Translocation of Kanab Ambersnails to Establish a New Population in Grand Canyon, Arizona

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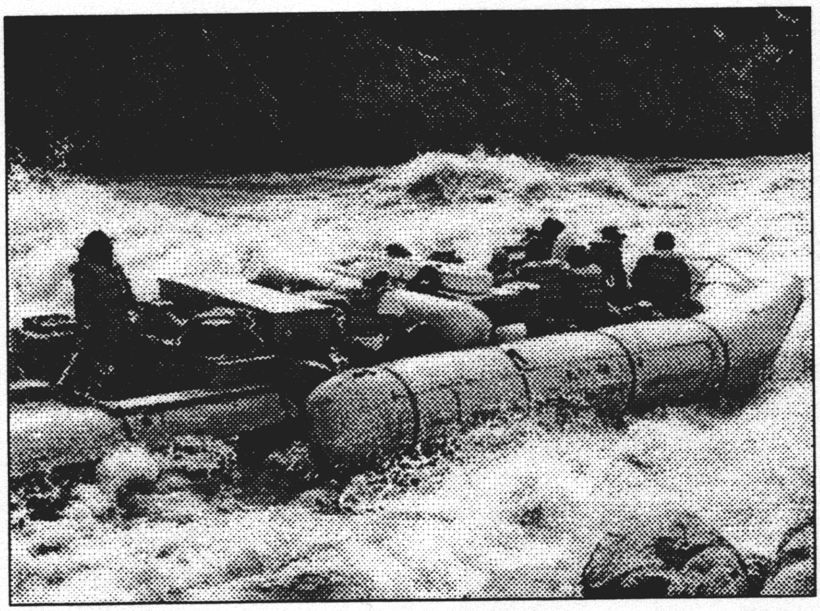

Technical Report 153
Nongame and Endangered Wildlife Program
Program Chief: Terry B. Johnson
Arizona Game and Fish Department
2221 West Greenway Road
Phoenix, Arizona 85023-4399

December 2000

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Recommended Citation

J.A. Sorensen and C.B. Nelson. 2000. Translocation of Kanab Ambersnails to Establish a New Population in Grand Canyon, Arizona. Nongame and Endangered Wildlife Program Technical Report 153. Arizona Game and Fish Department, Phoenix, Arizona.

Acknowledgments

We thank the following individuals for their contributions in the field: Dan Adikes, Roy Averill-Murray, Laurie Averill-Murray, Joe Bailey, Dave Baker, Ken Baker, Ken Bartlett, Jeff Behan, Tom Blackledge, Catherine Bland, Steve Bledsoe, Laurie Bonham, B.J. Boyle, Nikolle Brown, Bill Burger, Kirk Burnett, Karla Burnley, Joe Busch, Lita Byerly, Roger Cogan, Tim Dale, Necia Davidson, Brian Dierker, Brad Duncan, Rachael Earle, Stan Faeth, Bill Fagan, Matt Ferris, Kay Fielding, Ayoola Folarin, Chris Franke, Melinda Frankus, Maria Fruin, Josh Gilman, Robert Glennon, Dan Godec, Mark Gonzales, Kenton Grua, Sara Hatch, Brenda Healy, Joy Hernbrode, Stephanie Hettinger, Jim Hoffman, Joel Huettig, Lil Jonas, Christine Karas, Bruce Keller, Krissie Killoy, Chris Klug, Keith Kohl, Dennis Kubly, Steve Lamphear, Margie Latta, Elaine Leslie, Mike Mallett, Jerry Martinez, Vicky Meretsky, Verma Miera, Becky Muller, Nels Niemi, Bob Nelson, Lance Nelson, Eric North, Floria Parker-Jones, John Perez, Marianne Porter, Barb Ralston, Mike Randolph, Jessamy Rango, Beth Roeser, Tom Ryan, Elda Sanchez, Maaike Schotborgh, Mike Seidman, Matt Sheeney, Jim Shurtliffe, Thorry Smith, Della Snyder, Candan Soykan, Dave Speas, Tara Sprankle, Michelle Starr, Lew Steiger, Eric Swanson, Harlan Taney, Melinda Thompson, Susan Young, Eric Wallace, Melaine Webb, Guy Webster, Dave Wegner, Pete Weiss, Patrick Whitesell, Terri Williams, Bob Wilson, and Bob Winfree. Logistical and administrative support was provided by: Tony Morton and Tom Scoville (U.S. Bureau of Reclamation); Ralph Swanson (Central Utah Project Completion Act Office); Debra Bills and Larry England (U.S. Fish and Wildlife Service); Carol Fritzinger, Barry Gold, and Jake Tiegs (Grand Canyon Monitoring and Research Center); Larry Stevens (Grand Canyon Wildlands Council); Anne Hagele and R.V. Ward (National Park Service); Linda Allison, Mike Demlong, Jim Hatten, Ed Jahrke, Bill Persons, and Richard Winstead (Arizona Game and Fish Department); and a special thanks to the staff of The Phoenix Zoo for their continued support of the captive refugium population of Kanab ambersnails.

Project Funding

Funding for this project was provided by: voluntary contributions to Arizona's Nongame Wildlife Checkoff; the Arizona Game and Fish Heritage Fund; U.S. Bureau of Reclamation Grant No. 1425-97-FG-40-21760; Central Utah Project Completion Act Cooperative Agreement No. 7-FC-CU-AZ010; a private donation from Jerry R. Martinez; and a grant from the National Park Service Grand Canyon National Park.

EXECUTIVE SUMMARY

To alleviate operational restrictions on Glen Canyon Dam and further recovery objectives for the endangered Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis* Pilsbry), the Arizona Game and Fish Department partnered with the Central Utah Project Completion Act Office, the U.S. Bureau of Reclamation Upper Colorado Region, and the National Park Service to establish an additional wild population of the snail in Grand Canyon National Park. State, federal, tribal, and private cooperators affiliated with the Kanab Ambersnail Working Group and the Glen Canyon Technical Work Group participated in the environmental compliance process.

In mid-September 1998, 450 Kanab ambersnails (≤ 5 mm in shell size) were collected from Vaseys Paradise as founding stock for translocation efforts. These snails were collected from the lower vegetated zone, an area frequently inundated by river flows of 30,000 cfs (849.9 m^3/s) or less. Translocated snails were released at 3 sites (150 snails/site) which were selected through a National Environmental Policy Act review. An additional 450 snails were translocated in July 1999 to augment population densities and maintain genetic variability at each of the new sites (150 snails/site). The results of the ambersnail translocation and seasonal monitoring from October 1998 through October 1999 are summarized in this report.

No mortalities of ambersnails occurred during transit from Vaseys Paradise to the 3 translocation sites in either 1998 or 1999. Motorized boats were used to keep transit time within 5 days. Refrigerated holding containers helped reduce handling stress. No parasites were detected in any of the translocated snails. Resident native landsnails at the translocation sites were documented when encountered—*Catinella* sp. at "KeyHole Spring" and Lower Deer Creek, and *Zonitoides* sp. at Upper Elves Chasm.

In the first year of monitoring, Upper Elves Chasm proved to be the most successful of the 3 translocation sites. Survey methods were identical to those used at Vaseys Paradise. With each consecutive survey at this site, increasing numbers of ambersnails were found, and successful reproduction and recruitment of young snails occurred in 1999. Translocated ambersnails were also observed at the other 2 sites ("KeyHole Spring" and Lower Deer Creek), but few individuals were detected in 1999.

