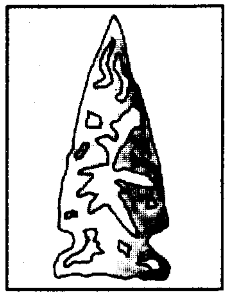
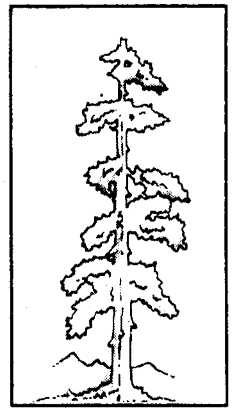
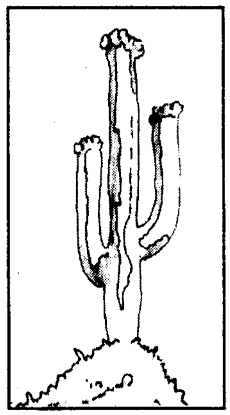
FINAL YEAR-END REPORT
KANAB AMBERSNAIL MONITORING AT VASEYS PARADISE







Prepared for:

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February 1999

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REPORT SUMMARY

The 1998 research and monitoring field work for Kanab ambersnails (*Oxyloma haydeni kanabensis)* at Vaseys Paradise, Grand Canyon, AZ comprised four site visits in April, May, July, and September. Population estimates were 9,500 in April, 7,000 in May, 8,000 in July, and 16,000 in September. Breeding seemed to have been delayed somewhat due to a late, cold spring; young snails were present in July, but constituted a larger proportion of observed snails in September. Habitat availability changed somewhat seasonally, but all changes were similar to changes in the previous years. PIT tagging of *Peromyscus crinitus* was successful. Two of 46 recaptures were of mice that had crossed the main spring pourout. Radulae have been isolated from *Catinella,* a succineid snail, and survived intact in a chemical model of a *Peromyscus* stomach. Genetic studies of succineid taxonomy continue at Northern Arizona University; the Vaseys Paradise population is least like the other 4 *Oxyloma* populations known from the southern Utah and northern Arizona.

INTRODUCTION

Kanab ambersnail is a terrestrial succineid snail associated with wetland and seep/spring vegetation on the Colorado Plateau. Its current taxonomic status is problematical as genetic investigations to determine relationships of several succineid populations in northern Arizona and southern Utah have been underway for more than a year, and results are not yet available (Paul Keim, Mark Miller, Northern Arizona University, pers. comm.). For the present, the species comprises at least two populations: one at Vaseys Paradise, in Grand Canyon National Park, and one on private land in southern Utah. The research we report was undertaken at Vaseys Paradise.

Vaseys Paradise is a small patch of spring-fed riparian vegetation 51 km downstream from Lee's Ferry on the Colorado River in Grand Canyon National Park, Arizona. The site has been described repeatedly in previous reports (Stevens et al. 1997a, 1997b, 1998).

At Vaseys Paradise, ambersnails are found in the spring-fed vegetation, usually associated with cardinal monkeyflower (*Mimulus cardinalis*), watercress (*Nasturtium officinale*), and sedge (*Carex aquatilis*). Life history and general habitat associations are described in previous reports (Stevens et al. 1997a, 1997b, 1998).

The 1998 tasks as approved by the Grand Canyon Monitoring and Research Center (GCMRC) included monitoring habitat, snail populations, and populations of mice (*Peromyscus* spp.) and research to determine the detectability and digestibility of radulae of succineid snails in the genus *Catinella*.

METHODS

Field Visits

We visited Vaseys Paradise during 3-5 April, 23-25 May, 19-21 July, and 26-28 September, 1998. Snail monitoring was entirely performed by Vicky Meretsky, David Wegner, Hélène Johnstone, Lilian Jonas, Clay Nelson, Eric North, Larry Stevens, Jeff Sorensen, and Peter Price; additional individuals served as recorders. Surveyors and boatmen were not associated with this contract, but all assistance was cordial and competent.

Habitat monitoring

Habitat monitoring to assess quantities of vegetation and changes in vegetation composition followed protocols described in Stevens et al. 1997a. During each visit, vegetation patches that were designated in 1994 and 1995 were surveyed and their composition described. In some instances, changes in vegetation required redesignating, adding, or eliminating patches.

Ambersnail monitoring

Snail monitoring followed protocols described in Stevens et al. 1997a. During each visit, all major patches were surveyed for snails. Survey samples were circular patches of vegetation 20-cm in diameter. Vegetation and substrate in the circular plots were described, and ambersnails within the plots were counted and measured. Presence of other snails, egg masses and snail shells was noted.

