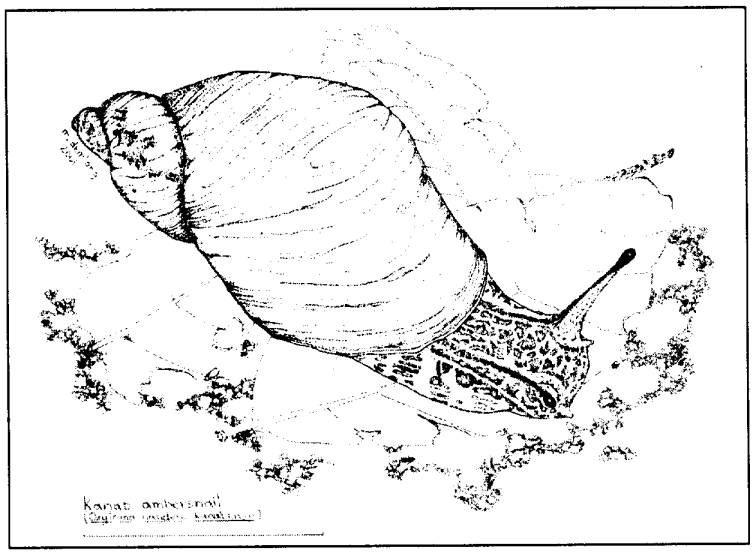
INTERIM CONSERVATION PLAN FOR *OXYLOMA (HAYDENI) KANABENSIS* COMPLEX AND RELATED AMBERSNAILS IN ARIZONA AND UTAH

Jeff A. Sorensen, Nongame Wildlife Specialist
Clay B. Nelson, Nongame Wildlife Specialist

Nongame Branch, Wildlife Management Division
Arizona Game and Fish Department



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Disclaimer

This Interim Conservation Plan delineates reasonable actions that are believed to be required to conserve, recover, and/or protect the species of concern described herein, and provide necessary information for taxonomic designations. This plan was prepared by the Arizona Game and Fish Department, with the assistance of Kanab Ambersnail Working Group cooperators, and is a contract deliverable to the U.S. Bureau of Reclamation, Upper Colorado Region. Conservation goals and information needs will only be attained and funds expended contingent upon appropriations, priorities, and budgetary constraints. Proposed responsible parties listed in the Implementation Schedule are not legally or financially bound by the conservation goals or information needs described in this plan, beyond their respective statutory responsibilities and authorities. In the creation of this plan, every effort was made to solicit input from interagency cooperators and investigators, and to provide consensus decisions and reasonable actions for the species of concern herein. However, this plan does not necessarily represent the specific views or the official positions or approvals of all individuals or agencies involved in the plan formulation. This plan is subject to modification as dictated by new findings, changes in species status, and the completion of conservation goals and information needs.

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EXECUTIVE SUMMARY

The Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis*, Pilsbry) is a federally endangered terrestrial snail with 2 extant populations in the southwestern United States. One population is located at a series of small ponds known as Three Lakes, approximately 10 km north of Kanab, Utah. The other population occurs at Vaseys Paradise, a large riverside spring in Grand Canyon National Park, 51 km downstream of Lee's Ferry, Arizona.

The Kanab ambersnail was federally listed in 1992 due to realized and potential threats to its populations from modification or loss of its wetland habitat. The Three Lakes population is threatened primarily from dewatering and/or modification of habitat by the private landowner. The Vaseys Paradise population is vulnerable to high flows of the Colorado River released from Glen Canyon Dam, 75.3 km upstream. As the flow of the Colorado River increases, habitat and snails at Vaseys Paradise are inundated and scoured away.

In 1995, the U.S. Fish and Wildlife Service produced a recovery plan for the Kanab ambersnail. Between 1994 and 1997, several supporting Biological Opinions with reasonable and prudent measures were written to assist in mitigating Glen Canyon Dam operations on the Vaseys Paradise population and aid in the overall recovery of the species. As a result, knowledge of Kanab ambersnail distribution, genetics, taxonomy, population dynamics, and ecology has increased. However, much uncertainty still exists concerning the taxonomic status and therefore, the management and recovery of the Kanab ambersnail and other *Oxyloma* populations in the southwestern United States.

Until a revised recovery plan is completed, this document serves as an interim step that represents a collective effort to synthesize management, recovery, and conservation objectives based on new information for southwestern *Oxyloma* populations, with an emphasis on the Kanab ambersnail. Abbreviated introduction and background information on these populations is presented, followed by narratives of species conservation goals, information needs, a list of potential funding sources, and an implementation schedule as identified by the majority of interested parties. Viewpoints and editorial suggestions are listed in the appendices.

SUMMARY OF CONSERVATION GOALS AND INFORMATION NEEDS

Task 1: Contribute to ambersnail conservation and recovery efforts, and ensure human-caused activities do not jeopardize ambersnail populations.

Task 2.1: Assist willing landowners to manage occupied ambersnail habitat occurring on private land.

Task 2.2: Develop and review cooperative agreements with willing landowners.

Task 3.1: Monitor the Vaseys Paradise population bi-annually and determine levels of current and potential threats.

Task 3.2 Conduct annual surveys of high vegetation zone habitat (above 100,000 cfs stage height) and snail densities at Vaseys Paradise.

Task 3.3: Develop a model for Vaseys Paradise habitat and ambersnail population response to high river flows.

Task 4.1: Develop regional monitoring protocol for southwestern ambersnail populations.

Task 4.2: Monitor the Three Lakes population bi-annually and determine levels of current and potential threats.
Task 4.3: Monitor translocated Kanab ambersnail populations in Grand Canyon bi-annually.
Task 4.4: Monitor Niobrara ambersnail populations at Indian Gardens and Minus 9 Mile annually.
Task 4.5: Monitor *Oxyloma* populations in south-central Utah annually.
Task 5.1: Produce annual maps of ambersnail population distribution and status.
Task 5.2: Conduct surveys of potential ambersnail habitat of the Colorado Plateau; document locations visited, new populations (and estimated size), landownership, habitat area, and potential threats.
Task 5.3: Conduct research into livestock grazing thresholds for maintaining suitable ambersnail habitat in south-central Utah.
Task 6.1: Conduct captive propagation studies to determine if different ambersnail populations interbreed.
Task 6.2: Compare molecular markers in offspring from interbreeding tests, and complete a full identification of molecular markers from a source population as a baseline.
Task 6.3: Conduct further study of ambersnail genotypes—more robust sample sizes, additional sequence data, and quantify within population variation.
Task 6.4: Conduct additional morphological studies paired with the molecular analyses to provide a better understanding of variation of within population characteristics or plasticity.
Task 6.5: Summarize and publish findings from new genetic and morphological studies; disseminate study results to all interested parties.
Task 7.1: Define a conservation strategy for the Vaseys Paradise and translocated populations.
Task 7.2: Define a conservation strategy for the Three Lakes population.
Task 7.3: Develop a State Conservation Agreement for non-listed *Oxyloma* populations in Arizona (Indian Gardens and Minus 9 Mile).
Task 7.4: Develop a State Conservation Agreement for non-listed *Oxyloma* populations in Utah.
Task 8: Define establishment success and failure criteria for translocated Kanab ambersnail populations.
Task 9: Disseminate available ambersnail information to interested parties—compile and distribute compilation binders of existing reports, memos, meeting minutes, and published articles; hold regular Kanab Ambersnail Work Group meetings to share info and discuss issues.
Task 10: Refine downlisting and delisting criteria for listed ambersnail populations in Arizona and Utah.
Task 11: Implement conservation measures to maintain vulnerable non-listed ambersnail populations in Arizona and Utah.
Task 12.1: Conduct additional captive propagation studies to further life history information needs (recruitment, growth, survival, mortality) needed for population viability analyses and/or models to estimate population response to habitat loss.
Task 12.2: Conduct additional tests of sampling methods and associated observation and extrapolation error with wild and captive ambersnail populations under controlled settings.
Task 13: Promote public outreach and environmental education on ambersnail conservation and ecosystem management.

Task 14: Provide training in ambersnail identification and survey, environmental compliance, and population genetics to participating cooperators.

Task 15: Create and maintain a centralized database of ambersnail research and monitoring data, accessible to all interested parties.

Task 16: Conduct additional surveys of potential ambersnail habitat outside of the Colorado Plateau.

Task 17.1: Acquire habitat on private land for ambersnail conservation; establish National Wildlife Refuges, state wildlife areas or parks, The Nature Conservancy nature preserves, conservation easements, or other permanently protected lands.

Task 17.2: Secure surface and sub-surface water rights on acquired lands for ambersnail habitat.

In this report, Arizona and Utah ambersnail populations identified as "Kanab ambersnail" are based primarily on morphological distinctions described by Pilsbry and S.K. Wu. Recent genetic analysis on ambersnail specimens from localities in Canada and the United States suggests that the Vaseys Paradise population is genetically distinct from other known *Oxyloma* populations, and their taxonomic identity should be revised. However, until the taxonomic identity of Vaseys Paradise ambersnails is resolved, we will continue to use the "Kanab ambersnail" designation.

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Jeff A. Sorensen and Clay B. Nelson

INTRODUCTION

The Kanab ambersnail (KAS: Succineidae *Oxyloma haydeni kanabensis* Pilsbry) is federally listed as an endangered mollusk with 2 extant populations in the southwestern United States (USFWS 1992, 1995). One population occurs at a series of small ponds on private land north of Kanab, Utah. The other population is located at a large spring that flows from the walls of Grand Canyon into the Colorado River, Arizona. KAS was listed as endangered due to realized and potential threats to its populations stemming from adverse modification or loss of its wetland habitat (USFWS 1992). This subspecies has received a considerable amount of attention due to the fact that the Grand Canyon population is negatively affected by increased flows of the Colorado River released from Glen Canyon Dam (GCD). The endangered status and potential threats to these populations has led to an intensive research, monitoring, and recovery effort that attempts to balance species conservation with adaptive ecosystem and resource management. As a result, we have increased understanding of KAS population dynamics, genetics, taxonomy, and distribution, as well as for several other *Oxyloma* species located within the southwestern United States.

However, the 1995 KAS Recovery Plan does not adequately reflect the current state of knowledge and management direction for these populations (Noss and others 1999). Until a revised recovery plan is completed, this document serves as an interim step that represents a collective effort to synthesize management, recovery, and conservation objectives based on new information for southwestern ambersnails, with an emphasis on KAS and other *Oxyloma* populations of Arizona and Utah.

An implementation schedule is provided at the end of this document that outlines specific actions, estimated duration and annual costs, and proposed responsible parties for the conservation of Arizona and Utah ambersnail populations. Since completion of these tasks is dependent on available funding and personnel, the activities and responsibilities listed in this schedule are not legally or financially binding to any cooperator, beyond the scope of their pre-existing statutory requirements and authorities. Also provided is a list of potential funding sources for southwestern ambersnail conservation efforts.

LEGAL STATUS

The Kanab ambersnail was listed under an emergency rule published on August 8, 1991 (56 FR 37671). On November 15, 1991, KAS was proposed for listing as an endangered species with critical habitat for the Utah population at Three Lakes, 10 km northwest of Kanab (56 FR 50824). A final rule listing KAS as an endangered species under the authority of the Endangered Species Act (ESA), as amended, was published on April 17, 1992 (57 FR 13661). No critical

habitat was designated in the final rule, due to lack of necessary economic information (USFWS 1992). The recovery priority of this subspecies is 6C (a subspecies with a high degree of threat and low recovery potential with possibility of conflict with human activities) (USFWS 1992).

In 1995, USFWS drafted a recovery plan outlining recovery objectives and tasks to assist in the downlisting of KAS (USFWS 1995). During this time, an Environmental Impact Statement on the Operation of GCD recommended that the flow regime be altered to include Beach/Habitat-Building Flows (BHBFs) aimed at restoring more natural ecosystem processes to the Colorado River corridor. However, these flows would conflict with the conservation of the Arizona KAS population by inundating and scouring away snails and habitat (Stevens and others 1997b, 2001; Meretsky and others 2000). To mitigate the proposed actions proposed by the Bureau of Reclamation on the operation of GCD, the USFWS also issued Biological Opinions in 1994, 1996, and 1997 (USFWS 1994, 1996, 1997). Collectively, the KAS Recovery Plan and related Biological Opinions on the operation of GCD have provided direction for recovery, research, monitoring and conservation of KASs since 1994.

Participating Cooperators

Many agencies, stakeholders, and interest groups have participated in the conservation of KASs in supporting or providing input into various research, monitoring, and conservation projects. The interagency KAWG functions as an informal KAS Recovery Team, since an official Recovery Team has not been designated, and this group was not assembled as a Federal Advisory Committee. The KAWG is comprised of representatives from: AGFD, Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), Central Utah Project Completion Act Office (CUPCA), GCMRC, Grand Canyon Trust, NPS, Northern Arizona University (NAU), The Phoenix Zoo (TPZ), USBR, USFWS, Utah Department of Wildlife Resources (UDWR), and Western Area Power Administration (WAPA).

Background

Distribution

The Succineidae is a morphologically diverse family of pulmonate landsnails represented by the genera *Oxyloma* Westerlund, *Succinea* Draparanaud, and *Catinella* Pease (Franzen 1963). Although succineids are terrestrial, they are restricted to moist habitats, and are often associated with wetlands, ponds, lakes, rivers, and springs (Harris and Hubricht 1982). All 3 genera are known to occur throughout the United States; however, our focus centers on known populations of *Oxyloma* spp. located in southern Utah and northern Arizona (Fig. 1).