While relatively few live ambersnails were detected at the translocation sites, neither were large numbers of empty shells, which would indicate massive mortality due to an unsuccessful introduction. We do not believe most of the ambersnails perished immediately following translocation to each site. On the contrary, we suspect that more ambersnails exist at each of the new sites than we detected by current sampling methods. Sampling translocated snails was difficult due to their small size, dark color, cryptic behavior, and the dense (and fragile) habitat they occupied.

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Translocation of Kanab Ambersnails to Establish a New Population in Grand Canyon, Arizona

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Introduction

In 1997, the Arizona Game and Fish Department (AGFD) entered into a cooperative agreement with the Department of Interior, Central Utah Project Completion Act (CUPCA) Office to conduct habitat evaluations for the establishment of a new wild population of Kanab ambersnail (KAS; Succineidae: *Oxyloma haydeni kanabensis* Pilsbry 1948) in Arizona. Additional funding from the U.S. Bureau of Reclamation (USBR) Upper Colorado Region for similar work was provided to AGFD. Following completion of the habitat evaluations in 1998, CUPCA and USBR supported KAS translocation efforts in Grand Canyon National Park, led by AGFD and the National Park Service (NPS). Furthermore, the CUPCA agreement and USBR grant amendments in 1998 and 1999 included financial and logistical support for establishing a captive KAS refugium at The Phoenix Zoo. Grand Canyon Monitoring and Research Center (GCMRC) provided logistic support (funded by USBR) for translocation efforts. These efforts promote KAS recovery goals (USFWS 1995) and help satisfy biological opinion requirements resulting from Section 7 consultations (USFWS 1997). This report summarizes KAS translocation efforts in Grand Canyon National Park and results from the first year of monitoring.

The need to establish a second wild population of KASs in Arizona originates from interagency management concerns and legal requirements (i.e. biological opinions) on the operation of Glen Canyon Dam. The U.S. Fish and Wildlife Service (USFWS) 1996 biological opinion on the experimental Beach/Habitat-Building Flow (BHBF), and subsequent 1997 biological opinion on the Fall Test Flow (USFWS 1997), set forth reasonable and prudent measures related to minimizing incidental take of KAS. Specifically, the USFWS established the following terms and conditions:

> "Before another habitat-building flow, Reclamation (USBR) will enter into informal consultation with the Service (USFWS) to evaluate test flow studies, the establishment or discovery of a second population of Kanab ambersnail in Arizona, and reinitiate formal consultation with the Service if incidental take will exceed the 10 percent as established in the 1995 biological opinion."

By the end of 1997, there was a collective interest among stakeholders in the Glen Canyon Technical Work Group and Adaptive Management Work Group to modify dam operations to increase the frequency of BHBFs, and to resolve restrictions for future BHBFs. One restriction to future experimental floods was the sole population of endangered KAS in Arizona, located at Vaseys Paradise (VP), 46.8 miles (75.3 km) downstream of Glen Canyon Dam along the Colorado River. Recent surveys (Spamer and Bogan 1993; Stevens and others 1997a; Sorensen and Kubly 1997, 1998) of over 100 springs, seeps, and wetlands across Grand Canyon and northern Arizona, failed to discover additional populations of KAS. Translocating ambersnails from the affected Arizona population to new establishment sites in the region offered a possible solution to removing operational constraints on Glen Canyon Dam.

Translocation is a tool for managing and recovering species of concern, that has many precedents in wildlife management (Griffith and others 1989). The translocation of wild and/or captive-reared wildlife can be used to introduce species into new habitat, reintroduce species into their historical range, or augment existing populations to bolster genetic variation or population density (Griffith and others 1989). Within Arizona, there have been numerous precedents of intentional translocations of game and nongame species. AGFD's *Wildlife of Special Concern in Arizona* (1996 Draft) lists several species that have been translocated/reintroduced into the wild: California condors (*Gymnogyps californianus*), Mexican gray wolves (*Canis lupus baileyi*), black-footed ferrets (*Mustela nigripes*), desert bighorn sheep (*Ovis canadensis*), pronghorn antelope (*Antilocapra americana sonoriensis*), Gila trout (*Oncorhynchus gilae*), razorback suckers (*Xyrauchen texanus*), Colorado pikeminnow (*Ptychocheilus lucius*), desert pupfish (*Cyprinodon macularius*), Gila topminnow (*Poeciliopsis occidentalis occidentalis*), Ramsey Canyon leopard frogs (*Rana subaquavocalis*), and Chiricahua leopard frogs (*Rana chiricahuensis*). Kanab ambersnails are the first intentionally translocated mollusks in Arizona. Few mollusk species receive such active conservation, but there have been previous attempts to translocate Polynesian tree snails (*Partula* spp.) to new habitat with some success (Pearce-Kelly and others 1995).

There are many factors to consider (i.e. biological, environmental, and administrative) when assessing the suitability of wildlife translocation. Wild-born animals are preferable to captive-reared stock for translocations (Griffith and others 1989). Captive breeding is not only expensive and time-consuming, but also increases the animals' risk of exposure to exotic pathogens, reduced fitness, loss of natural behaviors, and reduced genetic variability (Miller and others 1999). A diverse gene pool within a translocated population will help reduce founder effects and inbreeding depression, especially among small, isolated populations (Shaffer 1981; Miller and others 1999). Species demographics (i.e. fecundity, life span, population growth rate, breeding behavior, age/sex ratios) are also important to consider for successful translocations and improving a population's long-term survival under fluctuating environmental conditions (Shaffer 1981; Lande 1993; Miller and others 1999). Habitat suitability (i.e. quality, quantity, and management protection) is a focal concern in planning wildlife translocations. Administrative concerns, such as conservation goals and timelines, legal frameworks, effective monitoring programs, field logistics, funding, and personnel, are additional factors involved in planning and conducting wildlife translocations (Miller and others 1999).

STATUS AND DISTRIBUTION

In 1992, KAS was listed as endangered by the U.S. Fish and Wildlife Service (USFWS 1992). Kanab ambersnails are also recognized as "Wildlife of Special Concern" in Arizona (AGFD 1996 Draft). Kanab ambersnails were discovered in 1909 at a small seep called "The Greens" along Kanab Wash, Utah (Ferriss 1910). H.A. Pilsbry (1948) later identified these type specimens and assigned their current subspecific status.

In this report, Arizona and Utah ambersnail populations identified as "KAS" are based primarily on morphological distinctions described by Pilsbry (1948) and S.K. Wu (pers. comm.). Recent genetic analysis on ambersnail specimens from localities in Canada and the United States (Miller and others forthcoming) 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.

Two populations of KASs currently exist in the American Southwest. One population is located north of Kanab, Utah, on a privately owned wet meadow called Three Lakes. In 1991, the Arizona population was discovered at VP, a large, perennial spring in Grand Canyon National Park (Blinn and others 1992; Spamer and Bogan 1993). At that same time, "The Greens" population was believed to have become extirpated (USFWS 1995).

Ambersnail populations in the Grand Canyon region are geographically isolated from each other. Kanab ambersnails are believed to be relictual populations from the Late Pleistocene glaciation, when wetland habitat was more abundant (Szabo 1990; Spamer 1993; Stevens and others 1997b). Although the fossil record for *Oxyloma* is scarce, fossil shells have been found in the Grand Gulch area of southeastern Utah (Kerns 1993), the San Pedro Valley of southeastern Arizona (Bequaert and Miller 1973), and the Verde Valley of central Arizona (Nations and others 1981). Desertification of the American Southwest over the last 10,000 years has reduced the number and size of available habitats that could sustain KAS populations. The Grand Canyon region currently is the southern-most known range for this species.

