excluding missing or blank values. Asterisk (*) denotes an issue not included in analyses.

Potential Restoration Issues
Influence of Glen Canyon Dam on population
Conservation relevance
Quality of background information
Stock availability for restoration
Legal mandates, requirements
Habitat availability under present dam operations
Habitat availability under realistic future dam operations
Technical feasibility
* Agreement among stakeholders
Inexpensiveness (low cost=high score)
Time-frame for success (short=high, long=low)
Logistical ease
Ease of compliance
Are genetics issues easily resolved?
Lack of disease transmission potential
Urgency in relation to climate change impacts
Beneficial interactions with other species

declining, rare, or already included in existing conservation plans; 3) were of interest because: a) distribution and status data were insufficient; b) were species of individual agency concern, including Tribally important taxa; c) occurred incidentally; d) were known or suspected to be positively affected by dam operations; e) were known or suspected to be declining directly or indirectly due to dam operations; or f) were federally protected non-native taxa (i.e., feral burro). Lastly, the Committee conducted a post-process "reality check" to confirm whether the compiled information about each TMC was sufficient to forward a recommendation to the AMWG for further consideration. Reality check responses were summarized into 3 categories of response: "yes" (unanimous agreement of those voting), "mixed" (a mixture of yes and no votes), and "no" (unanimous agreement not to consider a taxon further in this process). Although a "no" vote may apply to the AMWG process, individual agencies still maintain management interests in those species, both within and outside the CRE. All of the above prioritization approaches involved multiple unweighted criteria, scoring by independent experts and knowledgeable TWG staff, and considerable discussion within the Committee. We also reviewed the trophic status of each TMC in relation to the overall CRE, and we discuss restoration requirements and long-term ecosystem management implications of these findings.

RESULTS

Overview

We assessed the status and restoration potential of a list of 85 TMC from the CRE (Appendix A; Table 2). A total of 18 taxa (21.2 percent) are presently or recently have been federally or state-protected. Four federally endangered fish species have been extirpated, as have 2 candidate leopard frog species, and 3 bird species. Formerly listed peregrine falcon and bald

Table 2: Summary of prioritization approaches for taxa of management concern (TMC) in the Colorado River ecosystem downstream from Glen Canyon Dam. Cells totals do not sum because some taxa qualify in multiple categories. Appendix A contains detailed accounts of the scoring of each TMC.

Criterion	Number of CRE TMC									
	Plants	Trematode	Insects	Snails	Fish	Amphibians	Reptiles	Birds	Mammals	Total
Extirpated	2?	0	2?	0	4	2	2	3 (4)	8	14-23
Federally ES or recent ES	0	0	0	1	5	2	0	9	1	18
Composite Score ≥50	0	1	3	1	8	3	3	9	19	47
3a. TMC about which little is known	1	0	9	0	3	2	5	6	26	52
3b. TMC of individual agency concern	6	0	3	1	8	4	3	16	21	62
3c. Rare or endemic TMC	1	1	3	1	0	1	0	5	2	14
3d-e. TMC affected by dam, (+ increasing or - decreasing)	6	1	4	1	8	4	4	13	11	52
Reality Check ("yes")	4	0	0	1	6	0	0	2	0	13
Reality Check ("mixed")	3	1	9	0	2	4	6	17	31	73
Total number TMC *	**7**	**7**	**9**	**1**	**8**	**4**	**6**	**19**	**31**	**85**

eagle are extant. All presently or formerly ESA-listed and candidate species also are recognized as Species of Greatest Conservation Need in Arizona's State Wildlife Action Plan (SWAP; AGFD 2006). Several TMC not federally listed have been extirpated, including one lizard and the likely extinct southwestern river otter, with loss of river ecosystem function (GCWC 2005). Only 2 species (HBC, KAS; 2.5 percent of the total TMC) are regularly monitored by the AMWG program, while the NPS monitors SWFL.

A total of 46 (54 percent) of the TMC had restoration potential scores ≥50, suggesting that they may warrant management attention or at least monitoring. All native migratory bird species are federally protected under the Lacey Act of 1900 and the Migratory Bird Protection Act of 1918, and their habitats whenever flows in the Colorado River are modified due to operations of Glen Canyon Dam under the Fish and Wildlife Coordination Act (FWCA) of 1934, as amended. Additionally, the habitat requirements of fish species that are not listed and protected by the Endangered Species Act of 1973, as amended, are similarly protected under the FWCA. However, the quality of status and distribution data on at least 52 (61 percent) of the TMC was inadequate to determine management needs or options, including rare invertebrate, herpetofaunal (especially amphibians and snakes), rodent, and migratory bird and bat taxa. In the following section, we describe extirpated, federally or state listed or former candidate taxa, and rare, endemic and at-risk TMC.

SPECIES ACCOUNTS

Extirpated Taxa

At least 14, and as many as 23 animal species have been extirpated from the CRE, all but two of those since the closure of Glen Canyon Dam in 1963 (Table 2; Appendix A). TMC known to have been extirpated include: 4 fish (Colorado pikeminnow, razonback sucker, and bonytail and roundtail chub), 2 amphibians (*Lithobates pipiens* and *L*. nr. *yavapaiensis*), zebra-tailed lizard, 4 birds (i.e., breeding southwestern willow flycatcher; yellow-billed cuckoo, Gambel's quail, and California condor, which was reintroduced outside the CRE ON 12 December 1996; and 3 mammals (including: badger – *Taxodea taxa*, southwestern river otter – *Lutra canadensis sonora*, and gray wolf, *Canis lupus*, extirpated from northern Arizona by 1945). The status of several apparently rare herpetofauna, including regal ring-necked snake, western threadsnake, and other snakes remains unknown.

***Razorback Sucker (RBS; Xyrauchen texanus*):** RBS were previously widely distributed and highly migratory in the Colorado River, but have been extirpated from the CRE (Dowling et al. 1996, Mueller et al. 2000). RBS presently are being raised and restocked into lower Colorado River reservoirs, including golf course ponds. RBS restoration downstream from Glen Canyon Dam may require continued stocking if recruitment fails and non-native predator control efforts are not successful. Discussion of RBS reintroduction into Grand Canyon is on-going. RBS in spawning condition and early stage larvae have recently been collected near the CRE inflow to Lake Mead, and the species is recruiting successfully in other parts of Lake Mead (http://www.usbr.gov/uc/feature/Razorback/index.html, accessed February 7, 2011)

***Colorado Pikeminnow (CPM; Ptychocheilus lucius*):** CPM were the largest native fish in the pre-dam Colorado River. Called "white salmon" or "Colorado River salmon" by early settlers, this species apparently undertook long annual migrations through much of the Colorado River basin (Sigler and Sigler 1996). Breeding populations are now restricted to the upper Colorado River basin. CPM is a large, piscivorous species, and restoration of CPM in the CRE likely will require analysis of reintroduction success in this regulated reach, as well as potential predation impacts on HBC.