Peromyscus monitoring

During each visit, we trapped for small mammals on two nights. We set 30-45 Sherman traps each night, and checked them early the following morning. Trapped mice were weighed, sexed, and scanned for the presence of tags. Passive integrated transponders (PIT tags) were injected into newly-trapped animals subcutaneously, following Animal Use protocols of Indiana University. Mice were released into the patch in which they were trapped. Traps were placed both upstream of the main pourout, in the lower portions of ambersnail habitat, and on downstream of the pourout, in desert vegetation.

Detection and digestion of *Catinella* radulae

Individuals of the genus *Catinella* were removed from Vaseys Paradise to the lab in order to remove radulae for experiments to determine their ability to persist in a chemical model of a *Peromyscus* stomach. Unfortunately, the individuals were too small for their radulae to be seen under field microscope, and the individuals died before we could determine a technique for dissecting out their radulae.

An Indiana University, Laura Hilden, performed dissections of ramshorn snails (Ampullariidae, once Pilidae: *Marisa* sp.) and apple snails (Ampullariidae, once Pilidae:*Pomacea* sp.) purchased in a local pet store. She readily found the radulae and later isolated and cleaned these by immersing them for several hours in a 1 M solution of NaOH (Walker 1906). These snails are significantly larger than *Catinella* found at Vaseys Paradise (length of 2+ cm, as opposed to < 1 cm).

Ms. Hilden then isolated radulae in the dried *Catinella* specimens using NaOH on the remains. We mounted one of these on a slide for future comparison. A dried *Catinella* was rehydrated and subjected to the chemical stomach model: the snail was immersed in 0.1-0.2 ml of warmed HCl at pH 2-3 for 20 min and spun to mimic agitation. The radula and the snail survived almost entirely intact. An additional 20 minutes of "digestion" with a boiling bead to provide some further physical force did nothing further. The snail was then subjected to a more direct analog of muscular contraction - it was gently kneaded with a thumb. This caused the radula to come loose from the snail body, and caused gaps in the "fabric" of the radula, rather as if a loosely woven fabric had been badly strained along some of its threads. Thus, it seems likely that *Catinlla* radulae, at least, will survive digestion by *Peromyscus*. The manipulated radula was mounted in Permount fixative on a slide, for future comparison with fecal pellet contents.

Data Management

Ambersnail and vegetation data are initially collected on data sheets which are then entered into Microsoft Excell spreadsheets. Summary spreadsheets are prepared from the data spreadsheets, and statistical data sets. Because most data are processed in at least two different ways, internal data checks occur automatically when the final data presentations are prepared. All data are protected by nightly back-ups at Indiana University. In addition, copies of all field data sheets are mailed to Dr. Lawrence Stevens at GCMRC.

Reporting

Spreadsheets have been submitted to Dr. Stevens in advance of these reports, and final versions will be sent electronically when this report is submitted in final form. Metric units are reported, with the exception of dam discharge which is reported in the units used by Bureau of Reclamation - cubic feet per second (cfs).

RESULTS

General

All 1998 monitoring work was successfully completed during the four visits to Vaseys Paradise. Mapping was finalized during consultation with GCMRC surveyors. Ambersnail population estimates were distributed to GCMRC staff as soon as habitat patch area was available from surveyors.

Environmental occurrences of note during the season comprised a 31,500 cfs flow in early spring, an noncompliant, rapidly downramped, low flow below 10,000 cfs during the April 1998 visit, and a local flash flood approximately two weeks before the September visit. A long, wet spring contributed to high Vaseys' spring outflow at least until July.

Spring temperature and outflow information for the season was as follows: April, 14.5°C, 0.64 cfs; [May 10 (Stevens, pers. comm) 14.5°C, 6.5 cfs]; May, 13°C; July, 17°C, 2.47 cfs; September, 16.5°C, 0.61 cfs).

Habitat monitoring

The area of patches surveyed was relatively constant during the year, ranging from 200 to 235 sq m (Tables 1-4; Figures 1-4). Patches 6NDS was under water during the April visit, and was essentially obliterated in the pourover during the flood event in September. The flood deepened and scoured the channel in which 6NDS was growing, which ended at patch 9. Red sediment was deposited along the upstream side of 6NDS, and a fine layer of sediment was deposited over much of the rest of patch 6, probably carried in spray. High outflows during the summer watered patch 6 heavily, and most of the platform was saturated in April and May, very moist in July, and moist in September.

