THE ENDANGERED KANAB AMBERSNAIL AT VASEYS PARADISE,

GRAND CANYON, ARIZONA:

1997 FINAL REPORT

Prepared by

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for

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EXECUTIVE SUMMARY

Introduction

The Kanab ambersnail (KAS; *Oxyloma haydeni kanabensis* Pilsbry), is a federally endangered landsnail with extant populations at two springs in the southwestern United States (Pilsbry and Ferris 1911, Pilsbry 1948, Spamer and Bogan 1993). One of these, the Vaseys Paradise (VP) population, is protected under the auspices of the National Park Service at Grand Canyon National Park. This cool, dolomitic spring pours from the sheer Mississippi Redwall Limestone cliff at Mile 32, and forms several small rivulets as it flows 100 m to the Colorado River. Lush wetland vegetation around the spring provides habitat for KAS, and the snail primarily occurs on four plant species: native crimson monkeyflower (*Mimulus cardinalis*), water sedge (*Carex aquatilis*), smartweed (*Polygonum amphibium*), and non-native watercress (*Nasturtium officinale)*. The KAS habitat at VP has increased by approximately 40% because of flood control on the Colorado River brought about by Glen Canyon Dam. However, high flows from the dam may scour this new KAS habitat, resulting in unacceptable levels of take.

The U.S. Fish and Wildlife Service (USFWS) Recovery Plan (1995) for KAS states that 10 additional KAS populations are to be discovered or established before the species can be downlisted or delisted. The 1996 USFWS Biological Opinion states that at least one of those populations must occur in Arizona before additional planned floods above powerplant capacity can be released from Glen Canyon Dam for ecosystem management downstream. In addition, that Biological Opinion requires that KAS habitat be monitored before and after, and six months after, any flows above 708 m^3/s (25,000 cfs), the maximum discharge level specified in the Glen Canyon Dam Environmental Impact Statement (1995).

The VP KAS habitat has been monitored since the fall of 1994, and the population has been monitored since March 1995, and particularly in relation to the planned test flow in March-April, 1996 (Stevens et al. 1997a and b, unpublished) by the interagency Kanab Ambersnail Monitoring Team. The KAS population and habitat at Vaseys Paradise was reduced by the 1996 test flow, but the population in the zone downslope from the 1275 m^3/s (45,000 cfs) stage increased by mid-summer 1996 to a size near the previous year's level.

Objectives

This document describes the results of cooperative interagency monitoring of VP KAS habitat and population in 1997. Continued monitoring of the VP population is providing important background information on the ecology, habitat use, natural range of population change, demography, and the role of predators, competitors and parasites. This information will be useful for river management in that it may indicate ways of reducing take of KAS during ecosystem management experiments, such as planned flooding.

Our specific objectives were to:

1. Monitor habitat development and continuing habitat recovery from the 1996 Bureau of Reclamation beach habitat building flow ("test flow").

2. Monitor KAS population density changes in the low zone [stage elevations ≤ ca. 1700 m^3/s (70,000 cfs)] on a bi-monthly basis through the 1997 growing season.
3. Determine whether upper stage zone KAS densities are comparable with those in the low zone.
4. Monitor population densities of potentially competing invertebrate species.
5. Monitor rodent densities at VP.
6. Monitor the frequency of *Leucochloridium cyanocittae* parasitism.
7. Provide administrative assistance for Arizona Game and Fish Department (AGFD) and USFWS recovery efforts.

In addition, this monitoring effort presents data on the impacts of three exceptional flows (>708 m^3/s) that occurred in 1997.

Results

KAS Habitat Conditions: KAS primary habitat in the 1996 flood (1275 m^3/s) zone increased through the 1997 growing season, reaching levels near the 1995 condition by late summer 1997. These data indicate that more than two years recovery period is necessary for recovery of KAS habitat following a 1275 m^3/s flow. Variation in recovery time among primary host plant species (especially crimson monkeyflower and watercress) is also partially attributable to the perennial versus annual life cycles of these plant species, respectively.

KAS Population Dynamics: The KAS population in the 1996 flood zone increased to 1995 levels by May 1997, and remained comparable to the 1995 levels throughout the 1997 summer and autumn. As with the habitat data, these data indicate that at least 2 yr are required for recovery of this population following a 1275 m^3/s flow; however, these KAS population estimates are based on mean values, and the variation around those mean values is often substantial, potentially affecting conclusions presented here regarding recovery rates. KAS are approximately annual in their life cycle, and only a single reproduction period was indicated by size class distribution data in 1997. The 1997 reproduction cycle was also comparable to that in 1995.

Eight of 50 snails (16%) were dormant in 17-18 March; dormancy was 0 of 118 and 155 during the May and August population surveys, respectively, and increased to 21 of 320 (6.6%) snails on 3-4 October 1997.

KAS occurred in equal abundance on monkeyflower, watercress and other host plant species (e.g., water sedge, horsetail and smartweed) in March (Kruskall-Wallis U=4.842, p = 0.089, n = 116 cases, df = 2) and May (KW U = 2.452, p = 0.293, n = 146 cases, df = 2), but were significantly more abundant on watercress in August (KW U = 25.6, p < 0.001, n = 99 cases, df = 2) and October (KW U = 25.829, p < 0.001, n = 119 cases, df = 2).

One KAS was accidentally killed by being stepped on during a survey at VP. This is the first case of accidental take we have observed. Two other (parasitized) KAS and 15 live eggs were collected and preserved by AGFD in August 1997.

Stage Elevation Effects: KAS are distributed across the stage elevation gradient at VP, and we monitored density in three stage zones: the stage zone lying downslope from the 1275 m^3/s stage, that lying between the 1275 m^3/s and 2000 m^3/s stages, and the zone lying above the 2000 m^3/s stage. KAS density/20 cm plot did not vary significantly among the three stage elevations at VP in 1997 (Kruskall-Wallis $p > 0.052$, $df = 2$). This finding indicates that KAS density was equivalent across stage elevation in 1997.

Potential Competitors: We have not observed any interaction between KAS and the other six common molluscs at VP. However, we are analyzing the distribution of other mollusc species at Vaseys Paradise in order to determine whether any relationship exists between KAS and other assemblage members at VP. Despite the occasionally great abundance of molluscs, such as the slug, *Deroceras laeve*, the likelihood of any strong, negative biological interaction is low.

VP Rodent Densities: *Peromyscus crinitus* was the only rodent species trapped at Vaseys Paradise in 1997, although a single immature *P. maniculatus* was observed in October. Rodent trapping success varied from 4.1% to 13.6%. Trapping success was approximately equivalent from February through May (10% to 13.6%), and then decreased to 8.3% in August and to 4.1% in October. Decreasing trapping success through the growing season was not related to estimated KAS population size (linear regression $F = 0.023$, $p = 0.889$, $df = 1,3$). This pattern does not support the hypothesis that mice are density dependent predators of KAS; however, more data are required over time to assess this potential interaction.

Flatworm Parasitism: A total of 4 of 65 (6.2%) of mature KAS (> 10 mm) were observed during the 2-3 August 1997 site visit with *L. cyanocittae* sporocysts. This frequency of parasitism is less than the 8.3-9.5% observed in 1995, but considerably more than the <1% observed in 1996 (Stevens et al. 1997a and 1997b). This year's data suggests that *L. cyanocittae* is a persistent parasite in this snail population. Observation of parasitized KAS that had been collected by AGFD indicated that KAS are still capable of producing egg masses (J. Sorensen, AGFD, pers. comm.).

Administrative Assistance to Arizona Game and Fish Department for KAS Recovery: The Grand Canyon Monitoring and Research Center provided logistical and staff support for KAS monitoring in 1997. The GCMRC also supported AGFD and USFWS KAWG-related efforts by providing logistical support, flow and other information and document review, as well as by hosting some of the seasonal KAWG meetings. AGFD received logistical support from GCMRC for two river trips in 1997 (April and September) to evaluate 31 sites along the Colorado River corridor for potential establishment of secondary KAS populations.

Exceptional Flows: The USFWS Biological Opinion requires monitoring of KAS habitat before and after flows greater than those allowed by the Record of Decision. Three exceptional flow events occurred in 1997: February-March (765 m^3/s), June (765 m^3/s) and November (870 m^3/s).

KAS habitat and population impacts were assessed before, after and 6 months after the first two exceptional flows. The February-March high flows inundated, and somewhat scoured, several low-lying watercress patches. Little additional scour resulted from the June 1997 high flows; however, those flows and the combined mainstream and Paria River floods in August 1997 largely prevented recolonization of habitat patches downslope from the 765 m^3/s stage. The November high flow inundated a wider range of patches, and resulted in the loss of 4.3 m^2 (14.4%) of the remaining habitat lying downslope from the 870 m^3/s stage. Although much of the original habitat below that stage remained after the November high flow, it had been scoured or buried under new deposits of sand and driftwood.

INTRODUCTION

The Kanab ambersnail (KAS; *Oxyloma haydeni kanabensis* Pilsbry), is a federally endangered landsnail with extant populations at two springs in the southwestern United States (Pilsbry and Ferris 1911, Pilsbry 1948, Spamer and Bogan 1993). The Vaseys Paradise (VP) population is protected under the auspices of the National Park Service at Grand Canyon National Park. VP is a cool, dolomitic spring which pours from the sheer Mississippi Redwall Limestone and forms several small rivulets as it flows 100 m to the Colorado River. The vegetation around the spring forms a lush stand of wetland and riparian habitat and is distributed in relation to steep moisture gradients. KAS primarily occurs on native crimson monkeyflower (*Mimulus cardinalis*), water sedge (*Carex aquatilis*), and smartweed (*Polygonum amphibium*); and non-native watercress (*Nasturtium officinale).* KAS are rare or absent on other plant species or on other substrates during the growing season at VP (Stevens et al 1997a).

Monitoring of the VP KAS habitat and population has been conducted since fall, 1994, and particularly in relation to the planned test flow in March-April, 1996 (Stevens et al. 1997a and b, unpublished). Size class frequency analyses over the growing season show that KAS has an approximately annual life cycle. Young ambersnails overwinter on host plant stems, driftwood and rock surfaces, and emerge from winter dormancy in March, and reproduce from June through August. As demonstrated in the winter of 1995-1996, warmer winters may result in early emergence from dormancy and two bouts of reproduction. Mean densities of ambersnails/m^2 were greater on watercress than on native monkeyflower in the latter half of the growing season in both 1995 and 1996. The KAS population and habitat at Vaseys Paradise was reduced by the 1996 test flow, but overall low zone population levels increased to near the previous year's level by mid-summer 1996. *Peromyscus crinitis* and *P. maniculatus* may be density dependent predators on KAS at Vaseys Paradise. Parasitism by a rare native trematode, *Leucochloridium cyanocittae*, decreased from 8.5-8.9% in 1995 to approximately 1% in 1996. DNA studies of this and three other *Oxyloma* populations in the Grand Canyon region indicate that the VP KAS population is genetically distinct from the Three Lakes (Utah) and the *O.h. haydeni* populations in Glen and Grand canyons (Miller et al., in press).

The U.S. Fish and Wildlife Service (USFWS) Recovery Plan (1995) for KAS states that 10 additional KAS populations are to be discovered or established before the species can be downlisted or delisted. The 1995 USFWS Biological Opinion states that at least one of those populations must occur in Arizona before additional planned floods above powerplant capacity can be released from Glen Canyon Dam for ecosystem management purposes downstream. In addition, the 1996 USFWS Biological Opinion requires that KAS habitat be monitored before and after, and six months after, any flows above 25,000 cfs (the maximum discharge level specified in the 1996 Glen Canyon Dam Environmental Impact Statement Record of Decision.

To successfully establish secondary populations, continued monitoring of the VP population is needed to provide background information on the ecology, habitat use, natural range of population change, demography, and the role of predators, competitors and parasites. Experimental rearing of KAS on each host plant species has been funded by the Bureau of Reclamation, and these laboratory experiments should help improve understanding of growth rates and fecundity (Stevens and Nelson 1997, unpublished).

This document describes the cooperative interagency monitoring of VP KAS habitat and population in 1997. The objectives of this project were to:

1. Monitor habitat development and continuing habitat recovery from the 1996 Bureau of Reclamation test flow.
2. Monitor KAS population density changes in the low zone (stage elevations ≤ ca. 1700 m^3/s, 70,000 cfs) on a bi-monthly basis through the 1997 growing season.
3. Determine whether upper stage zone KAS densities are comparable with those in the low zone.
4. Monitor population densities of potentially competing invertebrate species.
5. Monitor rodent densities at VP.
6. Monitor the frequency of *Leucochloridium cyanocittae* parasitism.
7. Provide administrative assistance for Arizona Game and Fish Department (AGFD) and USFWS recovery efforts.

In addition, this monitoring report documents the impacts of three exceptional flows (>708 m^3/s) that occurred in 1997 on KAS habitat and, when possible, KAS population.