***Bonytail and Roundtail Chub (BTC, RTC; Gila elegans and G. robusta, respectively)*:** BTC were previously known from near Glen Canyon Dam and Lake Mead (Minckley 1973), but at this time there are no known wild populations of *Gila* in the mainstream lower Colorado River downstream from Grand Canyon. Augmented populations are sustained by stocking in both Lake Havasu and Lake Mohave. The pre-dam distribution of RTC is not well documented, but is reported as primarily taking place in tributaries of the Colorado basin, not in the mainstem Colorado River downstream of Glen Canyon Dam (Holden and Stalnaker, 1975). Restoration or reintroduction of BTC and RTC generally have not been considered because of the potential for hybridization with HBC. Douglas and Douglas (2006) analyzed *Gila* genetics, concluding that the Grand Canyon population was distinct, but indicating some intergradation with other *Gila* species. Therefore, introduction of other *Gila* species into Grand Canyon is contraindicated, at least at present, as it might threaten the genetic integrity of the Grand Canyon HBC population.

Lowland Leopard Frog (Lithobates* nr. *yavapaiensis; LLF): A single population of leopard frog was detected in lower Grand Canyon at Surprise Canyon (Colorado River Mile 248R;

Brennan and Holycross 2005). This population has been documented along the Colorado River (L.E. Stevens, unpublished photograph) but not in recent decades, and primarily occurs several km upstream in Surprise Canyon. This leopard frog population is highly isolated and may be a unique form of *L. yavapaiensis* (Oláh-Hemmings et al. 2010).

Northern Leopard Frog (NLF, Lithobates pipiens): Northern leopard frog was detected at Cardenas Creek (RM 71L; Tompko 1976; Miller et al. 1981) and at -9 Mile Marsh upstream from Lees Ferry (Brennan and Holycross 2005). The Cardenas Marsh backwater has filled with sediment and both historical sites have been heavily colonized by *Phragmites australis*, rendering them unsuitable as NLF habitat. NLF have not been detected at Cardenas Marsh since 1975 or at -9 Mile Marsh since the late 1990s, and this species is considered to have been extirpated from the CRE. A small population also was detected at Hidden Sloughs (-6.5R) in the mid-1990's but was likely introduced there and has not persisted (J. Spence, NPS Biologist, personal communication). Historical records of northern leopard frogs exist from Bright Angel Creek and lower Kanab Creek, but recent, intensive searches by the U.S. Geological Survey and Northern Arizona University have failed to reveal any extant populations (C. Drost, U.S. Geological Survey biologist, personal communication).

Southwestern Willow Flycatcher: Migrant and breeding SWFL have been documented in the CRE at Lees Ferry and in lower Marble Canyon since the 1930s (Brown et al. 1987). However**,** breeding SWFL have disappeared from their historic range in eastern Grand Canyon, where they regularly nested until the late 1990s (Paxton et al. 2007). Loss of this nesting population has been attributed to external factors, such as winter habitat alteration, as well as changes in the CRE, such as increased brown-headed cowbird (*Molothrus ater*) brood parasitism (Brown et al. 1992; review in Paxton et al. 2007). Single male SWFL are still occasionally detected singing along the river in upper Grand Canyon, and limited breeding occasionally occurs along the Colorado River in Lake Mead, but such activities are erratic. Although SWFL occupies earlier successional stages of riparian habitat, effective conservation of SWFL could umbrella coverage of some of the more than two dozen other neotropical migrant birds that nest in the CRE riparian zone (Brown et al. 1987; Stevens et al. 2001). Many other neotropical breeding species also are negatively affected by cowbird brood parasitism.

Western Yellow-billed Cuckoo (YBCU; Coccyzus americanus occidentalis): Listed as a federally threatened species, YBCU requires gallery riparian forest, and therefore is not well-protected by conservation of endangered SWFL, which requires relatively early seral successional riparian vegetation (Layman and Halterman 1987, Brown et al. 1987). In contrast, YBCU requires more-or-less continuous tall-canopy riparian cottonwood and willow cover. YBCU is known in the CRE from a single report in Marble Canyon by Brown et al. (1987), at RM -14.2 in 1995, and at Lee's Ferry (LaRue et al. 2001), but it has not been detected in the CRE in more a decade. YBCU is identified as a Species of Greatest Conservation Need in Arizona's SWAP (AGFD 2006). Depending on how the NPS manages tamarisk in the wake of the arrival of tamarisk leaf beetles (*Diorhabda* spp.), suitable riparian habitat can be promoted that may support this and many other neotropical migrant birds in the CRE.

***Plains Gray Wolf* (*Canis lupus youngi*):** Wolves were extirpated from the region by 1945 (Rasmussen 1941, Hoffmeister 1986); however, John D. Lee reported seeing wolves on the south (left) bank of the river at Lees Ferry early in his tenure as ferryman there in the early 1960s

(Brooks and Cleland 2004). Wolf restoration is being tested to the south of the Grand Canyon region in Arizona; however, the subspecies most often suggested for restoration is the Mexican wolf (*C. l. baileyi*). Hoffmeister (1986) explicitly states that *C. l .baileyi* did not occur on either the south or north rims of Grand Canyon. Introduction of Mexican wolf north of the Colorado River could threaten the genetic integrity of the plains gray wolf farther north, and therefore is not advised. Consideration of wolf population restoration in the CRE was rejected by the Committee, as there is little to no relationship of dam operations on wolf recovery.

Extant Endangered Taxa

Overview: A total of 18 taxa (21.2 percent) are presently or recently have been federally or state-protected, either through the ESA, through separate federal legislation, or through state or Tribal recognition, including 2 taxa protected under federal legislation in addition to the ESA. Extant endangered species in the CRE include 1 terrestrial gastropod , 1 fish species, 4 bird species, and several incidentally-occurring listed bird taxa.