High flows (above 20,000 cfs) in the Colorado River scoured the lower ends of patches 11 and 12, and a 31,500 cfs flow in early spring inundated most of 11, 12, and 7L. Patch 7L escaped scouring because of its sheltered location on the downstream side of the debris fan.

Due to the high moisture levels in the matrix portions of patch 6 (outside the usually designated patches), and the concomitantly high densities of ambersnails outside the usually designated patches, patch 6RMDR was resurrected. The acronym denotes 6 Remainder, and the patch comprises the area not otherwise delineated on the platform downstream of the large rock outcrop between 8U and 6MU and the upstream edge of the main pourout. In the past, this patch has been a refuge for overwintering snails, but has been too dry to support ambersnails during the summer.

Area of monkeyflower (MICA in Tables 1-4) increased from 82 to 99 m^2 from April to May, a result, almost entirely, of expansion in 5M, probably a result of the new season's growth, especially in 6RMDR. Monkeyflower increased a similar amount between May and July as a result, primarily, of increases in 6MU and 8U, and was stable from July to September.

Watercress (NAOF in Tables 1-4) also increased from April to May, to 36.6 m^2, from expansion in several patches. Watercress area was relatively stable from May to July, and decreased to near-April levels in September.

Sedge (CAAQ in the Tables) occurs primarily on the platform supporting the 6 series of patches, with additional growth in 7L and 12. Little sedge was alive on the 6 platform in April, and there was a large jump in sedge area from April to May. Area increased again in July, from 17.6 to 28.3 sq m, and increased to 57.6 sq m in September. The September increase is due to the large portion of the 6 platform included in 6RMDR, and the large proportion (80%, next lowest in 1998 was 50%) of the vegetation in 6RMDR that was assigned as sedge). Because 6RMDR was large in September, more ambersnail circular surveys were performed, and as a result, our understanding of the vegetation was more thorough. Thus, midseason 1998 estimates of the amount of *Carex* may be low due to small sample size. This does not affect estimates of ambersnail density.

Ambersnail monitoring

Population estimates for the lower habitat area surveyed under this contract ranged from a low of 8,083 in July to a high of 16,090 in September (Tables 1-4). In April, snail densities were highest in watercress patches, and in 6RMDR, which seems to be overwintering habitat (Stevens 1997b). Most snails (93%) we found were out of dormancy (Table 1). Snail lengths were unimodal (Figure 5, Graph A), and averaged 7 mm.

Snail densities in May were highest in 203M, 203N, 5N, and 6MP, a mix of habitat types (Table 2). Snail length was bimodal, with peaks at 7 and 12 mm (Figure 5, Graph B).

In July, densities were highest in 8U, 9, and 6NU (Table 3). Patches 9 and 6NU are watercress patches; 8U is not a watercress-dominated patch, but it does have a section of rich soil which has often supported high snail densities. Length was strongly bimodal, with peaks at 3 and 13 mm (Figure 5, Graph C).

The September visit occurred during warm weather, and all snails we encountered were still active. The length histogram was unimodal, with most snails between 3 and 10 mm, with a slight peak at 4 mm; there were more small snails than in any earlier visit in 1998 (Figure 5, Graph D). The highest densities of the year occurred in patch 6NU, at 310 snails/sq m (Table 4). Densities were also higher than in any other patch in previous visits in 6NMX (a mixed monkeyflower/smartweed [*Polygonum amphibium*] patch), 6P (monkeyflower and smartweed), 5N (watercress) and 7U (watercress). These high densities are unremarkable in comparison with high densities of previous years (Stevens et al. 1998).

***Peromyscus* monitoring**

We caught 25 canyon mice (*Peromyscus crinitus*) during the 1998 monitoring season (Table 5). Overall trap success was 15% and we had 46% recaptures. Reproduction apparently did not begin until mid-late April; we caught no immature mice in April. Similarly, we caught only subadults and adults in September; reproduction may have ended slightly earlier.

The downstream area in which we set traps was roughly the same size as the area trapped in the upstream spring vegetation. More animals were caught in the spring vegetation, and recaptures were more common downstream, both suggesting that food may have been less available downstream. The high proportion of recaptures suggests we were seeing a relatively high proportion of the population. Two animals crossed the pourout channel: an adult male moved downstream between May and July, and an immature male moved upstream during the July trapping. Thus, while snails may supply food to some animals below the pourout, the water channel seems to function as a barrier that is not frequently crossed; >90% of captures did not involve a cross of the pourout. Males were caught more frequently than females, but the difference was not significant ($\chi^2 = 3.24$, df = 1, $0.10 > p > 0.05$).