Fossil *Oxyloma* have been collected in late Pleistocene deposits in the San Pedro River Valley, Arizona (Bequaert and Miller 1973), in Miocene-Pliocene deposits in Verde Valley, Arizona (Nations and others 1981), and in 9200 yr-old sediments near Lake Powell in southeastern Utah (Kerns 1993). Spamer (1993) collected fossil *Catinella* shells from "red earth" deposits along the Saddle Canyon trail in Grand Canyon.

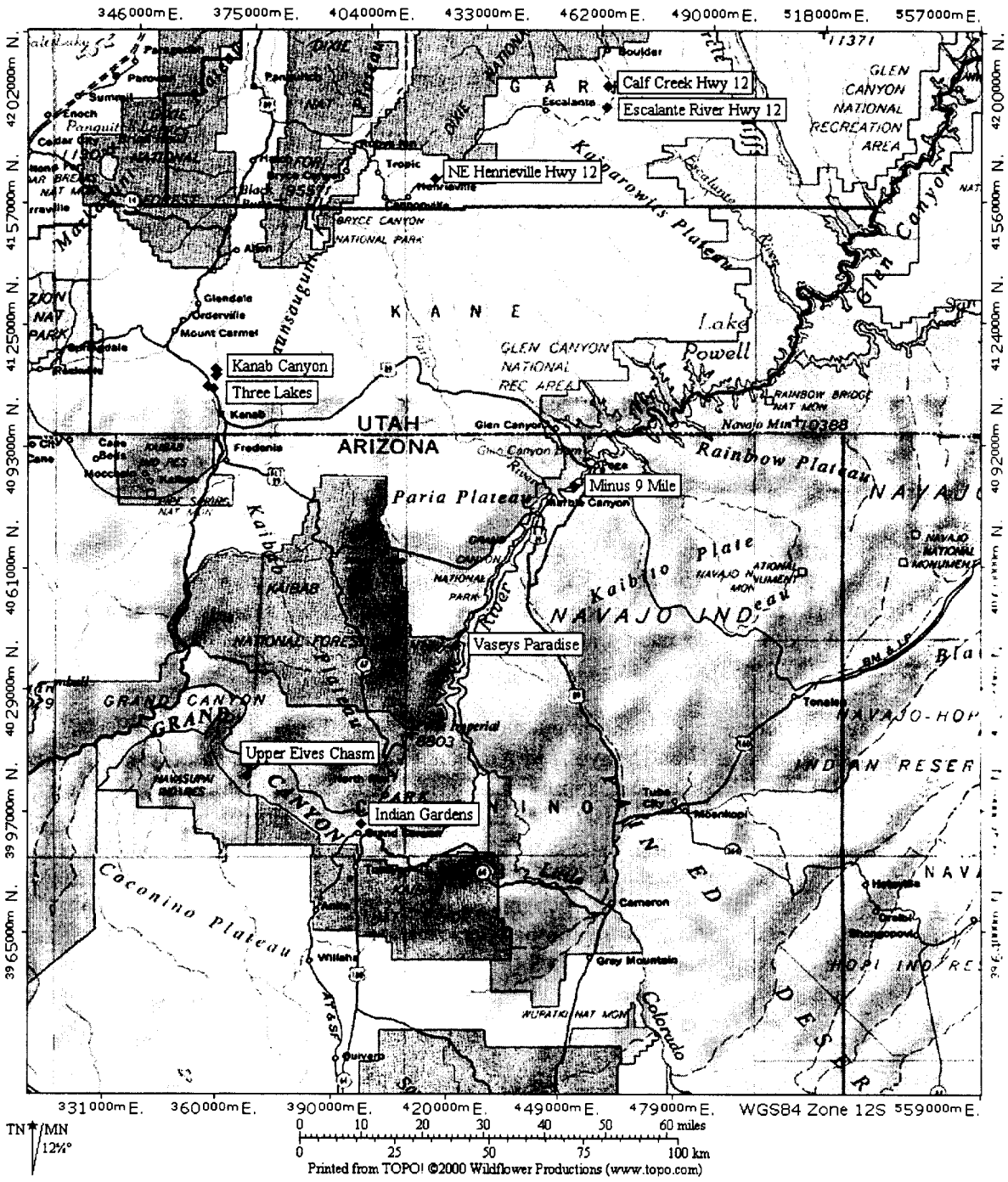

Figure 1. Known *Oxyloma* populations (natural and translocated) of the Colorado Plateau in northern Arizona and southern Utah, as of December 2001. Additional populations of *O. haydeni* and *O. retusa* in south-central Utah were discovered in 1998-99 by Meretsky (2000a) and Meretsky and North (2000), but UTM coordinates for those localities are unavailable.

J.H. Ferriss first collected live KASs in southern Utah in 1909 (Ferriss 1910; Chamberlin and Jones 1929; Pilsbry 1948; and Clarke 1991). Ferriss collected specimens from the type locality called "the Greens"—a vegetated seep approximately 10 km north of Kanab in Kanab Creek Canyon (Ferriss 1910). Since Ferriss did not report any geographical coordinates for the site, some uncertainty currently exists regarding the location of the type locality (L. England and V. Meretsky, pers. comm.). Investigations of the area previously thought to be "the Greens" in 1990 had revealed no ambersnails, and the population is presumed extirpated (USFWS 1995). In 1998, a group of meta-populations of the Niobrara ambersnail (NAS, *O. h. haydeni* Binney) were found in Kanab Canyon on BLM land and property owned by the Best Friends Animal Sanctuary (Meretsky 2000; Stevens and others 2000).

Currently, the only extant population of KASs in Utah is located at a series of small ponds known as "Three Lakes" (3L), on private land approximately 10 km northwest of Kanab (Clarke 1991; USFWS 1995; Spamer and Bogan 1993a). This population inhabits a wet meadow and marsh habitat (approximately 0.8 km [0.5 mi] long, and estimated at 2 ha [5 acres] in area) surrounding the 3L ponds (USFWS 1995). In June 1990, the 3L population was roughly estimated at 100,000 snails (USFWS 1995). Meretsky (1998) estimated the population in the habitat above the upper pond between 180,000 and 288,000 snails in June-August 1998.

In 1991, a second population of KASs was discovered at a riverside spring called Vaseys Paradise (VP), located approximately 53 km downstream of Lee's Ferry on the Colorado River, in Grand Canyon National Park, Arizona (Blinn and others 1992; Spamer and Bogan 1992, 1993a). Potential and occupied habitat at VP is estimated between 850 and 900 m^2 (Stevens and others 1997a, 1997b).

During surveys to locate additional populations of KASs, 2 populations of NASs were discovered within Glen and Grand canyons in Arizona. One NAS population occurs at Minus 9 Mile Spring (-9M) in Glen Canyon, approximately 10.5 km downstream from GCD on the Colorado River (Sorensen and Kubly 1997; Miller and others 2000). The other population occurs at Indian Gardens (IG) at 1100 m elevation on the Bright Angel Trail in Grand Canyon, approximately 135 km downstream of GCD (Stevens and others 1997a; Miller and others 2000).

Recent surveys of the southern Utah region have documented several additional populations of *Oxyloma* that are currently identified as NAS (in the Kanab Canyon area) and *O. retusa* (in the Henrieville area and Escalante River area along Highway 12) (Meretsky 2000; Meretsky and North 2000; Stevens and others 2000).

TAXONOMY

Traditionally, snail taxonomy has been based on shell morphology and differentiation of soft body parts. However, snails in the genus *Oxyloma* exhibit few distinct characteristics on which to base specific classifications. Therefore, identifying members of this genus presently requires not only examination of shell morphology, but also anatomical features such as genitalia, proportion and arrangement of organs, and pigmentation of tissue, as well as habitat assessment (Hoagland and Davis 1987). Moreover, substantial variation within populations, potential anatomical change over the lifetime of the individuals, overlapping habitat use and limited reliability in the

differentiation of anatomical structures continue to limit taxonomic resolution of this genus (Franzen 1964).

Regional taxonomic classification of the family Succineidae is currently based on morphological characteristics. Succineids generally are referred to as "ambersnails" due to the amber color of their shells. These shells are characteristically fragile, have a large aperture-to-shell length ratio, and are ovate with decreasing whorls coming to a point (Molloy 1995). NAS=*Oxyloma haydeni* (Binney) has 3 whorls forming a short spire, but differs from other species due to several slight variations in shell morphology. KAS=*Oxyloma haydeni kanabensis* (Pilsbry) is distinguished from other *Oxyloma* by a more slender and drawn out spire, and a shorter aperture than in *O. haydeni*. The genus *Catinella* is also commonly found throughout the American Southwest and is often mistaken for *Oxyloma* at first glance. Upon closer examination, *Catinella* can typically be distinguished from *Oxyloma* in the field from by their shorter, more robust whorls (S. Wu, pers. comm.). Although the classification of Succineidae is currently based on differences in shell morphology and reproductive tract, recent genetic analyses have contradicted some of these findings, leaving the taxonomy of many species in a state of uncertainty (Miller and others 2000; Stevens and others 2000).

In this report, Arizona and Utah ambersnail populations identified as "KAS" are based primarily on published morphological distinctions described by Pilsbry (1948), Spamer and Bogan (1993a, 2002), and S.K. Wu (pers. comm.). Recent genetic analysis on ambersnail specimens from localities in Canada and the United States (Stevens and others 2000) suggests that the Arizona population at VP is genetically distinct from other known *Oxyloma* populations, and their taxonomic identity should be revised (Noss and others 1999). However, until the taxonomic identity of VP ambersnails is resolved, we will continue to use the "KAS" designation.

HABITAT

Oxyloma are typically found in marshes and other wetlands watered by springs and seeps at the base of sandstone or limestone cliffs (Clarke 1991; Spamer and Bogan 1993a). The 3L site contains a series of spring-fed ponds and wet meadows, at the base of sandstone cliffs within the Kanab Creek drainage (USFWS 1995). Habitat for the 3L population of KAS is characterized by cattail (*Typha domingensis*) marshes and sedge (*Juncus* spp.) meadows.

In contrast, the VP site consists of a cool dolomitic spring that flows directly from the Mississippian Redwall limestone (USFWS 1995; Stevens and others 1997a). Spring water flows approximately 100 m down a steep gradient to the mainstem of the Colorado River. Spring flow is channeled along several small rivulets bordered by patches of lush vegetation (Stevens and others 1997a). Ambersnail habitat at VP is characterized by large patches of mixed vegetation composed primarily of native crimson monkeyflower (*Mimulus cardinalis*), non-native watercress (*Nasturtium officinale*), and native water sedge (*Carex aquatilus)* (Stevens and others 1997a, 1997b). Within this habitat, KASs are often found in the dead and decaying monkeyflower litter, and on live watercress stems and leafs. The spring also contains large amounts of poison ivy (*Toxicodendron rydbergii*), which does not comprise KAS habitat, but does minimize human intrusion. Available ambersnail habitat at VP has increased approximately 40% since GCD was installed in 1963 and began moderating Colorado River flows in Grand

Canyon (Stevens and others 1997a). Pre-dam habitat for KAS at VP was likely limited to above 100,000 cfs [2833 cms] stage height due to annual high flows.

The NAS population located at –9M in Glen Canyon is restricted to areas with damp or saturated cattail litter, common reed litter, watercress, and among sedges growing in saturated soil (Sorensen and Nelson 2001). The NAS population at IG is also restricted to permanently wet areas fed by a small spring. Habitat at IG consists of a large cottonwood (*Populus fremontii)* canopy with an under story of watercress (*Nasturtium* spp.), cattail (*Typha* spp.), seep willow (*Baccharis glutinosa*), sedges (*Carex* spp.), horsetail (*Equisetum* spp.), common reed (*Phragmites australis*), and coyote willow (*Salix exigua*) (Stevens and others 1997a; Sorensen and Kubly 1997).

The more recently discovered NAS and *O. retusa* populations in southern Utah share a common habitat type that is characterized by seep or spring-fed wetlands consisting of cattails (*Typha* spp.), American bulrush (*Scirpus* spp.), rushes (*Juncus* spp.), sedges (*Carex* spp.), watercress (*Nasturtium* spp.), and cutleaf water parsnip (*Berula erecta*) (Meretsky and North 2000; Meretsky and others forthcoming).

Genetic and Morphological Studies

After additional populations of *Oxyloma* were discovered in south-central Utah and northern Arizona (IG and –9M), questions arose concerning the taxonomic and genetic identity of these populations and their relationship to the VP and 3L populations. A better understanding of the taxonomic relationships and overall abundance of these snails became critical to the downlisting process. To address these questions, Miller and others (2000) performed amplified fragment length polymorphism (AFLP) analysis on 110 genetic base pairs in individuals sampled from each population to determine the extent of within and between population genetic variation among the 2 natural KAS populations at VP and 3L and the 2 NAS populations at –9M and IG. In addition, Stevens and others (2000) performed a "double-blind" analysis of mitochondrial DNA in conjunction with traditional morphological taxonomic identification methods on a suite of *Oxyloma* and other succineid populations from the United States and Canada. Stevens and others (2000) reports that the VP population is genetically distinct from all other *Oxyloma* populations studied in Canada or the United States, and may in warrant listing as a separate taxon. However, the morphological examinations of VP and 3L specimens in this study maintain that both populations are anatomically KAS (Stevens and others 2000).