Kanab Ambersnail: KAS occurs naturally in Arizona only at Vaseys Paradise Springs in the Colorado River in Grand Canyon, where it remains the focus of considerable taxonomic, ecological, and management debate (Spamer and Bogan 1993, Stevens et al. 2001). Although this taxon likely will be synonymized with *O. h. haydeni* on the basis of genetic analyses, until those analyses are published in the peer-reviewed scientific literature, KAS remains an endangered species and a highly restricted population, and therefore of concern in CRE management. The AGFD, NPS, FWS, Department of Interior Central Utah Project Completion Act Office, and Upper Colorado River Basin Office of the Bureau of Reclamation partnered beginning in 1996 to translocate populations of KAS into remote, off-river tributaries and springs in Grand Canyon, and the population in Royal Arch Creek has persisted since the 1998 translocation, with protection under the ESA. This effort helped mitigate planned flooding impacts at Vaseys Paradise under a FWS Reasonable and Prudent Measure in 1996 and 1997 to find or create at least one population of KAS not influenced by Glen Canyon Dam (summarized by Sorensen 2005).

Humpback Chub: HBC has received most of the species management attention in the AMWG program because Grand Canyon supports the largest naturally reproducing population of this endangered minnow species in the vicinity of the Little Colorado River (LCR). Intensive monitoring and non-native trout control programs (Grand Canyon Monitoring and Research Center 2008; Coggins et al. 2011; Yard et al. 2011) provide improved insight into long-term population trends, and *in situ* HBC population augmentation in the Little Colorado River upstream from the previously known range of HBC has been successfully undertaken by FWS, adding to the in-LCR population (Sponholtz and Stone 2004). Translocation also has been conducted by the NPS, FWS, AGFD, and collaborators into Shinumo and Havasu Creeks in central Grand Canyon, tributary populations that may help ensure in-Canyon persistence of the species (GCWC 2008; NPS 2011). The NPS and FWS also have discussed HBC translocation into Bright Angel Creek.

***California Condor (Gynogyps californianus)*:** External to the AMWG program and the National Park Service, reintroduction of endangered California condor into the Grand Canyon region has been remarkably successful, and Grand Canyon nests have successfully fledged young (Snyder

and Snyder 2000; Alagona 2004). Occupation and use of the CRE by condors is opportunistic, but external restoration efforts have restored this important top scavenger into the CRE. Management of condor-human interactions has proven challenging because condors are naturally attracted to human activities.

Mexican Spotted Owl (MSOW); Strix occidentalis lucida): MSOW occasionally occur in the CRE, coming down from their normal ranges at the back of nearly every large tributary in central Grand Canyon (REF). MSOW have been observed and photographed at the mouths of tributaries such as Shinumo Creek and National Canyon (LES unpublished data, LaRue et al. 2001). Although apparently incidental in the CRE, the high density of riparian rodents may attract this species; however, MSOW occurrence in the CRE is fairly rare and the population certainly does not depend on riparian or dam-related resources.

***Bald Eagle (BAEA; Haliaeetus leucocephalus)*:** Although fully delisted since 2007, BAEA are still protected under the 1940 Bald Eagle Protection Act, and therefore continue to be TMC in the CRE. Wintering BAEA colonized Grand Canyon beginning in 1982, and were regularly monitored until the mid-1990s (Brown et al. 1989). Their feeding behavior and distribution are strongly affected by dam operations and human recreational disturbance (Brown and Stevens 1997, Brown et al. 1998). However, CRE monitoring data on CRE bald eagles over the past decade are not known to us.

***Peregrine Falcon (PEFA; Falco peregrinus)*:** Delisted from endangered species status in 1999, PEFA have become a common top predator in the CRE (Brown et al. 1992, Stevens et al. 2009). Grand Canyon PEFA are presently monitored by NPS, but population trends and ecological impacts on the CRE avian assemblage, if any, are unclear.

Incidentally-Occurring Listed Species: Several other listed species occur or may occur on an incidental basis in the CRE, including: mountain plover (*Charadrius montanus*), which is proposed for listing as threatened (proposed rule June 29, 2010, FR 75 37353), and the recently delisted brown pelican (BRPE; *Pelicanus occidentalis*). The occurrence of these species is incidental in the CRE (Brown et al. 1987; Stevens et al. 1997a), and CRE management attention is unlikely to influence their populations.

Non-listed Extirpated or At-risk Taxa

Overview: Extirpated or at-risk species that are not federally listed make up the majority of those on the list in the CRE in post-dam time. The following list is not exhaustive, but represents a number of rare, endemic, or ecologically important taxa that have received little attention as being at-risk in the CRE.

Plants: Although no plant species to our knowledge have been verified as extirpated from the CRE, the status of rare and declining wetland and riparian taxa is of concern to long-term ecological processes. Although extirpated from Grand Canyon, Yerba mansa (*Anemopsis californica*) only occurred in GRCA at Indian Gardens on Garden Creek, not in or near the CRE. Nonetheless, the diminished presence and importance of Goodding's willow, Fremont cottonwood, coyote willow, honey mesquite, netleaf hackberry, and other plant species in the

CRE is of sufficient magnitude that loss of their respective ecological functions may limit associated faunal species and habitats.

The persistence of Goodding's willow trees (*Salix gooddingii*) in the CRE is unlikely because bank-dwelling beavers (*Castor canadensis*) in the mainstream have removed most of the pre-dam trees (Mast and Waring1997, Mortenson et al. 2008), and no recruitment is occurring. A recent survey by Grand Canyon Wildlands Council, Inc. (2009) found that Goodding's willow has been eliminated from 8 of 17 (47.1%) sites between Lees Ferry and Diamond Creek where the tree occurred prior to the closure of Glen Canyon Dam. At most sites, trees had been felled by beaver and continued beaver attack removed resprouting stems until the trees perished. Successful recruitment was not observed at any of those 17 sites, or elsewhere along the river during that and other vegetation surveys over the past three decades.

Fremont cottonwood (*Populus fremontii*) was relatively rare in the pre-dam CRE, but a large stand existed at Lees Ferry and the mouth of Bright Angel Creek, and a large individual tree existed near RM 193L in pre-dam time (Clover and Jotter 1944, Turner and Karpiscak 1980). This species shares a similar fate with Goodding's willow and cottonwood recruitment requirements are similar to those of the willow. Although cottonwood seedlings occasionally are detected along the river, establishment fails because, like Goodding's willow, virtually all individuals are attacked by beaver. These Salicaceae are renowned as ecologically important species in southwestern rivers, diversifying canopy and subcanopy structure, and supporting high concentrations of neotropical migrant birds (e.g., Carothers et al. 1974).

