THE ECOLOGY OF KANAB AMBERSNAIL

(SUCCINEIDAE: *Oxyloma haydeni kanabensis* Pilsbry, 1948)

AT VASEYS PARADISE, GRAND CANYON, ARIZONA:

1995 FINAL REPORT

A Cooperative, Interagency Report Prepared for:

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ABSTRACT

The Kanab ambersnail (KAS, SUCCINEIDAE: Oxyloma haydeni kanabensis Pilsbry), is a federally endangered landsnail with extant populations at two southwestern springs: one on private land near Kanab, Utah, and the other at Vaseys Paradise (VP) 51 km downstream from Lees Ferry along the Colorado River in Grand Canyon National Park (Spamer and Bogan 1993). The habitat and ecology of the VP KAS population was studied in 1994 and 1995. KAS occurred primarily on native Mimulus cardinalis (crimson monkey-flower) and non-native Nasturtium officinale (water-cress), and occasionally Carex aquatilis and Polygonum amphibium, growing on moist to saturated substrata wetted by the VP spring outflows. We defined patches of these two plant species as primary KAS habitat. KAS were rare to absent on other riparian plant species (secondary or marginal habitat, with few, if any, KAS) and bare substrata (e.g. soil or rock surfaces) at VP, and were not found at 81 other Grand Canyon springs. KAS densities were slightly (not significantly) higher on the two host plant species early in the growing season, but mean density on non-native Nasturtium during the latter half of the growing season was >4 times that on Mimulus ($p < 0.03$).

KAS has an approximately annual life cycle, as indicated by seasonal size class frequency analysis. Young KAS overwintered on host plant stems and emerged from winter dormancy in middle to late March. Large snails (>13 mm) were uncommon until early summer and reproduction occurred in mid-summer. KAS was parasitized by a trematode, Leucochloridium cyanocittae, with 8.3% to 9.5% of the mature snails sampled expressing sporocysts in August, 1995.

If the upper zone (above the 1275 m^3/s stage, 45,000 cfs) primary habitat area did not change appreciably from November, 1994 to September, 1995, the total estimated KAS population increased through the 1995 growing season from an estimated 18,476 snails on 30 March 1995 to 104,004 snails on 17 September 1995. Low stage zone (below 1275 m^3/s) vegetation developed after completion of Glen Canyon Dam, and supported 617 to 17,370 snails (3.3% to 16.7% of the total KAS population) from March to September 1995, respectively.

If primary KAS habitat and population distribution remains equivalent from summer 1995 to March 1996, 105.5 m^2 (11.8%) to 146.1 m^2 (16.1%) of primary habitat and 2,275 (11.4%) to 17,370 (16.7%) of the KAS population may be lost during a proposed high flow release from Glen Canyon Dam. Mitigation alternatives to reduce the impacts of this test flood on KAS may include: 1) physically moving KAS to higher stage elevations at Vaseys Paradise, 2) collecting live KAS for research and/or establishment of a captive breeding population, 3) permitting take of this magnitude, or 4) prohibiting or reducing the magnitude of the planned high release. Data gaps and VP monitoring issues were identified.

INTRODUCTION

The Kanab ambersnail (KAS, Oxyloma haydeni kanabensis Pilsbry 1948) is a federally endangered succineid landsnail that occurs at two springs in the American Southwest (Spamer and Bogan 1993; England 1991a, 1992), and also has been reported from Alberta, Canada (Harris and Hubricht 1982). Despite the broad range of the family in the Northern Hemisphere and southern Africa, little ecological information on Oxyloma or other succineids has been reported in the literature. The southwestern Succineidae include three genera: Succinea, Catinella and Oxyloma. The genus Oxyloma contains O. retusa (Lea 1834) and O. haydeni Binney (Wu 1993 and written communication, respectively) in the Southwest, as well as O. haydeni kanabensis Pilsbry 1948 (Spamer and Bogan 1993). Fossil Oxyloma have been collected in Late Pleistocene deposits in the San Pedro Valley in Arizona (Bequaert and Miller 1973) and in 9,200 yr-old sediments near Lake Powell in southeastern Utah (Kerns 1993). Living KAS were first collected by J.H. Ferriss in 1909 near Kanab, Utah in seep vegetation (Ferriss 1910; Pilsbrys 1948). KAS type specimens were originally designated as Oxyloma haydeni kanabensis Pilsbry (Pilsbry 1948); however, Pilsbry noted that further study might reveal this taxon to be a distinct species. Elevation to species status as O. kanabensis has been recommended by S.K. Wu (written communication).

Two KAS populations existed in the Kanab, Utah area, but one has apparently been extirpated because of habitat destruction (L. England, U.S. Fish and Wildlife Service, written communication). The remaining Utah population occurs around several small, spring-fed ponds, named Three Lakes, on Typha stems (England 1991a). The Three Lakes site lies on privately-owned land which is currently undergoing commercial development. KAS was proposed for emergency listing as an endangered species by the U.S. Fish and Wildlife Service in 1991 (England 1991a, 1991b), and was subsequently listed (England 1992).

The other extant KAS population occurs at Vaseys Paradise (VP, Colorado River km 51R) in Grand Canyon National Park, Arizona. VP is fed by a fast-flowing, cool spring, and supports a profuse growth of wetland and phreatophyte vegetation. The VP KAS population was first identified from the collections of Spamer in the summer of 1991 (Spamer and Bogan 1993a). Enumeration of mature KAS shells collected during bimonthly aquatic sampling in 1991 by Blinn et al. (1992) suggested that population size peaked in autumn. KAS was subsequently observed to be closely associated with native Mimulus cardinalis (crimson monkey-flower) and non-native Nasturtium officinale (water-cress) at VP. VP is a popular water source and attraction site for Colorado River runners; however, access is limited by the dense cover of Toxicodendron rydbergii (poison-ivy).

This study was undertaken to determine operational impacts of Glen Canyon Dam on the VP KAS habitat and population. This information will assist cooperating resource managers in understanding potential effects of planned high flows from Glen Canyon Dam on KAS, and will facilitate development of appropriate strategies to mitigate high flow impacts. The specific objectives were to: 1) determine KAS distribution and habitat relationships; 2) estimate KAS density and population size; 3) determine KAS demography over the course of a year; and 4) locate other KAS populations in Grand Canyon. Such information is needed if managers are to protect this endangered species.

METHODS

Study Site

Location: VP is a cool-water, dilute dolomitic spring that pours to the Colorado River from the Mooney Falls member of the Mississippian Redwall Limestone in Grand Canyon National Park, Arizona, 51 km downstream from Lees Ferry, Arizona (Fig. 1). The spring issues at 925 m elevation from three primary mouths, and divides into several large, and numerous small, rivulets as it flows ca. 100 m to the Colorado River. The climate is arid and continental, with a mean annual precipitation of 140 mm at Lees Ferry, the nearest weather station (Sellers and Hill 1974). Precipitation is bimodally distributed between summer and winter. Temperatures at Lees Ferry range from < -10°C in winter to > 45°C in summer. Although the east-facing aspect of VP allows the spring to thaw relatively quickly after freezing winter nights, Stevens (personal observation) observed that the spring was nearly completely frozen and covered in ice in early January, 1975. Aspect also protects the spring area from hot, direct mid-afternoon sunlight during summer. Along with nearby river-level springs, VP lies in the U.S. Bureau of Reclamation Glen Canyon Environmental Studies Program's (GCES) Geographic Information System (GIS) Reach 3 (Bureau of Reclamation 1995).

VP lies directly below the mouth of an ephemeral tributary basin that is 2 km^2 in area, and which occasionally floods and scours spring vegetation (e.g., on 1 April, 1992). In its geologic past, this small, unnamed tributary produced debris flows that formed the large talus cone onto which the spring pours.

Hydrogeology: Cooley et al. (1969) defined major groundwater basins of northeastern Arizona in relation to aquifers of Paleozoic Pennsylvanian and younger age. Huntoon (1974) reported that VP flow is derived from the Mississippian Redwall Limestone through one of several groundwater sub-basins in the northeast corner of the Kaibab Uplift. He traced VP flow approximately 3 km into the Redwall Limestone and concluded that it arose from meteoric sources on the North

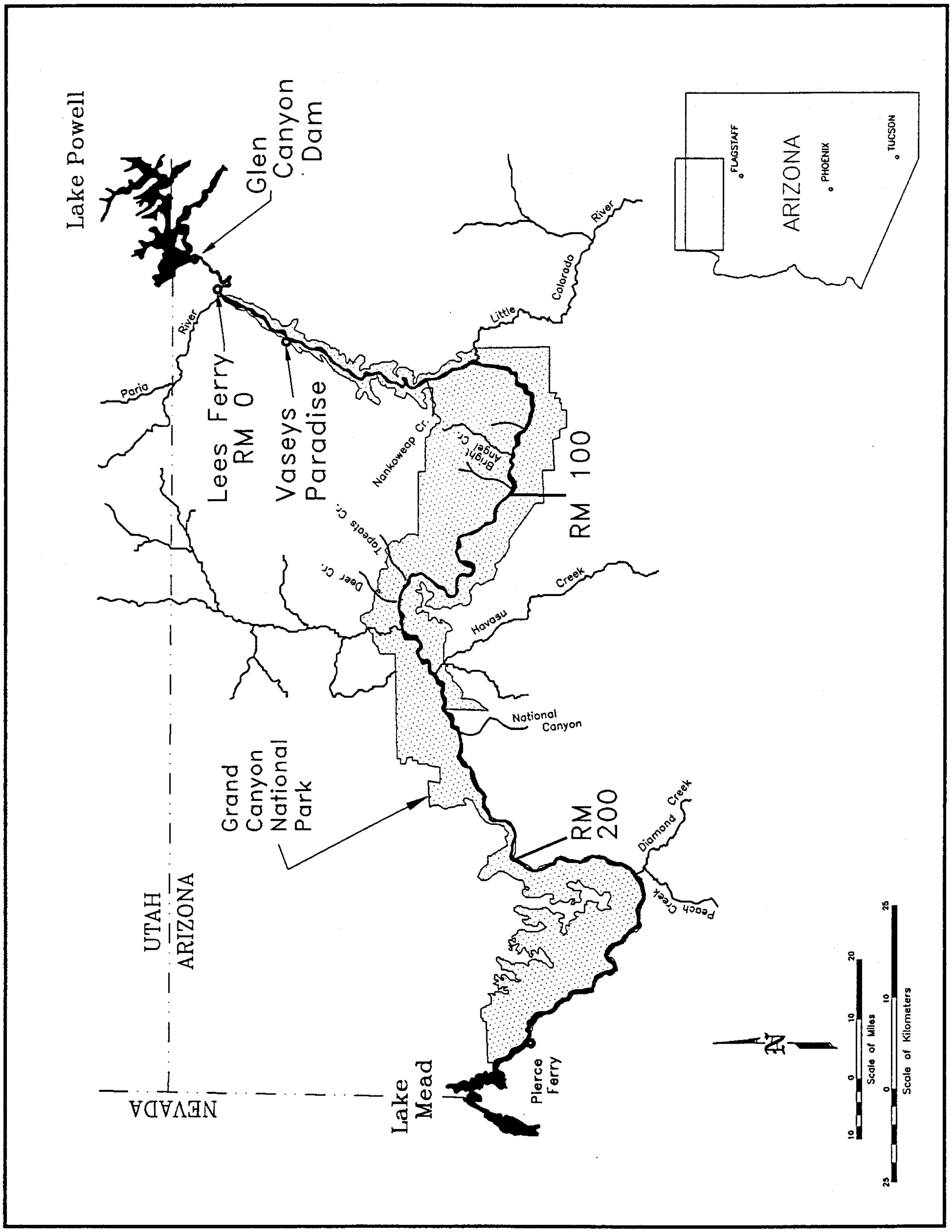

Figure 1: Map of study area at Vaseys Paradise in Grand Canyon, Arizona.

Rim of the Grand Canyon, approximately 17 km from its mouth. Therefore, VP drains at least 122 km^2, and perhaps as much as 803 km^2, of the Kaibab Plateau. VP is separate and distinct from several other nearby groundwater flow systems that deliver water of different geochemistries and temperatures to the Colorado River 48 to 56 km downstream from Lees Ferry (Huntoon 1981).