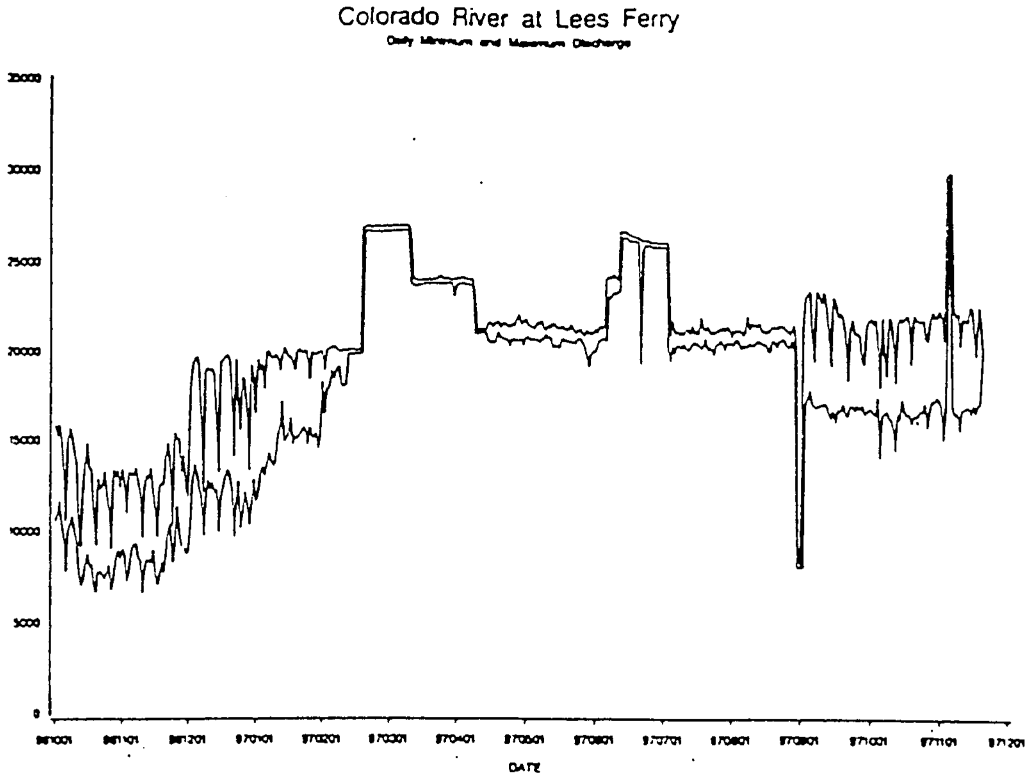
METHODS, RESULTS AND DISCUSSION BY OBJECTIVE

Study Area

VP is a cool-water, dilute dolomitic spring that issues from the Mooney Falls member of the Mississippian Redwall Limestone 0.4 mi (0.9 km) downriver from the mouth of South Canyon in Grand Canyon National Park, 31.5 mi (51 km) downstream from Lees Ferry, Arizona (Huntoon 1974). The spring issues at 3200 ft (925 m) elevation from three primary mouths and divides into several large, and numerous small, rivulets as it flows ca. 100 yd (90 m) m to the Colorado River. The climate is arid and continental, with a mean annual precipitation of 5.5 (140 mm) inches at Lees Ferry, the nearest weather station (Sellers et al. 1985). Precipitation is bimodally distributed between summer and winter. Temperatures at Lees Ferry range from <0°F in winter to >110°F in summer. Although the east-facing aspect of the spring allows it to thaw relatively quickly after freezing winter nights, Stevens (personal observation) noted that the spring was nearly completely frozen and covered with ice during freezes in early January 1975 and December 1990. Aspect also protects the spring site from hot, direct mid-afternoon sunlight during summer. VP lies in the U.S. Bureau of Reclamation Glen Canyon Environmental Studies Program's (GCES) Geographic Information System (GIS) Reach 3 and is therefore well georeferenced for long-term monitoring.

The Water Year 1997-98 Hydrograph

Water Year 1997 releases from Glen Canyon Dam included several exceptional flowevents from Glen Canyon Dam and from the Paria River (Figs. 1a and 1b). Anticipated high inflow into Lake Powell in January and February caused the Bureau of Reclamation to release constant flows of 27,000 cfs in March, and releases were increased to 27,000 cfs again in July.



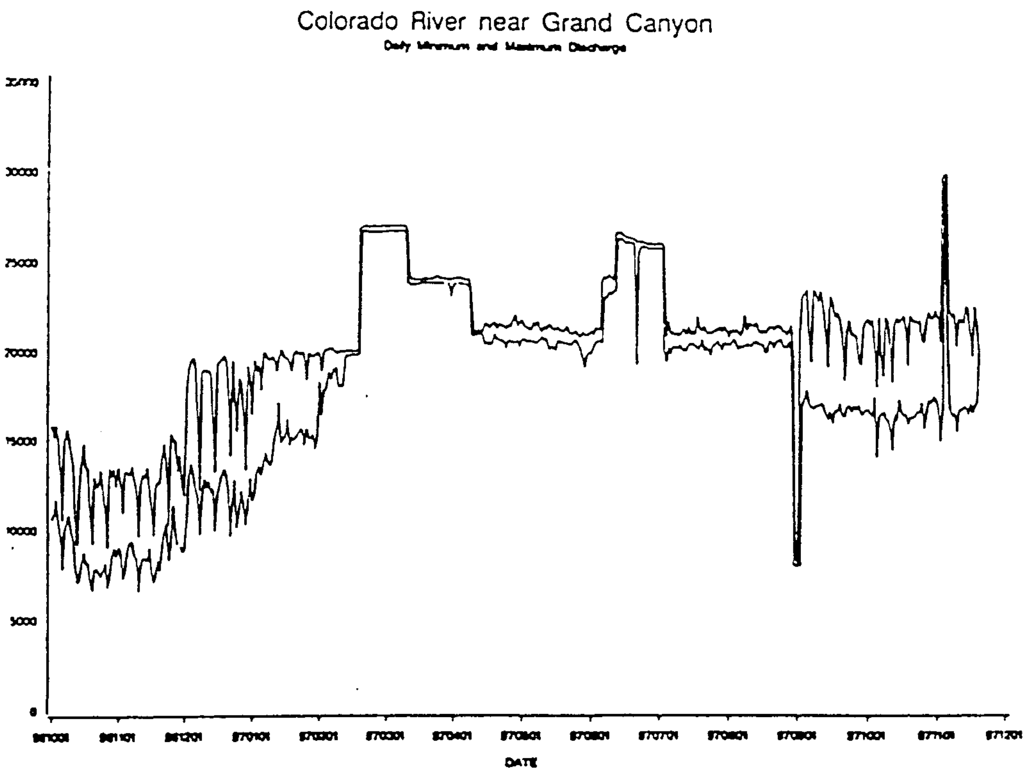


Figure 1: Water Year 1997 hydrograph from a) Lees Ferry and b) Grand Canyon near Phantom Ranch, Arizona.

At the beginning of Water Year 1998, high reservoir levels permitted the Bureau of Reclamation and the Grand Canyon Monitoring and Research Center to conduct a two-day 31,000 cfs Test Flow from 3-5 November 1997. These three high flows exceeded the ROD maximum flow of 25,000 cfs, and require pre-, post- and six-month post-event monitoring. In addition to the monitoring results for 1997, this report addresses those exceptional flow events. Also, the Paria River sustained several high flows from mid-August through September, at least one of which brought mainstream flows above 25,000 cfs, and those flows are also considered in this monitoring report.

Objective 1: Monitor KAS habitat.

Methods: Seasonal topographic surveys of KAS habitat patches at VP were conducted according to the methods of Stevens et al. (1997a and 1997b, unpublished), and on the schedule presented in Table 1. Patch areas were compared with previously collected data, beginning in March 1995.

The perimeters of all habitat patches lying downslope from the approximate 2000 m^3/s stage elevation (the "low zone" of Stevens et al. 1997a) were surveyed five times in 1997, with an additional partial survey on 9 November 1997. Detailed KAS population surveys were not conducted before mid-March or after mid-October, during the period of winter dormancy. Our population surveys in 1997 avoided the dormancy period, but captured the monitoring intervals recommended by the KAWG, and required by the USFWS Biological Opinions for the three exceptional flows that occurred in 1997.

Habitat surveys were conducted with a total station/prism combination, and mapping accuracy was consonant with the GCMRC survey protocol. The GCMRC GIS provided control network points (Arizona State Plane, Central Zone), which were used for instrument and backsight stations. This reference datum allowed accurate spatial referencing of map data, and provided suitable georeferencing for GIS analyses and future monitoring.

Surveyed elevation data were related to the stage-to-discharge model developed for the mainstream at VP, which was based on the Bureau of Reclamation STARS hydraulic model (Randle and Pemberton 1988) and on data reported in Stevens et al. (1997a and b, unpublished). A triangulated irregular network (TIN) topographic model of the low zone was produced for each topographic survey, allowing us to perform an hypsometric analysis of the rectified habitat patch area upslope and downslope from the 1275 m^3/s stage.

Patch composition, cover, substrate conditions, litter development, KAS number and maximum shell length, as well as the abundance of other mollusc species, were estimated or measured during each habitat and population survey. Increasing cover of poison ivy (*Toxicodendron rydbergii*) in Patch 6 limited assessment of patch size and composition there during middle and late summer.

Oblique photogrammetric images were collected in November 1997, and were compared with previous year's November images since 1994. Photographs were made from the top of the Redwall Limestone directly across the river from VP, a site which is accessible using the trail from Mile 30 (Fence Fault). Analysis of several high elevation patches was conducted from

Table 1: Trip dates and objectives for KAS habitat and population monitoring in 1997.

DATE	OBJECTIVES/ACTIVITY
15 February 1997	Pre-765 m^3/s flow habitat survey; rodent trapping.
17-18 March 1997	Spring 1997 KAS habitat and population monitoring; one-yr post-1996 1275 m^3/s Test Flow follow-up monitoring; and one-month post-February-March 1997 765 m^3/s flow monitoring; rodent trapping; oblique photogrammetry.
8 April 1997	Spot check of Vaseys Paradise (JAS)
15-16 May 1997	Spring 1997 monitoring; and pre-765 m^3/s June 1997 KAS habitat and population monitoring; rodent trapping.
24 June 1997	Spot check of VP by LES.
3-4 August 1997	Summer 1997 KAS habitat and population monitoring; 6-month post February-March 1997 765 m^3/s monitoring; and one-month post-June 1997 765 m^3/s flow monitoring; rodent trapping.
2-3 October 1997	Autumn 1997 KAS habitat and population monitoring, 6-month post February-March 1997 765 m^3/s monitoring; and one-month post-June 1997 765 m^3/s flow monitoring; rodent trapping.
29 October 1997	AGFD emergency KAS habitat and population rescue prior to planned 878 m^3/s Test Flow.
6-9 November 1997	Post-878 m^3/s Test Flow KAS habitat monitoring; oblique photogrammetry.

by planimetric mapping of vegetation polygons in relation to the photogrammetrically mapped polygons on the November 1994 photograph (Stevens et al. 1997a, unpublished). In addition, the photographs were visually appraised for gross vegetation change and site alteration.

Results and Discussion: The KAS habitat at VP was monitored in February, March, May, August and October in 1997, and a partial habitat survey was conducted in November 1997 (Tables 1-7; Figs.3-8).

The 15 February 1997 KAS habitat survey at VP revealed that patch areas had increased somewhat over the course of the 1996-1997 winter (Table 2; Fig. 2). This survey revealed a total of 88.46 m^2 of primary (monkeyflower, water sedge, and watercress) and secondary (horsetail and reed) KAS habitat downslope from the 1275 m^3/s stage, of which 23.87 m^2 was monkeyflower, 34.09 m^2 was watercress, and 30.5 m^2 was mixed, secondary habitat (Table 2). The relatively large amount of watercress habitat in February was largely comprised of newly emerged seedlings of this non-native annual species. The remaining area of low zone KAS habitat, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, consisted of a total of 199.05 m^2 of habitat, including 78.01m^2 of monkeyflower, 21.78 m^2 of watercress, and 99.26 m^2 of other habitat.

This site visit was used to assess the impacts of proposed constant 765 m^3/s flows, which occurred from mid-February to mid-March 1997. Given the "training" of VP vegetation by the 1996 Test Flow, and subsequent high flows in 1996, we had predicted some loss of KAS habitat or population in the area downslope from the 765 m^3/s stage zone during those flow events. Those predictions were supported by the March 1997 survey data.

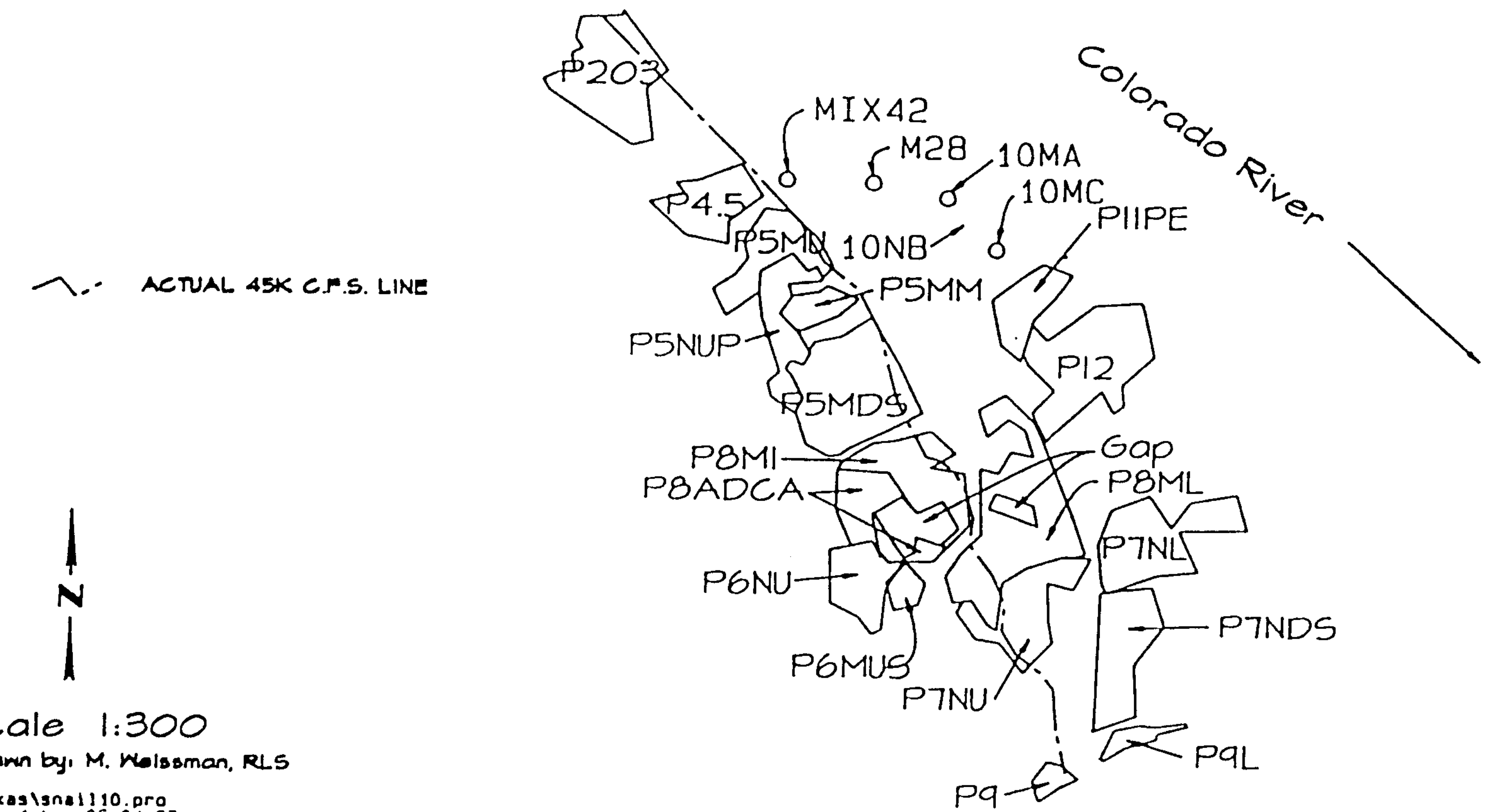
The 17-18 March 1997 KAS habitat survey and mapping effort at VP revealed a total of 57.13 m^2 of primary (monkeyflower, water sedge, and watercress) and secondary (horsetail and reed) KAS habitat downslope from the 1275 m^3/s stage, of which 16.67 m^2 was monkeyflower, 1.22 m^2 was watercress, and 39.24 m^2 was mixed, secondary habitat (Table 3, Fig. 3). The small amount of watercress habitat in March was attributed to the life cycle of this non-native annual species, which was largely in the seedling stage at that time. The remaining area of low zone KAS habitat, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, consisted of a total of 189.9 m^2 of habitat, including 77.61m^2 of monkeyflower, 18.38 m^2 of watercress, and - 93.91 m^2 of other habitat.