Although non-native tamarisk extensively colonized the lower riparian zone of the CRE immediately after dam closure, clonal coyote willow (*Salix exigua*) had become a co-dominant species by 1980 (Stevens 1985, 1989). In recent decades CRE coyote willow, like the other Salicaceae, has declined in response to intensive beaver attack, with every clone undergoing repeated harvest by beaver. Like Fremont cottonwood and Goodding's willow, coyote willow supports more than 100 native herbivore and primary consumer taxa. Insect taxa, such as larval viceroy butterfly (*Limenitis archippus*) are host specific on *Salix exigua* in the Southwest. The disappearance of viceroy butterflies from the CRE since 1982 reflects on-going reduction and disappearance of host plants along the river.

Honey mesquite (*Prosopis glandulosa* var. *torreyana*) is abundant on pre-dam terraces in from Mile 39 to 140 and from Mile 165 to Lake Mead, and makes up a large portion of the relict pre-dam riparian vegetation zone (Carothers et al. 1979, Anderson and Ruffner 1989; Waring et al. 2010). While this species is actively colonizing the lower riparian zone in post-dam time, no recruitment is occurring on on upper riparian terraces, where historically it was the dominant species (Waring et al. 2010). Two long-term issues about this pre-dam mesquite belt are the change in potential fire frequency driven by invasion of non-native *Bromus* grasses, and the potential for gradual replacement of mesquite by facultatively riparian catclaw (Fabaceae: *Acacia greggii*).

Netleaf hackberry (*Celtis laevigata* var. *reticulata*) also does not appear to be recruiting successfully in Grand Canyon. Individual stems of this clonal species in the CRE date back to 1776 (Salzer et al. 1996); however, most existing clones appear to be decadent and few seedlings have been reported in post-dam time. Hackberry is remarkably tightly restricted to the pre-dam 2-year flood return stage (ca. 2,830 m^3/s) along the Colorado River, but unlike honey mesquite, it does not appear to be colonizing the lower riparian zone. Therefore, hackberry may warrant monitoring and determination of flow and habitat requirements for sustainable management.

Several other non-listed native plants are endemic in the CRE riparian zone, and more than 150 plant taxa are known from fewer than 4 records there, including many first-records for the state of Arizona (e.g., Ayers and Stevens 1994, Ayers et al. 1994). Other common riparian taxa in the upper Colorado River in Utah and Glen Canyon are rare in Grand Canyon. Absence of these plant taxa may reflect natural physiological or biogeographic limitations, or susceptibility to river flow and sediment management.

Invertebrates: Several hundred of invertebrate taxa are rare but of unknown status in the CRE. Among these, several previously documented or reported insect species now are either extremely rare or may have been extirpated from the CRE, including: viceroy butterfly (*Limenitis archippus*; Garth 1950, L.E. Stevens unpublished data), dark buckeye (*Junonia genoveva nigrosuffusa;* L.E. Stevens unpublished data), and the recently described noctuid moth (*Schinia immaculata* Pogue 2004). Several endemic chironomid midges were collected along the Colorado River in the mid-1970s but have not subsequently been reported (Sublette et al. 1998), and several black fly and other nematoceran Diptera collected in the 1970s have not been found in the river corridor recent decades (Stevens, unpublished data). A single population of the nepomorph waterbug, *Belostoma* nr. *flumineum* (Belostomatidae) exists in Vulcan's Well Spring (179L; Stevens and Polhemus 2008). Niobrara ambersnail (*Oxyloma h. haydeni*) occur only at Leopard Frog Marsh (CR -9 L) Springs and at Indian Gardens on the Tonto Platform in Grand Canyon (Sorensen and Nelson 2003) and are the only documented extant populations of this genus in Arizona. The Niobrara ambersnail is identified as a Species of Greatest Conservation Need in Arizona's SWAP (AGFD 2006). The only known population of the trematode snail parasite, *Leucochloridium cyanocittae* McIntosh 1932 in Arizona occurs in endangered Kanab ambersnail and *Catinella* nr. *vermeta* snails at Vaseys Paradise (Sorensen et al., unpublished data).

Numerous endemic or extremely isolated insect populations are found adjacent to the CRE and particularly in the lower reaches of perennial springfed streams in Grand Canyon, but their status in the CRE remains unknown. Such species include masked clubskimmer (Odonata – dragonflies, *Brechmorhoga pertinax*) and Grand Canyon wetsalts tiger beetle (*Cicindela haemorrhagica arizonae*), both of which occur in tributaries segments near the Colorado River from Nankoweap Creek (Mile 52R) downstream to Stone Creek (Mile 132R). The distribution and status of the Little Colorado River hairy-necked tiger beetle (*Cicindela hirsuta coloradula*), which is endemic to the riparian zone of lower Little Colorado River, have not been determined (Stevens and Huber 2004; Pearson et al. 2005). The only known U.S. population of the saldid waterbug, *Micracanthia quadrimaculata* occurs at and below the pre-dam 10 year flood stage at "Upper Bass Cable Springs" near Mile 108R (Stevens and Polhemus 2008). Similarly, endemic or isolated nepomorph water bugs (Hemiptera: Belostomatidae, *Abedus breviceps* in Boucher Creek and Ochteridae, *Ochterus rotundus* at low elevation desert springs in the middle reaches of Grand Canyon), and several chironomid midge taxa described by (Sublette et al. 1998), and the empidid *Wiedemannia* (Sinclair 2007) occur at individual springs or springfed desert springs along the Colorado River. A newly described asilid robber fly (*Efferia tapeats* Aubrey et al. in prep.) occurs on CRE sandbars and in adjacent tributary riparian zones in the middle reaches of Grand Canyon. Numerous other rare or undescribed invertebrate species exist in the CRE, but their distribution, status, and the potential impacts of dam operations on them remain unstudied.

Vertebrates: Non-listed extirpated, seriously declining, or rare and apparently at-risk vertebrate species in the CRE include many species, of which several ecologically important taxa are described below.

1) The only population of CRE zebra-tailed lizard (ZTL; *Callisaurus draconoides*) was extirpated in 1983 when river-runner trucks conducting take-outs were redirected onto the upper sand dunes at Diamond Creek (Tompko 1976; Miller et al. 1981; Stevens et al. 2001, Brennan and Holycross 2005). ZTL still occur upstream in the Peach Springs Wash drainage, and a population could easily be reintroduced to the mouth of Diamond Creek.

2) The western threadsnake (*Leptotyphlops humilis*) is known in the CRE from three records in the CRE and lower Little Colorado River (Stevens 1983, Brennan and Holycross 2005, D. Stone, FWS, unpublished data). All records of this species are from sand-dominated habitats in the riparian zone of the Colorado River and the lower Little Colorado River; however, its present status is unknown. Likewise, a single record of regal ring-necked snake (*Diadophis punctatus regalis*) exists from RM 194L by LES in 1978. The large, sandbar grassland in which it was detected was eliminated by mid-1980's high flows. The status of several other rare CRE snake taxa also remains unknown.