Habitat

Like other succineid snails, KASs are restricted to perennially wet soil surfaces and decaying plant litter of springs and seep-fed marshes near sandstone or limestone cliffs (USFWS 1995). They are most abundant under fallen cattail stalks, monkeyflower leaf litter, young watercress, sedges, and rushes (USFWS 1995). The Three Lakes site is dominated by cattails, sedges, rushes, and willows. At VP, ambersnail distribution is concentrated in patches of crimson monkeyflower (*Mimulus cardinalis*), watercress (*Nasturtium officinale*), and water sedge (*Carex aquatilus*), which are considered primary habitat for VP KAS (Stevens and others 1997a). Vaseys Paradise also hosts an abundance of poison ivy (*Toxicodendron rydbergii*), which is not ambersnail habitat, but effectively deters most recreationists from trekking through the vegetation at this site.

Biology

Ambersnails are hermaphroditic, possessing both male and female reproductive tracts (Pilsbry 1948). Young snails develop from gelatinous egg masses attached to wet substrate, plant litter, leaves, or stems. Mature KASs can have shell lengths up to 23 mm (C. Nelson, pers. obs.). Kanab ambersnails have an approximately annual lifecycle, living 12 to 15 months (Clarke 1991). Young snails emerge from winter dormancy in early spring with the onset of warm weather and increased photoperiod (L. Stevens, pers. comm.). As KASs reach 10 mm in shell length, they become sexually mature and begin reproducing throughout the late spring and summer months. Peak reproduction typically occurs in the late summer (July-August), when densities of KASs are typically highest. A decline in mature KASs occurs in the summer and early fall. Young KASs enter winter dormancy in the fall (Stevens and others 1997a). Natural overwinter mortality of KASs at VP can range between 25 to 80% (Stevens and others 1997b; IKAMT 1998).

THREATS

The Three Lakes population is threatened by habitat loss and possible extirpation by commercial development (USFWS 1995). Habitat loss from high water releases from Glen Canyon Dam (USFWS 1995) also impacts the VP population. This population experienced a loss of 16% of total habitat and an undocumented number of snails during an experimental 45,000 cfs (1275 m^3/s) BHBF in March 1996 (Stevens and others 1997a, 1997b). These experimentally controlled floods from Glen Canyon Dam are designed to redistribute sediments from the channel bottom to the riverbanks. Natural disturbances may also threaten the VP KAS population. In September 1998 an ephemeral flash flood from the plateau above VP scoured and flattened KAS habitat near the downstream pourout (J. Sorensen, pers. obs.).

Interagency KAS investigators have identified 3 potential biological threats that may affect KASs at VP. Passerine birds and deer mice (*Peromyscus* spp.) are suspected to be KAS predators (Stevens and others 1997b). The parasitic trematode, *Leucochloridium cyanocittae,* may be another biological threat to individual KASs. Based on information gathered to date, these threats are not detrimental to VP KASs at the population level. No passerine birds at VP have ever been observed feeding on KASs, but Clarke (1991) reports observing American robins (*Turdus migratorius*) feeding on KASs in Utah. The deer mouse population at VP is relatively small, and there are numerous other invertebrate prey species available to the mice. Lastly, the trematode parasite occurs naturally in succineid snails, and is present in both Utah and Arizona KAS populations (pers. comm. V. Meretsky). Based on interagency studies (1995-1997), the trematode is estimated to be present in 1 to 10% of mature VP KASs (Stevens and others 1997a, 1997b; IKAMT 1998). Only 1 trematode parasite was observed on VP KASs in 1998 (M. Kaplinski, pers. comm.), while 4 parasitized KASs were found at VP in July 1999 (J. Sorensen, pers. obs.).

ENVIRONMENTAL COMPLIANCE

KAS translocations in Grand Canyon National Park followed AGFD's 12-step re-establishment process (AGFD 1987). This 12-step process was also used for the reintroduction of California condors, black-footed ferrets, and other species in Arizona. This process involves environmental assessments, National Environmental Policy Act (NEPA) compliance, and review by the Arizona Game and Fish Commission, AGFD staff, federal agencies, biologists, and the public. The KAS translocation 12-step process was initiated in November 1997 and completed in September 1998.

In July 1998, AGFD and NPS produced a biological evaluation for the translocation of KAS in Grand Canyon National Park (AGFD 1998a) for Section 7 consultation pursuant to the Endangered Species Act. After a 30-day period for public comment, the environmental assessment for establishing new KAS populations in Grand Canyon National Park was finalized in mid-August 1998 (AGFD 1998b) to complete NEPA compliance. Both the biological evaluation and environmental assessment for KAS translocations were reviewed by the Kanab Ambersnail Working Group, the Glen Canyon Technical Work Group, regional tribal representatives, AGFD staff, private organizations, and individuals. Comments received on both documents were incorporated in the final drafts. In September 1998, NPS submitted a decision of "Finding of No Significant Impact" on the proposed action. Less than a week later, the USFWS finalized a biological opinion on KAS translocation (USFWS 1998). With completion of the environmental compliance process, AGFD made the first translocation of KASs by mid-September 1998—at the end of the reproductive season and prior to the onset of winter dormancy.

TRANSLOCATION SITES FOR KAS

Three KAS establishment sites in Grand Canyon National Park (Figure 1) were selected as the preferred alternative in the final environmental assessment for KAS (AGFD 1998b). In keeping with historical convention, river miles are expressed as miles downstream of Lee's Ferry (Coconino County, Arizona), and located on either river right (RR) or left (RL). Specific release

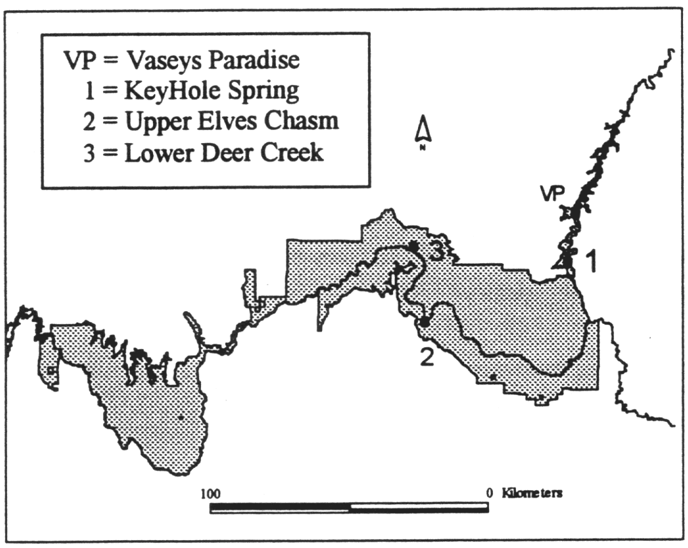

Figure 1. Locations of Kanab ambersnail establishment sites and Vaseys Paradise in Grand Canyon National Park, Arizona.

areas (e.g. patches of primary vegetation away from common trails and campsites) at each site were identified and geographically referenced using Universal Transverse Mercator (UTM) coordinates. Release areas are above the 100,000 cfs (2832.9 m^3/s) stage, and will not be affected by floods of that magnitude or less. All 3 sites were surveyed at least 5 times (different seasons over a 2 year duration) prior to the 1998 translocations (Sorensen and Kubly 1997, 1998; AGFD 1998b). Environmental variation, threat assessments, and inventories of native landsnail assemblages were examined during these early reconnaissance visits.