We had very small capture populations in any given visit, and complex mark-recapture statistics could not be attempted. We had too few individuals to estimate the number of parameters required. The differences in capture among the sexes suggests capturability varied at least by sex, possibly also by age. In addition, the data suggest a tendency to reenter traps after initial trapping - trap-happiness. For all these reasons, Lincoln-Peterson estimates are inappropriate, but they remain the most readily calculated. Depending on what one uses as the "marked" population (and using all animals for the entire season is unwise, given the relatively short lifespan of the species), very crude population estimates range from 12 to 36 for the upstream area. We inadvertently killed one mouse during the 1998 season (Table 5). Despite careful bookkeeping, a trap was left in the field after the July visit, and when it was found, there was a mouse in it. We have become yet more careful in our accounting for traps, as a result.

Detection and digestion of *Catinella* radulae

Radulae of aquatic snails were readily visible at 50-100 power. Tissue was readily digested by 1 M NaOH (pH>13). If larger radulae can survive base digestion with this corrosive an agent, it seems possible that smaller radulae may survive acid digestion with a less powerfully acid agent. However, muscular contractions in the stomach may tend to fragment the radula, and the individual teeth are very small relative to the whole structure.

DISCUSSION AND RECOMMENDATIONS

Vegetation

Vaseys Paradise has still not recovered the monkeyflower habitat it lost during the 1996 experimental flood (see Stevens et al. 1997b). Monkeyflower seems to reproduce primarily by vegetative means at Vaseys Paradise, probably because soil does not accumulate readily on the sloping surfaces. At least on the upstream end, on steep, bare limestone, vegetative reproduction is quite slow, and the plants that were above the flood line in 1996 have not extended their rootmat to retake the originally occupied area.

Other habitats (e.g., in 7L and in 11) have grown back, and at times the total amount of vegetation exceeds pre-flood levels. However, most of the regrowth is in watercress, a species that snails rarely use for overwintering. Watercress rapidly recolonizes wet, open areas, and watercress area is one of the most changeable statistics at Vaseys Paradise. Thus, while watercress regrowth has erased many traces of the scouring caused by the experimental flood, the functional role that was played by monkeyflower in the lower ends of patches 5, 4.5 and 203 has yet to be refilled.

Vegetation continues to shift at Vaseys Paradise. Some regions are relatively static with respect to vegetation composition; others, especially in patches 6, 7L and 8U change fairly rapidly. Discounting the rapid swings in watercress cover, plants favored by ambersnails continue to cover a large proportion of the site. Poison ivy, while it still constitutes a relatively small proportion of the platform containing the #6 patches, is increasing in density, reducing accessibility there.

Snails

Previous population estimates from early spring surveys (Feb-April) range from 5,200 - 10,900 individuals, or, eliminating the post-experimental flood estimate from April 1996, 7,300 - 10,900 (Stevens et al. 1997a, b, 1998). Depending on the amount of vegetation above the 100,000 cfs stage, the total estimate for spring 1998 may be somewhat higher. Snails may be easier to find when active, and we had very few inactive snails, relative to what we would have expected in earlier months.

Previous population estimates from surveys later in the growing season range from 2,600 - 108,000 (Stevens 1997a, b, 1998). The low estimate is from May 1996, following the experimental flood. But adjusting the low bound to the next lowest estimate, 9,700, still leaves a very wide range of values. Clearly, once reproduction begins, population estimates expand with the increase in immature snails. However, immature snails are comparatively difficult to detect, and they are subject to heavy mortality. Samples taken after reproduction has begun are useful to track reproductive output in a given year, but are less useful for population estimates.

Length histograms from our samples suggest most reproduction occurred late in the growing season, probably in response to a long, cold spring. Data from the previous year showed a strong reproductive pulse in August, and data from 1996 showed reproduction occurring from July through September, probably a result of an early summer (Stevens et al. 1997a, b, 1998). Ambersnails at Vaseys Paradise have evolved in a region of climatic variability and clearly time their reproduction fairly flexibly.

Peromyscus

This is the first year that mark-recapture data have been collected, so there are no grounds for comparison. Trap success rates were higher than those reported in 1997 (Stevens et al. 1998) but that may be a result of newer traps and more rigorous field protocols. There is no reason to think that either the mice or the snails are a recent addition to the vicinity, and no reason for concern about the presence of the predatory rodents at the spring. PIT tags worked quite well; animals are apparently unharmed by the injection, and tags are readily detected on recapture.