VP flows vary by approximately an order of magnitude annually, from <0.03 m^3/s during late summer through winter, to more than 0.15 m^3/s during the April through June snowmelt on the North Rim of the Grand Canyon. Stevens (personal communication) observed that VP virtually ceased flowing during a drought in spring and summer, 1977. The relative amount of flow from the three VP sources has shifted over the past century, and most discharge now issues from the downstream pourout (Turner and Karpiscak 1980:58-59).

Chemical analyses reveal VP to be a dolomite-type spring (Cole and Kubly 1976). Its waters are carbonate-rich, with approximately equal portions of calcium and magnesium, and relatively low concentrations of sulfate, chloride, silica, and sodium (Johnson and Sanderson 1968, Huntoon 1981, McCulley 1985). VP water is relatively dilute in comparison with most Grand Canyon springs, such as those immediately upstream and downstream, reflecting limited impact of groundwater basin geochemical alteration. VP is chemically comparable with the water of Bright Angel, Shinumo, Tapeats and Deer creeks, which are also dolomitic. Cole and Kubly (1976) commented that VP had the highest concentration of NO_2-NO_3 nitrogen and the highest N:P ratio of the other 4 dolomite streams in Grand Canyon; however, the reasons for this were not elucidated.

Vegetation: The vegetation of VP was first examined in detail by Clover and Jotter (1944), and VP has been widely photographed because of its scenic attraction. Historic photographs reveal little pre-dam vegetation below the approximate 2500 m^3/s stage, which was the pre-dam annual flood stage (Turner and Karpiscak 1980:58); however, post-dam spring and riparian vegetation had colonized down to the approximate 550 m^3/s stage in 1995.

VP vegetation is distributed in relation to steep moisture gradients, which radiate outward from the pourouts and rivulets. The nearly vertical walls of the spring are dominated by Mimulus cardinalis and Petrophytum caespitosum, with some Agrostis stolonifera and Brickellia longifolia. The rivulet and seep edges on the talus cone are dominated by Mimulus cardinalis, Adiantum capillus-veneris, Equisetum spp., Epipactis gigantea, Polygonum amphibium, Lobelia cardinalis, various other herbs, Elymus canadensis and Carex aquatilis, and abundant non-native Nasturtium officinale. Slightly upslope from the water's edge on the talus cone lie dense stands of Toxicodendron rydbergii, with occasional patches of Artemisia ludoviciana, Brickellia longifolia, Solidago occidentalis and decadent Cercis occidentalis. Salix exigua and Salix gooddingii occupy the middle riparian zone just out of contact with the rivulets. The vegetation at the Colorado River shoreline is a mixed wetland herb assemblage dominated by Juncus spp., Nasturtium officinale, Plantago lanceolata, Bromus wildenowii, and Tamarix ramosissima, with middle riparian zone bedrock exposures occupied by small patches of Dichanthelium lanuginosum, moss and herbs. The landscape surrounding the spring grades out to an upper riparian zone dominated by Fallugia paradoxa and a xeric assemblage of Great Basin and Mohave desertscrub (Warren et al. 1982).

The two primary plant species on which VP KAS occurs are perennial wetland species with similar regional distribution patterns and life history strategies (Kearney and Peebles 1960). Mimulus cardinalis Dougl. (crimson monkey-flower) is a member of the snapdragon family (Scrophulariaceae), and is found at elevations of 600 m to 2,600 m from Oregon to Utah, and south to northwestern Mexico. Crimson monkey-flower occurs in and along springs and streams, and produces large, orange to scarlet (or rarely yellow) flowers bimodally during April-May and August-October in Grand Canyon. It spreads through rhizomes, as well as by seed. Similarly, the Cruciferae, Nasturtium officinale L. (formerly Rorippa nasturtium-aquaticum (L.) Schinz & Thell; water-cress), occurs at elevations of 460 m to 2,130 m in and along springs, streams and ponds. This species was introduced from Europe and is widely distributed throughout the United States. It spreads by rooting at the nodes, and reproduces abundantly by seed.

Co-Occurring Fauna: Cole and Kubly (1976) recorded the following aquatic invertebrates at VP: Nematoda; Oligochaeta; Insecta (Ephemeroptera - Baetis; Odonata, Coenagrionidae; Hemiptera, Microvelia; Coleoptera, Hydrophilidae; Trichoptera, Heliopsyche; Lepidoptera, Paragyractis; Diptera, Tipula, Simuliidae, Diamesinae, Calopsectra, Euparyphus, Empididae); Gastropoda - Lymnaea. Spamer and Bogan (1993a) documented the presence of several other Mollusca at VP, including: lymnaeid Fossaria obrussa Say, physid Physella sp(p), succineid Catinella avara, C. vermeta, and C. sp. (S.K. Wu, written correspondence), and zonitid Hawaiia miniscula. Numerous terrestrial invertebrates inhabit VP, including lumbricines, pseudoscorpions, arachnids (especially Tetragnatha laboriosa), Carabidae, and other taxa.

During our visits to the site we have observed several vertebrate species which may be potential KAS predators. Oncorhynchus mykiss (rainbow trout) were commonly observed in the pool area at the stream mouth. Bufo spp. toads were observed. Hyla arenicolor (canyon treefrog) were common at VP from the mid-1970's to the mid-1980's, but have not been observed in recent years (Stevens, personal observation). Avian species observed at VP on 6 June, 1995, included two pairs of Sayornis nigricans (black phoebe), one pair of Sayornis saya (Says phoebe), and one to two pairs of Catherpes mexicanus (canyon wren). The first species is a summer resident, while the latter two and Corvus corax (common raven) may occur year-round. Anas discors (blue-winged teal), Gallinago gallinago (common snipe), Actitis macularia (spotted sandpiper), Regulus calendula (ruby-crowned kinglet), various Parulidae (warblers), Piranga ludoviciana (western tanager), and Passerina sp. (buntings) and other Emberizidae are migrant or erratic visitors at VP. Cinclus mexicanus (American dipper) are winter residents at VP and also may be potential KAS predator. Reptile and mammal species have not been documented at VP.

Data Collection

We visited VP 10 times from September, 1994 to September, 1995. Extensive topographic surveying and population sampling was conducted on: 15-16 September (survey) and 22 November (photogrammetry), 1994; 4 January (observation only), 15 February (observation only), 19-31 March (survey/sampling), 7-10 June (survey/sampling), 8 August (sampling), 13 August (sampling), 22 August (observation only), and 17-19 September (survey/sampling), 1995. The 7-10 June sampling trip included two technical climbers who assisted us by sampling KAS density among the vertical vegetation patches distributed around the pourout mouths.

KAS were sampled using a replicated, small-plot method in discrete vegetation patches at VP (Brower et al., 1990). Habitat patches were delineated on the basis of uniform cover of dominant plant species (i.e., Mimulus cardinalis, Nasturtium officinale, Adiantum capillus-veneris, Equisetum spp., mixed wetland and grass species, and Toxicodendron rydbergii). Because KAS distribution was strongly correlated with the presence of Mimulus, Nasturtium and occasionally Carex and Polygonum, and patches dominated by those species were designated as primary habitat. Patches dominated by other riparian plant species contained few, if any, KAS, and were designated as secondary (marginal) habitat. Within-patch sampling for KAS depended on patch size: we completely surveyed KAS in habitat patches < 1.0 m^2 in area; we surveyed one to three 20 cm-diameter plots in smaller (1-3 m^2) patches; and we sampled up to 25 20 cm-diameter plots in large patches. Particular sampling emphasis was placed on patches lying below the 1275 m^3/s stage, which was to be inundated by a planned experimental high flow from Glen Canyon Dam in spring, 1996 (Bureau of Reclamation 1995; Patten et al. 1995, unpublished).

The size and abundance of live KAS and other Mollusca were recorded in each 20 cm-diameter plot. In addition, plot substratum composition (bedrock, soil type), soil moisture, litter depth, litter composition, vegetation type and estimated percent cover were recorded. Shell lengths of each living KAS encountered were measured, and microhabitat associations were noted (e.g., substratum, litter, living

Nasturtium leaf, dead Mimulus stem, etc.). During each visit to VP, streamflow was estimated by timing the filling rate of 20 L buckets. We estimated additional rivulet flow and measured water temperature.

The FWS permitted collection of 10 live KAS in 1995; nine live KAS were collected as voucher specimens. KAS were relaxed by drowning them in water with a small amount of EtOH for eight hours. Specimens were then fixed in boiling water for one second and preserved in 70% EtOH for taxonomic verification and reference. Four of the nine live KAS were collected specifically because they had been parasitized by a platyhelminth trematode. One of these specimens was dissected following guidelines provided by Pennak (1953), and the two 12 mm-long trematode sporocysts were also preserved in 70% EtOH. Additional succineid specimens were collected from some other Grand Canyon springs through this and other studies. All specimens are housed in the National Park Service collections museum in the Northern Arizona University Geology Department, curated by Dr. James I. Mead. The five live-collected, non-parasitized KAS and several Catinella specimens from VP, and other succineids from other Grand Canyon springs, were sent to Dr. S. K. Wu at the University of Colorado for identification.

Surveying and Mapping

The perimeters of all primary habitat patches lying below the 1275 m^3/s stage (the "low zone") were surveyed in September, 1994 and March, June and September, 1995 (Figs. 2 A-D). The surveys were made with a total station/prism combination, with a mapping accuracy of $\pm$0.1 m. The Glen Canyon Environmental Studies (GCES) Geographical Information System (GIS) control network points (Arizona State Plane, Central Zone) were used for the instrument and backsight stations. This reference datum allowed accurate spatial referencing of the final map data, and provided suitable georeferencing for future monitoring.

A stage-to-discharge model was developed for the Colorado River at VP, based on the Bureau of Reclamation STARS hydraulic model (Randle and Pemberton 1988). The STARS computer program is a reach-averaged model that utilizes river cross-section geometry and channel slope as inputs. STARS cross-sections were surveyed at both ends of the pool immediately upstream of Vaseys Paradise, and at a natural constriction about 400 m downstream. STARS-predicted stage changes compared well with stage changes recorded at a nearby temporary U.S. Geological Survey streamflow monitoring station, located about 1.5 km upstream from the site. This close correlation allowed us to transfer STARS-predicted stages to the topography at the study site.