"KeyHole Spring" (47.1 mile RR). UTM: N4024308, E420484.
The name for this site is enclosed in quotation marks since it is a working title used by KAS researchers and administrators, but is not formally recognized as a legal site name by the U.S. Board of Geographic Names. This site has no known recreation use, and low vulnerability to

natural disturbance. The release area is located under a slight rock overhang, and adjacent to the spring drainage. Translocated KASs were released in a 5 m^2 patch of monkeyflower surrounded by patches of maidenhair ferns. The only resident, native landsnail observed at this site is *Catinella vermeta* (identified by J. Hoffman). This site is along the river corridor and accessible by existing game trails and ephemeral washes. It is isolated from other wetland habitat along the river corridor and nearby plateau. Total potential KAS habitat at this site is 9.7 m^2.

Upper Elves Chasm (116.6 mile RL). UTM: N4005750, E369300.
The release area is located above the first sawgrass patch, next to a large pool. Translocated KASs reside in a 5 m^2 patch of monkeyflower surrounded by hanging gardens of maidenhair ferns and monkeyflower. The release area is isolated from other potential KAS habitat and is elevated above the flood drainage. A lightly-used visitor trail passes by on the other side of the pool. The only resident, native landsnail observed at this site is *Zonitoides* sp. (identified by E. North). This site is accessible only by the river corridor, and requires climbing to access (greatly reducing the number of visitors). Total potential KAS habitat at this site is >23.5 m^2.

Lower Deer Creek Spring (136.1 mile RR). UTM: N4027916, E364729.
This site has no known recreation use and moderate vulnerability to natural disturbance (mostly to the floodplain marsh at the lower elevations). The trail leading back into Deer Creek Canyon passes above the spring. Dense poison ivy throughout the site keeps visitors out of the habitat (researchers used Tyvek™ suits, irrigation boots, and solvent gloves to reduce exposure to poison ivy). The release area is located along the upper slope, approximately 3 m below the spring pourout. Translocated KASs reside in an extensive patch (78.8 m^2 area) of monkeyflower, although they were initially released within a 4 m^2 area. The only resident, native landsnail observed at this site is *Catinella* sp. (identified by E. North). This site is located along the river corridor and accessible from a nearby trail. Researchers used climbing gear to descend from the overhanging cliff down to the release area. Total potential KAS habitat at this site is 480.5 m^2.

METHODS

COLLECTION AND TRANSPORT

In mid-September 1998, 450 pre-reproductive KASs (≤5 mm in shell size) were collected from the lower and upper vegetation zones of VP. Approximately 75% of the ambersnails were collected from the low zone, which is frequently inundated by flows up to 30,000 cfs (849.9 m^3/s). The remaining KASs were collected from the upper vegetation areas to enhance genetic variation. KASs were removed from host vegetation using entomological forceps or by hand, and immediately placed into sealable, clear plastic transport containers (2 L volume). A small quantity of primary vegetation and damp litter was placed in the container to maintain humidity and provide shelter and food for collected KASs. Illustrations of KAS shell morphology, *Catinella*, *Physa*, and *Fossaria*, were taped to the outside of each container to aid in mollusk identification. Each container was inspected by J. Sorensen to verify the genus and number of snails. Saturated paper towels lined the bottom of each container to help maintain moisture, ambient temperature, and provide cushion for transport. Small holes (approximately 0.5 mm diameter) in the lids of the containers provided ventilation during transport. Each container held a maximum of 50 KASs, and was labeled with the date, number of individuals, host vegetation, and patch origin.

An Oakton™ Digital Thermohygrometer was used to record air temperature (°C) and relative humidity (%) within VP KAS habitat approximately every half-hour while collecting ambersnails. A thermometer was attached to the inside of one transport container of each group to monitor temperature variation during transit. Prior handling experience has shown that ambersnails in enclosed containers can tolerate temperatures between 2 and 25°C (35.6 and 77°F) without mortality (J. Sorensen, pers. obs.). Riddle (1990) reports that *Oxyloma retusa*, a similar species, had up to 50% mortality when exposed to temperatures of 36.8°C (98.2°F) for approximately 4 hours. Transport containers were stored in a large ice chest while in transit to establishment sites. A layer of block ice and damp towels lined the bottom of the ice chest to maintain refrigeration. A fine mist spray bottle with VP water was used to maintain humidity. Motorized boats were used to keep transport time to within 5 days.

Translocated KASs were released within specific areas at each establishment site to facilitate future mating success and dispersal, as well as monitoring activities. Using entomological forceps, KASs were gently removed from the transport containers and carefully placed on host vegetation at the new site. After being released, they were observed for 5 minutes—all KASs observed were active and exhibited typical behaviors.

MONITORING

To maintain consistency in data collection, we used the same methods used to monitor the KAS population and habitat at VP (Stevens and others 1997a). Twenty-centimeter diameter survey rings were used to subsample vegetation patches at each site. Each release area was sampled with 15 plots, and the adjacent patches received 5 to 10 plots each. Along with mollusk observations, habitat variables associated with each sample plot were also reported on standardized datasheets (Appendix A). Topographical vegetative maps at KAS establishment sites were used to estimate baseline habitat area, seasonal changes, and future population estimates. When geographic reference control points were available, GCMRC surveyors completed topographical mapping using a Topcon™ GTS 310 total station and Husky™ TDS data collector (M. Gonzales, pers. comm.). In absence of control points, site vegetation patches were measured with 50 m tape measures. Topographical and sketch maps of vegetative polygons at each site are provided in Appendixes B, C, and D.

RESULTS

COLLECTION AND TRANSPORT

No KASs died during transit in either 1998 or 1999. Temperature within the transport containers ranged between 9.5°C (49.1°F) and 17°C (62.6°F) (mean=13.43°C, s=2.53, n=24). Relative humidity within the transport containers ranged between 68 and 89% (mean=81.57, s=6.78, n=24). Environmental conditions during the collection of VP KASs are presented in Figure 2 and 3.

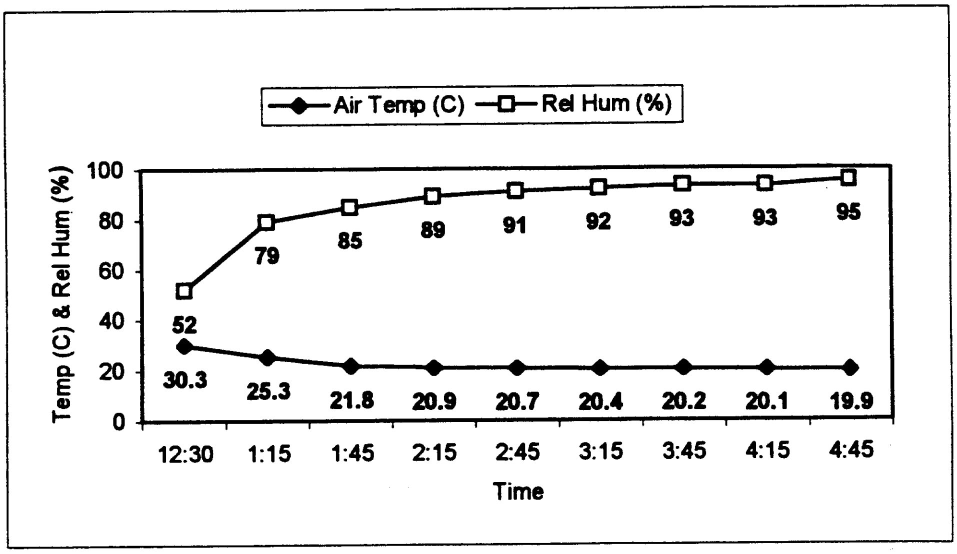

Figure 2. Environmental conditions within KAS habitat at VP on September 7, 1998.