The March survey constituted a post-765 m^3/s flow site visit, and we determined that the predicted habitat patches had been inundated. Those high flows scoured away some seedling watercress in patches 7L, 9L and 7Fan, and inundated all of patches 10-12. Any snails occupying those patches were likely to have been swept away; however, KAS densities in that stage zone were low (Table 3).

The 15-16 May 1997 KAS habitat survey and mapping effort at VP revealed a total of 69.77 m^2 of KAS habitat downslope from the 1275 m^3/s stage, of which 22.85 m^2 was monkeyflower, 2.31 m^2 was watercress, and 44.61 m^2 was mixed, secondary habitat (Table 4, Fig. 4). The remaining area of the KAS habitat in the low zone, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, consisted of a total of 201.87 m^2 of habitat, including 84.78 m^2 of monkeyflower, 23 m^2 of watercress, and 94.09 m^2 of other habitat.

The 3-4 August 1997 KAS habitat survey and mapping effort at VP revealed a total of 86.87 m^2 of KAS habitat downslope from the 1275 m^3/s stage, of which 36.22 m^2 was monkeyflower, 25.42 m^2 was watercress, and 25.23 m^2 was mixed, secondary habitat (Table 5; Fig. 5). The remaining area of the KAS habitat in the low zone, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, consisted of a total of 197.35 m^2 of habitat, including 94.27 m^2 of monkeyflower, 21.27 m^2 of watercress, and 81.81 m^2 of other habitat.

KAS Monitoring
February 1997 Survey



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Drawn by: M. Weissman, RLS

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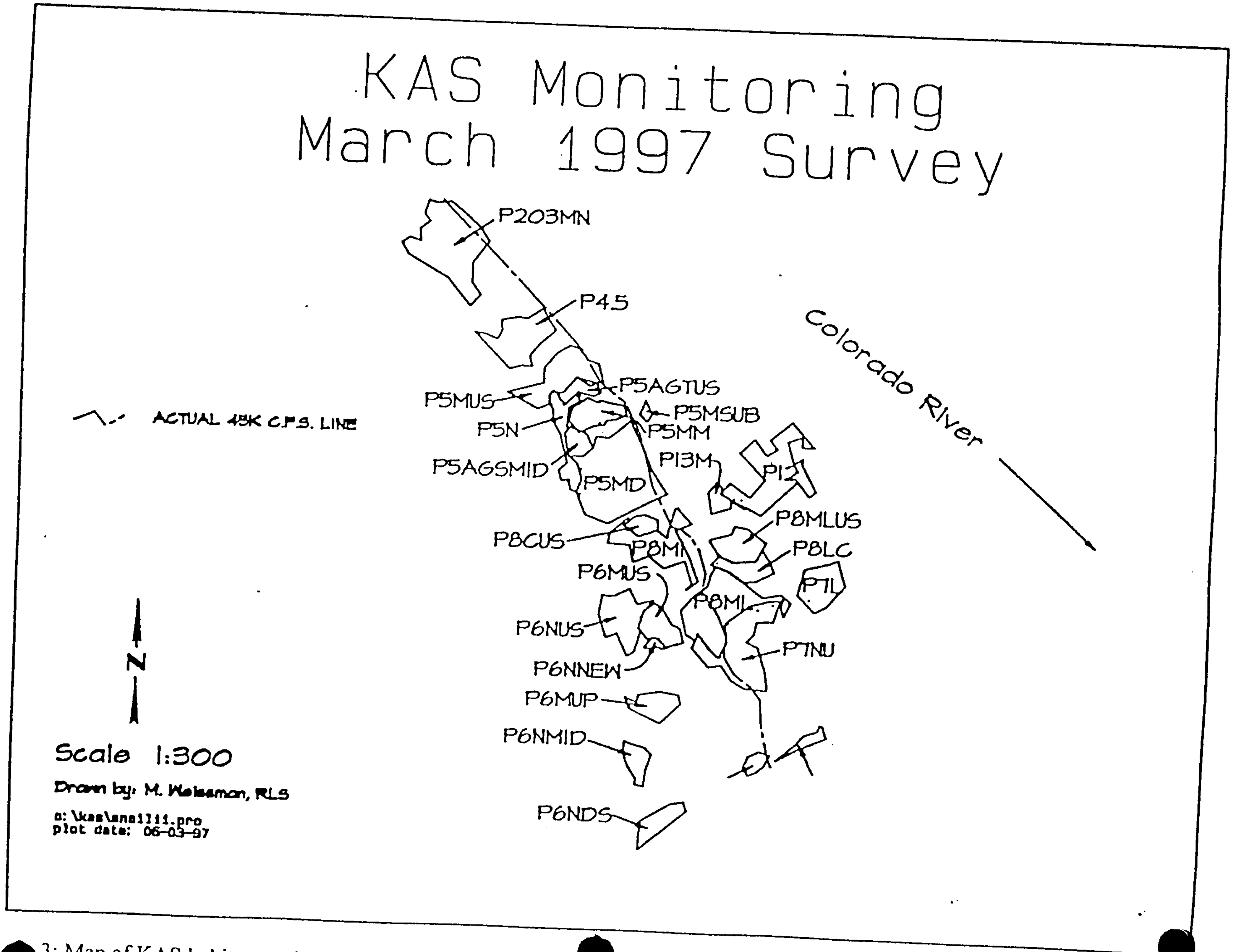
Table 2: Estimates of KAS habitat area above and below the 1275 m3/s stage, 15 February 1997.

Date	PatchID	Plant Sp.	Actual Area <1275 m3/s (m2)	Actual Area >45K (m2) (m2)	Actual Total Area (m2)
970217	P4.5	Mica*	0	10.82	10.82
970217	P5MM	Mica	0	3.59	3.59
970217	P5MD	Mica	1.76	18.01	19.77
970217	P5MU	Mica	0.59	9.51	10.1
970217	P5MSUB	Mica	0.096	0	0.096
970217	P6MUS	Mica	0	2.05	2.05
970217	P8ML	Mica	17.97	5.25	23.22
970217	P8MU	Mica	1.31	8.79	10.1
970217	P203	Mica	2.14	19.99	22.13
970217	P5N	Naof**	0	7.81	7.81
970217	P6NDS	Naof	0	1.9	1.9
970217	P6NM	Naof	0	1	1
970217	P6NU	Naof	0	6.85	6.85
970217	P7U	Naof	7.99	2.55	10.54
970217	P7L	Naof	13.45	0	13.45
970217	P7FAN	Naof	10.54	0	10.54
970217	P9	Naof	0.2	1.67	1.87
970217	P9L	Naof	1.81	0	1.81
970217	P10N	Naof	0.1	0	0.1
970217	P6POAM	Naof	0	0	0
970217	P6REM	Mix	7.59	90.73	98.32
970217	P8ADCA	Adca***	0	7.43	7.43
970217	P8C	Caaq****	0	1.1	1.1
970217	P11PE	Mix	5.66	0	5.66
970217	P12	Mix	17.12	0	17.12
970217	P42K	Mix	0.13	0	0.13
Subtotal	ALL	Mica	23.866	78.01	101.876
Subtotal	ALL	Naof	34.09	21.78	55.87
Subtotal	ALL	Other	30.5	99.26	129.76
TOTAL	ALL	All	88.456	199.05	287.506

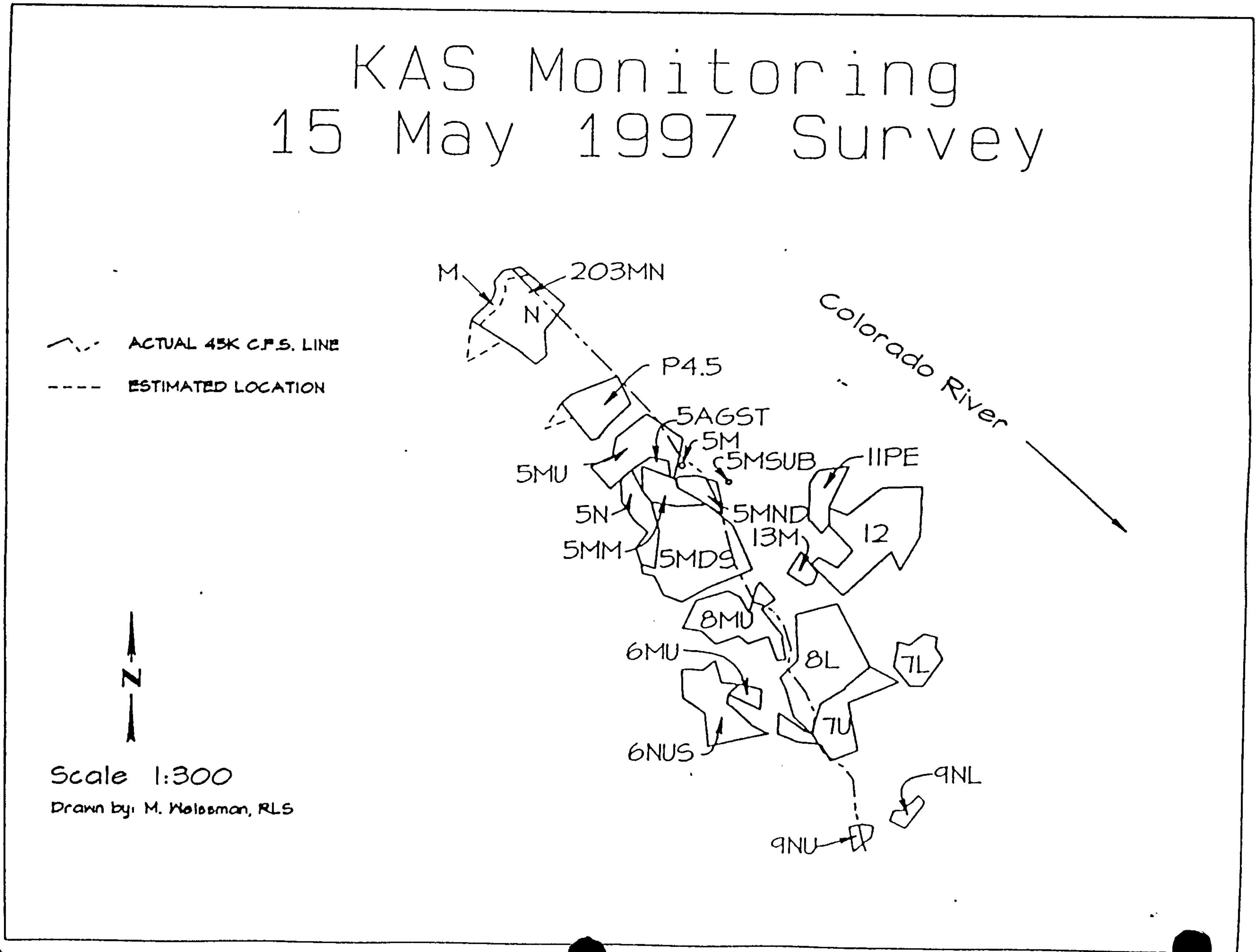
* Mica = Crimson monkeyflower (Mimulus cardinalis)
** Naof = Watercress (Nasturtium officinale)
*** Adca = Maidenhair fern (Adiantum capillus-veneris)
****Caaq = Water sedge (Carex aquatiilis)



Fi[illegible] 3: Map of KAS habitat patches lying downslope from the [illegible]000 m³/s stage at V[illegible]

Table 3: KAS habitat area and population estimates above and below the 1275 m3/s stage, 17-18 March 1997.

PatchID	Plant Sp.	Area <1275m3/s	Area >1275m3/s	Tot. Area (m2)	No. of # Plots	Est'd. No. KAS/m2	Est'd. KAS <1275m3/s	Est'd. KAS >1275m3/s	Est'd. Tot. No. KAS	Total KAS Counted	•	Est'd. KAS <1275m3/s	Est'd. KAS >1275m3/s	Est'd. Tot. No. KAS	5% Quant.	95% Quant
4.5	MICA	0	9.41	9.41	7	0.0	0	0	0	0	•	0	0	0	0	0
5MU	MICA	0.42	8.29	8.71	6	21.2	9	176	185	4	•	9	176	185	47	324
5MDS	MICA	0.71	18.07	18.78	12	18.6	13	336	349	7	•	14	336	350	50	698
5MMID	MICA	0	4.21	4.21	5	12.7	0	54	54	2	•	0	54	54	0	108
5MSUB	MICA	0.43	0	0.43	Tot. Count	0.0	0	0	0	0	•	0	0	0	0	0
6MUP	MICA	0	3.55	3.55	3	0.0	0	0	0	0	•	0	0	0	0	0
6MUS	MICA	0	3.71	3.71	3	10.6	0	39	39	1	•	0	40	40	0	79
8MI	MICA	0.82	4.22	5.04	9	7.1	6	30	36	2	•	6	30	36	0	72
8ML	MICA	6.81	5.98	12.79	10	0.0	0	0	0	0	•	0	0	0	0	0
8MLUS	MICA	4.41	0	4.41	3	0.0	0	0	0	0	•	0	0	0	0	0
10A	MICA	0.03	0	0.03	Tot. Count	0.0	0	0	0	0	•	0	0	0	0	0
10C	MICA	0.02	0	0.02	Tot. Count	0.0	0	0	0	0	•	0	0	0	0	0
13	MICA	1.67	0	1.67	3	0.0	0	0	0	0	•	0	0	0	0	0
203M	MICA	1.35	20.17	21.52	8	5.3	7	107	114	1	•	8	108	116	0	343
5N	NAOF	0	3.77	3.77	3	0.0	0	0	0	0	•	0	0	0	0	0
6NUS	NAOF	0	6.39	6.39	6	5.3	0	34	34	1	•	0	34	34	0	93
6NMID	NAOF	0	2.58	2.58	6	111.4	0	287	287	21	•	0	288	288	42	644
6NDS	NAOF	0	2.89	2.89	6	21.2	0	61	61	4	•	0	62	62	0	123
203N	NAOF	0.04	1.46	1.5	1	0.0	0	0	0	0	•	0	0	0	0	0
9N	NAOF	0.02	1.29	1.31	3	10.6	0	14	14	1	•	1	14	15	0	28
9NL	NAOF	1.16	0	1.16	3	10.6	12	0	12	1	•	13	0	13	0	25
5AGTUS	AGST-MIX	0	1.94	1.94	3	84.9	0	165	165	8	•	0	165	165	62	268
5AGSMID	AGST-MIX	0	1.89	1.89	3	21.2	0	40	40	2	•	0	41	41	21	61
6POAM	POAM	0	0	0	0	0.0	0	0	0	0	•	0	0	0	0	0
6REM	CAAQ-MIX	7.59	83.41	91	5	25.5	193	2124	2317	4	•	194	2125	2319	579	4056
7NU	NAOF-AGST	8.44	2.48	10.92	5	0.0	0	0	0	0	•	0	0	0	0	0
7NL	CAAQ-MIX	5.14	0	5.14	5	0.0	0	0	0	0	•	0	0	0	0	0
8CUS	CAAQ	0	1.48	1.48	4	15.9	0	24	24	2	•	0	24	24	0	48
8LC	CAAQ	3.12	0	3.12	Tot. Count	0.0	0	0	0	0	•	0	0	0	0	0
8ADCA	ADCA	0	2.71	2.71	3	21.2	0	58	58	2	•	0	58	58	29	87
10B	AGST	0.05	0	0.05	Tot. Count	0.0	0	0	0	0	•	0	0	0	0	0
11	PHAU-EQ MIX	4.05	0	4.05	Tot. Count	0.0	0	0	0	0	•	0	0	0	0	0
12	EQ-MIX	10.85	0	10.85	5	0.0	0	0	0	0	•	0	0	0	0	0
Subtotals	Mica	16.67	77.61	94.28	64	5.4	35	741	776	17	•	37	744	781		
Subtotals	Naof	1.22	18.38	19.6	28	22.7	13	396	409	28	•	14	398	412		
Subtotals	Other	39.24	93.91	133.15	36	14.1	193	2410	2603	18	•	194	2413	2607		
TOTAL	All	57.13	189.9	247.03	128	11.5	241	3547	3788	63	•	245	3555	3800	830	1027