A triangulated irregular network (TIN) topographic model of the upper zone ($>$1275 m^3/s) of VP was produced using close-range oblique stereo-pair photographs collected in November, 1994 (Fig. 3). These photographs were

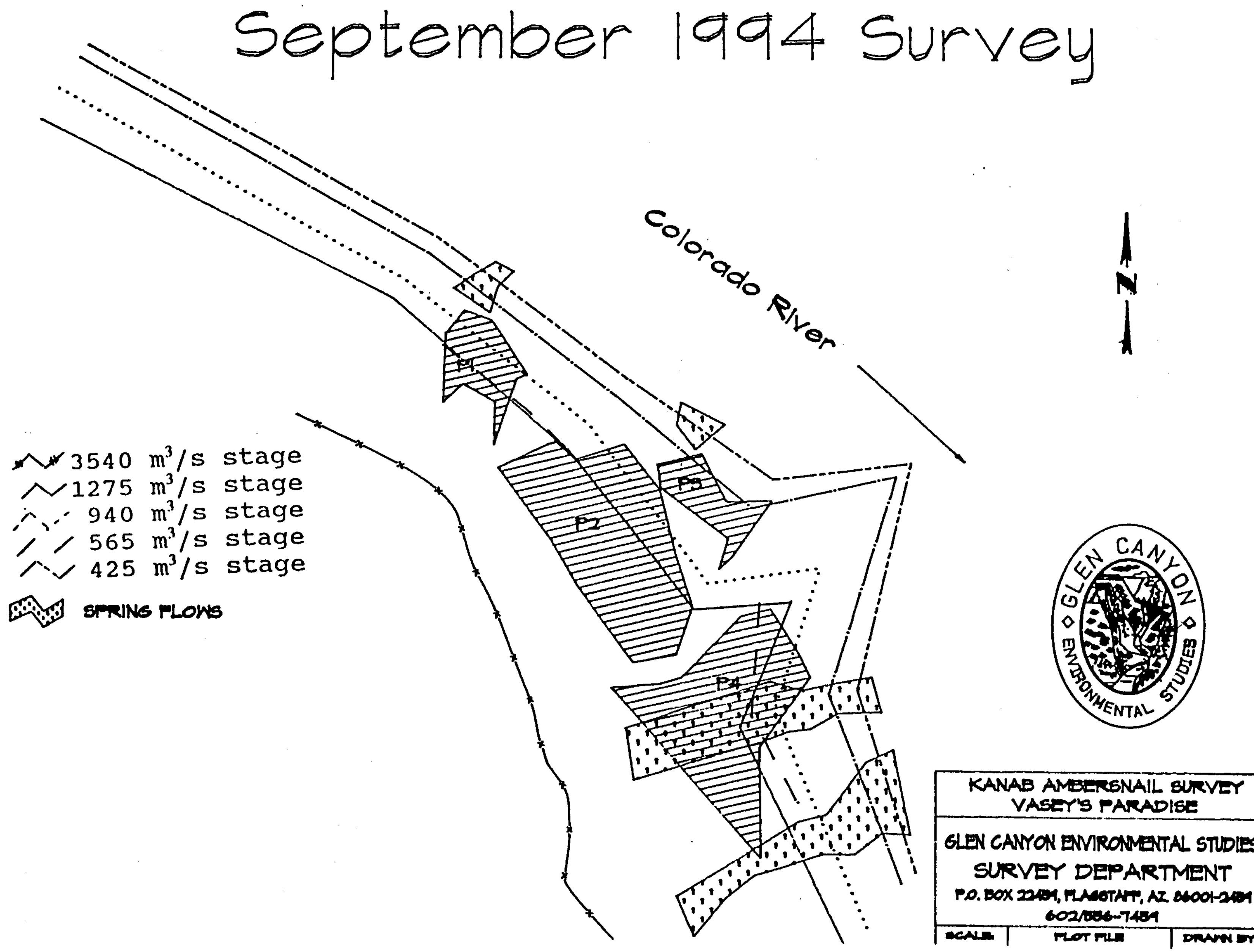

Figure 2A: Map of primary KAS habitat in the low zone (less than 1275 m^3/s) at Vaseys Paradise in September, 1994.

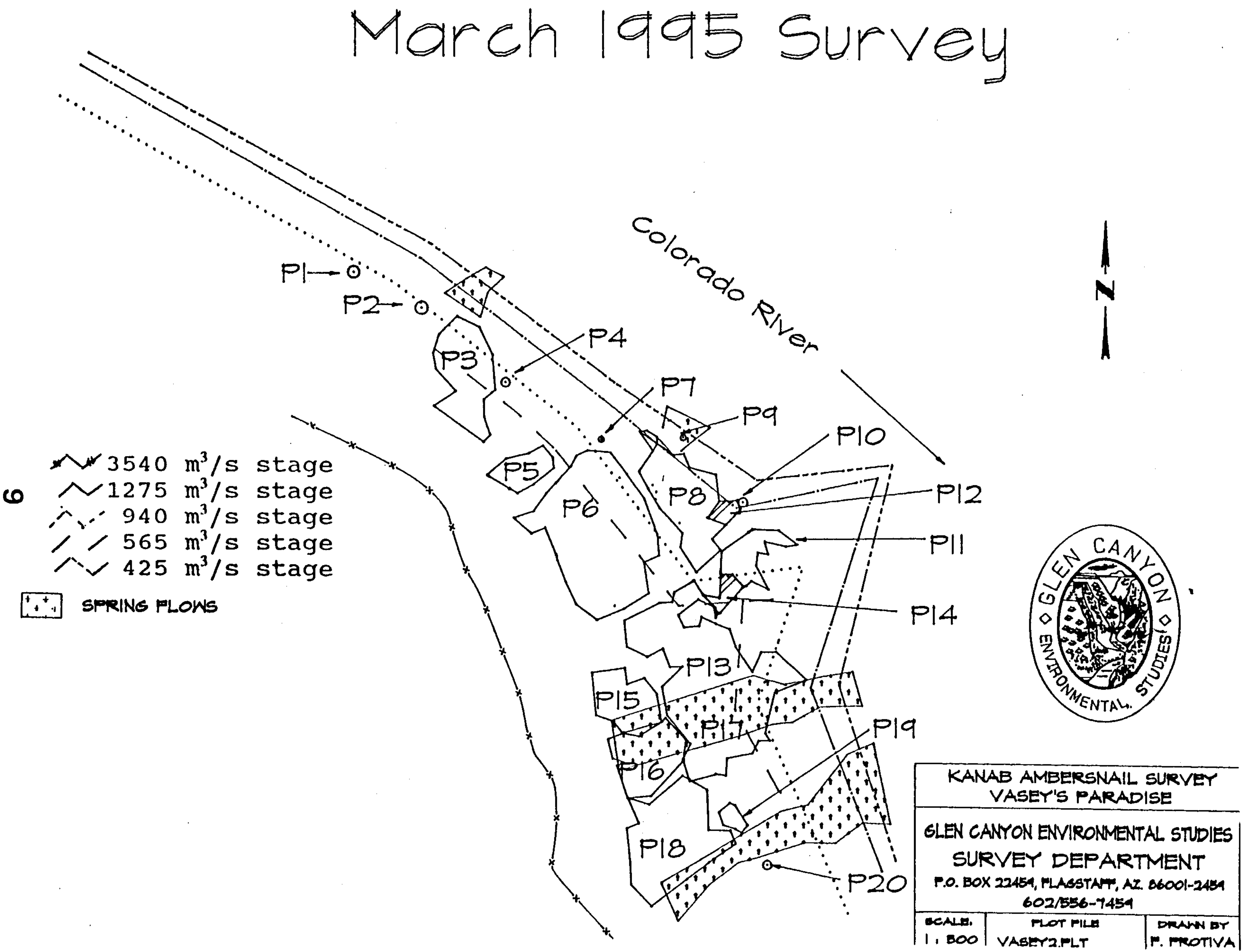

Figure 2B: Map of primary KAS habitat in the low zone (less than 1275 m^3/s) at Vaseys Paradise in March, 1995.

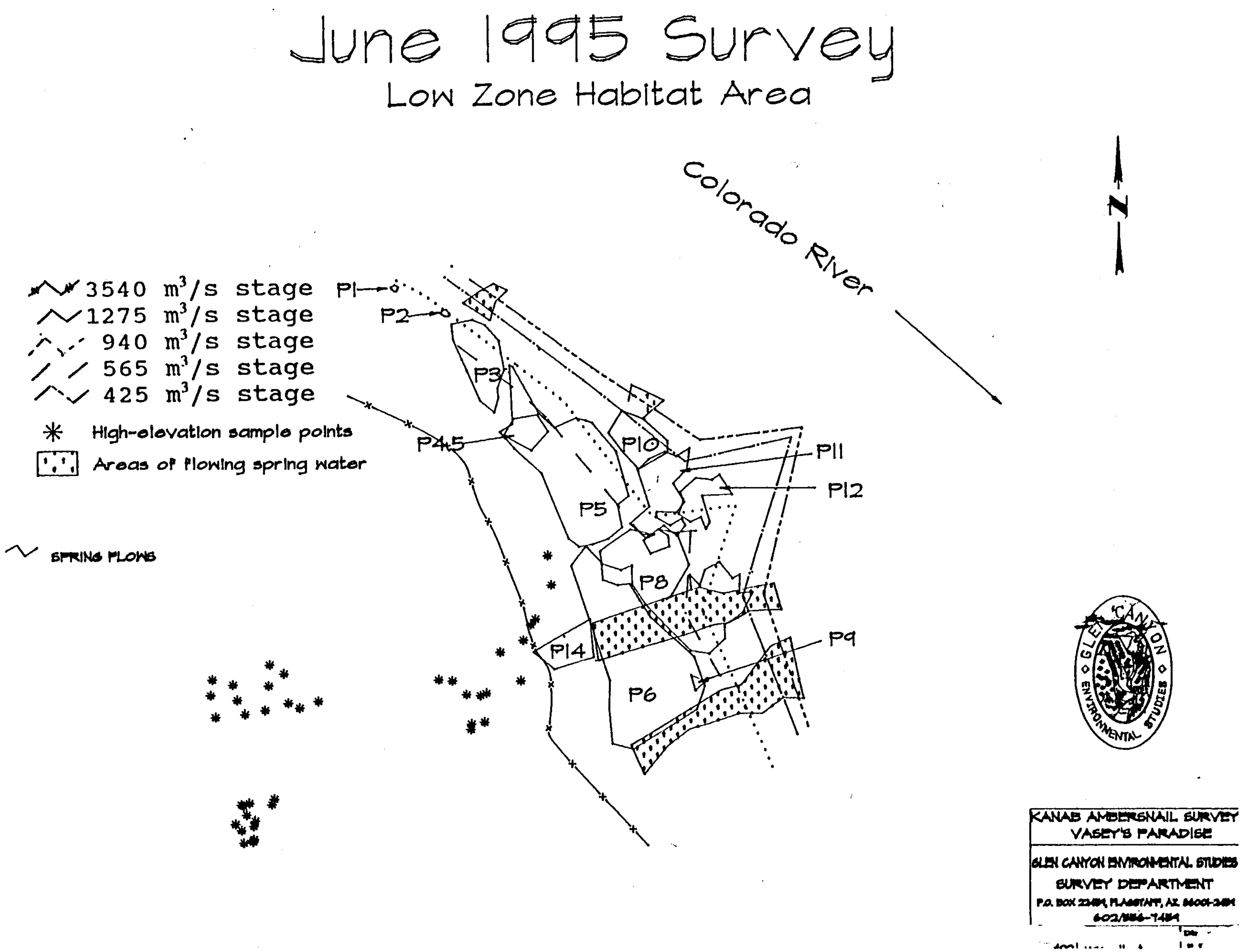

Figure 2C: Map of primary KAS habitat in the low zone (less than 1275 m^3/s) at Vaseys Paradise in June, 1995.