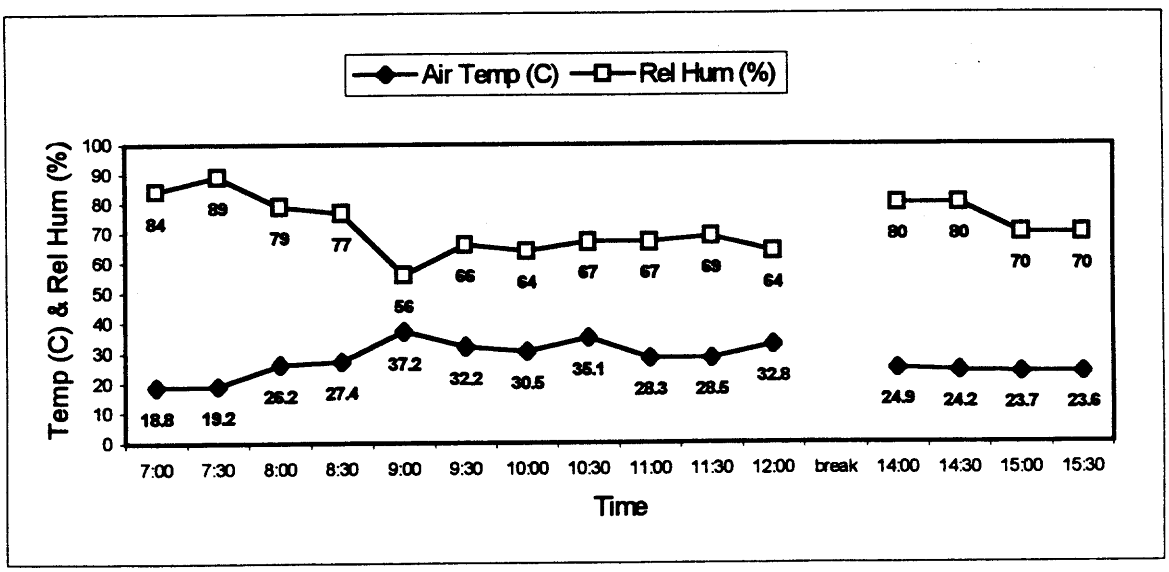

Figure 3. Environmental conditions within KAS habitat at VP on July 18, 1999.

MONITORING

The first survey of translocated KAS sites occurred in October 1998. Using a haphazard sampling distribution, 15 plots (20 cm diameter) were sampled at each release area. Results from the first year of monitoring at the KAS translocation sites are presented in Table 1 ("KeyHole Spring"), Table 2 (Upper Elves Chasm), and Table 3 (Lower Deer Creek Spring). Included in these tables are numbers of native landsnails and slugs found at each site, and rodent live trapping results.

Table 1. Status of translocated KAS at "KeyHole Spring" Site.

Survey Date	Founding Stock	Survey Plots[1]	Live KAS Observed	Dead KAS Collected	Dormant KAS	Live CAT Observed	Live DER Observed	Rodents Trapped[2]
Sept 1998	150	24	-	-	-	0	0	-
Oct 1998	-	30	5	3	1	8	0	-
Apr 1999	-	38	0	0	0	19	2	-
May 1999	-	33	3	3	0	6	0	3
July 1999	150	26	0	5	0	4	1	3
Oct 1999	-	31	3	4	1	7	10	-

Table 2. Status of translocated KAS at Upper Elves Chasm Site.

Survey Date	Founding Stock	Survey Plots[1]	Live KAS Observed	Dead KAS Collected	Dormant KAS	Live ZON Observed	Live DER Observed	Rodents Trapped[2]
Sept 1998	150	23	-	-	-	1	0	-
Oct 1998	-	25	6	0	0	0	3	-
Apr 1999	-	58	10	7	2	1	4	-
May 1999	-	13*	4*	0*	0	0*	0*	3
July 1999	150	38	17	3	0	4	3	1
Oct 1999	-	47	21	12	4	3	6	-

Table 3. Status of translocated KAS at Lower Deer Creek Spring Site.

Survey Date	Founding Stock	Survey Plots[1]	Live KAS Observed	Dead KAS Collected	Dormant KAS	Live CAT Observed	Live DER Observed	Rodents Trapped[3]
Sept 1998	150	26	-	-	-	0	0	-
Oct 1998	-	31	3	6	3	0	0	-
Apr 1999	-	55	0	1	0	7	3	-
May 1999	-	43	3	1	0	3	2	2
July 1999	150	39	1	10	1	2	3	0
Oct 1999	-	69	0	1	0	0	4	-

KAS=*Oxyloma haydeni kanabensis*, CAT=*Catinella* (succineid landsnail), ZON=*Zonitoides* (zonitid landsnail), DER=*Deroceras* (marsh slug)

[1]Includes all sample plots in adjacent and local patches; 15 plots surveyed in KAS release area.

[2]Used 10 baited live-traps within KAS release area and adjacent patches with one trap-night of effort; rodents captured were canyon mice (*Peromyscus crinitus*).

[3]Used 6 baited live-traps within KAS release area and adjacent patches with one trap-night of effort; rodents captured were canyon mice (*Peromyscus crinitus*).

*Partial survey due to medical evacuation; incomplete count of KASs.

Disturbance of release area habitat due to sampling was minimized, and had short temporal effects. With each repeat visit, we observed that vegetation had fully recovered at all sites. To reduce trailing effects we limited the number of researchers at each release area, used alternate routes along bedrock and rocky drainages when available, and actively placed plant litter and dead-down woody material along trails to reduce erosion and trail visibility.

Mean KAS shell size (mm) and resighting frequency (out of 150 founder transplants) at each site during each survey is presented in Table 4. Missing data points indicates that no live KASs were observed during that survey.

Table 4. Translocated KAS mean shell size and resighting frequency (from initial 150 transplants).

Survey Date	"KeyHole Spring"		Upper Elves Chasm		Lower Deer Creek Spring	
	Size (mm)	Resighted	Size (mm)	Resighted	Size (mm)	Resighted
Oct 1998	4.6	3.3%	8.0	4.0%	3.5	2.0%
Apr 1999	-	-	7.2	6.7%	-	-
May 1999	11.0	2.0%	13.2	Incomplete	8.6	3.3%
July 1999	-	-	4.3	11.3%	10	0.7%
Oct 1999	5.0	2.0%	7.5	14.0%	-	-

In comparison, the 1996 mark-recapture efforts for VP KASs had an overall resighting frequency of 3.4%. The area sampled at the new establishment sites equaled 9.4%, which is 5 to 8 times greater than the area sampled at VP in 1997 monitoring (average area sampled was 1.2 to 1.7% [IKAMT 1998]).

Among the 3 sites, KAS densities were the highest at Upper Elves Chasm. With subsequent surveys, we detected increasing numbers of KASs at this site within the first year of translocation. Few KASs were observed at the other 2 sites throughout the first year. Likewise, we did not find high numbers of dead shells, indicating KAS mortality, at any of the 3 sites.

Translocated KASs were successfully reproducing at Upper Elves Chasm in 1999. We observed mating KASs, 2 egg masses, and numerous young KASs during the July 1999 survey (prior to augmenting the site with additional founding stock). We are unsure if KAS reproduction was occurring at "KeyHole Spring" or Lower Deer Creek Spring since egg masses observed at these 2 sites could have been either KAS or *Catinella*.