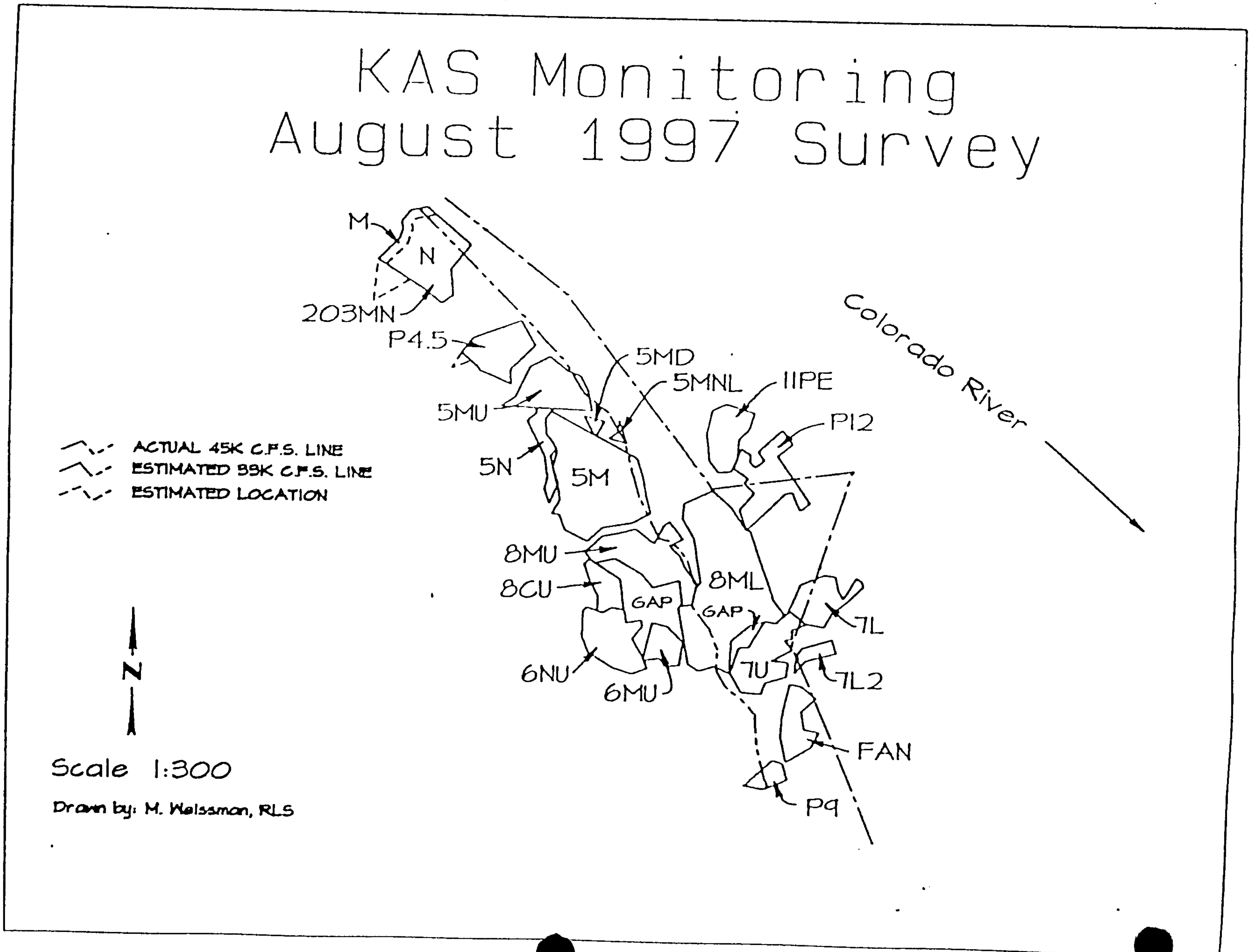
Fi 4: Map of KAS habitat patches lying

Table 4: KAS habitat area and population estimates above and below the 1275 m3/s stage, 15-16 May 1997.

PatchID	Plant Sp.	Area <1275m3/s	Area >1275m3/s	Tot. Area (m2)	No. of # Plots	Mean No. KAS/plot	sd KAS/ plot	Est'd. No. KAS/m2	Est'd. KAS <1275m3/s	Est'd. KAS >1275m3/s	Est'd. Total No. KAS	Est'd. KAS <1275m3/s	Est'd. KAS >1275m3/s	Est'd. Tot. No. KAS	5% Quant.	95% Quant.
4 5	MICA	0.00	10.51	10.51	7	0.8	0.90	26.5	0	279	279	0	454	454	195	714
5MUS	MICA	0.79	14.83	15.62	7	0.1	0.35	4.6	4	68	71	16	293	309	103	516
5MDS+5MD	MICA	1.76	21.24	23.00	15	1.4	1.18	45.5	80	966	1046	95	1149	1244	356	2541
5MSUB	MICA	0.39	0.00	0.39	Tot. Count	0.0		0.0	0	0	0	0	0	0		
6MMID	MICA	0.00	2.00	2.00	0**	0.7		21.0	0	42	42	0	24	24	0	48
6MUS	MICA	0.00	1.53	1.53	6	0.3	0.75	10.6	0	16	16	0	0	0	0	0
8ML	MICA	15.36	3.63	18.99	10	0.1	0.30	3.2	49	12	60	0	0	0	0	0
8MU	MICA	0.82	10.49	11.31	7	0.7	1.39	22.7	19	238	257	37	468	504	125	938
203M	MICA	2.01	20.55	22.56	8	0.7	1.16	22.7	46	467	513	80	816	896	0	1616
13	MICA	1.72	0.00	1.72	3	1.7	2.36	53.1	91	0	91	38	0	38	0	76
*100k	MICA	0.00	160.00	160.00	9	0.8	1.03	24.8	0	3962	3962	*0	*3962	*3962		
5N	NAOF	0.00	6.01	6.01	4	0.3	0.43	8.0	0	48	48	0	402	402	329	474
6NUS	NAOF	0.00	9.57	9.57	12	0.3	0.62	10.6	0	101	101	0	782	782	484	1079
6NMID	NAOF	0.00	1.50	1.50	4	0.3	0.43	8.0	0	12	12	0	119	119	73	174
6NDS	NAOF	0.00	3.20	3.20	6	0.2	0.37	5.3	0	17	17	0	58	58	0	116
9N	NAOF	0.93	0.72	1.65	0**	0.3		8.4	8	6	14	334	259	593	263	936
9NL	NAOF	1.38	0.00	1.38	3	0.0	0.00	0.0	0	0	0	0	0	0	0	0
203N	NAOF	0.00	2.00	2.00	0**	0.3	0.50	8.4	0	17	17	0	63	63	0	143
*100k	NAOF	0.00	40.00	40.00	4	0.3	0.43	8.0	0	318	318	*0	*318	*318		
5DEAD	MICA	0.49	2.29	2.78	12	2.7	1.97	84.9	42	194	236	42	194	236		
5AGSTD	AGST	0.00	1.60	1.60	10	0.5	0.67	21.4	0	34	34	0	34	34		
6REM	CAAQ-MIX	7.59	64.73	72.32	4**	8.3	14.29	262.6	1993	16998	18992	1993	16999	18992		
6POAM	POAM Mix	0.00	20.00	20.00	3	0.7	0.94	21.2	0	425	425	0	425	425		
7NU	NAOF-AGST	8.74	1.84	10.58	9	1.0	1.83	31.8	278	59	337	957	202	1159	705	1620
7NL	CAAQ-MIX	5.21	0.00	5.21	6	0.0	0.00	0.0	0	0	0	436	0	436	134	806
8CUS	CAAQ	0.00	3.63	3.63	4	0.5	0.50	15.9	0	58	58	0	58	58		
10	MIX	0.10	0.00	0.10	Tot Count	0.0		0.0	0	0	0	0	0	0		
11PE	P-E MIX	4.05	0.00	4.05	Tot Count	0.0		0.0	0	0	0	0	0	0	0	0
12	EQHY-MIX	18.43	0.00	18.43	6	0.2	0.37	5.3	98	0	98	43	0	43	0	128
Subtotals	Mica	22.85	84.78	107.63	73	0.7	1.05	21.0	289	2088	2376	265	3204	3469		
Subtotals	Naof	2.31	23.00	25.31	33	0.2	0.39	7.0	8	201	209	334	1683	2017		
Subtotals	Other	44.61	94.09	138.70	42	1.4	2.29	44.3	2411	17768	20179	3470	17912	21382		
TOTAL	All	69.77	201.87	271.64	148	0.8	1.3	24.5	2708	20057	22764	4070	22798	26868	[illegible]	[illegible]

* Upslope from "low zone" in the "upper zone" and not included in column means or totals.

** Not surveyed. KAS density estimated using patch area and mean snail density/plot in that habitat type, and area extrapolated between surveys.



Fi[illegible]: Map of KAS habitat patches lying downslope [illegible]

Table 5: KAS population estimates at Vaseys Paradise, 3-4 August 1997.

Patch ID	Dominant Plant Spp.	Area (m2) <1275 m3/s	Area (m2) >1275 m3/s	Total Area (m2)	No. of 20cm Plots	Raw Mean KAS/Plot	Raw sd KAS/Plot	Raw Mean KAS/m2	Est'd. No. KAS <1275m3/s	Est'd. No. KAS >1275m3/s	Est.d Tot. No. KAS	Est. Total KAS/Patch <1275 m3/s	Est. Total KAS/Patch >1275 m3/s	Est. Total KAS/Patch	Est. Total KAS/Patch sd	5% Quantile	95% Quantile
		20 cm PLOT DATA										BOOTSTRAPPED DATA					
4 5	Mica	0	10.2	10 20	5	1.4	1 02	44 6	0	455	455	0	454	454	147	195	714
5MU	Mica	0.45	11.81	12 26	3	1.0	0 82	31.8	14	376	390	14	376	390	185	103	650
5MDEAD	Mica	0.09	1.4	1.49	4	11	7.18	350.1	32	490	522	19	303	323	33	277	369
5M	Mica	1.31	26.92	28 23	3	0 0	0 00	0 0	0	0	0	46	943	989	679	90	2336
5MDS	Mica	0	0.58	0.58	7	1.6	2.72	50 0	0	29	29	0	29	29			
5MSUB	Mica	0.38	0	0.38	Tot. Count	0 0		0 0	0	0	0	8	0	8			
6MUS	Mica	0	3.74	3 74	3	0 0	0 00	0 0	0	0	0	0	0	0		0	0
6MMID	Mica	0	2.25	2.25	3	0 3	0 47	10 6	0	24	24	0	23	23	19	0	48
8ML	Mica	28.68	5.9	34.58	8	0 0	0 00	0 0	0	0	0	0	0	0			
8MU	Mica	0.87	10.92	11.79	6	1 3	1 60	42 4	37	463	500	37	465	502	243	125	938
10MA	Mica	0 02	0	0 02	Tot Count	0 0		0 0	0	0	0	0	0	0		0	0
13	Mica	2.41	0	2 41	4	0 5	0 50	15 9	38	0	38	38	0	38	19	0	76
203M	Mica	2.01	20.55	22 56	6	1.5	1 26	47.7	96	981	1077	80	815	895	466	0	1616
120k cfs	Mica	0	Not Survyd	Not Survyd	3	0.3	0 47	10 6	0			0					
5NU	Naof	0	3.78	3.78	3	3.7	0.94	116.7	0	441	441	0	442	442	66	361	521
5NL	Naof	0.2	0	0.20	1	1.0		31.8	6	0	6	0	8	8			
6NUS	Naof	0	9.35	9.35	0	Est'd=2.8		89.1	0	833	833	0	781	781	184	484	1079
6NMID	Naof	0	1.73	1.73	6	2 2	1 34	69 0	0	119	119	0	119	119	30	73	174
6NDS	Naof	0	3.65	3.65	6	0.5	0.76	15.9	0	58	58	0	58	58	36	0	116
7NUP	Naof	11.89	0	11.89	9	3.7	2 63	116 7	1388	0	1388	1389	0	1389	334	841	1934
7NL	Naof	6.33	0	6.33	6	2.2	2 61	69 0	437	0	437	434	0	434	213	134	806
9N	Naof	1.82	0.76	2.58	5	7.2	5.71	229 2	417	174	591	416	174	590	210	263	936
9NL("FAN")	Naof	5.18	0	5.18	Tot. Count	0 0		0.0	0	0	0	0	0	0		0	0
203N	Naof	0	2	2.00	2	0 0	0 00	0.0	0	0	0	0	64	64	39	0	143
120k cfs	Naof	0	Not Survyd	Not Survyd	3	3.7	0 47		0			0					
6POAM	Poam	0	64	64.00	3	0 0	0 00	0.0	0	0	0	0	0	0		0	0
6REM	Mix	7.59	17.81	25.40	3	0.3	0.47	10.6	80	189	269	47	110	157	129	0	314
7NL2	Mix	1.71	0	1.71	Tot. Count	0.0		0.0	0	0	0	0	0	0		0	0
10MB	Mix	0.2	0	0.20	Tot. Count	0 0		0 0	0	0	0	0	0	0		0	0
11PE	Phau/Eqhy	6.38	0	6.38	2	0 0	0.00	0 0	0	0	0	0	0	0		0	0
12	Eqhy	9.35	0	9.35	7	0.1	0 35	4.6	43	0	43	42	0	42	40	0	128
100kcfsRA	Mica	0	Not Survyd	Not Survyd	2	0 0	0 00	0 0	0			0					
Subtotal	Mica	36.22	94.27	130 49	52	1.4	1 2	45 6	217	2818	3035	243	3409	3652			
Subtotal	Naof	25.42	21.27	46.69	39	2.0	1.6	73 7	2248	1626	3874	2239	1645	3884			
Subtotal	Other	25.23	81.81	107.04	17	0.1	0 2	2 5	123	189	312	89	110	199			
TOTAL	All	86 87	197.35	284.22	108	1.4	1 2	46 4	2588	4633	7221	2571	5164	7735		2916	12898

The 2-3 October 1997 KAS habitat survey and mapping effort at VP revealed a total of 101.23 m^2 of KAS habitat downslope from the 1275 m^3/s stage, of which 41.88 m^2 was monkeyflower, 31.63 m^2 was watercress, and 27.72 m^2 was mixed, secondary habitat (Table 6; Fig. 6). The remaining area of the KAS habitat in the low zone, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, consisted of a total of 204.48 m^2 of habitat, including 91.85 m^2 of monkeyflower, 19.76 m^2 of watercress, and 92.87 m^2 of other habitat.