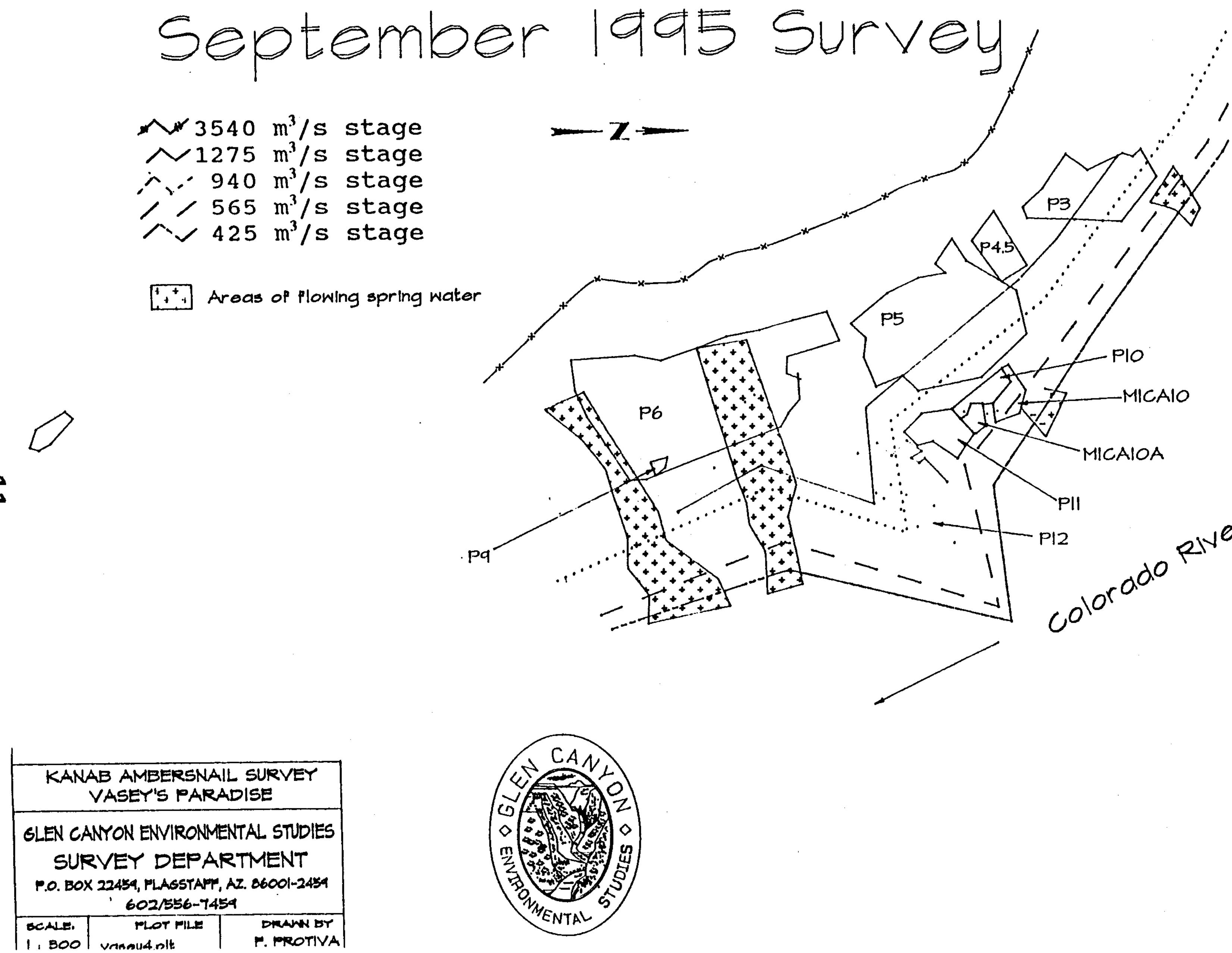

Figure 2D: Map of primary KAS habitat in the low zone (less than 1275 m^3/s) at Vaseys Paradise in September, 1995.

processed by the Bureau of Reclamation Remote Sensing Laboratory in Denver, Colorado, and tested against eight surveyed ground control points, including several collected by the climbers at the top pourouts. The estimated error associated with the high zone map is $\pm$0.5 m, corresponding to the GCES-GIS mapping accuracy standards. The STARS-generated stage-to-discharge model was then applied to these TIN models, allowing us to conduct an hypsometric analysis of the rectified area of primary KAS habitat in the "high zone" (above the 1275 m^3/s stage).

The vegetation of VP was mapped onto the photogrammetric and land-surveyed TIN model. Each vegetation patch (polygon) was mapped in the laboratory and then ground-truthed in the field. The percent cover of all plant species detected in each polygon was visually estimated, and binoculars were used to identify plant species in those patches which were not sampled (Fig. 3: Patches P through T). The vegetation designations were transferred to the GCES GIS for future monitoring.

Analyses

An hypsometric (stage versus area of inundation) analysis was conducted to determine potential loss of primary KAS habitat and individuals under a planned 1275 m^3/s release from Glen Canyon Dam, using the photogrammetric TIN model and the stage-to-discharge model using the GCES GIS. In this analysis the rectified areas of all primary KAS habitat lying below the 940 m^3/s stage (the maximum powerplant capacity discharge) were summed, as were those below the 1275 m^3/s stage near the maximum through-the-dam flow, and those lying above the 1275 m^3/s stage. In addition, the estimated area of vegetation lying below the pre-dam 10-year flood stage was calculated by surveying the pre-dam vegetation line at several locations at VP and summing habitat area below that stage.

KAS densities were estimated for the March, June, and September, 1995 sampling periods (Appendices). Total counts were used for habitat patches < 1.0 m^2. A bootstrapping method (Efron and Tibshirani 1993) was employed to provide confidence intervals for estimated KAS density from replicated 20-cm diameter plots in habitat patches > 1.0 m^2. The number of plots sampled from each large patch was resampled with replacement 20000 times, and the 5th and 95th percentiles of estimated numbers of KAS were derived from this procedure for each sampling period. Resampling was redundant in patches that were only sampled once; therefore, the total snail numbers in such patches were estimated using the single sample as a mean. Estimated patch totals, as well as the completely surveyed patches <1.0 m^2, were summed to derive a total low zone population estimate for each site visit.

KAS density was estimated in patches that were not sampled because of access difficulties (e.g., the 199.5 m^2 Mimulus Patch T, Fig. 3). Because live KAS occurred in high elevation patches and at the base of Patch T in June, 1995, KAS probably occurs throughout these high elevation Mimulus patches. In primary habitat patches above 1275 m^3/s that field crew were physically unable to reach, KAS density was estimated by applying the mean snail density for all samples in that vegetation type to the area of the unsampled patches. KAS population estimates were summed in small and large patches for each of the three stage zones. These total KAS population estimates are based on the assumption that primary habitat area above the 1275 m^3/s stage remained constant through the 1995 growing season, an assumption that can only be tested with further photogrammetric analysis. Also, this procedure homogenizes differences in KAS densities between the low and high zone patches, which may be important. Therefore, this procedure produces slightly different total KAS population estimates if the bootstrapped mean values from only the sampled high zone patches were used.

RESULTS AND DISCUSSION

Habitat Distribution

Primary habitat patches of Mimulus and Nasturtium exist throughout VP (Figs. 2, 3, 4; Appendix A). Hypsometric analysis of June, 1995 data revealed that 84.1 m^2 (9.3% of the total 905.8 m^2 of primary KAS habitat) existed below the 940 m^3/s stage, and 146.1 m^2 (16.1%) occurred below the 1275 m^3/s stage (Table 1; Fig. 4). A total of 759.6 m^2 (83.9%) of primary KAS habitat occurred above the 1275 m^3 stage elevation. A total of 395.0 m^2 of primary habitat (43.5% of the total) occurred below the 3540 m^3/s stage, the pre-dam 10-yr flood stage. The area of secondary (marginal) KAS habitat at VP in June was 882.4 m^2, and the total vegetated area of the spring was 1788.2 m^2.

Low zone (lying downslope from the 1275 m^3/s stage) primary habitat area expanded 1.4-fold from 86.1 m^2 in September, 1994 to 146.2 m^2 in June, 1995 (Table 1; Figs. 2A-C, Fig. 4). Although most plant species were deciduous at VP, the herbaceous Nasturtium did not freeze or die back, and was clearly visible as bright green vegetation on the oblique photography collected in late November, 1994 and on 15 February, 1995. Mimulus underwent some deciduous die-back, but also remained alive through the winter. Killing frosts may not have occurred at VP during the winter of 1994-1995, thereby permitting continued expansion of primary KAS habitat during the winter. Low zone primary habitat area was reduced to 105.5 m^2 in late summer, mainly by aestival die-back of Nasturtium and monsoon-related flood scour.

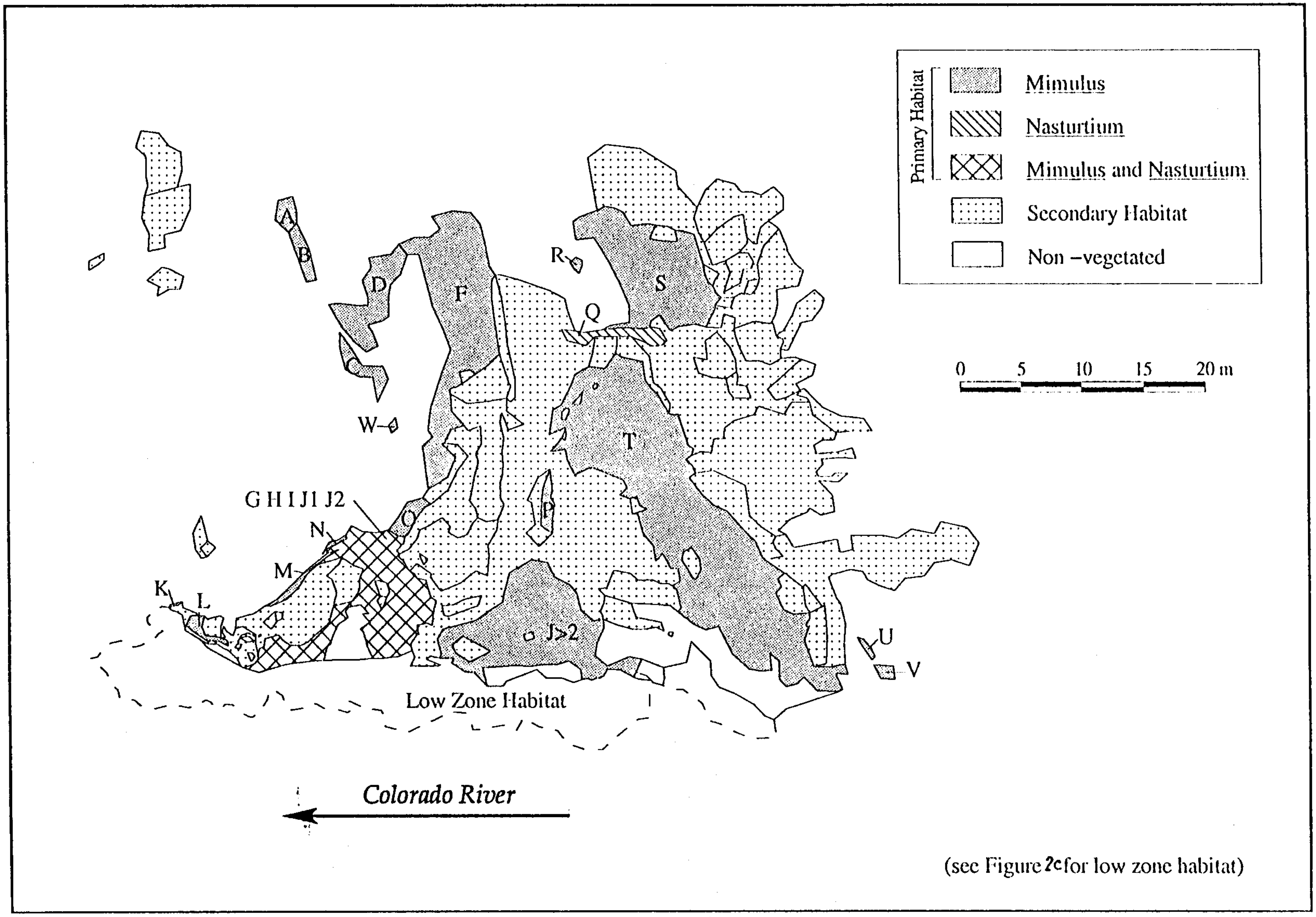

Figure 3: Primary and secondary (marginal) KAS habitat patches in the upper zone (greater than 1275 m^3/s stage) at Vaseys Paradise in November, 1994 (see Fig. 2C and Appendix A).