Significant genetic differentiation has been shown to exist among many common and widespread terrestrial mollusk species (Daniell 1994). In an effort to determine the extent of within and between population genetic variation among the 2 natural KAS populations at VP and 3L and the 2 NAS populations at –9M and IG, Miller and others (2000) used the amplified fragment length polymorphism (AFLP) technique to analyze 110 genetic base pairs in individuals sampled from each population. Results from these analysis revealed, "all 4 locations contain genetically distinct and unique populations...and statistical analysis indicate that this differentiation is highly significant." Furthermore, Miller and others (2000) speculated that each of these populations has been separated since perhaps the Pleistocene Epoch. In this test, –9M NAS had significantly lower within-population genetic variation ($p<0.0125$, $H_{HW}=0.0858$, $H_{HOM}=0.0608$), which

suggests that this population may have undergone severe bottlenecks in the past (Miller and others 2000). These bottlenecks most likely would have been attributed to frequent pre-dam flooding of the Colorado River. Surprisingly, the 3L KAS population and the IG NAS population were genetically more similar to each other (supported by >80% of bootstrap replicates) than VP KAS to 3L snails (Miller and others 2000).

To further clarify genetic and morphological discrepancies, Stevens and others (2000) performed a "double-blind" analysis of mitochondrial DNA in conjunction with traditional morphological identification methods on a suite of *Oxyloma* and other Succineid populations from the United States and Canada, including specimens from VP, 3L, -9M, and IG. This study used a typological approach (e.g. a classification method that disregards individual variation and considers all specimens to be replicates of the type specimen), rather than a morphometric approach (e.g. a classification method that compares measurements of body parts using multivariate statistics to determine taxonomic identity). Results from these analyses further support Miller and others (2000) findings, and reveal that the VP population is genetically unique compared to other *Oxyloma* populations, including 3L. However, morphologically, it is indistinguishable from 3L. Also, specimens collected by Meretsky and others (forthcoming), at several locations outside of Kanab, Utah, including the area believed to be the type locality, were typologically and genetically identified as NAS. Further investigation of the population in Kanab Canyon is needed to determine if KASs and NASs co-occur there, or if the population is exclusively NAS (Stevens and others 2000).

Harris and Hubricht (1982) identified KASs in 7 localities west of Edmonton and north of Sundre, Alberta, Canada, from collections made between 1970 and 1980. Stevens and others (2000) reported that ambersnail specimens collected from Alberta in 1998 were genetically similar and formed a geographical clade different from specimens in the Southwestern clade in Arizona and Utah. At least 2 Canadian specimens were putatively morphologically identified as KAS in this study (Stevens and others 2000), although some doubt exists to whether those specimens may have been reproductively immature, and therefore incorrectly identified. These results raise questions of possible convergence or anomalous distribution among the *Oxyloma* populations in North America (Stevens and others 2000).

While recent analyses have addressed the amount of genetic differentiation among some ambersnail populations, they have also revealed contradictions between morphological and genetic taxonomy. However, it appears that the KAS population at VP is clearly unique, even with respect to the KAS population at 3L (Stevens and others 2000). These findings validate present concerns regarding the protection of the KAS population at VP, and also warrant further morphological and genetic investigations of other *Oxyloma* populations throughout the United States and Canada.

Ecology and Life History

Life history studies conducted on experimental KAS populations reared exclusively on different host plant species found at VP indicate that snail growth, fecundity, and density may differ depending upon host plant utilization. Nelson (2001) found a clear trend of increased growth and fecundity in snails reared on non-native watercress (*Nasturtium*) compared to those reared on

native monkeyflower (*Mimulus*). The watercress-fed population had faster mean growth rates (0.11 mm/day [$s \pm 0.030$] on watercress, and 0.092 mm/day [$s \pm 0.026$] on monkeyflower), and produced significantly more eggs per mass than those on monkeyflower (Mann Whitney U=300, df=2, p=0.00016). The number of eggs per mass on watercress ranged from 7 to 27 with a mean of 14.19 ($s \pm 0.78$, n=47), while eggs per mass on monkeyflower ranged from 4 to 20, with a mean of 9.7 ($s \pm 0.7$, n=27) (Nelson 2001). Furthermore, VP population densities were significantly higher on watercress in late summer and autumn than on monkeyflower.

In August 1995, watercress habitat at VP had 205.5 snails/m^2 (s=211.8, n=11) compared to 44.1 snails/m^2 (s=66.94, n=13) on monkeyflower (Mann-Whitney U=35.5, p=0.03, d=1) (Stevens and others 1997a). In September 1995, watercress habitat at VP had 356.8 snails/m^2 (s=314.89, n=45) compared to 84.9 snails/m^2 (s=34.14, n=34) on monkeyflower (Mann-Whitney U=284.5, p<0.0001, df=1) (Stevens and others 1997a). However, Nelson (2001) found that host plant utilization did not influence hatching success (approximately 52% on watercress [$s \pm 5.6$, n=47] and 56% on monkeyflower [$s \pm 10.3$, n=27]), or hatching time (mean 26 days [$s \pm 1.1$, n=32] on watercress and 28 days [$s \pm 1.43$, n=8] on monkeyflower) in captive populations. Using lifetime fecundity and survivorship estimates to project VP population sizes over a 50-year period, Nelson (2001) found the intrinsic rate of increase (r) was <1 (indicating a decreasing population) for the population reared on monkeyflower and >1 (indicating a population increase) on watercress.

Since experiments were conducted to determine differences in life history traits of VP KASs occurring on different host plant species, it is difficult to ascertain what the general life history of *Oxyloma* is in any given habitat. However, using field observations and calculating the mean of life history traits among ambersnails reared on each host plant, an approximate life history model may be created for VP KASs. A detailed review of KAS life history traits is provided by Stevens and others (1997a) and Nelson (2001). Additional information that is needed to better understand *Oxyloma* population viability includes: growth, fecundity, and density of ambersnails on habitat other than monkeyflower and watercress; snail densities and area of occupied habitat above 100,000 cfs stage height at VP; frequency and severity of catastrophic events (natural or human-caused); possible carrying capacity or density dependent factors; percentage of overwinter mortality for total population and among different age classes; percentage of individuals annually lost to predation, disease, parasites, and physical injury (trampled or crushed); percentage of individuals annually lost to environmental extremes (desiccation, drowning, freezing); percentage of individuals that annually migrate or are removed from the population by river/stream flows and/or spring discharge; amount of immigration from local meta-populations (if any); and evidence of hybridization with other succineid species or conspecifics. No experimental research has been conducted on life history traits for 3L KASs or other *Oxyloma* populations in Arizona or Utah.

Analysis of size class distributions from the VP population indicates that KASs live from between 12 and 15 months, with peak reproduction occurring in mid-summer. Experimental KASs grow at an average rate of 0.1 mm/day, and become reproductively mature at approximately 11.5 mm (Nelson 2001). Cross-fertilized KASs typically produce 1.25 gelatinous egg masses that contain an average of 12 eggs per mass (Nelson 2001). Egg masses are typically laid on the undersides of host plant stems and leafs, or in moist soil. Nelson (2001) found that

average time to hatching is approximately 27 days, with about half of all eggs successfully hatching (variation in laboratory conditions may have decreased hatching success). Only about 5% of snails that successfully hatched in experimental enclosures at NAU survived to reproductive maturity (Nelson 2001).

At VP, winter dormancy for KASs begins in October and emergence from dormancy typically occurs in March. For winter dormancy, ambersnails adhere the aperture of their shells to a firm substrate such as host plant stems and leafs, as well as rocks, sticks, and bark. However, if winter conditions are mild, KASs appear to continue their life cycle without dormancy, or may go in and out of dormancy several times throughout this period (C. Nelson and L. Stevens, pers. obs.). The impact of winter dormancy on natural KAS population dynamics has not been studied thoroughly, although field surveys have indicated that high mortality may occur during this time; estimates of mortality at VP range between 25-80% (Stevens and others 1997b; IKAMT 1997).

Bootstrapped population estimates suggest the KAS population at VP has ranged from 18,476 individuals in March 1995 to 104,004 individuals in September 1995 (Stevens and others 1997a). However, these estimates are subject to possible error since various sampling methods were used and habitat area measurements were not refined. More recent data (1997-98, USBR 1999 draft) using standardized techniques indicate that total VP KAS population estimates range between 7286 and 29,630 snails in the Spring, and Autumn estimates range between 26,129 and 40,553 snails.

Total population numbers at VP are highly uncertain due to possible sampling error among researchers and variability in sampling effort. The fragile habitat and dense stands of poison ivy at VP make sampling difficult. As a result, some large vegetation patches are only sampled around the perimeter to avoid trampling ambersnail habitat and to reduce exposure to poison ivy. In addition, the assumption that snails are evenly distributed throughout each patch has not been tested thoroughly, and consequently, may inflate site population estimates (Sorensen 2001). Sorensen (2001) found that standardized subsampling of watercress habitat had overestimated VP KAS densities by 473% in a Summer survey and 489% in an Autumn survey when compared to total census counts. However, subsampling estimates were only 1% higher than total census counts in a Spring survey at VP (Sorensen 2001). A critical review of KAS sampling error, effects of extrapolation error, and habitat relationships to snail densities is provided in Sorensen (2001).

Parasites

While monitoring the KAS population at VP, researchers have periodically observed snails parasitized by the flatworm trematode *Leucochloridium cyanocittae*, typically in the summer months. Since 1995, when the parasite was first observed, parasitism rates have ranged between 1% and 10% among mature (>10 mm) KASs surveyed during summer monitoring trips (Stevens and others 1997a, 1997b). Parasitism has not been observed in snails <10 mm in length, or in other snail species found at VP, including *Catinella*. Monitoring of the KAS population at 3L in 1998 revealed that parasitism also occurs at this site (V. Meretsky, pers. comm.). There currently is no estimate on what percentage of the 3L population might be parasitized by this trematode.

The life cycle of the genus *Leucochloridium* is especially adapted for intermediate infestation of a succineid species with final infestation of a passerine bird host (Baer 1971). Parasitized snails are visually identified by the presence of 1 or 2 large sporocysts clearly visible in the snail's eyestalks. These sporocysts are often green and brown-banded, or even pink and brown-banded (Baer 1971). Each sporocyst contains numerous metacercariae, up to 100 individual worm-like cercariae packed together in a protein covering known as a brood sac (Baer 1971). Sporocysts can grow to a length of 12 mm, and pulsate rhythmically through the snail's eyestalk when exposed to light (J. Sorensen, pers. obs.). It is thought that this motion attracts birds, which may pull the sporocyst from the snail's eyestalk. The trematodes develop in the bird's gut and produces eggs, which are expelled in its feces and then ingested by another intermediate snail host, starting the process over (Baer 1971). Although this process may damage the snail's eyestalk, it does not necessarily kill its host. Live KASs have been observed at VP with damaged eyestalks, presumably resulting from sporocyst expulsion. Observations of parasitized snails reveal that they are capable of reproduction (Sorensen and Kubly 1997b), although fecundity is likely reduced (Esch and Fernandez 1994).

Predators

Terrestrial snails have numerous predators including insects, mammals, birds, and other snails (Godan 1983). In 1996, at VP, a deer mouse (*Peromyscus* sp.) was observed fleeing an open enclosure where marked ambersnails were released a few hours earlier—several of the marked snails had been eaten, with only the shells remaining (V. Meretsky, pers. comm.; Stevens and others 1997b). Further studies at VP indicate that the resident *Peromyscus* population is relatively small throughout the year, but may affect the size of the KAS population (V. Meretsky, pers. comm.; Stevens and others 1997b; IKAMT 1998; Meretsky and Wegner 2000). Experiments conducted by Nelson (unpublished) failed to reveal any intact portions of snail hard body parts (shell or radulae) in feces collected from the *Peromyscus* population at VP.

Clarke (1991) observed American robins (*Turdus migratorius*) feeding on snails at the 3L population. However, robins are uncommon visitors along the Colorado River corridor in Grand Canyon, and are unlikely to be a significant predator on VP KASs (USFWS 1995). Bird species regularly seen at VP include: common raven (*Corvus corax*), American dipper (*Cinclus mexicanus*), canyon wren (*Catherpes mexicanus*), black phoebe (*Sayornis nigricans*), and Say's phoebe (*S. saya*) (Stevens and others 1997a). There have been no direct observations of snail predation by birds at VP (Stevens and others 1997a).

THREATS

Due to the high reliance on wetland habitat, de-watering is a common threat to all southwestern *Oxyloma* populations. Realized and potential threats to the KAS population at 3L include inundation by flooding, livestock grazing, and extirpation from commercial development (USFWS 1995). The KAS population at 3L is at risk of losing habitat due to commercial development by the private landowner (USFWS 1995). Some habitat loss occurred in 1990-91, due to commercial development on the property and to a limited extent, trampling by livestock (USFWS 1995). Silt deposits from heavy rains buried a "significant portion" of the 3L habitat and population in September 1994 (USFWS 1995).