Snail radulae

Laboratory results suggest that radulae should survive digestion. Next, we will trap *Peromyscus* outside of Grand Canyon and try to feed them succineid snails in order to try to detect radulae in fecal pellets. Results of this experiment will help determine how often we expect to see radulae in fecal pellets of mice at Vaseys Paradise.

Other topics

In fulfillment of contract requirements, Dr. Meretsky attended two Kanab Ambersnail Working Group (KAWG) meetings, was available for conference calls during the others, and received and commented on minutes of all meetings. Developments during the year have altered our understanding of the genetics and conservation status of the various known populations of *Oxyloma* on the Colorado Plateau (Paul Keim, Mark Miller, Northern Arizona University, pers. comm.). The recovery plan for Kanab ambersnail is now more than 5 years old, and should, according to U.S. Fish and Wildlife Service policy, be revised (Debra Bills, U.S. Fish and Wildlife Service, pers. comm.). While such a revision is clearly in order, it might wisely be left until genetic studies of the Succineidae from NAU are more complete, in order to permit the Service to work from a clear understanding of the situation.

Preliminary data suggest that the *Oxyloma* population at Vaseys Paradise is the population that least resembles any of the others. Therefore, resource managers ought to contemplate a future in which that population is the only one of its species or subspecies, and consider what impact this situation would have on monitoring and research needs.

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Walker, B. 1906. An illustrated catalogue of the Mollusca of Michigan by Bryant Walker. Part I. Terrestrial Pulmonata (land snails). Wynkoop Hallenbeck Crawford Co., Lansing, MI.

Related publications in progress

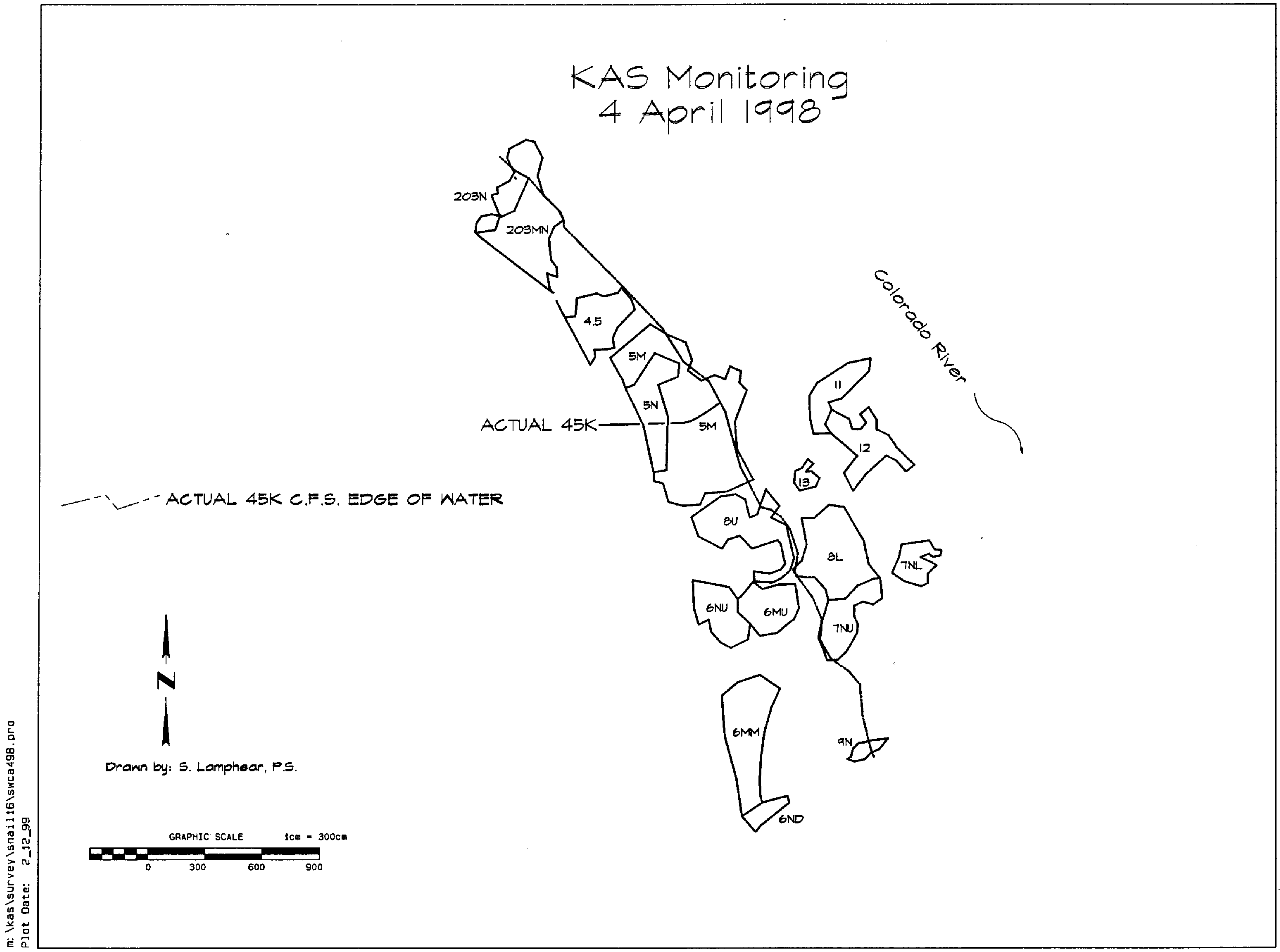
Meretsky, V.J., D.L. Wegner, and L.E. Stevens. Balancing endangered species and ecosystems: a case study of adaptive management in Grand Canyon. Environmental Management. In revision.