3) Muskrat (*Ondatra zibithecus*; Hoffmeister 1986; Stevens 1983; Stevens et al. 2001; NPS files) have been reported several times from the post-dam Colorado River corridor in Grand Canyon, and a skull was reported from Tapeats Creek in the 1990's. Additional evidence of this species' presence was detected after 2000 near Mile 77R. This is presently a rare species in the CRE, but muskrats have been detected recently at Lees Ferry and by GCMRC fisheries biologists as occasionally occurring in the lower Little Colorado River (Stone et al. 2008, 2010).

4) Southwestern river otter (SRO, *Lontra canadensis sonora*; Hoffmeister 1986; GCWC 2005; NPS files) is likely extinct in Grand Canyon. Although several reports of otter in the CRE exist from prior to 2000, repeated searches over 30 years have failed to document live individuals. If a resident population of SRO still exists, the introduction of extra-regional otter subspecies in upper Colorado River drainages and the Verde River is likely to eliminate the pure otter genotype through hybridization (Stevens et al. 2001). GCWC (2005) conducted an analysis of the potential for otter reintroduction into Grand Canyon to restore the missing ecological role of this top mammalian fish predator in the CRE; however, interagency concerns over potential impacts of otter on HBC have been raised and need to be resolved for restoration of the otter's ecological role (GCWC 2005)..

5) Bank-dwelling American beaver (Castoridae: *Castor canadensis*) play an important role consuming and disturbing the CRE riparian zone vegetation (Mortenson et al. 2008). Beaver strongly affect establishment and survivorship of Salicaceae (e.g., Goodding's willow and Fremont cottonwood) and other plant species along the river. Improved understanding of long-term beaver habitat availability, population dynamics, and distribution require additional research and more consistent monitoring.

6) Badger (*Taxodea taxa*) were last reported in the CRE in mid-winter 1990-1991 by National Park Service Biological Technician N. Kline at Hidden Sloughs (Colorado River Mile -6.5R;

Stevens unpublished data). Jacob Hamblin reportedly shot a badger near the mouth of Badger Creek (Colorado River Mile 8R) in the 1850's (Wixom 1997). Similarly, the distribution and status of other carnivore populations is poorly known and not regularly monitored along the river, including: Procyonidae - ringtail (*Basariscus astutus*) and raccoon (*Procyon lotor*); Canidae - coyote (*Canis latrans*) and gray fox (*Urocyon cinereoargeus*); Mustellidae - spotted skunk (*Spilogale gracilis*), striped skunk (*Mephitis mephitis*), and hognosed skunk (*Conepatus leuconotus*); Felidae - bobcat (*Lynx rufus*) and mountain lion (*Puma concolor*); and Ursidae - black bear (*Ursus americanus*).

7) The nativity of painted turtle (*Chrysemys picta*) is uncertain in Arizona, but there are multiple observations of this species in the pre-dam Colorado River in Glen Canyon and near Lees Ferry. S. Johnson recalled collecting turtles from the mouth of the Paria River in the late 1920's (oral communication, LES files). Observations and movie footage of this species were made by T. Nichols in Glen Canyon in the 1950's. Woodbury et al. (1959) reported several records of *C. picta* in Glen Canyon prior to the construction of Glen Canyon Dam. The species is now extremely rare in Arizona, and has been extirpated from the CRE.

8) Gambel's quail (*Callipepla gambelii*) were detected up until the early 1990's along the lower CRE (Brown et al. 1987, L.E. Stevens unpublished field notes), but have not been reported recently. This species may have been introduced into the CRE, but more information is needed, as it was previously abundant along the western South Rim (Brown et al. 1987). Although common on the North Rim, wild turkey (*Meleagris gallopavo*) occasionally colonize the river corridor, but populations rarely persist more than 1-2 yr.

9) Numerous vagrant and accidentally occurring bird species have been detected in the CRE. At least 61 waterbird species in five guilds have been detected in the CRE: shorebirds, waders, raptors, waterfowl, and kingfishers (Brown et al. 1987, Stevens et al. 1997, LaRue et al. 2001). Dam operations may affect waterbird populations directly (e.g., by forcing waterfowl and BAEA to shift their feeding strategies) or indirectly (e.g., stable flows may permit expansion of shoreline vegetation, increasing breeding habitat for mallards (*Anas platyrhynos*), but eliminating spotted sandpipers (*Actitis macularia)* breeding habitat – no breeding sandpipers have been reported in recent decades in the CRE. Many waterbird species occur in migration and use the river corridor as wintering habitat. Protected as a migratory bird species, but not otherwise federally listed, white pelicans (*Pelicanus erythrorhynchos*) regularly pass through Grand Canyon during the migratory period (April and October; Stevens et al. 1997). Single individuals or small flocks are regularly reported, and flocks in excess of 200 birds have been sighted on the river (LaRue et al. 2001). Concern about range connectivity for this species may result in increased conservation attention in the future (e.g., Anderson and King 2005). Several waterbird species occur as vagrants or accidental species, including: 2 records of magnificent frigatebird (*Fregata magnificens*), several records of trumpeter swan (*Cygnus buccinator*), a lone harlequin duck (*Histrionicus histrionicus,*seen between miles 49-52 in 2006-2007), and a single record of a snow goose (*Chen caerulescens*) observed at Lees Ferry in April 2011. Similarly, many rare terrestrial bird species occur as accidental or vagrant species in the CRE (e.g., painted bunting - *Passerina ciris*; groove-billed ani - *Crotophaga sulcirostris*; scissor-tailed flycatcher – *Tyrannus forficatus*). We excluded these vagrant or accidental bird taxa from the analysis unless they were ESA- or specifically federally protected.

10) Gila monster (*Heloderma suspectum*) are known from a very few detections in the lower CRE, primarily between Mile 202 to Diamond Creek on the left side of the river.

11) In the absence of monitoring, the impacts of dam operations on riverine amphibians may go undetected. For example, Rocky Mountain toad (*Anaxyrus w. woodhousei*) diet, movement, reproduction success, and potential hybridization with other congeneric taxa (i.e., red-spotted toad, *A. punctatus*) may be affected by season, flow, and nearshore habitat availability, but the ecology of this species in relation to flow regulation has yet to be examined in the CRE.