The October survey was also used as a pre-November Test Flow site visit, and we determined that 23.3 m^2 of potential KAS habitat lay downslope from the 934 m^3/s flood stage, of which only 0.16 m^2 was monkeyflower, 8.73 m^2 was watercress, and 14.41 m^2 was other vegetation (Table 6; Fig. 6). We predicted that five patches would be inundated and potentially scoured by the planned November Test Flow, although it was considered unlikely that the inundated vegetation would be completely eliminated.

The October site visit also represented the 6-month post-765 m^3/s February 1997 flow. Given the extensive "training" that VP vegetation has undergone in response to the 1996 Test Flow and the subsequent high, constant flows, we predicted, and found, little impact of the February 765 m^3/s flow through the 1997 growing season.

The 9 November 1997 survey of the KAS habitat downslope from the 934 m^3/s stage at VP revealed that several patches had been inundated by the 870 m^3/s Test Flow (Table 7; Fig. 7). Fresh deposits of sand were observed on the five patches lying downslope from the peak flood stage, and a large wrack and strandline of driftwood had been deposited at the site, particularly on Patch 12PE. Although overall vegetated habitat area only decreased from 29.79 m^2 to 25.49 m^2 (14.4%), it was apparent that the high flow had severely scoured the habitat, reducing the quality of the remaining habitat.

In conclusion, KAS habitat lying downslope from the 1275 m^3/s stage nearly doubled through the 1997 growing season, from 57.13 m^2 to 101.23 m^2. The vegetation was subsequently slightly reduced during the 870 m^3/s Test Flow on 3-5 November (Tables 2-7; Fig. 8). These findings indicate that recovery from the 1996 1275 m^3/s Test Flow required two full growing seasons. The habitat patches lying below the 765 m^3/s stage repeatedly have been inundated and somewhat scoured by high mainstream flows, and those habitat patches have not recovered to any significant extent over their September 1996 condition. Repeated high mainstream flows have prevented recovery of KAS habitat area below the 765 m^3/s stage; however, that habitat comprises only approximately 7.6% of the low zone habitat and is not high quality habitat. The habitat patches lying above the 1275 m^3/s stage continue to change in area in response to climate, spring outflow, and the life cycles of constituent species (Fig. 8).

Vegetation composition changed dramatically on low zone vegetation patches at VP (Tables 2-6). The composition of Patch 5N changed from a virtual monoculture of bent-grass (*Agrostis stolonifera)* in early spring to a monoculture of watercress in late summer, 1997. Similarly, Patch 9 changed from a monoculture of water sedge to watercress in < 2 months. Comparison of the area of high zone patch T, a large monkeyflower patch lying above the pre-dam 10-yr flood scour stage, was conducted using high angle oblique photographs of VP from 1994 to 1997. These photographs indicate that the detectable habitat area of Patch T decreases through the winter months in most years; however, inter-annual variation in high zone

KAS Monitoring
October 1997 Survey

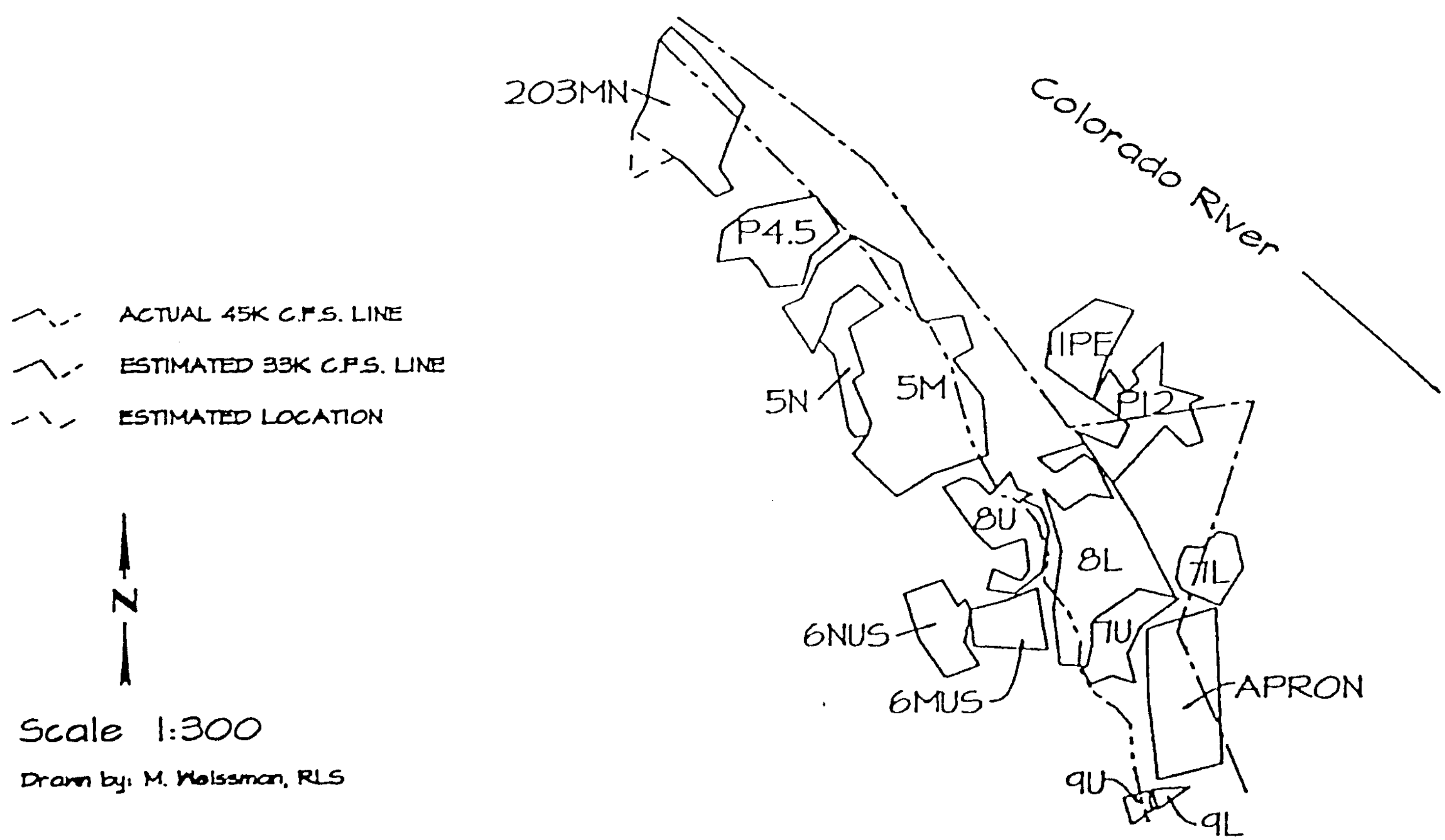
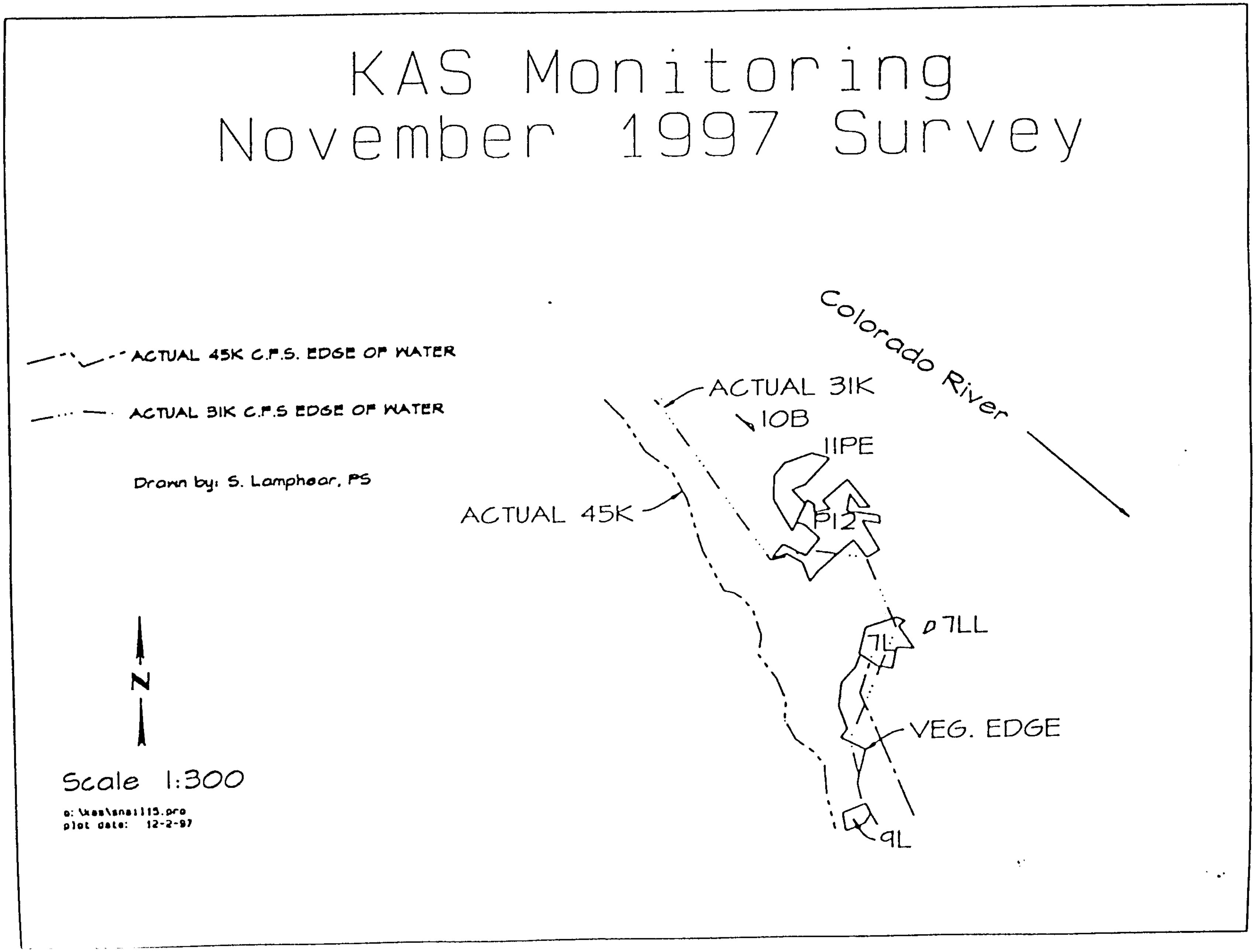


Table 6: KAS population estimates at Vaseys Paradise, 2-3 October 1997.