Meretsky, V.J., S.K. Wu, M.P. Miller, E. North, and L.E. Stevens. Rediscovery of Kanab ambersnail at the type locale. American Midland Naturalist. In prep.

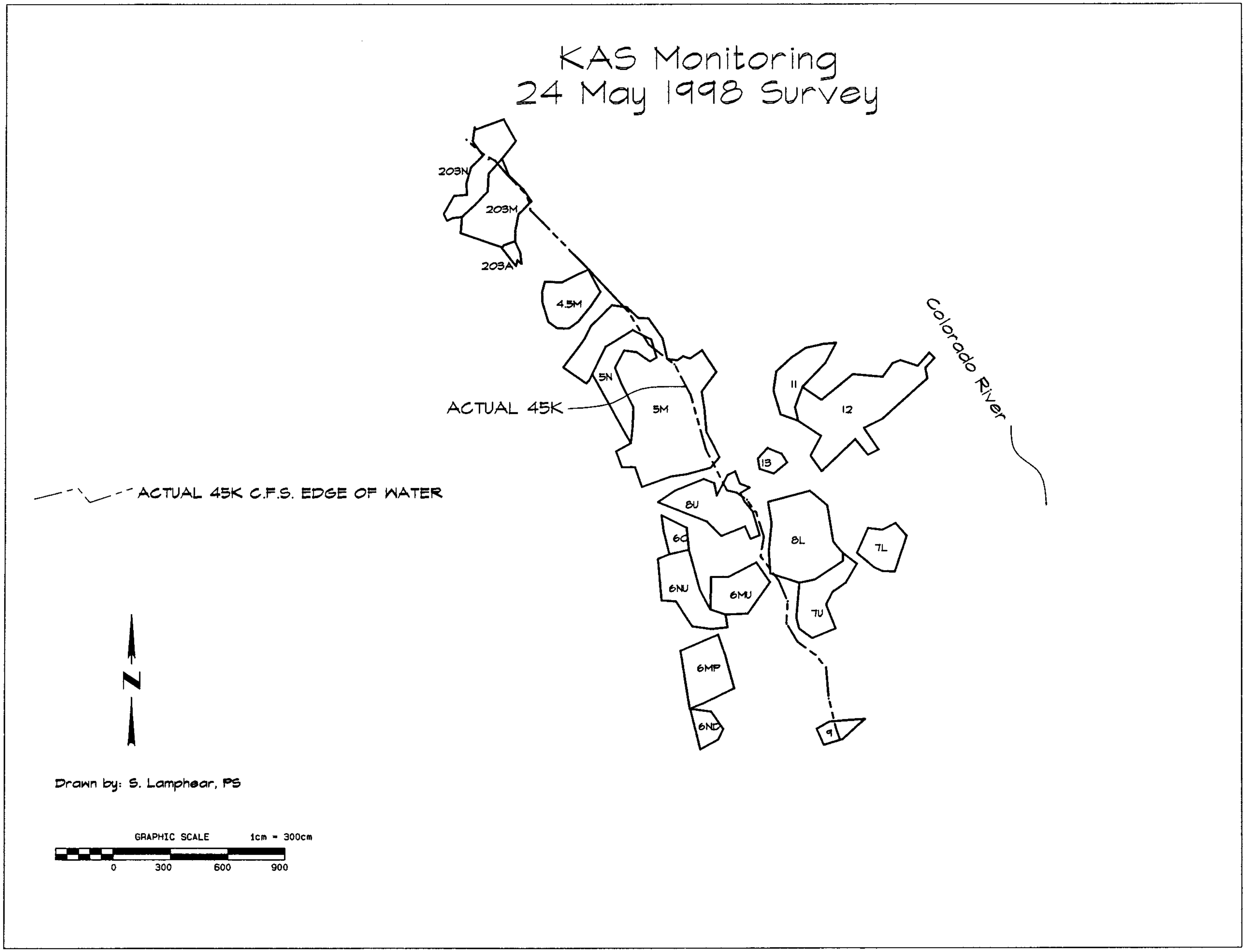
Presentations

Meretsky, V.J., M. P. Miller, C.B. Nelson, J.A. Sorenson, and L.E. Stevens. Conservation of an endangered succineid land snail. To be presented by the senior author at the Freshwater Mollusk Conservation Symposium, March, 1999.