At VP, habitat loss associated with natural and controlled flooding of the Colorado River below GCD has the greatest negative impact to the Arizona population. As the hydrograph increases to levels ≥20,000 cfs (567 cms), habitat and KASs at VP are inundated and scoured away (Stevens and others 1997b). In 1996, a 45,000 cfs (1275 cms) experimental flow from GCD inundated and scoured away approximately 14% of KAS habitat at VP (USFWS 2000). Other threats to this site also include recreational visitation from river runners due to the availability of fresh drinking water at the site (USFWS 1995). However, most river runners do not disturb occupied snail habitat because of the large amounts of poison ivy. Flash flooding from the VP springhead may also cause some damage to the habitat, as well as potential overland flow from the talus slope located directly above the spring (AGFD 1998a; Meretsky and Wegner 2000). Bighorn sheep (*Ovis canadensis*) grazing may also affect KAS habitat at VP. In 2000, L. Jonas (pers. comm.) observed bighorn sheep grazing at VP during low river flows.

The NAS population located at –9M is subject to inundation from even moderate flows of the Colorado River (>25,000 cfs [708 cms]), and more than 90% of the entire habitat is inundated at 45,000 cfs or more (Spence 1996; Sorensen and Nelson 2001). However, the vegetation has been protected from scour during past flooding events, as documented in the 1996 BHBF, due to a re-circulating eddy along its western perimeter (Sorensen and Nelson 2001). The IG population is threatened by trampling from off-trail hikers, large flash floods, and possible habitat loss/degradation due to landscape maintenance (L. Stevens, pers. comm.; Sorensen and Kubly 1997).

Threats to the other known NAS and *O. retusa* populations located throughout southern Utah include: degradation or loss of habitat due to commercial development, livestock grazing, de-watering, flash flooding, and roadway expansion. Meretsky and North (2000) reported lower densities of *Oxyloma* in grazed sites when compared to ungrazed habitat. No experimental research has been conducted on the amount of livestock grazing impact to ambersnail habitat and population resilience.

INVENTORY, MONITORING, AND RECOVERY EFFORTS

Spring and Seep Surveys in Northern Arizona and Southern Utah

In accordance with the KAS Recovery Plan (USFWS 1995) and related Biological Opinions on the operation of Glen Canyon Dam (USFWS 1994, 1996, 1997), interagency teams have conducted surveys of more than 350 springs, seeps, and wetlands across the American Southwest over the last 8 years, in an effort to locate additional populations of KAS (Stevens and others 1997a, 2000; Sorensen and Kubly 1997, 1998; Meretsky 2000a; Meretsky and North 2000; Webb and Fridell 2001; Meretsky and others forthcoming). An evaluation of potential sites in Arizona for secondary population establishment was conducted in 1997-98 (Sorensen and Kubly 1997, 1998; AGFD 1998a, 1998b). Through these efforts, additional *Oxyloma* populations have been discovered in Grand Canyon (at IG) (Stevens and others 1997a), Glen Canyon (at -9M) (Sorensen and Kubly 1997), Grand Staircase-Escalante National Monument (Meretsky and North 2000), and south-central Utah (Meretsky 2000a; Meretsky and others forthcoming).

Habitat and Population Monitoring of the KAS Population at VP

The VP population below the 100,000 cfs (2833 cms) stage height has been monitored quarterly since March 1995 (bi-annually starting in 2001), which has provided valuable information regarding KAS ecology and population dynamics. Monitoring efforts at VP include surveying patches of host plant vegetation for overall patch size and snail densities. Surveys included topographically mapping each vegetation patch using total station survey instruments and data recorders to determine patch area. Each patch was haphazardly sub-sampled by researchers using a 20-cm diameter ring and recording vegetation type, height, coverage, percentage live, distance to patch perimeter, duff and litter depth, soil type, soil moisture, and soil depth. In each plot, landsnails were counted and measured (shell length from apex to outside aperture edge). The substrate the snails were observed on was also noted. Snail densities from plots were bootstrapped to estimate the mean density within each patch, and totaled to estimate overall KAS population size at VP (Efron and Tibshirani 1993). Repeated surveys were used to track changes in habitat size and composition through time. The population estimate was coupled to a stage-discharge relationship model (Randle and Pemberton 1988), and used to predict the number of snails and area of habitat (0.1 m resolution) threatened by inundation up to 45,000 cfs (1275 cms) stage height. Stevens and others (1997a) and Meretsky and Wegner (2000) provide further details on the standardized sampling methods for VP KAS. Sorensen (2001) examined habitat relationships to snail densities at VP, and used stepwise logistic regression analysis to determine specific habitat variables that characterize high and low quality habitat. KAS were found in higher numbers during spring surveys on habitat that had >75% live vegetation, <50% absolute cover, and 25-74% saturated duff/litter. Autumn surveys had higher numbers of KAS on habitat with watercress or mixed plant species, >75% live vegetation, and <50 cm plant height.

Experimental KAS Populations at NAU and GCD

In 1996 and 1998, experimental populations of KAS and host plant vegetation from VP were established at NAU and at GCD, respectively. The NAU population was housed in sealed terrariums under optimum growing conditions in a greenhouse. The GCD population was exposed to semi-natural environmental conditions, and was reared in Plexiglas enclosures in the sluiceway at the base of the dam. Both of these experimental populations provided valuable demographic information under controlled and experimental settings. KAS life history traits, population dynamics, and winter dormancy from these captive populations are documented in Nelson (2001). In September 2001, both experimental populations were shut down, and the remaining snails were preserved for future genetic analysis.

Establishment of a Refugium Population at The Phoenix Zoo

In 1997, AGFD partnered with TPZ to establish a refugium population of VP KAS on zoo grounds. In collaboration with the Department of Interior, CUPCA, AGFD initiated the necessary environmental compliance work to collect and transport wild KASs from Grand Canyon National Park to TPZ, and monitor this captive population. Using grant funding from the USBR and logistical support from GCMRC, AGFD collected host plants and KASs for the zoo refugium. Concurrently, TPZ staff designed and constructed a working prototype and 2 permanent enclosures using funds from the zoo's conservation committee. Working together, the interagency cooperators and TPZ have successfully established the first captive population of

KAS with full protection under the ESA. In May 1999, 50 KASs of various size classes were collected from VP and released into the refugium. In April 2000, an additional 50 KASs were collected from VP and added to the refugium in an effort to maintain adequate population size and genetic diversity. AGFD documented successful growth and recruitment of KASs in the refugium between June 1999 and July 2000 (Nelson and Sorensen 2000; Sorensen and Nelson 2001). However, since September 2000, no live KASs have been located in the enclosure, and it is assumed that the population has expired. Reasons for the unsuccessful long-term establishment of this population may include insufficient initial stock size, and prolonged high ambient air temperature coupled with low humidity (Nelson and Sorensen 2000). An area misting system was installed at the KAS refugium in Autumn 2000 to help reduce high ambient air temperatures and increase area humidity.

Establishment of a Second Wild Population in Arizona

In September 1998, AGFD translocated 450 KASs from VP to 3 other sites (150 KASs/site) within Grand Canyon National Park in an attempt to establish a secondary population (Sorensen and Nelson 2000). The selection of all 3 sites ("KeyHole Spring", Upper Elves Chasm, and Lower Deer Creek Spring) and subsequent actions followed appropriate environmental compliance (AGFD1998a, 1998b, USFWS 1998) under the National Environmental Policy Act and AGFD's 12-step reintroduction process for species of concern (Johnson and Glinski 1987). A second full-scale translocation of 450 KASs from VP was conducted in July 1999 to augment the introduced populations at these 3 sites (Sorensen and Nelson 2000). Monitoring of these sites has continued regularly since September 1998, and has included minor augmentation of the secondary populations in 2000 to ensure genetic variability. Currently, only Upper Elves Chasm has shown positive results—successful recruitment, overwinter survival, and increasing density of snails relative to the VP population (Sorensen and Nelson 2000, 2001). This site has approximately 23.5 m^2 of occupied primary habitat within the release area, and more than 25 m^2 of adjacent hanging garden habitat that is increasingly being colonized since April 2000 (Sorensen and Nelson 2001).

Education and Dissemination of Information

Public education and the dissemination of ambersnail information among interested parties has been a continuous process. Journal articles, reports, and technical and educational presentations regarding KAS research, monitoring, and management have been produced by numerous cooperators involved in all aspects of KAS recovery. In 1997, L. Stevens, C. Nelson, and USBR set up a KAS interpretative panel at the GCD visitor catwalk, overlooking the GCD experimental population enclosures. This panel provides information on KAS biology, management and recovery needs, and has been viewed by more than 1 million visitors since 1998 (L. Stevens and C. Nelson, pers. comm..). In 2000, AGFD updated its webpage for VP KAS (www.azgfd.com) under the links to Wildlife and Fish, Nongame Species. With USBR funding, AGFD produced a 4-color educational brochure on KAS for the general public. Copies of these brochures were made available to the NPS, USBR, USFWS, and TPZ for distribution to the general public in 2000. In 2001, the NPS added a laminated copy of the KAS brochure to the information kiosk at Lee's Ferry ramp (J. Sorensen, pers. obs.). With additional funding from the USBR, AGFD has put together a KAS compilation binder of all available reports, journal articles, related

compliance documents, meeting minutes, review panel recommendations, interagency correspondence and comments, and selected photos and illustrations. In 2001, copies of this compilation binder were distributed among the interagency KAWG cooperators.

Review Panel Recommendations and Adaptive Management

Since 1994, research and monitoring efforts have provided managers and scientists with important information regarding KAS. However, uncertainty pertaining to management practices and future conservation needs for KAS still exists. In an effort to resolve some of these issues, an expert panel was convened in December 1999 to review the current body of knowledge surrounding KAS and provide possible recommendations for future research, monitoring and conservation of KASs. Panel members included landscape ecologists, malacologists, geneticists, and population biologists outside of the interagency KAWG. The review panel produced a report of general conclusions and recommendations (Noss and others 1999). Among these recommendations were: 1) conduct additional genetic and morphological studies, 2) conduct additional habitat studies, 3) no additional translocations, 4) encourage artificial "floods" up to historical levels (>45,000 cfs [1275 cms]), 5) use minimally invasive monitoring of VP, 6) no active flood-mitigation necessary for VP population, 7) revise the KAS Recovery Plan once the taxonomic uncertainties are resolved, and 8) widely and promptly disseminate new findings and use peer-review for new management goals and actions. In 2000, the KAWG reviewed the panel's recommendations and concluded with additional concerns, comments, and clarifications (KAWG 2000; Meretsky 2000b; Sorensen and others 2000; USBR 2000; Karas 2001). In July 2001, the KAS Ad Hoc Committee of the Glen Canyon TWG further reviewed these issues and prepared a summary report to the TWG (KAS Ad Hoc 2001) presenting management and conservation recommendations for VP KAS.

CONSERVATION GOALS AND INFORMATION NEEDS

This section provides a narrative of conservation and recovery tasks for *Oxyloma* populations in Arizona and Utah. It is intended to provide direction and justification for future management activities, recovery objectives, and research needs. These tasks were formulated under the following priorities: 1) prevent extinction of local populations, 2) information needs and downlisting actions, and 3) conditions that support delisting.

Task 1: Contribute to ambersnail conservation and recovery efforts, and ensure human-caused activities do not jeopardize ambersnail populations. In the case of VP KAS, federal actions and concerns are well documented and were implemented to maintain a viable population in Grand Canyon National Park. Much effort has gone into the inventory, research, monitoring, and mitigation of dam operations on the VP KASs since 1994 (USWFS 1994, 1996, 1997, 1998b, 2001; Stevens and others 1997a, 1997b; IKAMT 1997; Sorensen and Kubly 1997, 1998; Sorensen and Nelson 2000; Meretsky and Wegner 2000; Meretsky and others 2000). Interagency cooperators should continue to share information, discuss issues, and comment on management decisions at quarterly KAWG meetings. Both the VP and 3L populations of KAS are protected under Section 7 and 9 of the ESA.

State wildlife agencies in Arizona and Utah have recognized KAS as a species of concern, and recently have enacted regulations to prohibit take. In Arizona, Commission Order 42 (Crustaceans and Mollusks) prohibits the collection or take of KASs in Arizona. KAS was also listed as a proposed "Wildlife of Special Concern in Arizona" in October 1996 (AGFD 1996 draft). In Utah, KAS is on the UDWR "Utah Sensitive Species List" as a state endangered species. KAS is also specifically dealt with on the CIT Proclamation (R657: "Collection, Importation, Transportation and Possession of Zoological Animals"). Under section R657-3-22, KAS is classified as "Prohibited" for collection, but section R657-3-27 provides an exception allowing the UDWR to issue permits for the collection or possession of prohibited taxa for such purposes as scientific research. Neither AGFD or UDWR have specific provisions in their hunting and fishing regulations for the protection of ambersnail habitat.

The Navajo Nation Natural Heritage Program (www.abi.org/nhp/us/navajo/index.html) also lists KAS in the Navajo endangered species list under the "Group 4" category—any species or subspecies for which the Navajo Fish and Wildlife Department does not currently have sufficient information to support their being listed in Group 2 (threat of extirpation) or Group 3 (likely to become endangered), but has reason to consider them.

Task 2.1: Assist willing landowners to manage occupied ambersnail habitat occurring on private land. Offer cooperative assistance and conservation recommendations to Best Friends Animal Sanctuary in Kanab Canyon and the 3L site landowner to help maintain *Oxyloma* populations and habitat on their property. If additional populations are discovered on other private lands, conservation recommendations should also be offered to those landowners.