CRE Species Rarity

Three general patterns of rarity appear to exist among rare but unlisted species in the CRE. Relatively few species are unique to the CRE (Stevens and Polhemus 2008), although Grand Canyon endemic *Flaveria macdougallii, Euphorbia arron-rossii,* other endemic plant taxa, and several insect taxa occasionally occur along the river. Most endemic taxa in Grand Canyon appear to exist in springs or in harsh but evolutionarily persistent habitats (Phillips et al. 1987).

A more pronounced pattern of rarity involves propagules of headwaters species transported via hydrochory or gravity into the CRE, become established, but are too rare or physiologically stressed to reproduce. These "waif" species include the following examples. Only 3 individuals of poison ivy (Anacardiaceae: *Toxicodendron rydbergii*) are known at CRE springs (32R, 136R, and 142R). A single individual of Asteraceae: *Aster utahensis* was detected at 123L in the middle riparian zone by M. Yeatts (Hopi Tribe, personal communication). Only a few individual of common dunebroom (Fabaceae: *Pareyella fillifolia*) exist in the CRE (Lees Ferry, RM 68R, RM 91R). Four individuals of Euphorbiaceae: *Reverchonia arenaria* were detected at Mile 142R by Ayers and Stevens (1994). Many other unlisted waif plant species are rare and known only from $\leq$3 collections in the CRE. The presence of Glen Canyon Dam likely limits downstream dispersal of waif propagules (e.g., Shafroth et al. 2002), and likely has interrupted long-term distributional processes that may reduce CRE riparian diversity.

A third process is the upstream immigration into the CRE through anemochory or zoochory (wind or animal dispersal), and is more likely to occur in lower reaches of the river corridor. For example, the range of desert mistletoe (*Phoradendron californicum*) extends upriver as far as Mile 159R in catclaw. Scale-dependent dispersal (Aukema 2004) and the laxative properties of mistletoe berries (Willson and Travaset 1992) prevent Phainopepla (*Phainopepla nitens*), western bluebirds (*Sialia mexicana*) and other mistletoe seed dispersers from reaching the next *Acacia* upstream in the steep, narrow, sparsely vegetated Muav gorge. Similarly, whipple yucca (Liliaceae: *Yucca whipplei*), creosotebush (*Larrea tridentata*), ocotillo (*Fouquieria splendens*) and other Mohave Desert plant species have extended their ranges upstream as far the Muav Gorge, but have been blocked by the steep topography of that reach (Stevens and Polhemus 2008). In contrast, desert-broom (*Baccharis sarothroides*) likely colonized upriver via anemochory and has extended its range upstream through the CRE to the upper Muav Gorge. Its germination requirements involve unvegetated silty fine sand and moist soils after flooding (Stevens and Waring 1985), conditions which rarely exist in the contemporary CRE. Its continued expansion into the eastern basin of Grand Canyon is likely reduced by the coarser grainsize of the post-dam river corridor (Stevens 1989). Upstream colonization is generally slower than downstream or gravity-based waifing recruitment and non-

native plant distribution, although both processes are important long-term biogeographic processes in the CRE riparian zone (Stevens and Waring 1985).

Non-native Species

While the focus of this report is on native TMC, the diversity and ecological roles of non-native taxa deserves mention. The total number of non-native taxa in the CRE likely exceeds 300 species (Stevens and Ayers 2002). The list of non-native species is strongly dominated by more than 200 species of plants, several of which strongly preempt colonization space, increase fire frequency, and affect food resources and pollinator populations (e.g., *Tamarix* spp., *Bromus* spp.). Several dozen non-native inverterate taxa have been detected in the CRE, including: important fish parasites (e.g., Asian tapeworm, *Bothriocephalus acheilognathi;* and anchorworm, *Lernaea cyprinacea*; Hoffnagle and Cole 1999); important food species for fish (e.g., *Gammarus lacustris*) and birds (e.g., tamarisk leafhopper, *Opsius stactogalus*); nursery escapees (e.g., *Anatis lecontei* ladybird beetles); nuisance species (e.g., New Zealand mudsnail, *Potomopyrgus antipodarum;* rock dove – *Columba livia*, European starling – *Sternus vulgaris, and* house sparrow- *Passer domesticus*); and non-native predators (e.g., *Procambaruss* crayfish and softshelled turtles in lowermost Grand Canyon. Pending invasions by other invertebrates, such as (*Dreissena rostriformis bugensis)* guagga mussel and *Halyomorpha halys* stinkbugs, may substantially alter CRE structure. Among CRE vertebrates, approximately 19 non-native fish species have been detected in the Colorado River in recent decades, with salmonids implicated in declines in native fish (Marsh and Douglas 1997; Yard et al. 2011). Feral burros were intentionally removed from the CRE by the NPS in 1982, but burros remain federally protected.

Non-native species, as well as several native populations that have proliferated in post-dam time, strongly affect ecosystem form and function in the CRE. However, interactions among these species are complicated and require further study before restoration of native populations. Among several examples are the following:

1) Although non-native rainbow trout (RBT) removal around the Little Colorado River confluence coincided with stabilization of a declining HBC population, field data and modeling indicates that HBC recovery began prior to trout removal. In addition, the role of relatively warmer water during the same time period confound conclusions regarding the benefit of nonnative fish removal (Coggins 2008; Yard et al. 2011).
2) Translocation of HBC into Shinumo Creek (RM 109R) is being undertaken following attempts to remove non-native rainbow trout by electrofishing (GCWC 2008, NPS 2011); however, robust populations of native speckled dace (*Rhinichthys osculus*) and bluehead sucker (*Catostomus discobolus*) co-exist with RBT in that stream, indicating that in some settings, native and nonnative fish species coexist over long time periods. This topic merits additional research.
3) Large Goodding's willow trees commonly co-occur with non-native tamarisk, and the willow has largely been lost to beaver foraging (the beaver population in Grand Canyon is likely much larger than in pre-dam time; Mortenson et al. 2008). Therefore, successful restoration of Goodding's willow stands requires both the elimination of space-preempting nonnative plant species as well as protection of plantings from beaver attack.
4) SWFL and other native neotropical migrant birds in the CRE preferentially nest in non-native tamarisk (Brown and Trossett 1989), a common phenomenon throughout Arizona, and SWFL decline has been related to native brown-headed cowbird brood parasitism. To