TABLES



Fiaure 1: Aoril 1998 KAS habitat surveu at Vaseus Paradise



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Fiaure 2: Mau 1998 KAS habitat surveu at Vaseus Paradise

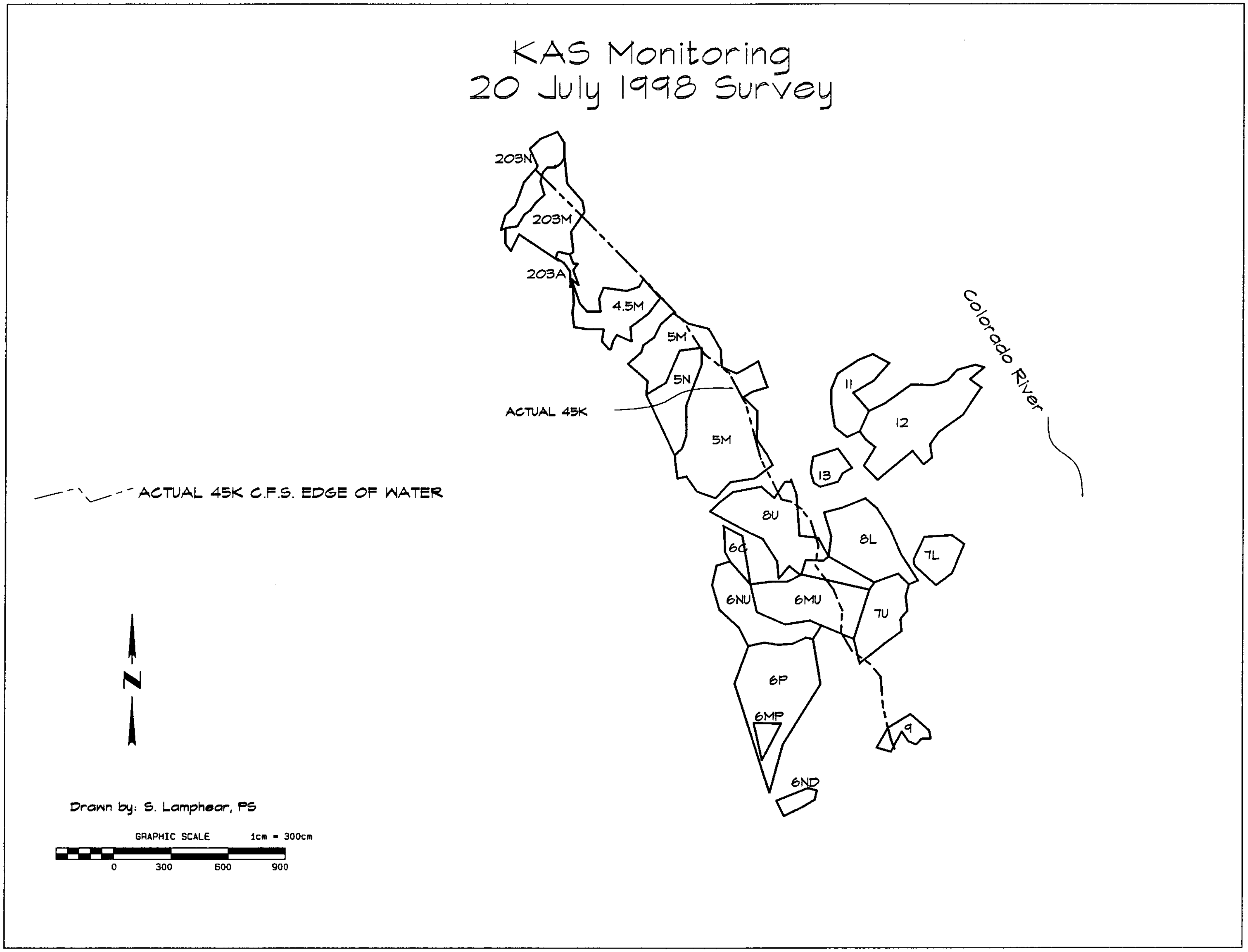

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Figure 3: July 1998 KAS habitat survey at Vaseus Paradise