Task 2.2: Develop and review cooperative agreements with willing landowners. Formal agreements and guarantees between willing private landowners and resource agencies would help secure long-term conservation efforts of ambersnail habitats and populations located on private land. For federally listed KAS, private landowners can participate in conservation efforts through Safe Harbor Agreements and Habitat Conservation Plans. For non-listed species, private landowners can participate in State Conservation Agreements, Candidate Conservation Agreements, or Candidate Conservation Agreements with Assurances to help prevent those populations at risk, of concern, or in decline.

Task 3.1: Monitor the VP population bi-annually and determine levels of current and potential threats. Interagency monitoring of VP KASs began in 1995, but sampling methods and seasonal surveys were not refined till 1996. Since that time, VP surveys have been conducted regularly in early Spring (March-April), late Spring (May-June), mid-Summer (July-August), and Autumn (September-October) each year through 2000. Due to budget cuts and recommendations of the KAS Review Panel (Noss and others 1999) and KAWG (2000), VP monitoring surveys have been reduced to only Spring and Autumn starting in 2001. Spring surveys are needed to determine VP KAS survivorship following overwinter dormancy. Based on sample error tests by Sorensen (2001), spring surveys would likely provide the most accurate assessment of population size. Autumn surveys are needed to document successful recruitment and evaluate habitat changes over the Summer, especially any impacts from high flows or plateau flash floods.

Task 3.2 Conduct annual surveys of high vegetation zone habitat (above 100,000 cfs stage height) and snail densities at VP. Only 2 surveys have been conducted on the habitat above 100,000 cfs stage height at VP—a pair of technical climbers conducted the first survey in June 1995 (Stevens and others 1997a) and J. Sorensen conducted the second survey in July 2000. Both surveys were primarily reconnaissance visits to investigate presence and densities of KAS in the hanging garden habitat near the springheads. Quantifying the area of primary habitat and KAS densities in this high zone is essential to determining whether sufficient snails and habitat will continue to exist at VP following historic high river flows (W. Minckley, pers. comm., Sorensen 2001). The 1995 and 2000 surveys found KAS inhabiting monkeyflower and watercress habitat along the VP waterfall, but in both surveys the density of snails relative to the low zone habitat (below 100,000 cfs [2833 cms]) population was much lower. The 1995 survey found high zone KAS densities at 0.03-0.04 snails/m^2, while the low zone KAS densities were 20-160 snails/m^2 (Stevens and others 1997a). The 2000 survey found KAS densities in the high zone at 0.02-.25 snails/m^2. An annual survey of the high zone habitat during the Autumn would allow easier access (due to seasonally reduced spring discharge) and likely reveal higher densities of snails (due to successful recruitment).

Task 3.3: Develop a model for VP habitat and ambersnail population response to high river flows. The KAS Ad Hoc Committee recommended the need to develop a computer model to better estimate Colorado River flow effects to the VP habitat and KAS population. Used in conjunction with ground-truth field surveys and a database of 10 or more years of comparable monitoring data on this population, a computer model on VP habitat and population dynamics will provide a non-invasive tool for resource managers to estimate flow effects on this population. This model should include estimates of long-term population trends, effects of climatic cycles, variances in habitat coverage and quality, ambersnail life history traits, and thresholds for catastrophic disturbances and minimum viable population sizes.

Task 4.1: Develop regional monitoring protocol for southwestern ambersnail populations. To better coordinate survey efforts among interagency cooperators, a standardized monitoring protocol should be developed that is applicable to a wide range of habitats on the Colorado Plateau dependent on available financial and trained personnel resources. Intensive sampling efforts at VP and the translocation sites in Grand Canyon are useful in providing specific information on habitat area, disturbance, recovery, colonization, snail densities, and recruitment. This information is necessary to develop computer models on habitat and population responses to high flows. Less intensive survey efforts at other *Oxyloma* sites in Arizona and Utah can provide rough population estimates, trends, or presence/absence, and document habitat disturbance, loss, or recovery over time.

Task 4.2: Monitor the 3L population bi-annually and determine levels of current and potential threats. Currently, there is no regular monitoring schedule for the 3L population, and only a few surveys have been conducted by independent contractors since 1996 (Meretsky 1998). A bi-annual schedule of monitoring surveys (similar to the VP survey efforts) at this site would help determine population size, trends, and document habitat use and potential loss. Private landowner permission is needed to access this site and to conduct these surveys.

Task 4.3: Monitor translocated KAS populations in Grand Canyon bi-annually. Since October 1998, translocated KAS populations in Grand Canyon have been seasonally monitored using standardized sampling techniques for VP KASs. Due to budget cuts, monitoring surveys have been reduced to only Spring and Autumn starting in 2001. Spring surveys are needed to determine KAS survivorship following overwinter dormancy. Autumn surveys are needed to document successful recruitment and habitat changes over the summer, especially any impacts from plateau flash floods.

Task 4.4: Monitor NAS populations at IG and –9M annually. Since 1996, monitoring surveys of IG and –9M have occurred annually, if not seasonally in some years. Periodic surveys of these populations will help determine annual presence/absence, document habitat disturbance from natural or anthropogenic impacts, and possibly population trends if standardized sampling techniques are used over a consistent timeframe.

Task 4.5: Monitor *Oxyloma* populations in south-central Utah annually. Initial inventories and habitat surveys of numerous *Oxyloma* populations in south-central Utah and along the Virgin River drainage were conducted between 1997 and 2001 (Meretsky and North 2000; Webb and Fridell 2001). Periodic surveys of these populations will help determine annual presence/absence, document habitat disturbance from natural, anthropogenic, or livestock impacts, and possibly population trends if standardized sampling techniques are used over a consistent timeframe.

Task 5.1: Produce annual maps of ambersnail population distribution and status. Annually, a GIS-based map of all known *Oxyloma* populations in Arizona and Utah should be created and disseminated to all cooperators and investigators. These maps would document ambersnail distribution (using Universal Transverse Mercator [UTM] coordinates), provide current status, and indicate level of monitoring efforts over time.

Task 5.2: Conduct surveys of potential ambersnail habitat of the Colorado Plateau; document locations visited, new populations (and estimated size), landownership, habitat area, and potential threats. Since 1995, habitat surveys for KASs and other *Oxyloma* populations have been conducted at more than 150 sites in Arizona (Stevens and others 1997a; Sorensen and Kubly 1997, 1998; unpublished data on Arizona Strip surveys by Stevens and North) and over 200 sites in Utah (Meretsky 2000a; Meretsky and North 2000; Meretsky and others forthcoming; Webb and Fridell 2001). Most of these surveys focused on wetland habitats across the Colorado Plateau and neighboring regions. In 1998-99, Stevens and others (2000) collected ambersnails from numerous localities outside of Arizona and Utah, including: Nevada, Washington, Nebraska, Iowa, Illinois, and Alberta, Canada. Despite these exhaustive efforts, there remain many additional sites and potential habitats that may harbor undocumented *Oxyloma* populations. The KAS Review Panel recommended as a high priority the need to conduct additional habitat surveys of the Colorado Plateau and outside regions for possible ambersnail populations (Noss and others 1999). A list of all sites searched and associated geo-reference information should be compiled and disseminated among investigators to better coordinate future survey efforts.

Task 5.3: Conduct research into livestock grazing thresholds for maintaining suitable ambersnail habitat in south-central Utah. There currently is little data to document the effect of livestock grazing levels and thresholds to sustain viable populations on potential and existing ambersnail habitat (Meretsky 2000a; Meretsky and North 2000; Meretsky and others forthcoming). Meretsky (2000a) reports that livestock grazing reduced carrying capacity of approximately 25% of potential ambersnail habitat in Kanab Canyon, especially to the wet meadows. She further remarks that year-round livestock grazing on these sites is likely detrimental to sustaining long-term populations of ambersnails. Additional experimental research with fenced in control areas, and areas with incremental grazing thresholds (e.g. 25%, 50%, 75%, 100% area use, or seasonal use/resting periods during the Summer) are needed to properly assess livestock impacts to ambersnail habitat and population resilience. These experiments should be conducted over a timeframe of multiple years to document habitat and population recovery rates, recolonization success/failure of extirpated sites by local meta-populations, and to account for climatic conditions (i.e. wet periods or prolonged drought).

Task 6.1: Conduct captive propagation studies to determine if different ambersnail populations interbreed. Currently, different species in the genus *Oxyloma* are distinguished based on differences in reproductive anatomy, and several authors have suggested that KAS deserves specific rank based on the anatomy of its penial complex relative to other species in the genus (Harris and Hubricht 1982; Pilsbry 1948; Spamer and Bogan 1993a). However, recent genetic analyses have indicated that the anatomically based taxonomic designations for species of the genus are not congruent with molecular genetic data obtained through the use of several different techniques (Miller and others 2000). In fact, results suggested that populations of different morphospecies inhabiting the Southwest are more closely related to each other than they are to populations of comparable, morphologically identical *Oxyloma* species from across North America (Stevens and others forthcoming). From a Biological Species Concept perspective, it is critical to understand the degree that differences in reproductive anatomy among morphospecies prevent or diminish the capacity for species of this genus to interbreed. This information can be obtained through the use of a series of breeding experiments, where single individuals from different morphospecies are paired under laboratory conditions to determine if viable offspring can be produced.

Task 6.2: Compare molecular markers in offspring from interbreeding tests, and complete a full identification of molecular markers from a source population as a baseline. All landsnails are hermaphroditic (Tompa 1984), and selfing has been documented in several succineid species (Bayne 1974; Patterson 1970). Prior observations of KASs from VP have shown that individuals are capable of producing viable offspring when isolated (Nelson 2001). As a result, DNA-based molecular analyses will be required to determine if egg masses produced in interspecific breeding experiments are the product of reciprocal gamete exchange of individuals from different species. In addition, the identification of a full set of molecular markers from a source population (any *Oxyloma* population will suffice) is needed to establish a baseline against which more detailed genetic analyses of other morphospecies can be compared.

Task 6.3: Conduct further study of ambersnail genotypes—more robust sample sizes, additional sequence data, and quantify within population variation. The KAS Review Panel recommended this task as another high priority (Noss and others 1999). Additional work is required to better

understand the distribution and relationships of *Oxyloma* populations in North America. The previous study by Stevens and others (2000) was based on only a 350 bp region of the mitochondrial cytochrome B gene, and relatively few individuals from the populations surveyed were included in analyses. Although this study resolved evolutionary relationships among many populations of *Oxyloma* in the Southwest, relationships for many others could not be completely resolved due to the limited sampling of both genes and individuals. Therefore, the molecular analyses of additional genes, specimens, and populations will provide important information regarding the distribution of genetic variation among morphospecies and populations within the genus. Further, such studies may identify other *Oxyloma* populations from the American Southwest that are closely related to either of the 2 protected, genetically different, KAS populations.

Task 6.4: Conduct additional morphological studies paired with the molecular analyses to provide a better understanding of variation of within population characteristics or plasticity. An expanded examination of ambersnail morphology that emphasizes within population variation is also needed to help resolve the legal status of KAS. Both typological and morphometric approaches may be needed to quantify population plasticity. More robust sample sizes of mature specimens from each locality are required for this task (S. Wu and M. Miller, pers. comm.). At least 2 or more mollusk taxonomists familiar with Succineid snail identification should be used to provide separate (blind test) opinions on anatomical and shell morphology identifications. Unfortunately, this effort will be very time consuming and costly. These findings will need to be paired with the above mentioned molecular analyses to help determine the taxonomic identity each population.

Task 6.5: Summarize and publish findings from new genetic and morphological studies; disseminate study results to all interested parties. It is imperative that results and insights from new genetic and morphological studies be summarized succinctly and published in a peer-reviewed journal. These findings should also be disseminated to all interested parties to facilitate communication and coordination of conservation efforts.

Task 7.1: Define a conservation strategy for the VP and translocated populations. Efforts are underway to define management goals for VP and translocated KASs by the KAWG and KAS Ad Hoc Committee. These groups are working to adopt and incorporate recommendations into the draft Grand Canyon Adaptive Management Program Strategic Plan (KAS Ad Hoc 2001).

Task 7.2: Define a conservation strategy for the 3L population. Currently there are no formal land management plans or dedicated conservation efforts for the 3L population. The 3L site is still under private ownership, and is subject to potential habitat loss due to planned commercial development, occasional flash flooding, and future livestock grazing.

Task 7.3: Develop a State Conservation Agreement for non-listed *Oxyloma* populations in Arizona (IG and –9M). Currently there are no formal land management plans for the IG and –9M populations of NAS in Arizona. The IG and –9M sites are under the jurisdiction of NPS in Grand Canyon National Park and Glen Canyon National Recreation Area, respectively. Both sites are subject to potential habitat loss due to natural and anthropogenic impacts.

Task 7.4: Develop a State Conservation Agreement for non-listed *Oxyloma* populations in Utah. Currently there are no formal land management plans or funded conservation efforts for non-listed *Oxyloma* populations in Utah. Many of these populations are located on various state, federal, and private lands, and may subject to potential habitat loss due to commercial development, livestock grazing, de-watering, and/or flash flooding.

Task 8: Define establishment success and failure criteria for translocated KAS populations. In 1998, the USFWS and NPS proposed a step-down criteria for defining establishment success and failure for translocated KAS populations in Grand Canyon National Park. Both the KAWG and KAS Review Panel have commented on this criteria and provided minor revisions. While not finalized, the following step-down criteria has generally been accepted by the KAWG and remains current for the evaluation of KAS establishment success or failure.