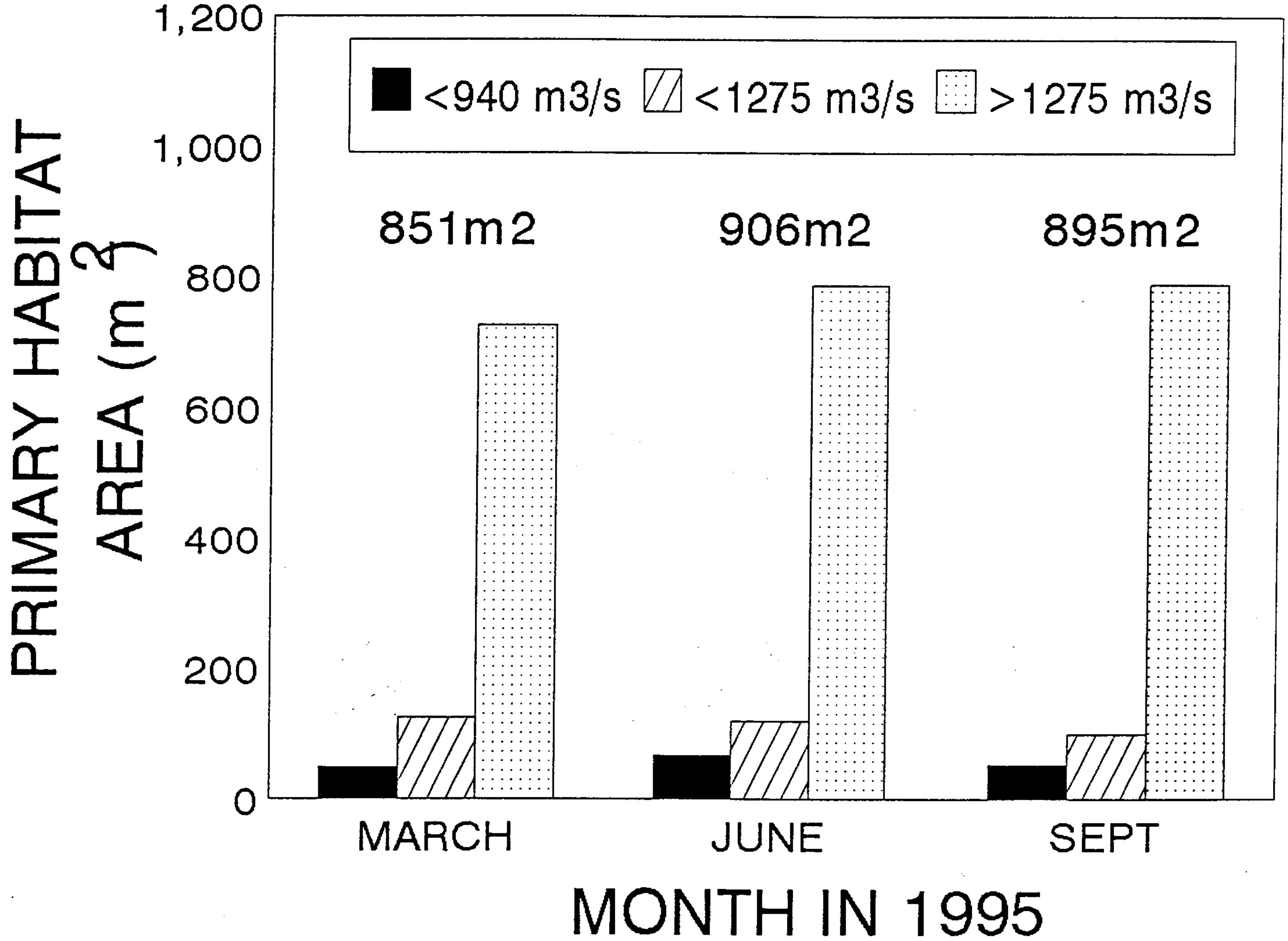

Figure 4: Primary KAS habitat area (m^2) in three stage zones at Vaseys Paradise, June, 1995. The slight differences in high zone habitat area reflects surveyed change above the 1275 m^3/s stage in patches 4 through 9 during the 1995 growing season.

Table 1: Summary of photogrammetric analyses and land surveys of potential KAS habitat in September 1994, March 1995 and June 1995 at three stage elevations at Vaseys Paradise, Grand Canyon National Park, Arizona (Fig. 4; Appendix A).

DATE	SURVEYED AREA Below 940m^3/s (m^2)	SURVEYED AREA Below 1275m^3/s (m^2)	PHOTOGRAMMETRIC AND SURVEYED AREA Above 1275m^{3}s (m^2)[a]	TOTAL HABITAT AREA (m^2)[a]
Sept., 1994[b]	41.3	86.0	---	---
March, 1995	49.3	125.1	726.1	851.2
June, 1995	84.1	146.2	759.6	905.8
Sept., 1995	52.8	105.5	789.6	895.1

[a] Estimated based on photogrammetric mapping from November, 1994, coupled with June, 1995 low zone land surveys. The slight increase in primary habitat lying below the 1275 m^3/s stage zone through the 1995 growing season was attributable to increases in topographic surveys conducted in that zone and not part of the photogrammetric analysis.

[b] An incomplete survey of total KAS habitat lying below the 1275 m^3/s stage.

KAS Distribution

The taxonomic identity of KAS and Catinella specimens was verified by Dr. S.K. Wu (written communication). KAS occurred in primary habitat patches across all sampled stage elevations above the 566 m^3/s stage at VP during all sampling periods (Table 2; Fig. 5; Appendix A). In June, 1995 the climbers reported numerous live KAS and shells from the large, nearly vertical Mimulus patch on the upstream side of the primary pourout (Fig. 3: Patch F), and from the large Mimulus and Nasturtium patch (Patch GHIJ12) directly downslope from the base of the middle pourout falls; however, KAS shells were rare and no live KAS were found in upper elevation Mimulus patches between the two downstream pourouts (Fig. 3: Patches A, B and C; Appendix A).

KAS commonly and consistently occurred on living and dead lower stems of Mimulus cardinalis, and living Nasturtium officinale stems and leaves throughout the period of study (Appendix A). KAS occurred rarely and irregularly in mixed Polygonum amphibium and Carex aquatilis patches, and very rarely in Adiantum capillus-veneris patches. Adiantum and Carex dominated only one (1.8%) of 55 plots containing live KAS in June, 1995. KAS were rarely encountered on other substrata. No live KAS were found in the upper elevation Petrophytum caespitosum, grass, mixed herb, nor in any Toxicodendron-dominated patches. No live KAS have been found thus far on Bromus wildenowii, Elymus canadensis, Agrostis stolonifera, Salix exigua, Solidago occidentalis, Toxicodendron rydbergii or

Table 2: Summary of KAS population analyses from March, 1995 to September, 1995 at three stage elevations at Vaseys Paradise, Grand Canyon National Park, Arizona (Fig. 5; Appendix A). Row totals may not sum because of overlap in the two low zones. This analysis is based on the assumption that high zone (above 1275 m^3/s) habitat area did not change in 1995.

DATE	ESTIMATED VP KAS POPULATION BELOW 940m^3/s STAGE	ESTIMATED VP KAS POPULATION BELOW 1275 m^3/s STAGE	ESTIMATED VP KAS POPULATION ABOVE 1275m^3s STAGE	TOTAL ESTIMATED VP KAS POPULATION
March, 1995	186	617	17983	18600
% of Total	(1.0)	(3.3)	(96.7)	(100)
June, 1995	1246	2275	17749	20024
% of Total	(6.2)	(11.4)	(88.6)	(100)
Sept., 1995	7564	17370	86634	104004
% of Total	(7.3)	(16.7)	(83.3)	(100)

Cercis occidentalis, plant species which are abundant at VP. KAS usually occurred near or at the water's edge, but not in subaqueous habitats, and no live KAS or shells have been found on the downriver side of the spring. Three (3.3%) live KAS were found on moist rock surfaces in June, 1995, and KAS on rock surfaces were rarely more than a few decimeters from primary vegetation.

Mean KAS density was greater on Nasturtium than on Mimulus during all surveys; however, the ratio of KAS grand mean density varied between the two primary host plant species over the growing season (Fig. 6). In March, 1995 mean KAS density on Mimulus was 31.9/m^2 (sd = 37.26/m^2, n = 17), and 45.3 (sd = 59.71, n = 12) snails/m^2 on Nasturtium, and not significantly different between the two plant species (Mann-Whitney U = 91.5, p = 0.623, df = 1). In June, 1995 mean KAS density on Mimulus was 16.06 (sd = 31.33, n = 39) snails/m^2, and 21.4 (sd = 30.54, n = 61) snails/m^2 on Nasturtium, again not significantly different between the two plant species (Mann-Whitney U = 2160.5, p = 0.08, df = 1). The ratio of mean KAS density on Nasturtium as compared to that on Mimulus was low, ranging from 1.3 to 1.4 in spring and early summer, 1995.

In contrast, KAS density varied strongly between the two host plant species during and after the peak of reproduction in middle to late summer (Fig. 6). In August, 1995 mean KAS density on Mimulus was 44.1 snails/m^2 (sd = 66.94, n = 13), significantly lower than the mean KAS density of 205.5 snails/m^2 (sd = 211.80, n = 11) on Nasturtium (Mann-Whitney U = 35.5, p = 0.03, df = 1). In September, 1995 mean KAS density on Mimulus rose to 84.9 snails/m^2 (sd = 134.14, n = 35), significantly lower than the mean KAS density of 356.8

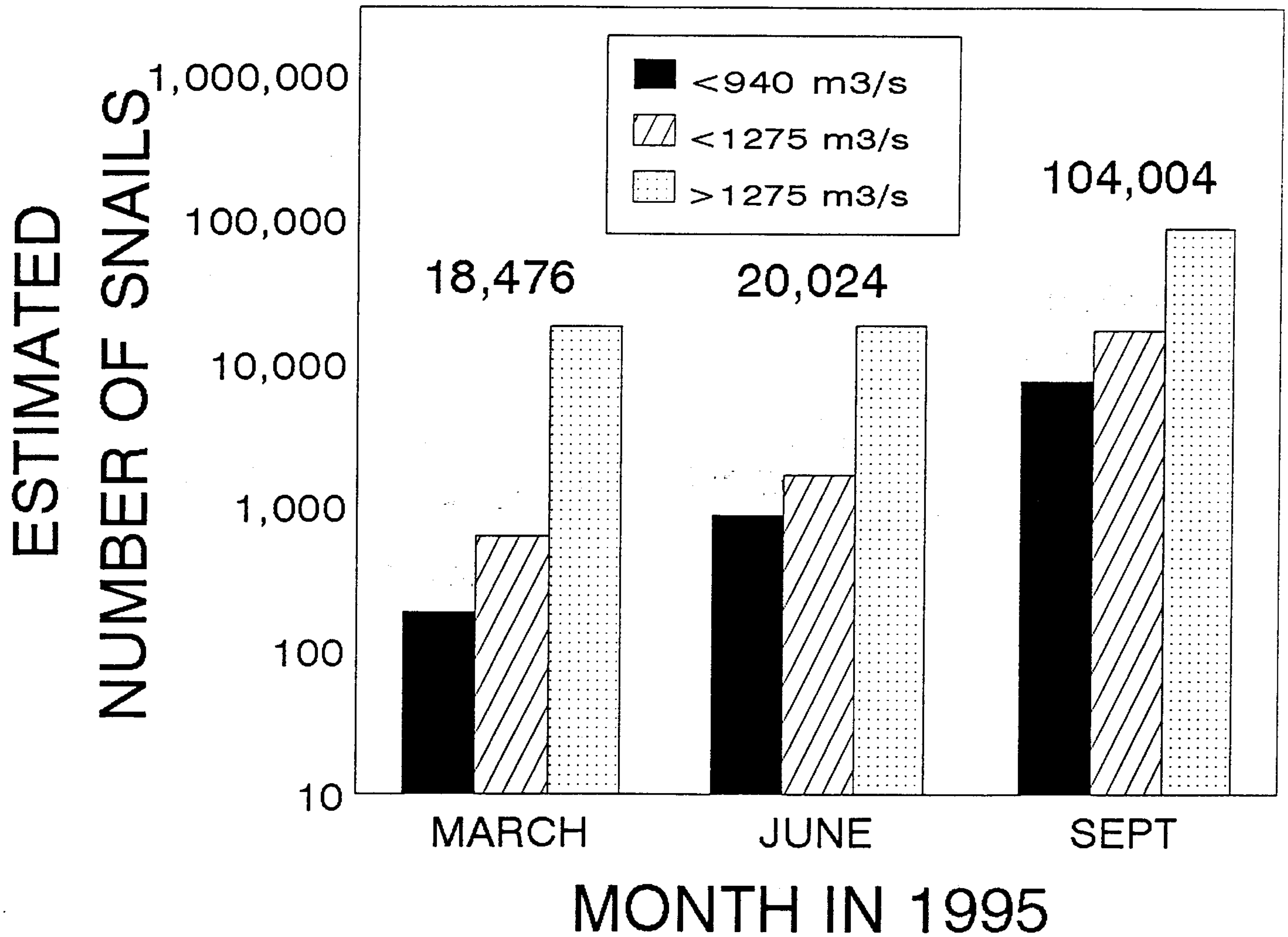

Figure 5: Estimated total number of KAS by stage zone in March, June and September, 1995.