Most of the observed KASs did not disperse outside of their release area (patch P1M) at any of the 3 sites. However, during the October 1999 survey at Upper Elves Chasm, we found a few dormant KASs that had migrated into the adjacent patches dominated by maidenhair ferns (*Adiantum capillus-veneris*) and monkeyflower. These adjacent patches are typically drier and are home to *Zonitoides*, a landsnail that lives within the soil/duff substrate (E. North, pers. comm.).

Parasites were not detected in translocated KAS or in any native landsnails at the 3 sites. Likewise, there was no apparent competitive exclusion of resident native landsnails at the translocation sites. Densities of *Catinella* and *Zonitoides* in the release areas and adjacent patches did not show appreciable change with KAS introductions. Dead shells of all species were noted during each survey, and no increased mortality of resident landsnails was observed following KAS translocations.

OBSERVATION ERROR STUDIES

In May and July 1999, we conducted comparisons of researcher sampling error under field conditions. There was little discernible difference in the number of ambersnails counted within a 30x30 cm plot (with 5 min effort total) among veteran (i.e. C. Nelson, J. Sorensen, and E. North) and novice (i.e. K. Fielding and B. Fagan) investigators during 3 different tests. In May 1999, K. Fielding and J. Sorensen independently counted 11 Niobrara ambersnails (*Oxyloma haydeni haydeni*) in a 30x30 cm plot at Lee's Ferry -9 mile Spring. Twenty-three hours later, K. Fielding found 10 ambersnails in the same plot, while J. Sorensen found 7. Both investigators reported finding a 2 mm hatchling during each test. In the third test, at VP in July 1999, another 30x30 cm plot yielded the following results among researchers: J. Sorensen found 15 KASs and 1 egg mass, B. Fagan found 11 KASs, E. North found 10 KASs, and C. Nelson found 19 KASs and 1 egg mass (E. North noted that he did not disturb the habitat during his search and may have underestimated the number of KASs there).

Before KASs were collected for the second translocation in July 1999, a homogenous patch of watercress along the rock apron at VP (Patch 7U-Apron) was subsampled as part of the standard VP monitoring survey. We selected this patch because the habitat along the rock apron is often dense with ambersnails, but is frequently trampled by recreationists and inundated with river flows up to 30,000 cfs (849.9 m^3/s). Eight plots (each 20 cm diameter) were haphazardly subsampled across this 14.5 m^2 patch, with a total of 95 KASs observed. If extrapolated, subsampling yields an estimated mean of 378.2 KASs/m^2 within this patch. After the subsampling was completed, a total census search of 7.5 m^2 of this patch was conducted using a grid of 0.5 m^2 quadrats. Researchers counted 498 KASs within this area. Total census provided an extrapolated estimate of 66.4 KASs/m^2 within this patch--this was a 470% difference from the subsample estimate.

Other tests of observation error were conducted to determine if we were detecting accurate numbers of released KASs. In July 1999, both "KeyHole Spring" and Upper Elves Chasm sites were subsampled prior to release of an additional 150 KASs at each location.

No resident KASs were detected at "KeyHole Spring" prior to the 1999 augmentation. On the following day (less than 15 hours elapsed), only 22 KASs were found within and around the specific release points (5 plots in an area measuring approximately 0.5 m^2). Most KASs found on this repeat survey remained within 5 cm distance of their specific release points; only 1 KAS was found to have dispersed as far as 61 cm.

At Upper Elves Chasm in July 1999, we found 17 resident KASs in 15 plots. These snails were all <8 mm in shell size and presumed to be progeny from the first translocation in September 1998. Again, we resampled the release area on the following day after introducing another 150 young KASs. Only 13 KASs were found in 7 plots (within approximately 1 m^2 area). No "fresh" mortalities (empty KAS shells) were found during either this resample or the one at "KeyHole Spring" in July 1999.

At both sites, 10 rodent live traps were baited and set within and around the release areas following KAS augmentation in July. Traps were checked the next morning during the resample.

At "KeyHole Spring" we captured 3 canyon mice (*Peromyscus crinitus*) and 1 at Upper Elves Chasm.

An additional observation error test was conducted on a captive population of KASs at TPZ between July and November 1999. At the end of May 1999, the KAS refugium at TPZ received an initial stocking of 50 ambersnails for their enclosed, outdoor terrarium (total habitat area measured 1.152 m^2). This small population was surveyed on a weekly basis using 5 plots (the same haphazard subsampling used at VP and the 3 translocation sites), followed by total census sampling of all habitat within the enclosure. The results of this paired sampling test are illustrated in Figure 4 (note: KASs were successfully reproducing during this time period, so a net increase in KAS numbers above 50 occurred in Week 4). Subsampling found between 12.1 and 51.9% of the KASs sampled using the total census method. The combined area sampled from the 5 plots measured 0.155 m^2, or 13.4% of the total available habitat within the enclosure.

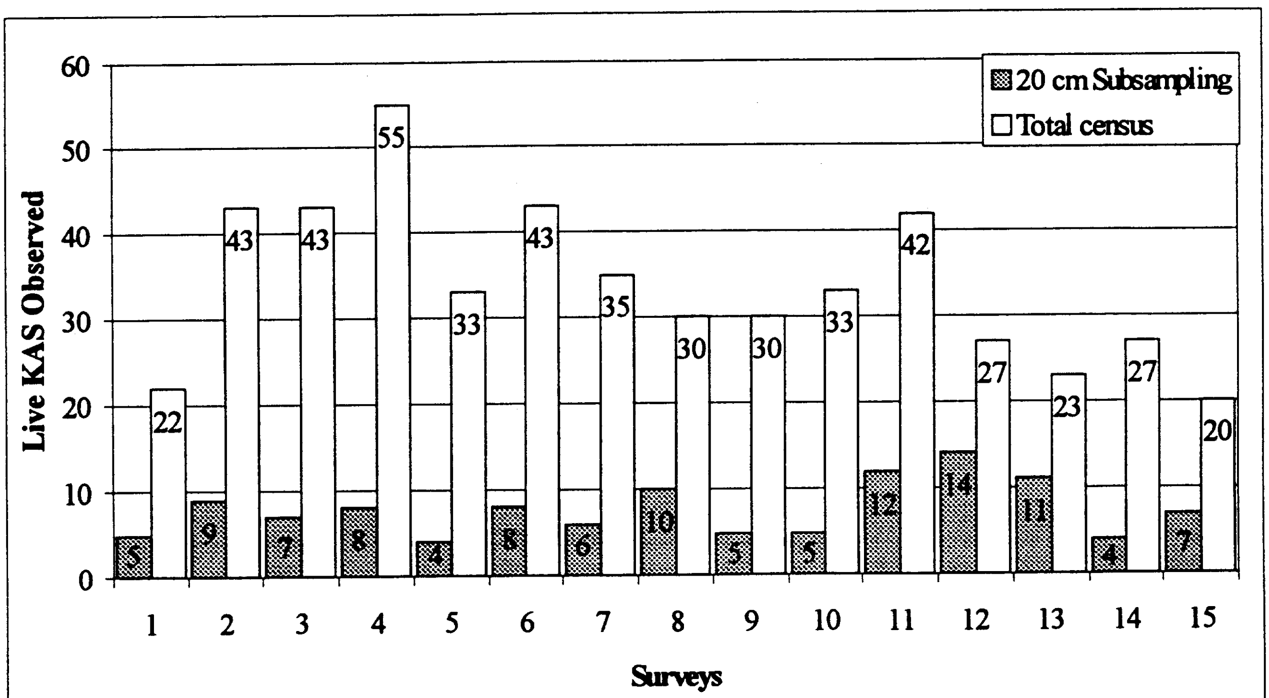

Figure 4. Observation error test on The Phoenix Zoo ambersnail refugium. Difference in total number of snails found using 5 subsample plots versus a total census.