Step 1 - Evaluate overwintering success:
- At least 30% of translocated individuals survive and emerge from winter dormancy (or percent is similar to VP population); proceed to step 2.
- Less than 30% of translocated individuals survive (or significantly different from VP population); proceed to step 3.

Step 2 - Evaluate reproduction potential and success:
- Evidence of egg masses and population size class shifts in late summer (2 to 5 mm in length); requires population estimates by quantitative methods; proceed to step 3.
- Little or no evidence of egg masses; few or no young snails; proceed to step 3.

Step 3 - Evaluate habitat suitability and feasibility of population augmentation:
- If necessary, augment population with small numbers to ensure genetic variability; proceed to step 4.
- Attempt a second large-scale introduction; proceed to step 4.

Step 4 - Evaluate recruitment and overwintering potential:
- Young snails persist and are high in numbers before October; proceed to step 5.
- Few snails persist in October; proceed to step 6.

Step 5 - Population status remains stable for a designated period of time (perhaps 3 years or more).

Step 6 - Reassess long-term suitability of introduction effort. This represents 2 failed attempts.

Establishment of translocated KAS populations in Grand Canyon would be considered successful when: 1) population densities, fecundity, and recruitment are similar to those of the parent population at VP; 2) habitat remains suitable while accommodating environmental uncertainties including changes in weather, food supply, predators, and other factors; and 3) the trend of population growth must be positive or at equilibrium with the available habitat for a certain period of time, perhaps 3 years (USFWS 1998a). The KAS Review Panel suggested that 10-30 years (generations) might be required to determine translocation success (Noss and others 1999).

Task 9: Disseminate available ambersnail information to interested parties—compile and distribute compilation binders of existing reports, memos, meeting minutes, and published articles; hold regular KAWG meetings to share info and discuss issues. In Autumn 2001, AGFD provided copies of a 3-ring binder that contained a compilation of KAS information to interested parties in the KAWG. This product was funded by the USBR in support of the KAS Review Panel's recommendation to widely disseminate current and new information to all interagency cooperators. This compilation provides a useful reference for resource managers in formulating conservation goals, planning future research, and implementing management plans.

Task 10: Refine downlisting and delisting criteria for listed ambersnail populations in Arizona and Utah. The 1995 KAS Recovery Plan assigned provisional criteria of maintaining 10 separate and robust populations of KAS with long-term, protected habitat before the subspecies could be considered for downlisting (USFWS 1995). The KAS Review Panel argued that the arbitrary number of populations proposed in the KAS Recovery Plan was not based on scientific data, and recommended that new criteria be developed based on new information on population distributions and revised taxonomic designations (Noss and others 1999). Currently, there are no delisting criteria proposed for KAS. Interagency cooperators and the USFWS should begin identifying a range of delisting criteria for KAS now—providing various options depending on the results of additional population distribution and taxonomic studies. If the ambersnails at VP are determined to be a unique taxon, then downlisting or delisting criteria may not be identified (D. Bills, pers. comm.).

Task 11: Implement conservation measures to maintain vulnerable non-listed ambersnail populations in Arizona and Utah. No formal conservation measures currently exist for the IG and –9M NAS populations in Arizona. Inventory and monitoring efforts on these populations have been conducted at least bi-annually by AGFD, NPS, and interagency cooperators/contractors since 1996 (Stevens and others 1997a; Sorensen and Nelson 2001). Since both Arizona NAS populations exist on lands administered by NPS, they receive modest protection from unauthorized collection and take. However, there is a need to formalize NPS management plans to better secure occupied NAS habitat at IG and –9M from natural and anthropogenic impacts. NAS habitat at IG borders a high use campground, a main corridor trail, and pack animal corrals, and at times is subject to flash flooding, visitor intrusion, trail maintenance, and use-area renovation (L. Stevens pers. comm.). Interagency cooperators/contractors have talked with NPS maintenance crews about protecting IG NAS habitat (L. Stevens pers. comm.), but no formal management plans to protect this population are in place.

UDWR does not have any specific management plans, active research plans, or recovery efforts for any mollusks, including KAS (G. Oliver, pers. comm.). Specifically, UDWR's Aquatics Section has the responsibility for managing mollusks. A 231-page UDWR report on mollusks of conservational concern in Utah (www.utahcdc.usu.edu/ucdc/ViewReports/mollrpt.htm) was written by G. Oliver. Habitat surveys in Utah by BLM and UDWR biologists and interagency cooperators/contractors have been in progress since 1998 (Meretsky 2000a; Meretsky and North 2000; Meretsky and others forthcoming; Webb and Fridell 2001). With the creation of the Grand Staircase-Escalante National Monument in Utah, BLM has begun fencing off fragile spring and seep habitats to livestock grazing (Meretsky and North 2000). These efforts should help restore

overgrazed wetland habitats, and may provide potential expansion sites for local metapopulations of ambersnails.

Task 12.1: Conduct additional captive propagation studies to further life history information needs (recruitment, growth, survival, mortality) needed for population viability analyses and/or models to estimate population response to habitat loss. Nelson (2001) investigated the life history of VP KAS under experimental conditions, and documented valuable demographic data for this population. Additional studies are needed to determine if other *Oxyloma* spp. differ demographically on other habitat types such as cattails, sedges, and rushes. While the utility of performing population viability analyses on a r-selected species with less than 10 years of census data is not likely to be useful at this time, further advances in modeling techniques and more complete demographic data may eventually yield more accurate estimates of population persistence and responses to environmental change. Experimental captive populations of ambersnails allow researchers and resource managers to manipulate environmental conditions, habitat quality, and founding stocks to better understand a test population's response to impacts, without further endangering wild populations.

Task 12.2: Conduct additional tests of sampling methods and associated observation and extrapolation error with wild and captive ambersnail populations under controlled settings. Sorensen (2001) investigated observation and extrapolation error in standardized sampling methods used at VP. A comparison of subsampling and total census efforts was conducted on watercress habitat at VP, but was not conducted on monkeyflower or mixed vegetation habitats. In both tests, subsampling proved to overestimate snail densities in the Summer (by 473%) and Autumn (by 489%) at VP (Sorensen 2001). A similar test was conducted on the refugium population of KASs at TPZ containing mixed habitat. Subsampling also overestimated snail densities by 223% in TPZ's KAS refugium (Sorensen 2001). A review of previous VP monitoring data showed cases of inadequate sampling effort of large, highly variable vegetation patches (Sorensen 2001). Inadequate sampling effort and invalid assumptions of snail distribution and density can increase the potential for extrapolation error on total population estimates (Sorensen 2001). To illustrate this point, he used Spring-to-Spring transitions of VP population estimates in a time series diffusion approximation to assess population quasi-extinction (i.e. a population size threshold where a population is unable to recover sufficiently to avoid extinction). In this analysis, when the contribution of a large, under-sampled patch of KAS habitat to total population size was reduced in half, the probability of attaining various extinction thresholds increased, and the mean time to reach those thresholds decreased. Further tests of observation and extrapolation error will help improve KAS population estimates by quantifying associated errors due to sampling and data analysis. In addition, future monitoring efforts can be improved by identifying historic trends and variability in snail densities per habitat type, and therefore enable researchers to concentrate their sampling efforts in areas with greater variation in snail numbers. The KAS refugium at TPZ could provide an ideal controlled setting for observational studies under semi-natural environmental conditions and mixed habitat.

Task 13: Promote public outreach and environmental education on ambersnail conservation and ecosystem management. Continued public outreach and environment education will benefit the various species and habitats of concern. Each agency and investigator should make reasonable efforts to provide public outreach and environmental education as appropriate—through

professional presentations, classroom talks, published articles, peer-reviewed manuscripts, media stories and interviews, wildlife documentaries, Internet websites, and educational brochures and photos.

Task 14: Provide training in ambersnail identification and survey, environmental compliance, and population genetics to participating cooperators. As suggested and endorsed by various KAWG participants, the need for specific training opportunities in ambersnail identification, survey techniques, environmental compliance, and population genetics would be useful for interagency cooperators. These training sessions (estimated 1-2 hrs each) could be conducted during quarterly KAWG meetings by invited outside experts and/or qualified KAWG members. These training opportunities would help increase cooperator communication, coordination, and knowledge base.

Task 15: Create and maintain a centralized database of ambersnail research and monitoring data, accessible to all interested parties. In 2001, AGFD began designing a centralized database of available ambersnail monitoring and research data. It is anticipated that this database will provide easier access for all cooperators and contractors to shared information. A centralized database will also serve as a more effective archive of raw and meta-data that can be used for various data analyses and reference for developing management plans. GCMRC's data archives are accessible through their website; this location would be a convenient repository for the ambersnail database.

Task 16: Conduct additional surveys of potential ambersnail habitat outside of the Colorado Plateau. As recommended by the KAS Review Panel (Noss and others 1999), additional habitat surveys outside the Colorado Plateau are needed to verify potential ambersnail habitat or undocumented populations. These surveys will help complete species inventories across many regions and determine the full extent of rare succineids in North America. It is suggested that priority be given to areas immediately adjacent to the Colorado Plateau, dependent on available funding and trained personnel.

Task 17.1: Acquire habitat on private land for ambersnail conservation; establish National Wildlife Refuges, state wildlife areas or parks, TNC nature preserves, conservation easements, or other permanently protected lands. Acquisition of private land for ambersnail conservation will help reduce conflicts of interest between private landowners and state and federal agencies. Subsequent designation of these newly purchased areas as National Wildlife Refuges, state wildlife areas or parks, TNC nature preserves, conservation easements, or other permanently protected lands will ensure long-term conservation for those ambersnail populations. However, acquisition will only be considered if private landowners are willing to sell those areas where ambersnail populations occur.

Task 17.2: Secure surface and sub-surface water rights on acquired lands for ambersnail habitat. Certified rights to ground and surface waters are necessary to maintain ambersnail habitat on acquired lands. Acquisition will only be considered if private landowners are willing to sell the associated water rights and property where ambersnail populations occur.

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IMPLEMENTATION SCHEDULE

The implementation schedule provided in this section outlines specific actions, estimated duration and annual costs, and proposed responsible parties for the conservation of Arizona and Utah ambersnail populations. Since completion of these tasks is dependent on available funding and personnel, the activities and responsibilities listed in this schedule are not legally or financially binding to any cooperator, beyond the scope of their pre-existing statutory requirements and authorities. The task numbers correspond to the individual activities described in the Conservation Goals and Information Needs section. Each task was assigned a priority based on recommendations from the KAS Review Panel (Noss and others 1999), consensus decisions among interagency cooperators (Karas 2001; KAS Ad Hoc 2001 draft), and the priorities list developed by the USFWS in the 1995 Kanab ambersnail Recovery Plan (USFWS 1995).

Key to acronyms used in the implementation schedule:

AGFD = Arizona Game and Fish Department
BLM = Bureau of Land Management
CUPCA = Central Utah Project Completion Act Office
FWS = U.S. Fish and Wildlife Service
GCMRC = Grand Canyon Monitoring and Research Center
KAWG = Kanab Ambersnail Working Group
NPS = National Park Service
UDOT = Utah Department of Transportation
UDWR = Utah Department of Wildlife Resources
USBR = U.S. Bureau of Reclamation
USFS = U.S. Forest Service
TNC = The Nature Conservancy
TPZ = The Phoenix Zoo
Tribal = Tribal nations of the Colorado Plateau
WAPA = Western Area Power Administration
Indep = Independent contractors or organizations

SOUTHWESTERN AMBERSNAIL CONSERVATION AND RECOVERY IMPLEMENTATION SCHEDULE

Priority	Task	Task Description	Task Duration	Proposed Responsible Parties	Estimated Annual Cost
1	1	Contribute to ambersnail conservation and recovery efforts, and ensure human-caused activities do not jeopardize ambersnail populations.	Ongoing	AGFD, BLM, CUPCA, FWS, GCMRC, NPS, TNC, UDOT, UDWR, USBR, WAPA	Variable costs
1	2.1	Assist willing landowners to manage occupied ambersnail habitat occurring on private land	Ongoing	BLM, FWS, TNC, UDOT, UDWR, USFS	Variable costs
1	2.2	Develop and review cooperative agreements with willing landowners.	5-6 years	BLM, FWS, UDWR	Variable costs
1	3.1	Monitor the VP population bi-annually and determine levels of current and potential threats.	Ongoing	AGFD, GCMRC, USBR, Indep	$12,000
1	3.2	Conduct annual surveys of high vegetation zone habitat (above 100,000 cfs stage height) and snail densities.	Ongoing	AGFD, GCMRC, USBR, Indep	$2000
1	3.3	Develop a model for VP habitat and ambersnail population response to high river flows.	1-2 years	AGFD, GCMRC, USBR, WAPA, Indep	$40,000
1	4.1	Develop regional monitoring protocol for southwestern ambersnail populations.	Ongoing	AGFD,BLM, FWS, UDWR, Indep	$12,000
1	4.2	Monitor the 3L population bi-annually and determine levels of current and potential threats.	Ongoing	BLM, TNC, UDWR, Indep	$25,000
1	4.3	Monitor translocated KAS populations in Grand Canyon bi-annually.	Ongoing	AGFD, CUPCA, GCMRC, FWS, NPS, USBR, Indep	$40,000
1	4.4	Monitor NAS populations at IG and –9M annually.	Ongoing	AGFD, CUPCA, NPS, USBR, Indep	$5000
1	4.5	Monitor *Oxyloma* populations in south-central Utah annually.	Ongoing	BLM, TNC, Tribal, UDOT, UDWR, USFS, Indep	$15,000
1	5.1	Produce annual maps of ambersnail population distribution and status.	Ongoing	AGFD, BLM, FWS, GCMRC, UDWR, USBR, USFS, Indep	$3000
1	5.2	Conduct surveys of potential ambersnail habitat of the Colorado Plateau; document locations visited, new populations (and estimated size), landownership, habitat area, and potential threats.	2-3 years	AGFD, BLM, CUPCA, FWS, NPS, TNC, Tribal, UDWR, USBR, USFS, WAPA, Indep	$50,000
1	5.3	Conduct research into livestock grazing thresholds for maintaining suitable ambersnail habitat in south-central Utah.	2-3 years	BLM, TNC, UDWR, Indep	$40,000
1	6.1	Conduct captive propagation studies to determine if different ambersnail populations interbreed.	2 years	Indep, AGFD, GCMRC, TPZ, USBR, WAPA	$50,000
1	6.2	Compare molecular markers in offspring from interbreeding tests, and complete a full identification of molecular markers from a source population as a baseline.	2 years	Indep, GCMRC, CUPCA, USBR, WAPA	$75,000
1	6.3	Conduct further studies of ambersnail phenology—more robust sample sizes, additional sequence data, and quantify within population variation.	3-4 years	Indep, GCMRC, USBR, WAPA	$75,000