Patch ID	Plant Spp.	Area (m2) <934m3/s	Area (m2) 934-1275 m3/s	Area (m2) >1275 m3/s	Total Area (m2)	20 cm PLOT DATA: No. of 20cm Plots	Raw Mean KAS/Plot	Raw sd KAS/Plot	Raw Mean KAS/m2	Est'd No. KAS <934m3/s	Est'd No KAS 934-1275m3/s	Est'd No KAS >1275m3/s	Est'd Tot. No. KAS	BOOTSTRAPPED DATA: Est. Total KAS/Patch <934 m3/s	Est. Total KAS/Patch 934-1275m3/s	Est. Total KAS/Patch >1275 m3/s	Est. Total KAS/Patch	Est. Total KAS/Patch sd	5% Quant.	95% Quant
4.5	Mca	0	0.01	15.14	15.15	6	1.8	1.21	57.3	0	1	867	868	0	1	884	884	237	482	1286
5M	Mca	0	6.93	38.18	45.11	17	1.5	1.94	46.8	0	324	1787	2112	0	325	1792	2117	681	1098	3294
5MSUB	Mca	0	0.126	0	0.13	Tot Count	0.0		0.0	0	0	0	0	0	0	0	0			
6MMID	MICA	0	0	0	0.00	0	0.0		0.0	0	0	0	0	0	0	0	0			
6MUS	Mca	0	0	8.13	8.13	3	0.7	0.94	22.3	0	0	137	137	0	0	130	130	107	0	260
8ML	Mca	0	29.52	2.55	32.07	6	0.3	0.47	9.5	0	282	24	308	0	314	27	341	198	0	681
8MU	Mca	0	1.46	8.86	10.32	6	1	1.15	31.8	0	46	282	328	0	46	281	328	154	0	602
10MA	Mca	0.03	0	0	0.03	Tot Count	0.0		0.0	0	0	0	0	0	0	0	0			
M30K	Mca	0.13	0	0	0.13	Tot Count	0.0		0.0	0	0	0	0	0	0	0	0			
M42K	Mca	0	0.13	0	0.13	Tot Count	0.0		0.0	0	0	0	0	0	0	0	0			
203M	Mca	0	3.54	20.99	24.53	7	0.3	0.70	9.5	0	34	200	234	0	34	200	234			
120kMICA	Mca	Not Survyd	Not Survyd	Not Survyd	Not Survyd	6	0.8	1.07	25.5	0	0	0	0	0	0	0	0			
5NU	Naof	0	0	6.88	6.88	6	10.2	6.57	324.7	0	0	2234	2234	0	0	2229	2229	589	1204	3175
6NUS	Naof	0	0	6.91	6.91	6	10.8	4.71	343.8	0	0	2375	2375	0	0	2384	2384	421	1723	3116
6NMID	NAOF	0	0	0	0.00	0	0	0	0.0	0	0	0	0	0	0	0	0			
6NDS	Naof	0	0	2.25	2.25	3	0.7	0.47	22.3	0	0	50	50	0	0	48	48	18	24	72
7NU	Naof	0	7.11	0	7.11	6	5.5	1.98	175.1	0	1245	0	1245	0	1245	0	1245	183	868	1547
7NL	Naof	4.38	1.38	0	5.76	6	1.3	1.6	41.4	181.2452	57	0	238	187	58	0	246	120	0	458
9N	Naof	0	0.55	0.72	1.27	6	0.3	0.47	9.5	0	5	7	12	0	6	8	14	8	0	27
9L(APRON)	Naof	4.35	13.86	0	18.21	Tot. Count	0		0.0	0	0	0	0	0	0	0	0	0	0	0
203N	Naof	0	0	3	3.00	6	3	2.16	95.5	0	0	286	286	0	0	273	273	73	184	398
120kNAOF	Naof	Not Survyd	Not Survyd	Not Survyd	Not Survyd	3	12.3	5.79	391.5	0	0	0	0	0	0	0	0			
6POAM	Poam	0	0	28	28.00	3	0.3	0.47	9.5	0	0	267	267	0	0	300	300	245	0	584
6REM	Mix	0	7.59	59.24	66.83	4	0.8	1.3	25.5	0	193	1509	1702	0	182	1423	1605	1384	4786	0
7NL2	Mix	0.5	0	0	0.50	Tot Count	0		0.0	0	0	0	0	0	0	0	0	0	0	0
8ADCA	ADCA	0	0	1.88	1.88	3	4	2.94	127.3	0	0	239	239	0	0	239	239	101	0	378
8CAAQ	Caaq	0	0	3.75	3.75	4	6.3	6.46	200.5	0	0	752	752	0	0	745	745	385	80	1522
10MB	Mix	0.05	0	0	0.05	Tot. Count	0.0		0.0	0	0	0	0	0	0	0	0			
11PE	Phau/Eqhy	8.04	0	0	8.04	6	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0
12	Eqhy	5.82	5.72	0	11.54	6	0.0	0.0	0.0	0	0	0	0	0	0	0	0	0	0	0
Subtotal	Mca	0.18	41.72	91.85	133.73	49	0.5	1.07	16.1	0	687	3298	3985	0	720	3315	4035			
Subtotal	Naof	8.73	22.90	19.76	51.38	40	3.5	2.25	112.5	181	1307	4953	6441	187	1309	4941	6437			
Subtotal	Other	14.41	13.31	92.87	120.59	28	1.4	1.86	45.4	0	193	2767	2961	0	182	2707	2888			
TOTAL	All	23.30	77.93	204.48	305.71	117	1.7	1.8	55.4	181	2188	11018	13387	187	2212	10962	13361		10439	17407



KAS Monitoring
November 1997 Survey
ACTUAL 45K C.F.S. EDGE OF WATER
ACTUAL 31K C.F.S EDGE OF WATER
Drawn by: S. Lamphear, PS
Colorado River
ACTUAL 31K
10B
11PE
P12
ACTUAL 45K
7LL
7L
VEG. EDGE
9L
N
Scale 1:300
o: \kas\snail15.pro
plot date: 12-2-97

Table 7: KAS habitat area below the 878 m3/s stage, 3 October to 9 November 1997.

PatchID	Plant Sp.	3 Oct 1997 Area <935m3/s	9 Nov 97 Area <935m3/s	Change in Area (m2)	%Change in Area (m2)
7L	CAAQ-MIX	5.56	4.89	0.67	12.05
7LL	MIX	0.20	0.21	-0.01	-5.00
9NL	NAOF	4.35	1.46	2.89	66.44
10B	MIX	0.10	0.11	-0.01	-10.00
11PE	P-E MIX	8.04	5.98	2.06	25.62
12	EQHY-MIX	11.54	12.84	-1.30	-11.27
TOTAL	All	29.79	25.49	4.30	14.43

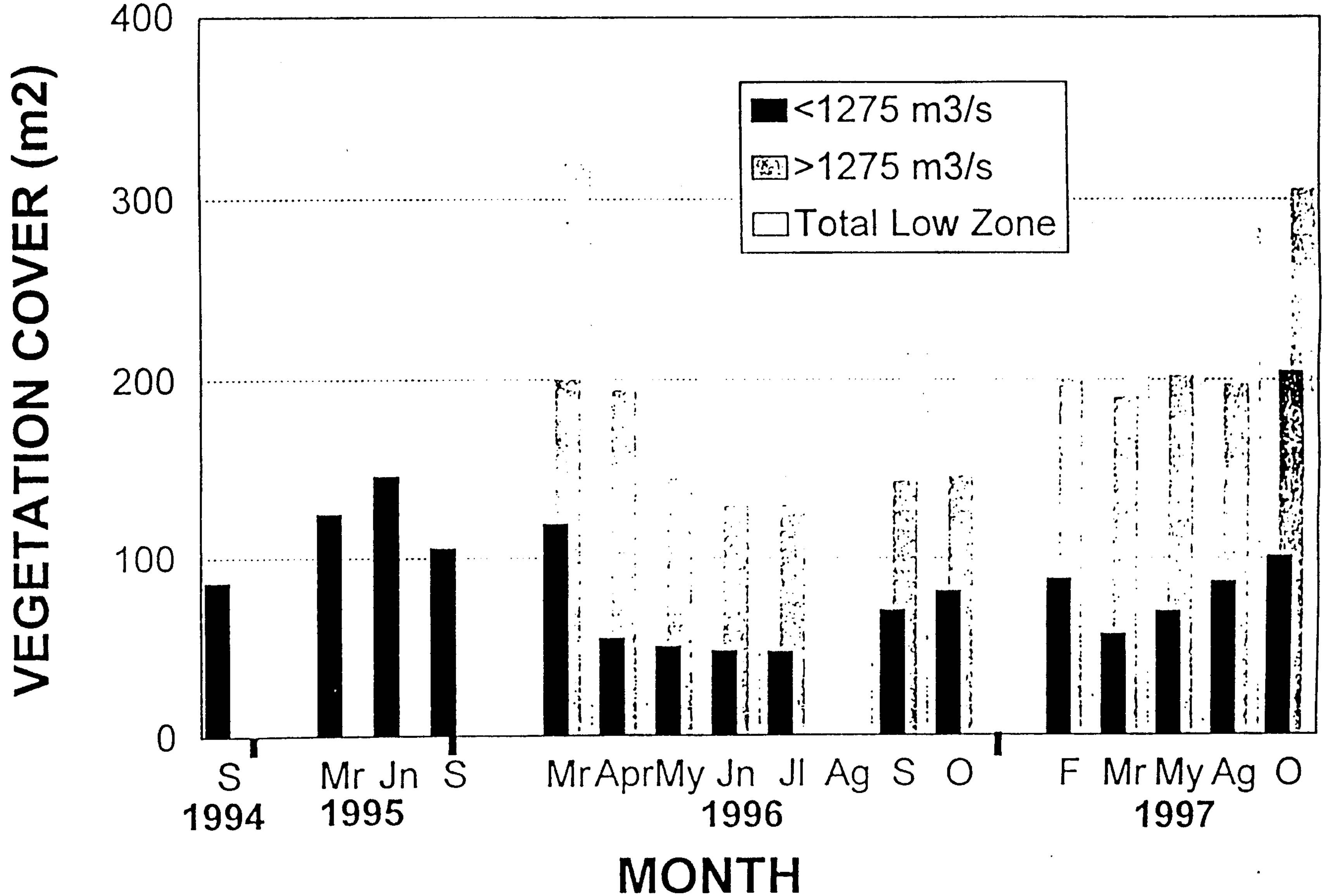
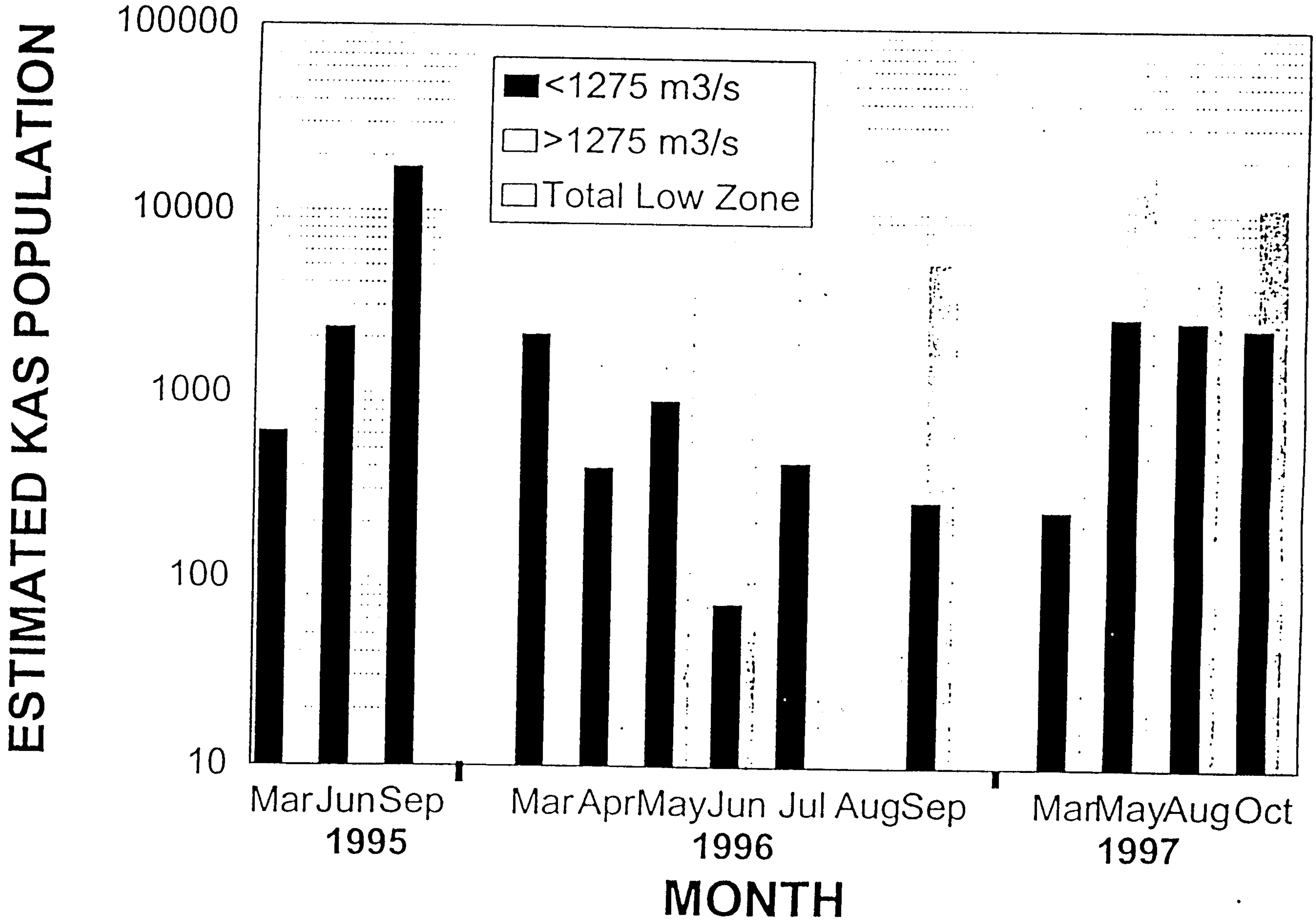


Figure 8: KAS habitat cover (m^2) in the low zone downslope and upslope from the 1275 m^3/s stage at Vaseys Paradise, 1994-1997.



[illegible]e 9: KAS population estimates in the low zone downslop[illegible] upslope from the 1275 m^3/s stage at Vaseys Paradise, 19[illegible]97.

area of this large habitat patch are apparent. The area of Patch T was estimated to be 200.46 m^2 in November 1994 (determined photogrammetrically by the Bureau of Reclamation, as reported in Stevens et al. 1997a), 171.48 m^2 in November 1995, 104.97 m^2 in November 1996, and 154.83 m^2 in November 1997. Thus the exceptionally dry winter of 1995-1996 apparently resulted in reduced area of Patch T. The coverage of monkeyflower, an obligate semi-aquatic species should be expected to be reduced in dry years. These data suggest that Patch T, and by extension, the other upper elevation KAS habitat patches, are dynamic and respond to interannual variation in spring discharge; Patch T area changes are apparently in response to seasonal climate, which varied dramatically over the period of study.

Objective 2: Monitor low zone KAS population density through the 1997 growing season. *Methods:* KAS density in the zone below the approximate 934 m^3/s stage was surveyed approximately bi-monthly through the 1997 growing season (Tables 1 and 3-7), using the methods of Stevens et al. (1997a and b, unpublished). We sampled numerous randomly-placed 20-cm diameter (0.03 m^2) plots in each habitat patch in the three stage zones indicated in Objective 1 (above). The shell length of each KAs encountered in each plot was measured and the snails were evaluated as to their dormancy. The schedule of sampling was developed through discussion with the Kanab Ambersnail Working Group (KAWG).

Results and Discussion: The 17-18 March 1997 KAS survey at VP revealed an estimated total of 241 KAS downslope from the 1275 m^3/s stage, of which 35 were in monkeyflower patches, 13 were in watercress patches, and 193 were in mixed, secondary habitat (Table 3, Fig. 9). The remaining area of low zone KAS habitat, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, contained an estimated 3547 KAS, including 741 in monkeyflower patches, 369 in watercress patches, and 2410 in other habitat. The pattern of low KAS population density in watercress in early spring is consonant with the observation that they overwinter in drier settings, somewhat removed from the water's edge habitats required by watercress. The March survey also demonstrated that the 765 m*3*/s high flow inundated KAS habitat, but no KAS were found in inundated vegetation patches (e.g., 7L, 11 and 12, in Table 3).

The 15-16 May 1997 KAS survey at VP revealed an estimated total of 2708 KAS downslope from the 1275 m^3/s stage, of which 289 were in monkeyflower patches, 8 were in watercress patches, and 2411 were in mixed, secondary habitat (Table 4, Fig. 9). The remaining area of low zone KAS habitat, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, contained an estimated 20057 KAS, including 2088 in monkeyflower patches, 201 in watercress patches, and 17768 in other habitat. The low KAS population density in watercress patches was probably still related to the high spring discharge and the low availability of watercress at that time.