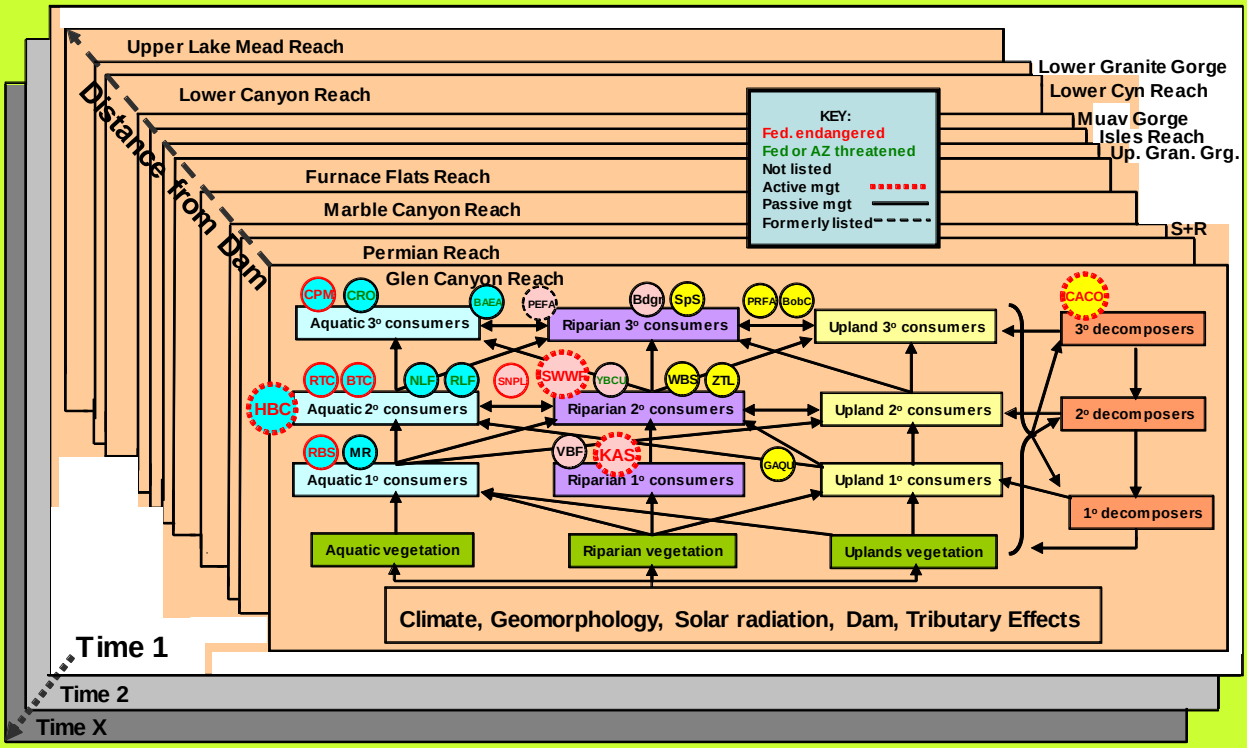
what extent does SWFL restoration require maintenance of suitable vegetation stands from which cowbirds are excluded?

5) The upstream movement of non-native crayfish (*Procambarus clarkii*) from Lake Mead, the potential for downstream dispersal from Glen Canyon and headwater tributaries south of Grand Canyon, and the potential for accidental or deliberate introduction into the CRE poses a serious threat to Grand Canyon's 50 or so perennial tributaries. These are some of the only remaining largely pristine streams in western North America, and are among the only streams in Arizona not invaded by crayfish. As important natural laboratories and sentinel sites for understanding stream-riparian ecosystem ecology and restoration, these streams should be rigorously protected from crayfish invasion.
6) On-going invasion of *Dreissena* mussels into the lower Colorado River basin almost certainly will be followed by invasion into upper basin streams and reservoirs. The impacts of this mussel on the CRE and Grand Canyon tributaries are unknown, but may strongly affect river ecosystem structure and function (Nalepa 2010).
7) Conflicting reports exist over the ecological significance of New Zealand mudsnail (NZM) in the CRE. Cross et al. (2010) reported no impact of NZM on the CRE foodbase, while Melis et al. (2010) and Rosi-Marshall et al. (2010) simultaneously reported extensive impacts of NZM on the CRE foodbase.
8) Tamarisk leaf-beetles (*Diorhabda* spp.) are presently defoliating tamarisk stands throughout the CRE. Despite the recent closure of the beetle release program, this non-native beetle species is well established upstream of Colorado River, and is presently erupting in the CRE. *Diorhabda* invasion may greatly negatively influence river corridor bird habitat and populations, as most of the two dozen neotropical migrant bird species in Grand Canyon nest commonly or preferentially in tamarisk. The NPS is actively monitoring this developing situation which, next to the completion of Glen Canyon Dam, is likely to be the largest anthropogenic change to the CRE in recent history.

Trophic Status of TMC

The CRE encompasses clear water to usually turbid reaches (Fig. 1) through a complex suite of wide or narrow reaches, and TMC populations are variously distributed through those reaches across time and in response to flow regimes (Schmidt and Graf 1990; Schmidt et al. 1998; Walters et al. 2000; Stevens and Polhemus 2008). We mapped the trophic status of extirpated and at-risk TMC in the CRE, demonstrating that focal TMC (i.e., HBC, KAS, and SWFL) occupy lower and middle trophic positions (Fig. 2). While those focal species occupy selected aquatic, wetland, and riparian habitats, respectively, they may not provide adequate protection for most other CRE TMC and ecological processes. Therefore, the usefulness of this small group of endangered species for understanding and managing the full array of ecosystem dynamics is limited (Stevens et al. 2001). Two groups of species in the CRE terrestrial domain have not received sufficient monitoring or conceptual modeling attention: top riparian predators, and rare or endemic taxa, including insects. Additional monitoring data are needed on such species to develop a more robust aquatic-terrestrial conceptual ecosystem model for the CRE, and such an effort will likely better serve long-term CRE management.

SIMPLIFIED CONCEPTUAL MODEL OF THE COLORADO RIVER ECOSYSTEM, SHOWING THE TROPHIC POSITION OF EXTIRPATED AN LISTED FAUNA



and reintroduction efforts. Also, the issue of range restoration for native fish remains outstanding. For example, a large concentration of HBC occurred at the mouth of the Paria River at the time of dam construction (Minckley 1973), but HBC have since disappeared from that reach, and little attention to range restoration of HBC has been entertained by the AMWG to date. Such information and discussion may play an important role in the planning and implementation of population reintroduction and restoration actions.