DISCUSSION

The low resighting frequency of KASs at new establishment sites are likely due to observation error associated with our current sampling techniques, rather than population density. Assuming the mice density at "KeyHole Spring" and Upper Elves Chasm is not significantly higher than what we observed during the July 1999 observation error tests, mice predation of the translocated snails is not a likely cause for the observed low densities of KASs. Likewise, since the initial and repeat surveys in July 1999 were conducted approximately 15 hours apart (overnight), avian predation is also unlikely to be a factor in the reduced number of KASs found.

Since translocated KASs are small (≤5 mm in shell size), dark brown in color, and generally cryptic in behavior, they are difficult to find in natural settings. In addition, the release areas selected for translocated KASs are very dense with monkeyflower--some plots measuring a depth of 1 m. Given these circumstances, current survey techniques employing 20 cm diameter sample plots may not be adequate to detect actual numbers of KASs at establishment sites. The release areas at each site are relatively small (approximately 5 m^2) and only permit a limited number of "random" plots.

Status of Recovery and Biological Opinion Activities

The following list summarizes progress on KAS Recovery Plan (USFWS 1995) objectives and Biological Opinion activities by AGFD:

<u>1995 KAS Recovery Plan Objectives:</u>

- OBJ 1.1 (ongoing). Conduct mitigation activities and management review of human-caused impacts (high flows from Glen Canyon Dam) to VP KASs.
- OBJ 1.3 (ongoing). Initial monitoring of secondary KAS populations translocated in Grand Canyon National Park.
- OBJ 3 and 4 relating to the VP KAS population (completed). Participate in interagency studies of VP KAS between 1995 and 1997 (assisted with contracted studies 1998-99).
- OBJ 3.2 (completed). Conduct habitat surveys and evaluation of potential sites for KAS establishment in 1996-1998 (Sorensen and Kubly 1997, 1998).
- OBJ 3.33 (completed). Develop topographical habitat maps of new KAS population sites in Grand Canyon National Park (Appendix B, C, D).
- OBJ 4.5 (completed). Determine preliminary genetic relationships of regional *Oxyloma* populations (Miller and others 1997).
- OBJ 5 (completed). Establish a captive (refugium) population of VP KASs at The Phoenix Zoo.
- OBJ 6.1 (completed). Develop and distribute a 4-color educational brochure on KAS biology, ecology, and interagency recovery efforts.

<u>Biological Opinion activities:</u>
1996, 1997, and 1998 Biological Opinion activities relating to KAS.

- Translocate founder stock of VP KASs to 3 new sites in Grand Canyon National Park for establishment of secondary populations and conduct initial year of monitoring (completed).
- Translocate founder stock of VP KASs to The Phoenix Zoo for establishment of a captive (refugium) population and conduct weekly monitoring (completed).

Proposed Establishment Criteria

In 1998, the USFWS and NPS proposed the following preliminary criteria for defining establishment success for translocated KASs in Grand Canyon National Park:

> The establishment of a new, wild population of the Kanab ambersnail can be considered successful when: 1) the population densities, fecundity, and recruitment mimic those of the parent population at Vaseys Paradise; 2) long-term habitat suitability must allow the population to persist while accommodating environmental uncertainties including changes in weather, food supply, predators, and other factors; and 3) the trend of population growth must be positive for a certain period of time, perhaps 3 years.
>
> It is assumed that the 3 populations will receive maximum protection since the areas are not subject to land use practices, which may result in habitat alteration or loss. Natural disturbances (e.g. flash flood, mass failure) and recreation impacts are the most likely threats. Disease, predation, and other impacts must be considered.
>
> Overall, the goal is to result in at least 1 self-sustaining population within a natural environment which is capable of persisting with no or minimal human intervention. Maintenance of the genetic integrity of the new population may require long-term specific management actions.

In addition, the USFWS and NPS proposed step-down criteria for determining establishment success/failure for KAS translocations. This draft step-down approach was used as a guide to evaluate the need to augment new translocation sites with additional founding stock of VP KASs in 1999.

<u>Draft step-down criteria for success/failure of Kanab ambersnail introductions:</u>

Step 1 - Evaluate overwintering success

a) at least 30% of translocated individuals survive and emerge from winter dormancy (or percent is similar to Vaseys Paradise population); proceed to step 2.
b) less than 30% of translocated individuals survive (or significantly different from Vaseys Paradise population); proceed to step 3.

Step 2 - Evaluate reproduction potential and success

a) 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.
b) 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 of augmentation

a) if necessary, augment population with small numbers to ensure genetic variability; proceed to step 4.
b) attempt a second large-scale introduction; proceed to step 4.

Step 4 - Evaluate recruitment and overwintering potential

a) young snails persist and are high in numbers before October; proceed to step 5.
b) few snails persist in October; proceed to step 6.

Step 5 - Population status remains stable for a designated period of time

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

RECOMMENDATIONS

The results of the observation error tests suggest our current subsampling methods may not accurately represent the actual number of KASs at the translocation sites. In all likelihood, KAS densities at the new sites are probably much higher than we have observed. Due to the high error associated with our subsampling, we believe that extrapolating population estimates using bootstrap statistics would not be useful or remotely accurate at this time. Furthermore, we do not advise increasing sampling effort using additional 20 cm diameter plots or total census search. More than 15 plots/release area would begin to violate the randomness of subsampling due to the small area of habitat where the snails were released. In addition, greater sampling effort would likely cause more damage to release area habitat, which we prefer to avoid.

Based on our first year of monitoring results, a population of translocated KASs appears to be establishing at Upper Elves Chasm. With each subsequent survey we have detected an increase in KAS density and recruitment of young ambersnails. If the population at Upper Elves Chasm is successful, then we have moved one step closer to achieving KAS recovery objectives, reducing biological opinion restrictions on the operation of Glen Canyon Dam, and conducting future BHBFs. We recommend periodic limited augmentation of VP KASs to Upper Elves Chasm to help maintain genetic diversity and boost population densities. In addition, the proposed criteria for establishment success should be reviewed more broadly by the scientific community and resource agencies before being finalized. Continued research into KAS life history, sampling methods, and further monitoring is needed to assess KAS establishment success at the translocation sites.

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APPENDIX A: MONITORING DATASHEET

KANAB AMBERSNAIL SURVEY FORM Page:___ of ___ Reader:________________

SITE:______________________ Date:________ (MM/DD/YY) Recorder:_______________

O/U: Overstory or Understory veg layer
%LIVE: Percent of veg that is live, not dead
%COV: Percent of ground shaded by veg
TOT%COV: Sum of %COV for all veg in plot
PERIM DIST: Edge of Plot to edge of Patch

SUBSTRATE TYPE:
RO: Bedrock
SA: Sand
SO: Soil
SI: Silt/Fine

MOIST:
D: Dry
M: Moist
S: Saturated
F: Flowing

PATCH ID	PLOT #	VEGETATION						TOTAL %COV	PERIM DIST (cm)	SUBSTRATE				DUFF/LITTER		MOLLUSK SPP	COMMENTS
		SPP	O/U	% LIVE	% COV	DENS H M L	DEPTH (cm)			TYPE	DEPTH (cm)	MOIST DMSF	%SAT 0-100	DEPTH (cm)	MOIST DMSF	Status, shell length (mm), attached to:	