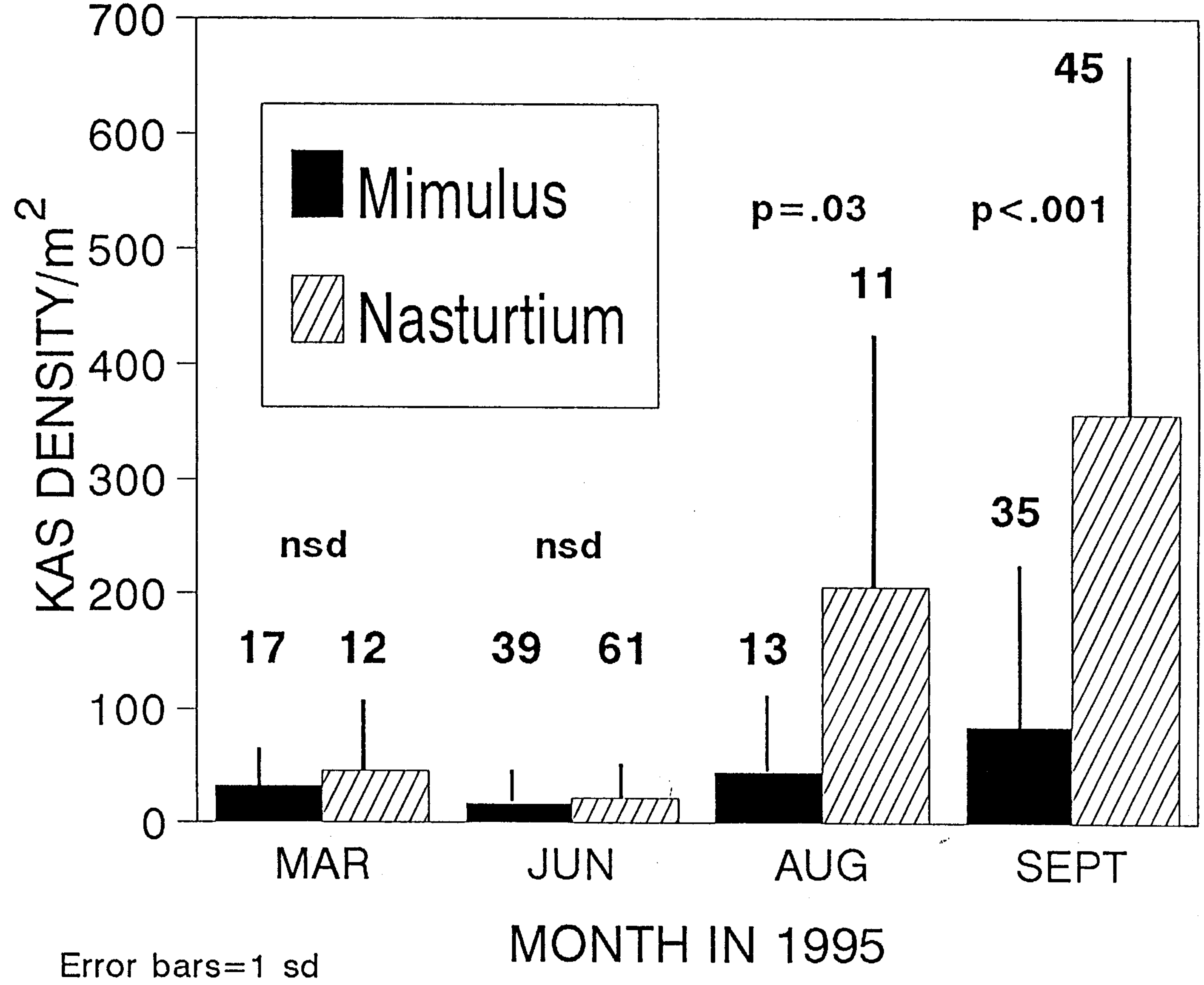

Figure 6: Mean KAS density on Mimulus and Nasturtium in March, June, August and September, 1995 at Vaseys Paradise, Grand Canyon, AZ. A Mann-Whitney U test was used to derive p values.

snails/m^2 (sd = 314.89, n = 45) on Nasturtium (Mann-Whitney U = 284.5, $p < 0.0001$, df = 1), with a grand mean KAS density in primary habitats of 207.6 snails/m^2. Thus, the ratio of mean KAS density on Nasturtium compared to Mimulus increased to 4.2 and 4.7 in late summer, 1995.

KAS Population Estimation

We compared estimated KAS abundance in the low zone (below the 1275 m^3/s stage) with the total estimated population through the growing season in 1995 at VP (Table 2; Fig. 5; Appendix A). An estimated 617 KAS (3.3%) of the 18600 total population occurred below the 1275 m^3/s stage zone on 30 March, 1995. Three (6.3%) of 48 KAS examined still retained mucosal plugs, indicating that the population was just completing emergence from winter dormancy at that time. An estimated 2275 (11.4%) of the total 20024 KAS occurred below the 1275 m^3/s stage on 10 June, 1995. Following the peak reproduction period, an estimated 17370 (16.7%) of the total 104004 KAS occurred below the 1275 m^3/s stage on 17 September, 1995 (Table 2; Fig. 5).

In September, 1995, lower densities of KAS were observed in high zone Patch GHIJ12 (mean = 91.6 snails/m^2) than in low zone surveyed patches (mean = 112.8 snails/m^2). If we had applied the bootstrapped KAS density of Patch GHIJ12 (derived from sampled plots), rather than the grand mean for all low zone Mimulus patches, to extrapolate total KAS abundance in all high zone Mimulus patches, the total September KAS population would have been estimated as 92764 snails, rather than the 104004 reported through extrapolation with the grand mean KAS density/m_2.

The 1995 data suggest that KAS undergoes large changes in population size, possibly through high winter mortality rates; however, if June to September proportions of KAS in the low zone and total habitat remain equivalent over the winter, an estimated 11.4% to 16.7% of the VP KAS population will be at risk during the planned 1275 m^3/s in spring, 1996.

Demography

Demographic analyses based on size class distribution indicated KAS to be an annual species (Fig. 7). The peak of KAS reproduction is in mid-summer (July and August), and KAS overwinters mostly as small size classes on rocks, litter and Mimulus stems, maturing in spring and early summer. In September, 1994, >95 % of the KAS observed were 2 to 5 mm in length, and empty shells of recently deceased mature individuals were numerous. In March, 1995, KAS lengths ranged from 2.0 to 11.0 mm, with a mean length of 7.1 mm (sd = 2.02 mm, n = 48). In June, KAS lengths ranged from 3.5 to 16.0 mm, with a mean length of 11.2 mm (sd = 2.36 mm, n = 90). On 13 August, KAS lengths ranged from 1.0

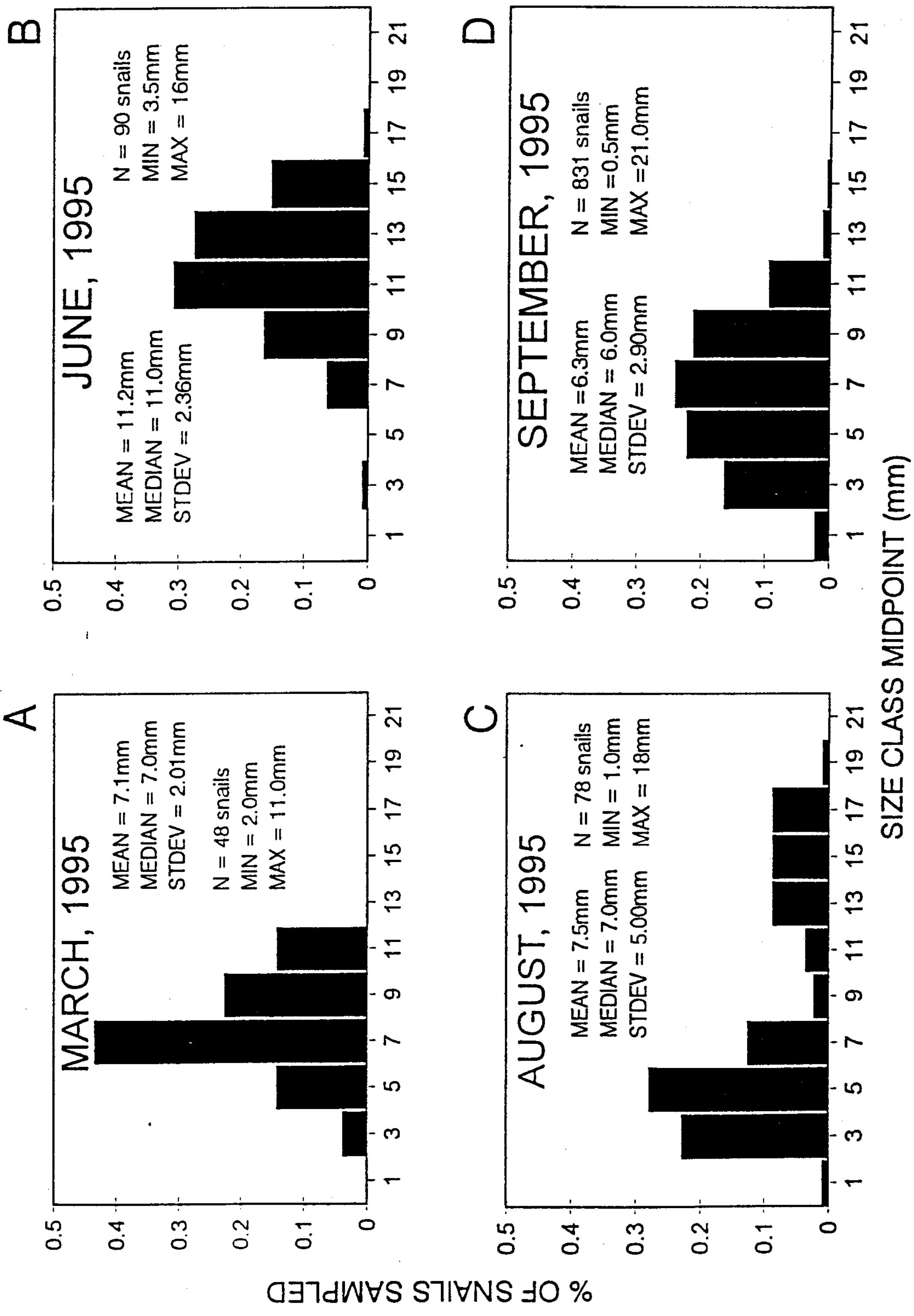

Figure 7: KAS shell length (size class) histograms at Vaseys Paradise in A) March, B) June, C) August and D) September, 1995.

to 18.0 mm, with a mean of 7.5 mm (sd = 5.00 mm, n = 78). On 17 September, KAS lengths ranged from 0.5 to 21.0 mm and mean size had decreased to 6.3 mm (sd = 2.90 mm, n = 831).

Loose, gelatinous egg masses were observed draped on the undersides of moist to wet live stems, or on the moist root mats, of Nasturtium, and dead or decadent stems of Mimulus in August, 1995. KAS were abundant on those plots containing egg masses and other snail species were rare or absent, therefore the egg masses were, in all likelihood, those of KAS. Egg masses contained 5-25 eggs/mass that were approximately 0.7 mm in diameter. The mean egg mass density/m^2 was 5.2 (sd = 11.895, n = 37 plots) and 5.3/m^2 (sd = 15.005, n = 24) on 8 and 13 August, respectively, in low zone habitat patches. No data on the egg development or on emergence success were found.

Other Vaseys Paradise Invertebrates

KAS shares VP habitats with several other molluscs, including the succineids, Catinella vermeta and C. sp. Mature Catinella are considerably smaller than KAS and have a distinctive whorl pattern, as compared to KAS (Fig. 8). Physella sp(p). are common up to the base of the Redwall Formation cliff in subaqueous and saturated habitats. The terrestrial limacid slug, Deroceras laeve, is widely distributed at VP. Hawaiia miniscula was also observed in Adiantum capillus-veneris litter above the 3550 m^3/s stage. Figure 8 may provide easier field identification of KAS and other succineid species' shells at VP for future studies.