Priority	Task	Task Description	Task Duration	Proposed Responsible Parties	Estimated Annual Cost
1	6.4	Conduct additional morphological studies paired with the molecular analyses will provide a better understanding of variation of within population characteristics or plasticity.	3-4 years	Indep, GCMRC, USBR, WAPA	$100,000
1	6.5	Summarize and publish findings from new genetic and morphological studies; disseminate study results to all interested parties.	1-2 years	Indep, AGFD, GCMRC, USBR, WAPA	$40,000
1	7.1	Define a conservation strategy for the VP and translocated populations.	1-2 years	AGFD, FWS, KAWG	$5000
1	7.2	Define a conservation strategy for the 3L population.	1-2 years	UDWR, FWS, KAWG	$5000
1	7.3	Develop a State Conservation Agreement for non-listed *Oxyloma* populations in Arizona (IG and –9M).	2-3 years	AGFD, KAWG	$15,000
1	7.4	Develop a State Conservation Agreement for non-listed *Oxyloma* populations in Utah.	2-3 years	UDWR, KAWG	$15,000
1	8	Define establishment success and failure criteria for translocated KAS populations.	1 year	AGFD, FWS, KAWG	$5000
2	9	Disseminate available ambersnail information to interested parties—compile and distribute compilation binders of existing reports, memos, meeting minutes, and published articles; hold regular KAWG meetings to share info and discuss issues.	Ongoing	AGFD, BLM, FWS, GCMRC, KAWG, NPS, UDWR, USBR, Indep	$7000
2	10	Refine downlisting and delisting criteria for listed ambersnail populations in Arizona and Utah.	1-2 years	AGFD, FWS, KAWG, UDWR	$15,000
2	11	Implement conservation measures to maintain vulnerable non-listed ambersnail populations in Arizona and Utah.	3-4 years	AGFD, BLM, FWS, NPS, TNC, UDWR, USFS, Indep	Variable Costs
2	12.1	Conduct additional captive propagation studies to further life history information needs (recruitment, growth, survival, mortality) needed for population viability analyses and/or models to estimate population response to habitat loss.	3-4 years	AGFD, CUPCA, GCMRC, TPZ, USBR, WAPA, Indep	$30,000
2	12.2	Conduct additional tests of sampling methods and associated observation and extrapolation error with wild and captive ambersnail populations under controlled settings.	2-3 years	AGFD, CUPCA, GCMRC, TPZ, USBR, WAPA, Indep	$15,000
3	13	Promote public outreach and environmental education on ambersnail conservation and ecosystem management.	Ongoing	AGFD, BLM, CUPCA, FWS, NPS, TNC, UDWR, USBR, Indep	$5000
3	14	Provide training in ambersnail identification and survey, environmental compliance, and population genetics to participating cooperators.	Ongoing	AGFD, FWS, KAWG, NPS, UDWR, Indep	$5000
3	15	Create and maintain a centralized database of ambersnail research and monitoring data, accessible to all interested parties.	1-2 years	AGFD, GCMRC, USBR, Indep	$10,000
3	16	Conduct additional surveys of potential ambersnail habitat outside of the Colorado Plateau.	2-3 years	AGFD, BLM, CUPCA, FWS, NPS, TNC, Tribal, UDWR, USBR, USFS, WAPA, Indep	$50,000

Priority	Task	Task Description	Task Duration	Proposed Responsible Parties	Estimated Annual Cost
3	17.1	Acquire habitat on private land for ambersnail conservation; establish National Wildlife Refuges, state wildlife areas or parks, TNC nature preserves, conservation easements, or other permanently protected lands.	5-6 years	BLM, FWS, TNC, UDWR, Indep	Variable Costs
3	17.2	Secure surface and sub-surface water rights on acquired lands for ambersnail habitat.	5-6 years	BLM, FWS, TNC, UDWR, Indep	Variable Costs

POTENTIAL FUNDING SOURCES

This section identifies several federal, state, and private programs offering potential funding (with specific eligibility requirements) that may be applicable for implementation of conservation goals and information needs for Southwestern ambersnails. This is not an exhaustive list, but provides some guidance to researchers, resource managers, institutions, and landowners in pursuing funds for work outlined in this plan.

Grand Canyon Monitoring and Research Center Grants

GCMRC provides annual funds for various research and monitoring projects that contribute to resource protection, management, and information needs for threatened and endangered species along the Colorado River in Glen and Grand Canyon. Contact: GCMRC, 2255 North Gemini Drive, Room 341, Flagstaff, Arizona 86001-1637. Phone: 928-556-7363.

U.S. Bureau of Reclamation Grants

The Upper Colorado Region office provides annual funds for specific research and monitoring projects that further Biological Opinion objectives on the operation of Glen Canyon Dam and contribute to resource protection, management, and information needs for threatened and endangered species in Glen and Grand Canyon. Contact: USBR, UC-320, 125 South State Street, Room 6107, Salt Lake City, Utah 84138-1102. Phone: 801-524-3734.

Central Utah Project Completion Act Office Cooperative Agreements

The U.S. Department of the Interior, CUPCA Office provides annual funds for specific research and monitoring projects that contribute to resource protection, management, and information needs for threatened and endangered species in areas outside of Utah that are associated with the Colorado River Storage Compact (notably Glen and Grand Canyon). Contact: CUPCA, 302 East 1860 South, Provo, Utah 84606-7317. Phone: 801-379-1254.

Western Area Power Administration Grants

In specific cases, WAPA provides funds for research and monitoring projects that further Biological Opinion objectives on the operation of Glen Canyon Dam and contribute to resource protection, management, and information needs for threatened and endangered species in Glen

and Grand Canyon. Contact: WAPA, P.O. Box 281213, 12155 West Alameda Avenue, Lakewood, Colorado, 80228-1213. Phone: 720-962-7259.

U.S. Fish and Wildlife Service ESA Section 6 Funds

Under Section 6 of the ESA, USFWS provides annual funds to state wildlife agencies to implement recovery actions, survey and monitor sensitive species, candidate assessment, and other related activities. In Arizona, contact: Branch Chief, Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, 2221 W. Greenway Rd., Phoenix, Arizona 85023-4399. Phone: 602-789-3500. In Utah, contact: Utah Division of Wildlife Resources, 1594 W. North Temple, Ste 2110, P.O. Box 146301, Salt Lake City, Utah, 84114-6301. Phone: 801-538-4700.

U.S. Fish and Wildlife Service Partners for Fish and Wildlife Funds

USFWS provides technical and financial assistance to willing private landowners who want to improve fish and wildlife habitat on their property. This program is open to private individuals, tribes, counties, and state agencies. In Arizona, contact: USFWS-AESO, 2321 West Royal Palm Road, Suite 103, Phoenix, Arizona 85021-4951. Phone: 602-242-0210. In Utah, contact: USFWS-UESO, 145 East 1300 South, Suite 404, Salt Lake City, Utah 84115. Phone: 801-524-5001.

Bureau of Land Management Grants

In specific cases, BLM provides funds for research and monitoring projects that contribute to resource protection, management, and information needs for threatened and endangered species on BLM-administered lands in northern Arizona and southern Utah. Contact: BLM, 345 East Riverside Drive, St. George, Utah 84770. Phone: 435-688-3239.

National Park Service, Grand Canyon National Park Small Grant Research Fund

As available, the Grand Canyon National Park Research Office provides funds (up to $5000) to support interagency agreements and cooperative research between the NPS and non-NPS researchers to help defray costs associated with working in those areas of Grand Canyon that are managed as wilderness. Long-term and continuing projects are not eligible. Contact: Grand Canyon National Park, Science Center, Research Office, 823 North San Francisco Street, Suite B, Flagstaff, Arizona 86001. Phone: 928-226-0163.

Bring Back the Natives Initiative

This initiative is a cooperative venture among the USFS, BLM, and National Fish and Wildlife Foundation to restore health of riverine and aquatic systems and their native species. Cost-share funding for ambersnail conservation efforts may qualify under the "Every Species Counts" Program—to assist in the conservation of sensitive flora and fauna. Contact: National Fish and Wildlife Foundation, 1120 Connecticut Avenue Northwest, Suite 900, Washington D.C. 20036. Phone: 202-857-0162.

Arizona Game and Fish Department, Heritage Funds

Through the Arizona Heritage Fund (state lottery revenues), AGFD provides funds for inventory, identification, protection, and management of sensitive species in Arizona. Contact: Heritage Fund Grant Coordinator, Director's Office-Funds Planning, AGFD, 2221 West Greenway Road, Phoenix, Arizona 85023-4399. Phone: 602-789-3530.

Arizona Department of Water Resources, Arizona Water Protection Fund

The Arizona Department of Water Resources provides annual funds to protect water of sufficient quality and quantity to maintain, enhance, and restore rivers and associated riparian habitats, including fish and wildlife dependent on those habitats. Contact: Arizona Department of Water Resources, 500 North Third Street, Phoenix, Arizona 85004. Phone: 602-417-2460.

North American Wetlands Conservation Act Grants

While primarily designed to implement the North American Waterfowl Management Plan, this fund may have some application for conservation of Southwestern ambersnails in certain locations. Grants may be used to enhance or restore habitats on federal, state, or private lands. A 1:1 non-federal match is required. Contact: North American Wetlands Conservation Council, USFWS, 4401 North Fairfax Drive, Room 110, Arlington, Virginia 22203. Phone: 703-358-1784.

National Fish and Wildlife Foundation Challenge Grants

The National Fish and Wildlife Foundation provides cost-share funds for habitat protection and restoration, species conservation and applied conservation, applied research and policy development, education, and training for natural resource professionals. A 1:1 non-federal match in the form of funds, contributed goods and service, or lands is required. Contact: National Fish and Wildlife Foundation, 1120 Connecticut Avenue Northwest, Suite 900, Washington D.C. 20036. Phone: 202-857-0162.

Grand Canyon Association Annual Grants Program

The Grand Canyon Association (a private, non-profit organization) provides annual funds to Grand Canyon research projects not funded through federal appropriations. Contact: Grand Canyon Association, Annual Grants Program, P.O. Box 399, Grand Canyon, Arizona 86023. Phone: 928-638-2481.

National Science Foundation Research Grants

The National Science Foundation provides grants, contracts, and cooperative agreements for biological research projects through academic institutions and non-profit research organizations. All proposals must be submitted through their website: www.fastlane.nsf.gov Contact: National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230. Phone: 703-292-5111.

APPENDIX A. COMMENTS RECEIVED ON THE AUGUST 2001 DRAFT

Date: September 20, 2001
From: G. Burton, WAPA
To: Jeff Sorensen, AZGF
Subject: Comments on Draft Interim Ambersnail Conservation Plan

Jeff,

Great job! I don't have much to add and some of my comments are probably not within the KAWG's ability to address. Also, I apologize for not getting these comments to you sooner.

My first general question is who funds and implements this plan? Under what circumstances are use of power revenues appropriate?

The document needs to make clear up front that the VP ambersnail is a unique and different organism. Perhaps a quick rundown of its individuality right after the fourth sentence of the **Introduction**. From then on it could be referred to as "the VP ambersnail" or some other unique moniker throughout the rest of the document to separate it from other KAS or *Oxyloma*.

Along with the thought above, a table summarizing the status of the various populations in the various locations would help. This might be placed under **A. Distribution**. I think Dennis Kubly will make a similar comment since it was his observation.

Editorial Comments:

In **Task 6** in the **Executive Summary** and pages 15 and 16, add "Conduct" to the front of the second two statements to make them active sentences.

In the list of priorities (1-3) under **III. Conservation Goals and Information Needs** at the top of page 13, the first priority "prevent extinction of..." needs to be expanded by adding "immediate actions and information needs to prevent extinction of...." In the **Implementation Schedule,** page 21, there are tasks listed (e.g. 6.1, 6.2, 6.3) that are listed as priority 1, but are information needs not actions that will prevent extinction.