The 3-4 August 1997 KAS survey at VP revealed an estimated total of 2588 KAS downslope from the 1275 m^3/s stage, of which 217 were in monkeyflower patches, 2248 were in watercress patches, and 123 were in mixed, secondary habitat (Table 5, Fig. 9). The remaining area of low zone KAS habitat, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, contained an estimated 4633 KAS, including 2818 in monkeyflower patches, 1626 in watercress patches, and 189 in other habitat. Mid-summer KAS population density typically increases dramatically as reproduction occurs and snails concentrate in watercress patches, which had developed fully at that time.

The 2-3 October 1997 KAS survey at VP revealed an estimated total of 2369 KAS downslope from the 1275 m^3/s stage, of which 687 were in monkeyflower patches, 1488 were in watercress patches, and 193 were in mixed, secondary habitat (Table 6, Fig. 9). The remaining area of low zone KAS habitat, lying between the 1275 m^3/s and the approximate 1700 m^3/s stages, contained an estimated 11018 KAS, including 3298 in monkeyflower patches, 4953 in watercress patches, and 2767 in other habitat. The KAS population was decreasing with natural mortality of very small snails, and the population was gradually shifting from watercress onto drier monkeyflower and water sedge microhabitats in anticipation of winter and the onset of dormancy.

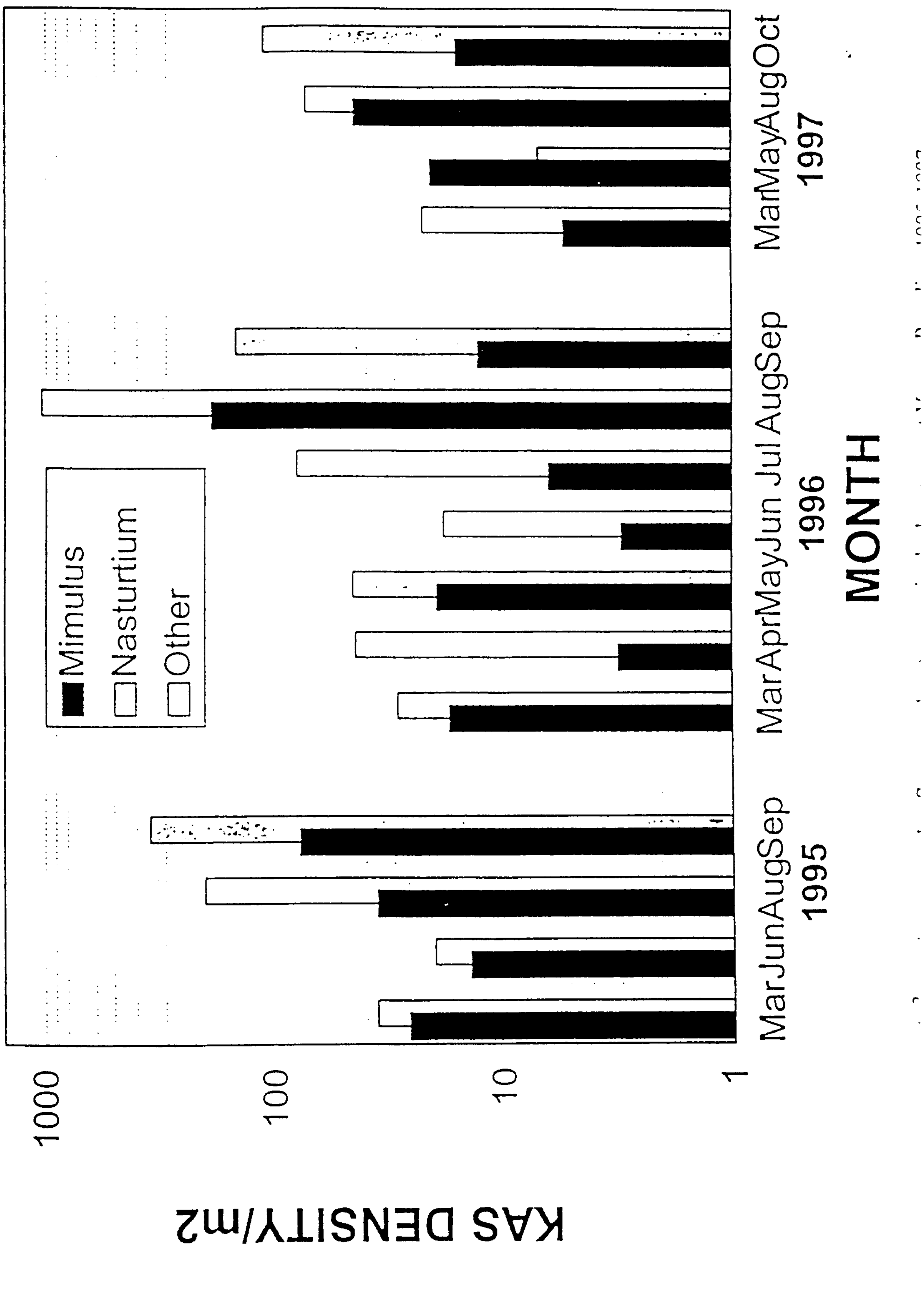
The October survey was also used as a pre-November Test Flow site visit, and we determined that an estimated 181 KAS potentially existed downslope from the 934 m^3/s flood stage, all of which occurred in watercress (Table 6). Six hours of searching for KAS in these patches revealed only 40 snails in Patch 7L, and no snails in patches 11 and 12. The discrepancy in estimated versus actual KAS was attributed to the non-random distribution of KAS in Patch 7L. That patch is a mixed vegetation patch, with peripheral watercress and monkeyflower. In addition, KAS probably roll out of upslope vegetation into the edges of Patch 7L, increasing the non-random distribution patterns. We predicted that five patches would be inundated and potentially scoured by the planned November Test Flow, and that no more than approximately 200 snails (1.5% of the estimated 13,387 KAS in the overall low zone) would be taken by the Test Flow.

Immediately prior to the November Test Flow, JAS of the Arizona Game and Fish Department rescued 14 KAS and 0.25 m^2 of habitat (10 clumps of primary and secondary mixed vegetation) from the potentially inundated zone of Patch 7L downslope from the 934 m^3/s stage for a captive breeding population at the Phoenix Zoo. These collections required 1.5 hr of searching for KAS and 1 hr for habitat collections.

The October KAS population survey also represented the 6-month post-765 m^3/s February 1997 flow site visit. Given the extensive "training" that VP vegetation has undergone in response to the 1996 Test Flow and the subsequent high, constant flows, there has been little recolonization of the lowest stage elevation habitat patches by KAS. Therefore, there was little impact of the February 765 m^3/s flow through the 1997 growing season.

We documented KAS dormancy patterns through the 1997growing season. Eight of 50 snails (16%) were dormant in 17-18 March; dormancy was 0 of 118 and 155 during the May and August population surveys, respectively, and increased to 21 of 320 (6.6%) snails on 3-4 October 1997.

We also evaluated KAS distribution on its several host plant species through the 1997 growing season (Fig. 10). KAS were equally abundant on monkeyflower, watercress and other primary host plant species (e.g., water sedge, horsetail and smartweed) in March (Kruskall-
Figure 10


KAS DENSITY/m2
1000
100
10
1
Mimulus
Nasturtium
Other
MarJunAugSep
1995
MarAprMayJun Jul AugSep
1996
MarMayAugOct
1997
MONTH

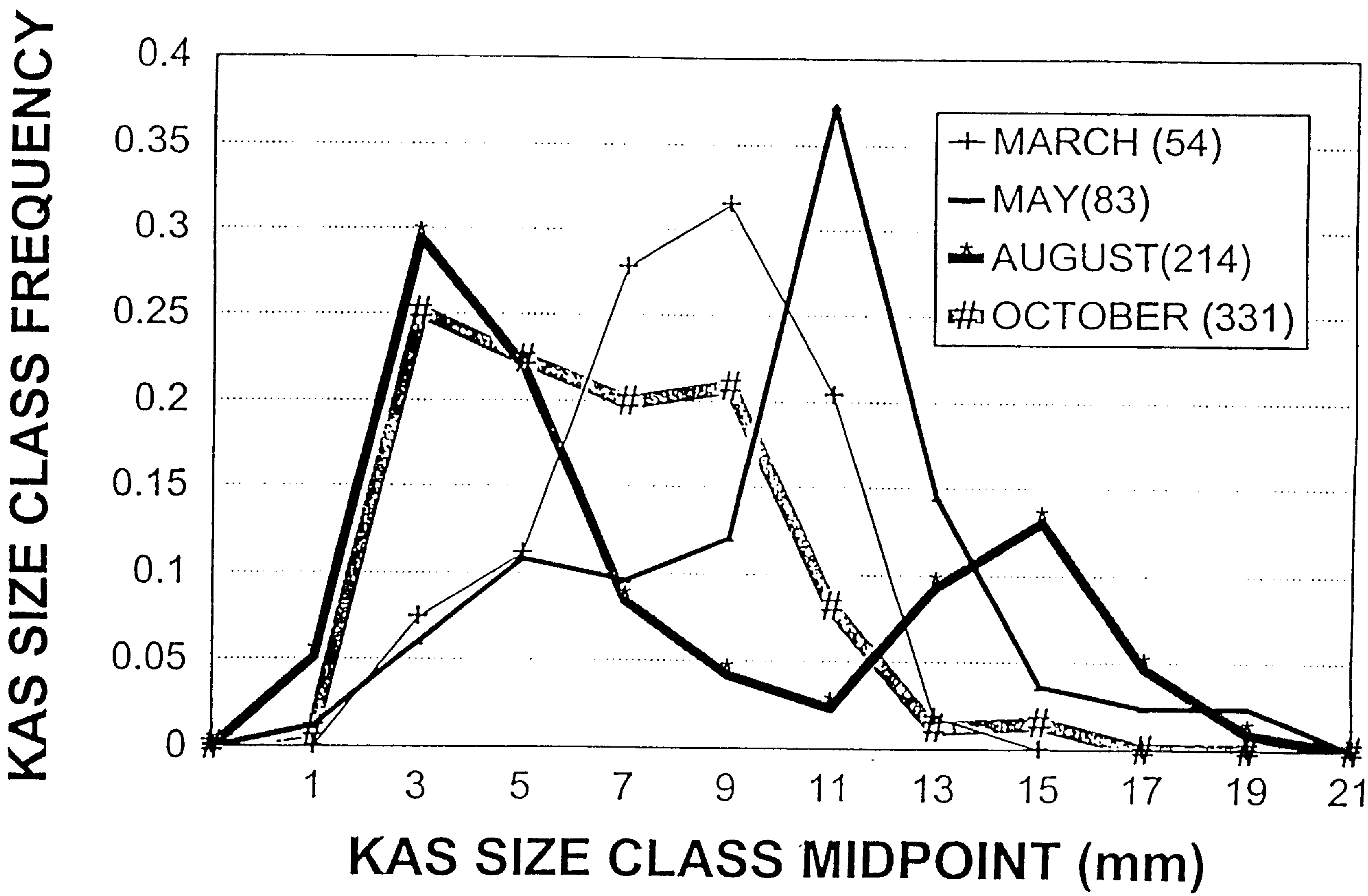


Figure 11: KAS size class frequency distribution in the low zone at Vaseys Paradise in 1997.

Wallis U=4.842, $p = 0.089$, n = 116 cases, df = 2) and May (KW U = 2.452, $p = 0.293$, n = 146 cases, df = 2), but was significantly greater on water-cress in August (KW U = 25.6, $p < 0.001$, n = 99 cases, df = 2) and October (KW U = 25.829, $p < 0.001$, n = 119 cases, df = 2). These patterns are overlain with the phenology of watercress. In 1997, watercress germination took place in spring, and the plants matured in middle and late summer. KAS seem to prefer young and pre-flowering watercress, and may avoid mature plants. LES is exploring dietary preferences in the laboratory at Northern Arizona University. Thus, as in 1995 and 1996, KAS preferentially exist on watercress, particularly during the middle and late summer.

We analyzed KAS size class distribution, again finding a pattern similar to that observed in 1995 by Stevens et al. (1997a, unpublished). Medium-sized KAS emerged in March and by mid-May numerous reproductively mature KAS were observed (Fig. 11). Reproduction occurred in mid-summer, and the August survey revealed a bimodal population consisting of numerous small (<5 mm) KAS and lower densities of large (>13 mm) snails. By October, reproduction had largely ceased, and the majority of the population were approaching the medium size range.

In conclusion, the KAS population existing downslope from the 1275 m^3/s stage exhibited population dynamics similar to those noted in 1995 by Stevens et al. (1997a, unpublished). Low winter survival resulted in a relatively small population of medium-sized KAS in the spring of 1997. The estimated low-zone population increased by more than 3.5-fold through the 1997 growing season, and then entered winter dormancy (Tables 2-6; Fig. 9). Little impact of either the two spring/summer 765 m^3/s flows or the November 870 m^3/s Test Flow was apparent because of low quality habitat in the inundated zone. Repeated high mainstream flows have prevented recovery of habitat area and the KAS population below the 765 m^3/s stage. The KAS population existing upslope from the 870 m^3/s stage is large and apparently healthy.

Objective 3: Determine whether upper stage zone KAS densities are comparable with those in the low zone.

Methods: The demography of KAS in the upper zone ($\geq$ ca. 2000 m^3/s stage) had not been evaluated since 1995, and may serve as an important local control for understanding KAS population dynamics. The lower portion of VP upper zone can be accessed along flowing waterways without damaging vegetation, at least during the spring and early summer months. Vegetation overgrows those waterways in middle and late summer, restricting access to the high zone. The same sampling protocols were employed as in Objective 2 (above), and we evaluated KAS density in three stage zones: the stage zone lying downslope from the 1275 m^3/s stage, that lying between the 1275 m^3/s and 2000 m^3/s stages, and the zone lying above the 2000 m^3/s stage. The steepness of the terrain, and the extensive dominance by poison ivy has thus far thwarted extensive topographic surveying or habitat mapping in the upper zone. If that task is deemed necessary, it is probably better and more safely undertaken using oblique photogrammetry.

Results and Discussion: KAS density/20-cm diameter plot did not vary significantly among the three stage elevations at VP during any of the four population surveys in 1997 (Kruskall-Wallis p > 0.052, df = 2 for four sampling periods; Table 8). This finding indicates that KAS density was

Table 8: Summary table of mean and standard deviation of KAS on 20 cm-diameter plots at VP by month in 1997. Host plant species include monkeyflower (1), watercress (2), and other (3). Stage zones include: 1=downslope from the 1275 m^3/s stage, 2=between the 1275 m^3/s and the approximate 2000 m^3/s stage, and 3=upslope from the 2000 m^3/s stage. No stage zone 3 patches were sampled in March 1997.