VP KAS are parasitized by the trematode, Leucochloridium cyanocitttae, at VP (Paul Lewis, personal communication). Four of 42 (9.5%) and 3 of 36 (8.3%) mature ($\geq$13 mm) KAS examined on 8 and 13 August, 1995, respectively, expressed trematode sporocysts. Visibly infested snails contained one or two pink and green- or brown-banded sporocysts measuring approximately 10 mm long by 2.5 mm wide. The sporocysts were clearly visible, moving around inside the snail and pulsating up into the eyestalks at approximately 2 s intervals. At least 9 of the other 33 mature snails examined on 13 August had damaged eyestalks, and appeared sluggish and senescent. If these KAS were parasitized, but not expressing sporocysts when observed, $\geq$25% of the VP KAS population may be parasitized by this trematode. Only one of 831 KAS expressed sporocysts on 17 September, 1995; however, very few KAS $\geq$13 mm occurred that late in the season.

Parasite body masses were large in relation to the body mass of the infested snails, and parasitized snails occurred in both Mimulus and Nasturtium patches. Three parasitized KAS were collected on 13 August, 1995, employing the same techniques as in the initial collections in June, 1995. One of the parasitized snails was dissected.

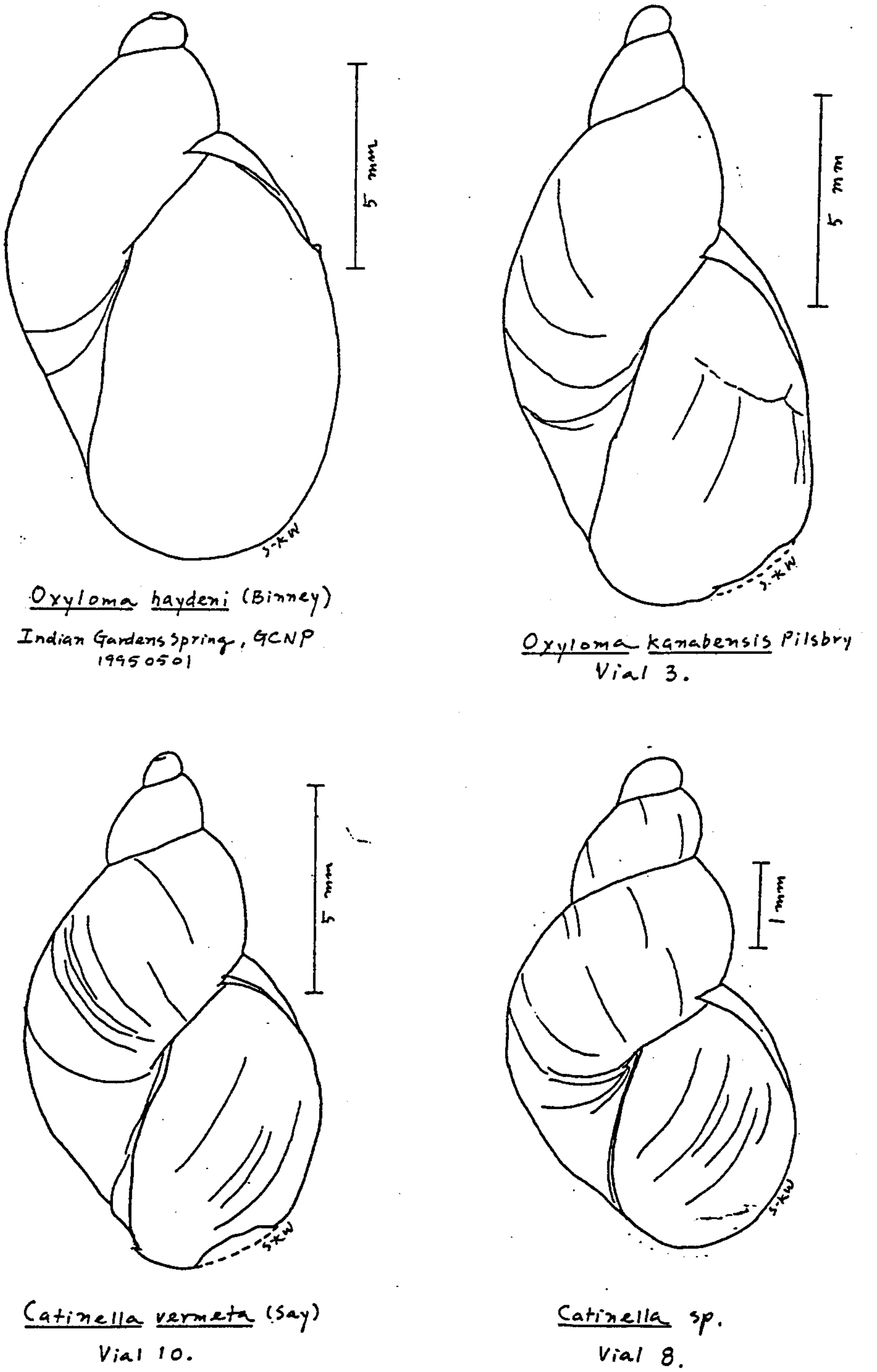

Figure 8: Taxonomic detail of Oxyloma haydeni kanabensis, O. haydeni, Catinella vermeta and C. sp.

The literature on the biology of platyhelminthine parasites that use Mollusca as first intermediate hosts was examined, and this trematode has a typically complex life cycle.

> *"The life cycle of the genus Leucochloridium is especially adapted to infestation of many kinds of passerine definitive hosts. The molluscan first intermediate host is always a marsh-living Succinea species...The miracidium develops within the mollusc into a much-branched sporocyst within which tailless cercariae are formed. These encyst within the sporocyst and each metacercaria can be seen to be surrounded by a thick protein coat. The metacercaria-filled sporocysts become very large, up to 12 mm in length, and pulsate rhythmically; their walls are striped with alternating red and green or brown bands, giving them the appearance of small caterpillars.*
>
> *At this stage the sporocysts penetrate a tentacle of the mollusc which they dilate and cause to pulsate. When the mollusc moves on to a leaf the movements of the tentacles and their pronounced colour attract birds. The tip of the tentacle usually only has to be touched, either by the leaf or by the bird's beak, for the sporocyst to break out and creep around on the leaf, where it is eaten by the bird. A single parasitized mollusc can product [sic] sporocysts containing metacercariae for a considerable time and can thus be a source of infestation for many birds."* (Baer 1971)

Baer also indicated that trematodes are sufficiently plastic in development that no definitive host may be required for successful completion of the life cycle. Therefore, avian definitive hosts may not necessarily be involved in the KAS - Leucochloridium interaction.

KAS Distribution at Other Grand Canyon Springs

Review of the literature and examination of 81 other Grand Canyon springs from 1991 to 1995 revealed no additional KAS populations in Grand Canyon (Table 3). Although at least six species of snails were found at these sites, KAS was only found at VP. Many of these springs appear to have suitable Mimulus and/or Nasturtium habitats (e.g. Upper and Lower Deer Creek springs); however, KAS in the Grand Canyon appears to be restricted to VP.

Oxyloma haydeni was observed and collected from the Indian Gardens Campground spring in 1995. This is the first population of O. haydeni known from Arizona. The O. haydeni population occurred on stems of Typha sp. and Nasturtium sp. in a small spring that emerges in the middle of the upper (overnight) campsite area, flows through the day-use picnic area, and past the mule corrals. The O. haydeni population remained small (approximately several hundred individuals) throughout the 1995 growing season in this approximately 100 m^2 habitat (Petterson, personal observation).

Catinella vermeta was observed in several riverside marshes in Marble Canyon (i.e., 37.5L, 51.5L, 55.5R). C. vermeta occurred on the undersides of driftwood and in decaying organic matter at these newly developing marshes. These observations demonstrate a novel ecological linkage in this regulated river ecosystem, as fluvial marshes have developed as new post-dam habitats (Stevens et al. 1995) that are being colonized by native Mollusca.

Table 3: Spring sites examined for KAS in Grand Canyon, 1994-95. Springs in the Little Colorado River drainage upstream from the confluence were investigated by Mr. Dennis Stone, FWS, Flagstaff, AZ.

SITE (RIVER KM AND SIDE)	SNAIL SPECIES OBSERVED
-13.5L	None
-0.8R	None
Paria River mouth (H. Yard)	Pupillidae (P)
41.8R Cave Springs	None
48.3L	None
48.3R	None
Skull Cave Seep (50.8R)	None
Vaseys Paradise (51.2R)	KAS, Catinella (C, 2spp), Physella sp.(Ph), Deroceras (D), Hawaiia(H)
51.3R Spring	None
55.5R	C
55.6R	None
55.7R	None
60.3L Mainstream Marsh	C
62.6R	None
62.8R	None
74.0R	None
Saddle Canyon (75.6R)	C
76.4R	C
80.1R	C
82.7L Mainstream Marsh	C
Nankoweap Cyn seep	None
Nankoweap Big Spring	None
Kwagunt Mainstream Marsh(89.3R)	C
Little Colo. R. Mouth (98.1L)	None
Blue Springs and 7 other LCR springs from Blue Springs to to ca. km 14.75 upstream from the LCR mouth	None
111.0R	None
112.6R seep (x 3)	None
113.4L seep	None
Hance Spring (123.9R)	C
136.8R	None
Phantom Ranch Typha marsh(141.6R)	Ph
Upper Roaring Springs	C
Transept Canyon Spring (BA Cr.)	H?

Table 3 (continued)

SITE (RIVER KM AND SIDE)	SNAIL SPECIES OBSERVED
Lower Ribbon Falls (BA Cr.)	C
Pipe Cr. spring	C?
Indian Gardens (Up.Garden Cr.)	Oxyloma haydeni
Hermit Canyon seep (152.9L)	None
Santa Maria Spring (Hermit Cyn)	None
Turquoise Canyon seep (160.9L)	None
Shinumo Creek (175.4R)	C
Elves Chasm (186.6L)	C
201.1L	None
Thunder River (214R)	C, Cionella lubrica, Discus cronkhitei, Glyphyalinia indentata, Zonitoides arboreus, D, Oreohelix strigosa, Sonorella coloradoensis
Deer Creek Spring (218.9R)	C
Lower Deer Spring (219R)	C,Ph
222R	None
224L	None
225L	Ph
228R	None
238R	C,H
Havasu Creek (252.6L)	Ph
267.9R	H
Fern Glen seeps (270.3) x 3	None
274.3L seep	None
275.1 seep	None
Mohawk Big Spring	None
Lower Honga Spring (286.4L)	None
Lava Well (288.8L)	None
Lower Lava Spring (288.9L)	None
294.4L Seep	None
312.3L Mainstream Marsh	None
Spring Canyon	H
329.0R Spring	None
330.6R Spring	C,Ph
341.1R Spring	None
Three Springs (346.7L)	None
T/S Spring(Peach Springs Wsh)x2	None
Travertine Cyn (368.5L)	None
395.8L Spring	None
Clay Tank Cyn (400.6L)	Ph

CONCLUSIONS AND MANAGEMENT CONSIDERATIONS

At present the VP KAS population appears to be relatively large and self-sustaining; however, KAS is restricted to wetland vegetation at VP, and especially native Mimulus and non-native Nasturtium. Although numerous, pristine springs in Grand Canyon support apparently suitable stands of Mimulus and Nasturtium, KAS was not found elsewhere in Grand Canyon. The disjunct distribution of this taxon is apparently an example of post-Pleistocene habitat isolation, which has generated relatively high levels of endemism among the biota of hanging gardens, springs and seeps throughout the Southwest.

Human activities have influenced VP KAS by affecting the composition and distribution of host plant species. Colonization of VP by non-native Nasturtium offinale has provided KAS with an important alternate host plant. The temporal development of Nasturtium populations at VP has not been studied, but it has increased in cover, as has that of Toxicodendron rydbergii, over the past 20 years (Stevens, personal observation). Construction of Glen Canyon Dam increased low zone vegetation at VP (Turner and Karpiscak 1980: 58-59), which has undoubtedly allowed the KAS population size to increase. More than 40% of the present primary KAS habitat at VP lies downslope from the pre-dam 10-year flood stage of 3540 m^3/s, and most of this is new, post-dam habitat.