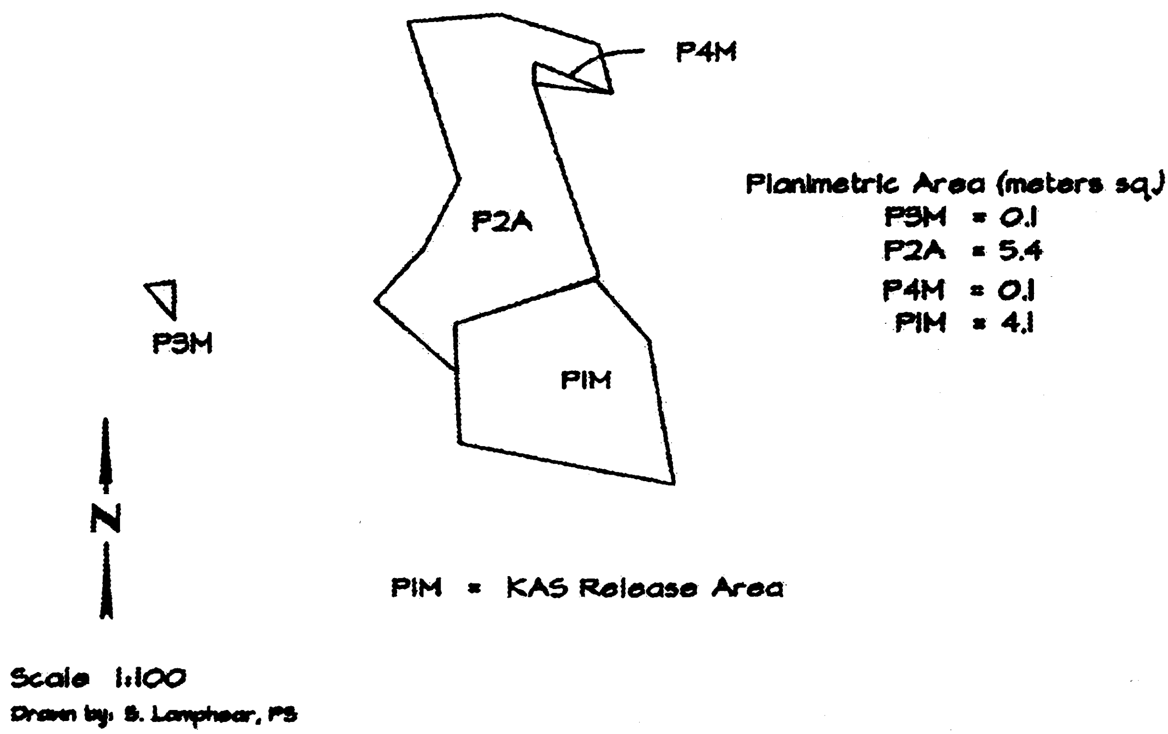
Veg Spp: MICA= monkeyflower, NAOF=watercress, TYSP=cattail, ADCA=maidenhair fern, PHAU=reeds, SAEX=coyote willow, SAGO=Goodding willow, BASP=seep willow, CASP=sedges, JUSP=rushes, EQHY=horsetail, CEOC=redbud, TARA=tamarisk, TORY=poison ivy, POAM=knotweed, EPGI=orchid, CLCA=sawgrass, CISP=thistle, AQCH=columbine

Mollusk Spp: KAS=Kanab ambersnail, *Oxyloma* CAT=*Catinella* DER=*Deroceras* (slug) FOS=*Fossaria* PHY=*Physa-Physella* ZON=*Zonitoides* HAW=*Hawaiia*

APPENDIX B: "KEYHOLE SPRING" SITE MAP

Vegetative Polygon Map

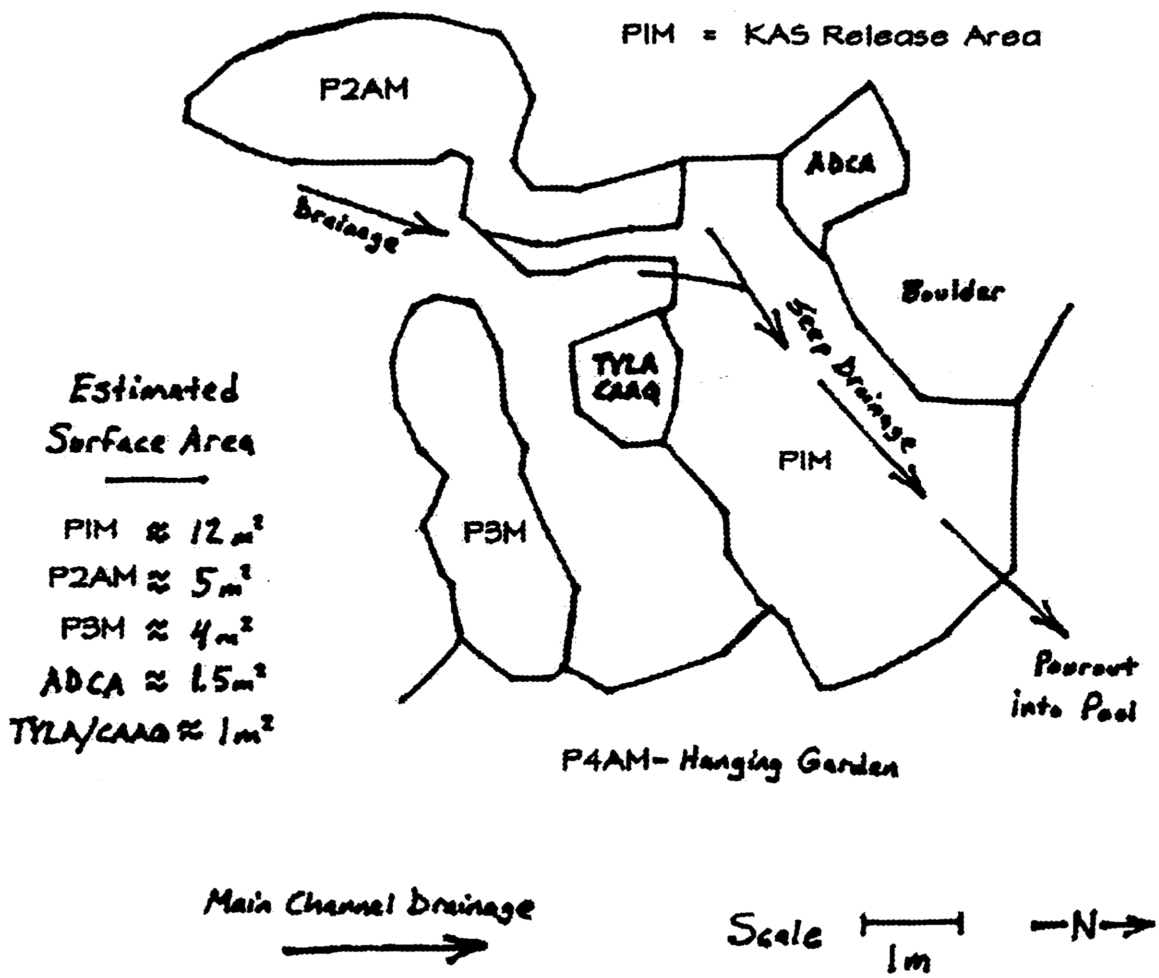
Topographically surveyed on August 5, 1998
Created by Steve Lamphear, GCMRC



APPENDIX C: UPPER ELVES CHASM SITE MAP

Vegetative Polygon Map

Surveyed on July 21, 1999
Illustrated by Jeff Sorensen, AGFD



APPENDIX D: LOWER DEER CREEK SITE MAP

Vegetative Polygon Map

Topographically surveyed on August 10, 1998
Created by Steve Lamphear, GCMRC