In **Task 3.2** on page 14, last sentence, add "reveal" or a similar word to "and likely reveal higher densities...."

In **Task 8**, Step 3 on page 17, delete the second "of" in the sentence.

From: Norm_Henderson@nps.gov
Sent: Tuesday, October 16, 2001 9:16 AM
To: jsorensen@gf.state.az.us
Subject: Comments on KAS interim conservation plan

Please disregard the last email. I included some preliminary comments that were not appropriate to your most recent draft.

Jeff -

Good job putting this plan together and thanks for organizing the meeting here in Page. I thought it went very well.

Here are my comments on the plan and our discussions on 9/26/01:

1. The scope of the plan is a little confusing. The term ambersnail, Kanab ambersnail, Oxyloma species, Succineids etc. are all discussed in the plan to the point that the focus of the plan is not clear. I recommend that the plan be clearly focused toward the KAS since it is the endangered species. The other ancillary species and morphs should be brought into the plan only with regards to the KAS. This point is especially important since it seems that succineids in general and Oxyloma specifically are very common within North Ameraica. Why would we need or desire a plan to conserve a family or genera that is so wide-spread?

2. The expert panel recommendations and and all the response comments should not be included in the plan. I recommend that the plan mention (and reference) that a panel was convened, highlight the central recommendations, and maybe indicate that there was some disagreement within the KAWG (and other stakeholders) about their applicability. Including all the comments is distracts from the main focus of your plan.

3. If you do include all the comments, you must include the KAWG review of the expert panel report (Karas, 2001). The KAWG response to the expert panel report were the only comments not included in the document.

4. Clearly AGFD wrote the plan but it is not clear who is responsible for its implementation.

5. I thought the discussion in Page about Oxyloma sp. taxonomy was very interesting and should be highlighted in the plan. Especially the concept that even if the taxonomy/genetics of the snail were more clearly described, we may

be faced with a multitude of distinct species within isolated habitats. This seems to downplay the urgent need to get the taxonomy worked out.

6. I question the need for long-term monitoring the size of the VP population. Large variation in population size between years is common for these snails. So much so that it would seem impossible to tease out the effects of dam ops from this natural variation. What would seem best is that sufficient habitat be preserved for the species, and that no actions be taken to signficantly alter or threaten that habitat. Further, why is biennial monitoring proposed if population size is important? It seems that one time a year woud give you adequate information to make this estimate.

7. It would seem that surveys relatively close and upstream of the VP population are warranted. Since the argument is that the VP population potentially came from upstream sources, it would be very important to determine if any of these sources still exist. Specifically, the upper canyons of Lake Powell should be looked at.

Any questions, give me a call.

nrh

From: Lisa_Church@ut.blm.gov
Sent: Wednesday, September 05, 2001 2:28 PM
To: Jeff Sorensen
Subject: KAWG meeting on Sept 26 at Glen Canyon Natl Rec Area office in Page, AZ

Some of the concerns I had , focused on the need for agencies , ie the feds here, we still graze livestock in suitable habitats, I know it may be a research question , but how much is to much and how much should be allowed, were running into that question right now, with Vicki's last report she said grazing in Kanab Canyon by livestock reduced suitable habitat for snails by 25% and I have range cons fighting that ....so It will be good to have a conservation plan with some guidance in those types of situations, potentially suitable, suitable, occupied vs unoccupied etc...
Maybe we can look at it on the 26th...thanks...but the plan looks great...Lisa

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Draft Interim Conservation Plan
for Ambersnails of the
Southwestern United States

Review Comments
by
Bureau of Reclamation
Upper Colorado Region Office
Salt Lake City, Utah
October 12, 2001

1. Title Page: The title of this document probably should be expanded to illustrate our emphasis on management of Kanab ambersnail (the Vasey's Paradise taxon) and other related ambersnails in the Grand Canyon region.

2. Title Page, Authors: We would prefer to see the authors of this document identified, rather than an agency or work group. This attribution gives appropriate credit and identifies parties who have intimate knowledge of the document if contacted for information in the future.

3. The Executive Summary does not appear to provide the most up-to-date information on the confused identity of the Vasey's Paradise ambersnail, or of conflicts with provisions in the recovery plan and biological opinions on operation of Glen Canyon Dam that have resulted from that confusion.

4. Page 1, INTRODUCTION, 1: It would be helpful to the reader to identify changes in understanding of the taxonomy and distribution of Kanab ambersnail very early in this section, and to contrast our present understanding with that at the time of listing and issuance of the recovery plan. For example, the second sentence could begin with "At the times of listing and release of the recovery plan, Fish and Wildlife Service believed that there were two populations of Kanab ambersnail. One was located at....." A second paragraph could then be used to briefly describe recent changes in our knowledge of the Vasey's Paradise snail and other related succineids.

5. Page 1, INTRODUCTION, 2: Other than the identities of the authors, this information would more appropriately go in an ACKNOWLEDGMENTS section. Nelson and Sorensen should be identified as authors on the title page.

6. Page 1, BACKGROUND, DISTRIBUTION, 1: Suggest beginning the sentence with "The Succineidae is a morphologically diverse family..." Suggest the following sentence, at top of page 2, begin with "Although succineids are terrestrial..."

7. Page 2, second full paragraph, last sentence: Fifth line, change ending to "...since Ferriss did not report..." We understand that Stevens and others already have submitted a draft manuscript to the Grand Canyon Monitoring and Research Center. Has it been finalized?

8. Page 2, last paragraph: Should the citation of "Meretsky and others forthcoming" be "in press," rather than "forthcoming?" Or are you using forthcoming as a replacement for in press? If so, the citations in Literature Cited probably should be in the format: So and So. Forthcoming. I saw a snail reproduce. Peeping Toms Journal.

9. Page 3, HABITAT, 1: In the first sentence, is Oxyloma a singular or plural noun? Sentence 5: Suggest replacing "dead and decaying plant litter of monkeyflower" with "dead and decaying monkeyflower litter." Suggest changing penultimate sentence by removing "in 1963" from end of the sentence and inserting it between "was installed" and "and began moderating." A figure of annual maximum discharge measured at the Lees Ferry gage for the period of record would be helpful.

10. Page 3, HABITAT, 2: In the third sentence "a large cottonwood canopy with an understory of ....Fremont cottonwood..." is identified. Is all the cottonwood Fremont cottonwood? In the next sentence "spring fed" should be "spring-fed."

11. Page 3, DESCRIPTION OF REGIONAL TAXONS, 1: The plural of taxon is taxa. The first sentence states that snail taxonomy traditionally has been based on shell morphology. Is this true at the species level? In sentence 2, suggest beginning the sentence with "Therefore, identifying members of this genus," which allows deleting the dangling prepositional phrase "for identification" from the end of the sentence, and replacing "genital structure" with "genetalia."

12. Page 3, DESCRIPTION OF REGIONAL TAXONS, 2: As above per use of taxa versus taxons. Suggest beginning second sentence with "Succineids generally are referred to as "ambersnails,"...

13. Page 4, carryover paragraph: In the seventh sentence of this paragraph, suggest replacing "in the field from Oxyloma" with "from Oxyloma in the field."

14. Page 4, GENETIC AND MORPHOLOGICAL ANALYSES: It is our understanding that the morphological analysis conducted in the study by Stevens and others was a typological, rather than a morphometric (multivariate statistical) approach. If correct, it would benefit the reader to provide more information on the approach used in the study. In the second sentence of the last paragraph were the "ambersnail specimens" referred to here from all succineid genera? Or were they just Oxyloma?

15. Page 5, ECOLOGY: The introductory clause "In summary," could be removed from the third sentence. Is there a reason why standard errors are abbreviated with capital letters, whereas standard deviations are abbreviated with lower case letters? This paragraph could be split at the sentence beginning with "In August 1995"; in that same sentence change "205.5 snail/m2" to "205.5 snails/m2."

16. Page 6, last paragraph: The third sentence identifies "1997-1998 preliminary data." Aren't these data in final form at this time?

17. Page 7, carryover paragraph: Suggest replacing "discussed" with "provided" in the last sentence.

18. Page 7, Parasitism: The word "revealed" is misspelled in the last line of the first paragraph in this section. In the second line of the second paragraph, the word "Succineid" should not be capitalized.

19. Page 7, Predators: Suggest removing "Possible" or "possibly" from the second sentence; are any of these taxa known predators? Or at least potential predators? Have other studies been conducted to ascertain whether snail shells or radulae survive intact in passage through mouse digestive tracts?

20. Page 8, carryover paragraph: Suggest removing "A number of" from the second full sentence, making the common names singular, and replacing "phobes" with "phoebe."

21. Page 8, THREATS, 2: In the third sentence, was this amount of habitat just "inundated" or "inundated and scoured?"

22. Page 8, THREATS, 3: Is the threat to NAS at IG from NPS workers performing landscape maintenance no longer present?

23. Page 9, RECOVERY, INVENTORY, RESEARCH, AND MONITORING, 2: Replace "BHBF's" with "BHBFs." In the fourth sentence, it might be more appropriate to identify that FWS issued biological opinions in response to proposed actions by BR on the operation of Glen Canyon Dam.

24. Page 9, Habitat and Population Monitoring of the KAS Population at VP: Suggest replacing "and" with "which" after the parentheses.

25. Page 10, carryover paragraph: To what discharge is the stage-discharge relationship calibrated at Vasey's Paradise? What portion of the habitat, and to what discharge level, is surveyed for KAS? Page 10, carryover paragraph: (Sorensen 2001) could be omitted from the penultimate and last sentences.

26. Page 10, Establishment of Experimental KAS Populations at NAU and GCD: What is the present status of these populations?

27. Page 10, Establishment of a Refugium Population at The Phoenix Zoo: "CUPCA" is not in the list of acronyms at the end of the main body of text.

28. Page 11, Establishment of a Second Wild Population in Arizona: Suggest making "action" plural and removing "had" from second sentence. Should "Glenski" in sentence 3 be "Glinski?"

29. Page 12, Recent Genetic and Morphological Studies: Hasn't this information already been presented earlier in the document?

30. Page 12, Review Panel Recommendations and Adaptive Management: Suggest making "exist" plural in first sentence. The KAS Ad Hoc report and recommendations were accepted by the Technical Work Group at their September 2001 meeting, so they can be considered final. Since these documents have been put together in a folder and have been distributed, is there still a necessity for having the appendices to this document?

31. Page 13, Task 1: Is there a reason why only federal or (and?) state lands are included? Aren't KAS populations protected on private lands? No mention is made here of reaching a conclusion on KAS critical habitat. Should that be addressed? Are any additional protections afforded to species listed as "Wildlife of Special Concern in Arizona?" In sentence 3, we suggest changing "have" to "has." Should requirements for Fish and Wildlife Service permits be identified in paragraph 3?

32. Page 14, Task 2.1: Suggest changing sentence 2 to begin with "Offer cooperative assistance..." and remove ", as requested" from end of sentence. Language also should be changed to include presently unknown landowners who may have Oxyloma on their property.

33. Page 14, Task 3.1: If the autumn survey is being conducted, why does the sentence read "would be?"

34. Page 14, Task 3.2: The mention of "unpublished data" here brings up the question of whether ensuring that all unpublished data are available for analysis is a task in this plan?

35. Page 14, Task 3.3: Tasks left without justification will be easier to drop from the priority list in the face of insufficient funding. Is the model expected to take the place of monitoring? If not, what is its intended purpose?

36. Page 14, Task 4.1: Why?

37. Page 14, Task 4.2: Why?

38. Page 14, Task 4.3: Why?

39. Page 14, Task 5: No explicit need for collection of ambersnails is identified or for the identification of sufficient numbers of individuals for either genetic or morphological and anatomical studies.

40. Page 15, carryover paragraph: Suggest changing "remains" to "remain" and "habitat" to "habitats" in third full sentence.

41. Page 15, Task 6.1: Earlier in the document, the AFLP technique was referenced as the technique used by Miller and others. Here it is stated that they used "several different techniques." Suggest capitalizing "southwest" in penultimate sentence.

42. Page 15, Task 6.2: Is the word "phenology" correctly used?

43. Page 16, Task 6.3: As previously, there is no acknowledgment of multivariate morphometric approaches to taxonomy that have largely supplanted the older typological approach.

44. Page 15, Task 8: Should this analysis also include the sufficiency of the translocation effort? It seems to assume that sufficient translocation of individuals was accomplished to provide for success of the populations.

45. Page 18, Task 11: It is our understanding that Glen Canyon National Recreation Area is presently revising its management plan for the river corridor. Perhaps that plan, and the corollary Grand Canyon National Park plan should be referenced. In the first full paragraph, we suggest replacing "not even" with "including" in the first sentence and "conservational" with "conservation" in the third sentence.

46. Page 19, carryover paragraph: Suggest removing "a" from penultimate sentence. In the last sentence, suggest replacing "provides" with "could provide."

47. Page 19, Task 14: Who is expected to store and maintain the database?

48. Page 19, Task 16.2: Begin task with capital S.

49. Page 20, IMPLEMENTATION SCHEDULE: Capitalize "ambersnail" in last line. In Key to acronyms, last line "contractors" is misspelled.

Debra Bills (USFWS) provided extensive written comments and edits (10/23/01)—marked draft available for review from AGFD.