MONTH	PLANT SP.	STAGE ZONE	MEAN NO. KAS/PLOT	SD KAS/ PLOT	NO. OF PLOTS
3	1	1	0.00	0.00	8
3	1	2	0.22	0.68	50
3	2	1	0.33	0.58	3
3	2	2	0.93	2.82	30
3	3	1	0.00	0.00	10
3	3	2	0.67	0.72	15
5	1	1	0.46	1.39	13
5	1	2	0.70	1.11	40
5	1	3	0.78	1.09	9
5	2	2	0.27	0.52	30
5	2	3	0.25	0.50	4
5	3	1	0.48	1.33	21
5	3	2	2.07	6.23	28
5	3	3	0.00	.	1
8	1	1	0.20	0.42	10
8	1	2	1.11	1.93	27
8	1	3	0.33	0.58	3
8	2	1	3.30	2.87	10
8	2	2	3.15	4.04	20
8	2	3	3.67	0.58	3
8	3	1	0.88	1.96	16
8	3	2	0.17	0.41	6
8	3	3	0.00	0.00	4
10	1	1	0.33	0.52	6
10	1	2	1.36	1.85	42
10	1	3	0.83	1.17	6
10	2	1	5.50	2.17	6
10	2	2	5.71	6.44	24
10	2	3	12.33	7.09	3
10	3	1	0.44	1.15	18
10	3	2	2.93	4.70	14

equivalent across stage elevation at VP in 1997, and therefore habitat-based population estimation is equally reliable across that stage elevation. We summarize all KAS habitat and population estimates at Vaseys Paradise from 1995-1997 in Table 9.

Objective 4: Monitor population densities of potentially competing invertebrates.

Densities of *Catinella* spp., *Deroceras laeve* and other molluscs were monitored on plots sampled though the 1997 growing season using the techniques outlined in Objectives 1 and 2. No limitation of KAS by other mollusc populations was apparent; however, more definitive analyses of the existing data are warranted.

Objective 5: Monitor rodent densities.

Methods: Rodents are known to feed on landsnails, and are suspected to be predators of KAS (Stevens et al 1997b, unpublished). Rodent densities have been monitored at VP since April 1996. We placed up to 50 Sherman live traps in and around the low zone for one or more nights during each site visit in 1997. Traps were baited with dry rolled oats, and collected the following morning. Patch, species, mass, sex and condition were recorded for each animal trapped, and animals were toe-clipped to determine recapture success.

Results: We trapped only *Peromyscus crinitus* at Vaseys Paradise in 1997, and trap success varied from 4.1% to 13.6% (Table 10). Trap success was approximately equivalent from February through May (10% to 13.6%), and then decreased to 8.3% in August and to 4.1% in October. Decreasing trapping success through the growing season was not related to estimated KAS population size (linear regression $F = 0.023$, $p = 0.889$, $df = 1,3$). This pattern does not support the hypothesis that mice are density dependent predators of KAS; however, more data are required over time to assess this potential interaction.

Objective 6: Monitor the frequency of *Leucochloridium cyanocittae* parasitism.

Methods: Leucochloridium cyanocittae flatworms parasitize KAS at VP at rates of 1% to nearly 10% (Stevens et al. 1997a, unpublished). Rates of parasitism were monitored in 1997 by visual inspection of mature KAS (>10 mm) during the August site visit, and recording the number of large snails which were or were not expressing sporocysts or other evidence of parasitism (e.g., eye stalk damage), according to the protocols described by Stevens et al. (1997a, unpublished).

Results: A total of 65 mature KAS (> 10 mm) were observed during the 2-3 August 1997 site visit. Of these, four (6.2%) expressed *L. cyanocittae* sporocysts. This frequency of parasitism is less than the 8.3-9.5% observed in 1995, but considerably more than the <1% observed in 1996 (Stevens et al. 1997a and 1997b). This year's data suggests that *L. cyanocittae* is a persistent parasite in this snail population.

Table 9: Summary of KAS habitat area and population estimates at Vaseys Paradise, March 1995 through October 1997

Estimated KAS habitat area at Vaseys Paradise, 1995-1997. Stage >1700m3/s is adjusted using digitized November photogramme

		<1278 m3/s				1278-1700 m3/s				>1700 m3/s stage (1994)				Area	Est'd Adj'd.	GRAND TOTAL				% OF ESTD TOT VEG IN
DATE	JDAY	Mica	Naof	Other	Total	Mica	Naof	Other	Total	Mica	Naof	Other	Total	Adjustment	Area (m2)	Mica	Naof	Other	Total	<1278m3/s ZONE
Mar 95	81	78.8	30.2	16.2	125.2	116.1	22.3	38.6	177	531.9	7.3	0	539.2	0.855	461.2	640.8664	67.74414	54.8	763.411	18.4
Jun 95	102	83.8	51.6	10.7	146.1	204.3	13.7	2.4	220.4	531.9	7.3	0	539.2	0.855	461.2	743.0664	71.54414	13.1	827.711	17.7
Sept 95	261	55.4	23.1	21	99.5	190.1	58.4	1.5	250	531.9	7.3	0	539.2	0.855	461.2	700.4664	87.74414	22.5	810.711	12.3
Mar 96	447	66.23	38	15.21	119.44	82.88	50.3	66.72	199.9	531.9	7.3	0	539.2	0.524	282.4	427.6411	92.12294	81.93	601.7141	10.8
Apr 96	474	14.38	14.17	26.45	54.88	88.35	41.98	63.66	193.99	531.9	7.3	0	539.2	0.524	282.4	381.2611	58.87294	90.11	531.3441	10.3
May 96	508	14.31	13.22	22.67	50.2	94.12	44.3	>3.28	>142.42	531.9	7.3	0	539.2	0.524	282.4	390.9411	61.34294	22.67	474.9641	10.6
Jun 96	534	13.22	13.97	20.58	47.77	80.89	38.17	10.02	129.08	531.9	7.3	0	539.2	0.524	282.4	372.6411	55.96294	30.6	458.2241	10.4
Jul 96	567	12.72	13.98	20.58	47.28	81.39	38.17	10.02	129.58	531.9	7.3	0	539.2	0.524	282.4	372.6411	55.65294	30.6	458.2141	10.3
Sept 96	625	24.47	18.54	27.52	70.53	64.76	23.73	54.38	142.87	531.9	7.3	0	539.2	0.524	282.4	387.7811	48.11294	81.88	485.7741	14.2
Oct 96	663	26.43	24.84	30.23	81.5	72.27	52.97	20.61	145.85	531.9	7.3	0	539.2	0.524	282.4	377.2511	81.63294	50.84	509.7241	16.0
Feb 97	777	23.87	34.09	30.5	88.46	78.01	21.76	99.28	199.05	531.9	7.3	0	539.2	0.772	416.3	512.5430	61.50811	129.78	703.81	12.8
Mar 97	808	18.67	1.22	38.24	57.13	77.61	18.38	93.91	189.9	531.9	7.3	0	539.2	0.772	416.3	504.8430	25.23811	133.15	663.33	8.6
May 97	867	22.85	2.31	44.61	69.77	84.78	23	94.09	201.87	531.9	7.3	0	539.2	0.772	416.3	518.2930	30.84811	138.7	687.84	10.1
Aug 97	947	38.22	25.42	25.23	88.87	84.27	21.27	81.81	187.35	531.9	7.3	0	539.2	0.772	416.3	541.1530	52.32811	107.04	700.52	12.4
Oct 97	1007	41.88	31.63	27.71	101.22	91.85	19.78	92.87	204.48	531.9	7.3	0	539.2	0.772	416.3	544.3030	57.02811	120.58	722	14.0

Estimated KAS Population size using mean density/m2 by habitat and stage zone, 1995-1997

		<1278 m3/s				1278-1700 m3/s				>1700 m3/s stage				GRAND TOTALS				% OF ESTD TOT POP IN
DATE		Mica	Naof	Other	Total	Mica	Naof	Other	Total	Mica	Naof	Other	Total	Mica	Naof	Other	Total	<1278m3/s ZONE
Mar 95	81	483	124	7	614	1478	1122	40	2640	4799	127	0	4926	6760.3	1372.507	47	8180	7.5
Jun 95	162	1519	735	0	2254	4391	327	6	4724	8333	102	0	8435	15243.06	1163.551	6	16413	13.7
Sept 95	261	8742	8058	218	17018	18977	18399	5	37381	51370	2027	0	53397	78044.55	28485.08	223	107787	15.8
Mar 96	447	1373	542	200	2115	1626	1303	190	3119	5602	80	0	5682	8601	1825	390	10816	10.4
Apr 96	474	73	327	0	400	486	2286	343	3135	1516	178	0	1694	2075	2781	343	5229	7.8
May 96	508	956	128	98	1182	1812	1026	>17	>2858	7106	77	0	7182	9874	1231	98	11302	10.5
Jun 96	534	33	38	1	73	468	568	1	1037	1483	45	0	1527	1864	652	2	2637	2.8
Jul 96	567	161	268	1	430	997	5238	135	6360	3398	404	0	3802	4548	5810	136	10502	4.1
Sept 96	625	114	84	70	268	1134	3597	541	5272	3896	333	0	4229	5144	4014	611	9768	2.7
Oct 96	663	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY
Feb 97	777	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY	NO SURVY
Mar 97	808	35	13	193	241	741	396	2410	3547	3380	118	0	3498	4156	527	2603	7286	3.3
May 97	867	288	8	2411	2706	2068	201	17768	20057	8069	47	0	8116	11448	256	20178	31881	8.5
Aug 97	947	217	2248	123	2588	2818	1626	189	4633	9551	468	0	10019	12584	4342	312	17240	15.0
Oct 97	1007	687	1307	193	2187	3298	4953	2767	11018	12237	687	0	12924	16222	6047	2960	26129	8.4

Table 10: Rodent trapping data at Vaseys Paradise in 1997.

DATE	NO. TRAPS	RODENT SPECIES	HABITAT PATCH	MASS(g)	SEX	CONDITION	TOECLIPPING HIND	TOECLIPPING FORE	RECAPS	SUMMARY	TRAP SUCCESS%
970316	40	PECR	P6NU	18.4	F	IMM	R3	NONE	No	Pc 4 (2 recap)	10.0
970316	40	PECR	6 Backgrnd	23.4	M	NON-REPRO	L4,R4	NONE	Recap		
970316	40	PECR	6 Backgrnd	23.5	M	NON-REPRO	NONE	L2	No		
970316	40	PECR	P7U	21.4	F	NON-REPRO	R5	NONE	Recap		
970318	38	PECR	P6ML	23.5	M	NON-REPRO	NONE	L2	Recap	Pc 5 (3 recap)	13.2
970318	38	PECR	P60 POAM	23.7	M	Begin-REPRO	L4	NONE	Recap		
970318	38	PECR	P6 POAM	21.3	F	NON-REPRO	L5,R5	NONE	Recap		
970318	38	PECR	P6CAREX	22.8	M	NON-REPRO	NONE	NONE	No		
970318	38	PECR	P5M	16.6	F	NON-REPRO	R3	NONE	Recap		
970516	22	PECR	P5MML	21.8	F	REPRO	L4	R4	No	Pc3 (2 recap)	13.6
970516	22	PECR	P5MDS	24.2	M	REPRO	L4,R4	NONE	Recap		
970516	22	PECR	P5MDS	25.3	F	GROUND, FLEAS?	R5,L5	NONE	Recap		
970804	24	PECR	P8L	25	F	REPRO MALE	L6,L4,R4	NONE	No	Pcrinitus 2 (0 recap)	8.3
970804	24	PECR	12 UNMAR	19.8	F	NON-REPRO	NONE	NONE	No		
971002	49	PECR	P5MD	29.3	F	LACTAT. MATURE	NONE	NONE	No	Pecr (2), Pema(1)	4.1
971002	49	PECR	P5MD	15.1	F	LACTAT. IMM	NONE	NONE	No	0 Recap	
971002	49	PEMA	IMM FOUND, NOT TRAPPED								

In August JAS removed two live KAS that were expressing sporocysts for behavioral observations. The KAS were transported to Phoenix where he observed that parasite behavior is phototropic: sporocysts withdraw into the snail's body cavity and shell in the dark, and actively pulsate in the eyestalks when exposed to light. Macrophotos and close-range video photography was conducted on the two parasitized KAS by AGFD. JAS also reported that the parasitized KAS produced egg masses: one egg mass of 10 eggs was found on wet litter within the first 48 hours of captivity, and the second egg mass, containing 5 eggs, appeared in the next 24 hours. These egg mass sizes are less than about half the normal clutch size for KAS, but his observations demonstrate that parasitized KAS are capable of at least some reproduction. JAS preserved both the parasitized KAS and the egg masses as voucher specimens. Anatomical dissection of one specimen (15 mm size) with two sporocysts revealed no changes to its reproductive tract other than it had been pushed aside by the sporocysts (J. Hoffman, pers. commun.). Both sporocysts were 12 mm long and 2 mm wide, and occupied 80% of the snail's head. One sporocyst was dissected and contained 97 cercariae (J. Hoffman, pers. commun.).

Objective 7: Provide administrative assistance for Arizona Game and Fish Department and U.S. Fish and Wildlife Service recovery efforts.

The Grand Canyon Monitoring and Research Center provided logistical and staff support for KAS monitoring in 1997. The GCMRC also supported AGFD and USFWS KAWG-related efforts by providing logistical support, flow and other information and document review, as well as by hosting seasonal KAWG meetings.

MANAGEMENT IMPLICATIONS

KAS monitoring remains a high priority for adaptive Colorado River management. The USFWS Biological Opinions currently prohibit future planned high flows from Glen Canyon Dam for ecosystem management purposes until a second population of KAS are discovered or established in Arizona. The data presented here demonstrate that more than two yr are required for recovery of KAS habitat and population following a 1275 m^3/s high flow event, such as the 1996 Test Flow. However, these KAS population estimates are based on mean values, and the variation around those mean values is often substantial, potentially affecting conclusions regarding recovery rates. Repeated high flow events will result in "training" of KAS habitat and population to higher stage elevations. Establishment of a baseline condition of habitat and population sizes may help refine KAS management strategies in this ecosystem.

We recommend that approximately bi-monthly monitoring of KAS habitat and population be continued in 1998, with continued assessment of potential rodent predation and flatworm parasitism, in addition to monitoring the impacts of exceptional flow events.

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