Reintroduction of extirpated CRE species requires several phases of effort, including: a) development of the administrative context; b) compiling relevant information, stock assessment, and prioritization, c) plan development, d) multi-agency compliance, e) implementation, potentially with multiple stocking efforts, and f) monitoring and feedback.

a) Administrative oversight for reintroduction can be complex. The NPS has direct oversight of natural and cultural resource management of the CRE, as it carries out NPS statutorily-based actions in behalf of the Secretary of the Interior (U.S. Department of the Interior 2006:45). However, several agencies also have oversight for CRE fish and wildlife management. . Other agencies/entities that advise and assist the NPS on management of Grand Canyon plant and wildlife species include: individual NPS units; the FWS, AGFD; several Native American Indian tribes; the Bureau of Reclamation; the U.S. Geological Survey; the State of Arizona; and various other cooperating stakeholders in the Glen Canyon Dam AMWG. Each of these entities has its own mission, and differences in management focus are the norm, making reintroduction of some extirpated species more difficult. The first step in a reintroduction program is to have clearly defined interagency agreement on the effort and clear identification of funding; however, while the administrative context for reintroduction of extirpated species is explicit in the policies of the NPS and in AMWG Goal 3, reintroduction actions remain administratively challenging. For example, reintroduction of razorback sucker into the CRE is regarded as the easiest and most justifiable action, but discussions of this topic began before 1989 and continue to the present day without any action. Administratively successful examples include translocation of KAS into Royal Arch Creek and HBC into Shinumo Creek (NPS 2011).

b) The second step in CRE reintroduction projects involves compilation of sufficient information on the ecology, life history, diseases and parasites, status of remaining populations as potential stock, reasons for extirpation, trophic role(s), relationships to other species, and other information to support reintroduction efforts. . This information needs to be evaluated in a matrix approach to allow the CRE managing agencies to clearly justify and prioritize reintroduction efforts, including where and when reintroduction efforts should be conducted. The action prioritization process should include consideration of all aspects of reintroduction, including: legal and managerial justification, funding, stock availability and genetic issues, potential socio-ecosystem impacts, , reintroduction logistics, treatment for diseases and parasites, risks and contingency planning, monitoring protocols and schedules, reporting, feedback related to improvement of techniques, public relations, and administrative accounting. Clear definiation of such issues are critical to NPS and other resource-managing agency's decisions regarding reintroduction or rehabilitation of TMC.

c) Development of a reintroduction, translocation, or population augmentation plan is based on the findings in (b) above. The plan should include all aspects of the reintroduction process, including detailed stock assessment to guarantee, to the greatest extent possible, that the

reintroduced stock is the most fit and genetically the most capable of surviving the translocation process and proliferating in the renewed landscape. Parasite treatment may be required, as the stock to be translocated should be parasite-free. Also, it is important to determine the level of population take that an existing native species can withstand and still remain functional. The plan must be regarded as a living document, as it will require continued updating as challenges are discovered in the initial phases of the effort. The plan will require agreement by the cooperating agencies.

d) Compliance requirements for species translocation, augmentation, or reintroduction differ and overlap to various extents among the several stakeholders with wildlife management responsibilities in the CRE. NPS compliance requirements for such activities include attention to autecological (stock source), synecological, cultural, other tribal, recreational, natural quiet, and other resource impacts, in accordance with National Environmental Policy Act and the Code of Federal Regulations (24.4.5i.i, 24.6.a.2). FWS reintroduction requirements involve consideration of Section 7 of the 1973 ESA and other obligations. Wildlife reintroduction actions by the AGFD involve a 12-step reintroduction process (AGFD 1987) and Arizona Game and Fish Commission approval. All wildlife stewardship agencies generally have interacted in proposing and accomplishing previous translocation, augmentation, or reintroduction projects in the region (e.g., KAS, California condor, HBC).

DISCUSSION

Ecosystem management requires adequate understanding of the ecological role and potential for restoration of extant as well as extirpated species and processes. Understanding the feasibility and advisability of restoration of extirpated species is mandated through Goal 3 of the AMWG mission, and also is mandated by the wildlife managing agency stakeholders, most notably the NPS, FWS, and AGFD, and several Native American Tribes. Filling information gaps about missing or declining species is needed to more fully inform the Secretary about Glen Canyon Dam impacts, as well as providing information for the compliance requirements of AMWG cooperating agencies needed to foster reintroduction efforts. Through its multi-stakeholder structure, AMWG is uniquely poised to recommend to the Secretary of the Interior the technical, interagency, and societal information needs and processes through which to achieve the purposes of AMWG's Goal 3. However, there is at present no commitment that the AMP will fund species restoration efforts, as such activities are the specific purview of the resource managing agencies. Nonetheless, the AMWG can play an important and beneficial multi-agency advisory role to the Secretary in evaluating TMC restoration priorities and potential in the CRE, and AMWG may benefit from monitoring information on reintroduced or translocated TMC.

The responsibility of the AMWG is to advise the Secretary of the Interior on the environmental and economic impacts of Glen Canyon Dam operations, and the potential to mitigate impacts within the context of existing law. Our analysis here addresses a motion from AMWG in relation to Goal 3 of the AMP to compile information on the restoration needs and potential for missing and at-risk native species in the CRE. We provide previously uncompiled background information, and an assessment approaches to prioritize TMC reintroduction potential. We offer this information as guidance to the AMWG, recognizing the diverse views among AMWG stakeholders as to the AMP's responsibilities regarding CRE management. Our primary objective here has been to present information on the status and priorities for

management of rare and declining CRE species to better help AMWG manage the river corridor as an ecosystem.

Two administrative issues emerged from this analysis that previously have not been discussed by the AMWG. First, many TMC were recognized from the CRE that may warrant management attention, if not by the AMWG, then by other managing agencies. A total of 47 (54 percent) of the 85 TMC considered in here had potential restoration scores $\geq$ 50 percent (Table 2; Appendix A). Also, many species with scores <50 percent lacked critical information on distribution, habitat use, or population status. There appears to be considerable opportunity for improving the quality of basic information on TMC.

Second, AMWG monitoring recommendations currently focus primarily on HBC, as well as flow and sediment transport, with minor attention to KAS. However, at least 5 species (1 plant, 1 lizard, and 3 non-listed fish) scored higher than HBC in our analysis. Concern for the 3 non-listed CRE fish arose from the desire of the Committee to prevent those species from becoming federally endangered. The zebra-tailed lizard scored above HBC because it would be such an inexpensive and easily-accomplished restoration action. AMWG may choose to engage in further discussion of the restoration potential of these TMC, and we hope that the information provided here contributes to those discussions and to improved stewardship of the CRE.

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APPENDIX A:

TAXA OF MANAGEMENT CONCERN IN THE CRE,

SCORING SHEETS, ALTERNATIVE APPROACHES,

AND COMMENTS BY EXPERTS

(Provided in electronic Excel format only)