Managing agencies responsible for the preservation of VP KAS require a cost-effective, low-impact monitoring program. A lead agency should be identified and that agency should be responsible for coordinating the training of field staff, conducting field work, maintenance of a long-term database, and annually reporting to the other agencies with management responsibility on the status of KAS. The following data appear to be needed for this effort: 1) annual photogrammetric analysis of primary habitat patch distribution; 2) collection of water flow and quality data on a seasonal basis; and 3) seasonal estimation of KAS density and habitat area in low zone habitat patches (e.g., April, early August, October, and mid-winter), including detailed surveying of patch areas. The extreme vertical relief of VP and profuse growth of poison-ivy (Toxicodendron rydbergii) renders on-the-ground monitoring nearly impossible above the 2800 m^3/s stage. The delicate stem architecture of the host plant species, and the possible confusion of KAS with Catinella spp. (particularly among small size classes) suggests that monitoring should be accomplished by no more than two or three carefully trained personnel.

Additional data are needed for successful recovery of KAS and for improved ecosystem management of the Colorado River. 1) An improved and verified stage to discharge relationship is needed for VP. 2) Data are needed on physical (e.g., slope aspect), water quality and dietary factors that may limit the successful establishment of secondary KAS populations. 3) KAS apparently has an annual life

cycle, and this hypothesis should be tested though a mark and recapture study.
4) Historic vegetation change at VP should be documented more thoroughly.
5) Interactions between VP KAS fecundity and trematode parasitism, and identification of the definitive host (if any exists), require further investigation.
6) Lastly, examination of the genetic constitution and variability of VP KAS, Three Lakes KAS, and other Oxyloma species may provide insight into KAS history and recovery. Unfortunately few data exist on the ecology of other succineid species, rendering comparative analyses difficult.

Construction of a detailed VP KAS population model would seem advantageous; however, several factors argue against this effort. KAS have remarkably specific habitat requirements (i.e., along the edges of rivulets on dead or decadent Mimulus stems or throughout the canopy of Nasturtium), but those habitat parameters change on short-term (daily) to long-term ($\geq$yearly) bases through variation in VP flow, mainstream flow, precipitation intensity and winter freezing events. These difficulties preclude a detailed habitat-based model, and argues for genetics research and a more general estimate of population size, using techniques similar to those employed in this study.

Although planned flooding is recommended for restoration of sandbars and aquatic riverine habitats in this river ecosystem (Bureau of Reclamation 1995), flows of 1275 m^3/s may result in the loss of up to 16.1% of the KAS habitat, and up to 16.4% of the KAS population. While both host plant species are faculative hydrophytes, their weak root structure may not withstand high flow velocities associated with high mainstream stages. During the pre-dam era, flows in excess of 1275 m^3/s were annual events and the KAS population recovered from innumerable similar and higher floods; however, flow regulation, the availability of rapidly changing habitat, and interactions with the trematode parasite may have altered the resiliency of the KAS population.

Alternatives for mitigation of planned high flow impacts on the VP KAS population include: 1) relocation of wintering KAS from the lower riparian zone to higher stage elevations; 2) removal of low zone KAS for establishment of secondary and/or captive breeding populations; 3) allowing modification of the KAS population occurring in the low zone; 4) prohibiting or reducing the magnitude of the proposed high flow event; or 5) other strategies. Agreement as to the most appropriate strategy can best be achieved through cooperative interagency discussion.

This report includes information only drawn from observations made during September 1994 through 1995. Additional insight into the biology of KAS and the role of Glen Canyon Dam operations on its habitat may improve understanding of this endangered species. Readers are advised to consult more recent reports for additional information.

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APPENDIX A

Appendix A: Oxyloma haydeni kanabensis primary habitat patch areas and bootstrapped or otherwise estimated density estimates on 30 March, 1995, 10 June and 17 September, 1995 at Vaseys Paradise. The "March ID" column represents patch identifier names that were standardized during June and September surveys. "DOMNT PATCH VEG" refers to the dominant vegetation cover within the patch: M - Mimulus, N - Nasturtium, Mix - mixed patches of Carex, Polygonum and other species. Bootstrapping was conducted using 20,000 replications to estimate the mean.

31 MARCH, 1995

PATCH ID	MARCH ID	DOMNT PATCH VEG	HABITAT PRIMARY VEGETATION AREA (m^2) <940 m^3/s	<1275 m^3/s	>1275 m^3/s	TOTAL	KAS POPULATION ESTIMATED KAS DENSITY/m^2 <940 m^3/s	<1275 m^3/s	>1275 m^3/s	TOTAL
1	1	MIX	0.0	0.5	0.0	0.5	0	0	0	0
2	2	MIX	0.1	0.6	0.0	0.6	0	0	0	0
3	3	M	3.5	12.9	18.6	31.5	98	361	518	880
4	4	MIX	0.0	0.3	0.0	0.3	0	2	0	2
4.5	5	M	0.0	0.0	11.0	11.0	0	0	350	350
5.1	6	M	4.9	21.5	50.4	71.9	6	26	61	88
5.2	-	N	-	-	-	-	-	-	-	-
6.1	15	M	0.0	0.0	16.0	16.0	0	0	447	447
6.2	16	N	0.0	0.0	19.6	19.6	0	0	978	978
6.3	18	MIX	0.0	0.0	37.2	37.2	0	0	40	40
7	17	N	0.0	38.9	0.0	38.9	0	124	124	249
7.5	7	M	0.1	0.1	0.0	0.1	0	0	0	0
8	13	M	3.3	9.2	29.8	38.9	11	31	102	134
9	19	N	0.0	0.0	2.7	2.7	0	0	20	20
10.1	8	M	26.0	26.0	0.0	26.0	61	61	0	61
10.2	-	N	-	-	-	-	-	-	-	-
10.5	9	M	0.1	0.1	0.0	0.1	4	4	0	4
11	10	N	0.3	0.3	0.0	0.3	0	0	0	0
11.5	12	MIX	2.4	2.4	0.0	2.4	0	0	0	0
12	11	MIX	8.4	9.8	0.0	9.8	7	8	0	8
12	14	MIX	0.2	2.6	0.4	2.9	0	0	0	0
20	20	M	0.0	0.0	0.3	0.3	0	0	0	0
22	22	A	0.0	0.0	1.0	1.0	0	0	0	0
A	101	M	0.0	0.0	3.7	3.7	0	0	0	0
B	102	M	0.0	0.0	4.7	4.7	0	0	0	0
C	103	M	0.0	0.0	6.1	6.1	0	0	0	0
DE	1045	M	0.0	0.0	20.9	20.9	0	0	584	584
F	106	M	0.0	0.0	77.5	77.5	0	0	2164	2164
GHIJ	107	MN	0.0	0.0	62.6	62.6	0	0	2274	2274
J3-8	108	M	0.0	0.0	73.5	73.5	0	0	2053	2053
OTHERM	991	M	0.0	0.0	282.9	282.9	0	0	7901	7901
OTHERN	992	N	0.0	0.0	7.3	7.3	0	0	368	368

PATCH ID	MARCH ID	DOMNT PATCH VEG	HABITAT PRIMARY VEGETATION AREA (m^2) <940 m^3/s	<1275 m^3/s	>1275 m^3/s	TOTAL	KAS POPULATION ESTIMATED KAS DENSITY/m^2 <940 m^3/s	<1275 m^3/s	>1275 m^3/s	TOTAL
10 JUNE, 1995										
1		MIX	0.0	0.0	0.5	0.5	0	0	0	0
2		MIX	0.0	0.0	0.5	0.5	0	0	6	6
3		M	3.8	16.5	13.2	29.7	68	294	235	529
4		MIX	0.0	0.0	0.4	0.4	0	0	0	0
4.5		M	0.0	0.0	10.3	10.3	0	0	208	208
5.1		M	4.6	23.5	64.0	87.4	66	339	926	1265
5.2		N	-	-	-	-	-	-	-	-
6.1		M	0.0	0.0	111.7	111.7	0	0	2910	2910
6.2		N	-	-	-	-	-	-	-	-
6.3		MIX	-	-	-	-	-	-	-	-
7		N	16.5	27.8	12.5	40.3	376	633	285	918
7.5		M	-	-	-	-	-	-	-	-
8		M	16.4	27.4	5.1	32.5	362	605	112	717
9		N	0.0	0.0	0.8	0.8	0	0	40	40
10.1		M	16.1	16.1	0.0	16.1	281	281	0	281
10.2		N	-	-	-	-	-	-	-	-
10.5		M	-	-	-	-	-	-	-	-
11		N	18.1	23.8	0.4	24.2	93	122	2	124
11.5		MIX	-	-	-	-	-	-	-	-
12		MIX	8.4	10.7	0.0	10.7	0	0	0	0
12		MIX	0.2	0.0	0.0	0.2	0	0	0	0
20		M	0.0	0.3	0.0	0.3	0	0	0	0
22		A	0.0	0.0	1.0	1.0	0	0	0	0
A		M	0.0	0.0	3.7	3.7	0	0	0	0
B		M	0.0	0.0	4.7	4.7	0	0	0	0
C		M	0.0	0.0	6.1	6.1	0	0	0	0
DE		M	0.0	0.0	20.9	20.9	0	0	0	0
F		M	0.0	0.0	77.5	77.5	0	0	1893	1893
GHIJ		MN	0.0	0.0	62.6	62.6	0	0	2001	2001
J3-8		M	0.0	0.0	73.5	73.5	0	0	2363	2362
OTHERM		M	0.0	0.0	282.9	282.9	0	0	6668	6668
OTHERN		N	0.0	0.0	7.3	7.3	0	0	101	101

PATCH ID	MARCH ID	DOMNT PATCH VEG	HABITAT PRIMARY VEGETATION AREA (m^2) <940 m^3/s	<1275 m^3/s	>1275 m^3/s	TOTAL	KAS POPULATION ESTIMATED KAS DENSITY/m^2 <940 m^3/s	<1275 m^3/s	>1275 m^3/s	TOTAL
17 SEPTEMBER, 1995										
1		MIX	0.0	0.6	0.0	0.6	0	1	0	1
2		MIX	0.0	1.1	0.0	1.1	0	0	0	0
3		M	4.9	16.6	20.6	37.2	583	1976	2452	4428
4		MIX	0.0	0.4	0.0	0.4	0	19	0	19
4.5		M	0.0	0.0	8.2	8.2	0	0	715	715
5.1		M	7.7	26.6	49.8	76.4	1749	6061	11340	17401
5.2		N	0.0	0.0	9.0	9.0	0	0	4944	4944
6.1		M	0.0	0.0	77.8	77.8	0	0	1685	1685
6.2		N	0.0	0.0	33.4	33.4	0	0	7165	7165
6.3		MIX	-	-	-	-	-	-	-	-
7		N	4.4	14.2	15.3	29.5	1609	5215	5633	10848
7.5		M	1.4	0.0	0.0	1.4	124	0	0	124
8		M	0.0	5.2	33.7	38.9	0	426	2785	3211
9		N	0.0	0.0	0.7	0.7	0	0	657	657
10.1		M	6.7	6.7	0.0	6.7	279	279	0	279
10.2		N	4.5	0.0	0.0	4.5	228	0	0	228
10.5		M	-	-	-	-	-	-	-	
11		N	8.9	8.9	0.0	8.9	2844	2844	0	2844
11.5		MIX	-	-	-	-	-	-	-	-
12		MIX	14.3	18.9	0.5	19.4	150	198	5	204
12		MIX	0.2	0.0	0.0	0.2	0	0	0	0
20		M	0.0	0.3	0.0	0.3	0	0	0	0
22		A	0.0	0.0	1.0	1.0	0	0	0	0
A		M	-	-	-	-	-	-	-	0
B		M	-	-	-	-	-	-	-	0
C		M	-	-	-	-	-	-	-	0
DE		M	-	-	-	-	-	-	-	0
F		M	-	-	-	-	-	-	-	0
GHIJ		MN	0.0	0.0	62.6	62.6	0	0	5737	5737
J3-8		M	-	-	-	-	-	-	-	-
OTHERM		M	0.0	0.0	469.6	469.6	0	0	41070	41070
OTHERN		N	0.0	0.0	7.3	7.3	0	0	2446	2446