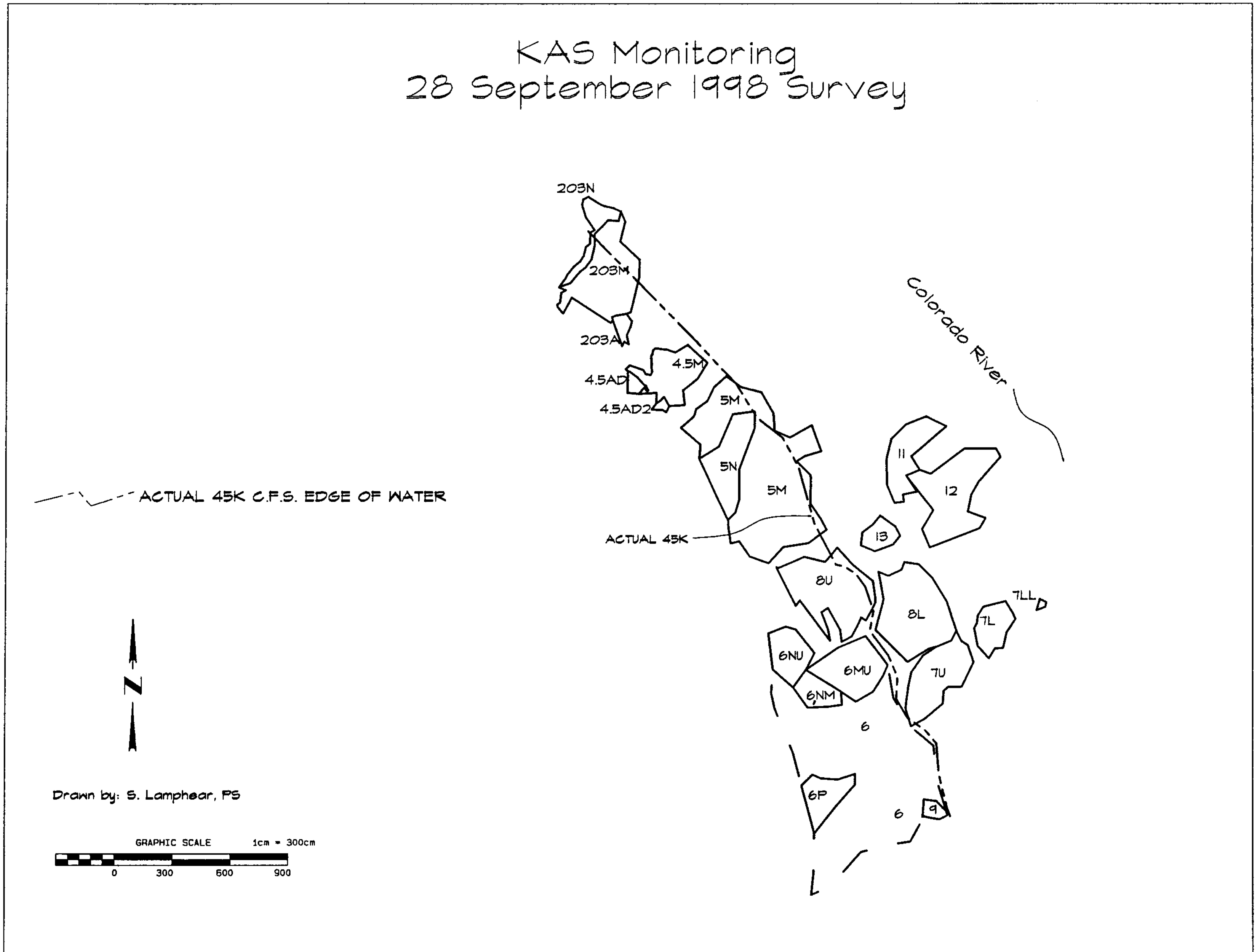

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Figure 4: September 1998 KAS habitat survey at Vaseys Paradise

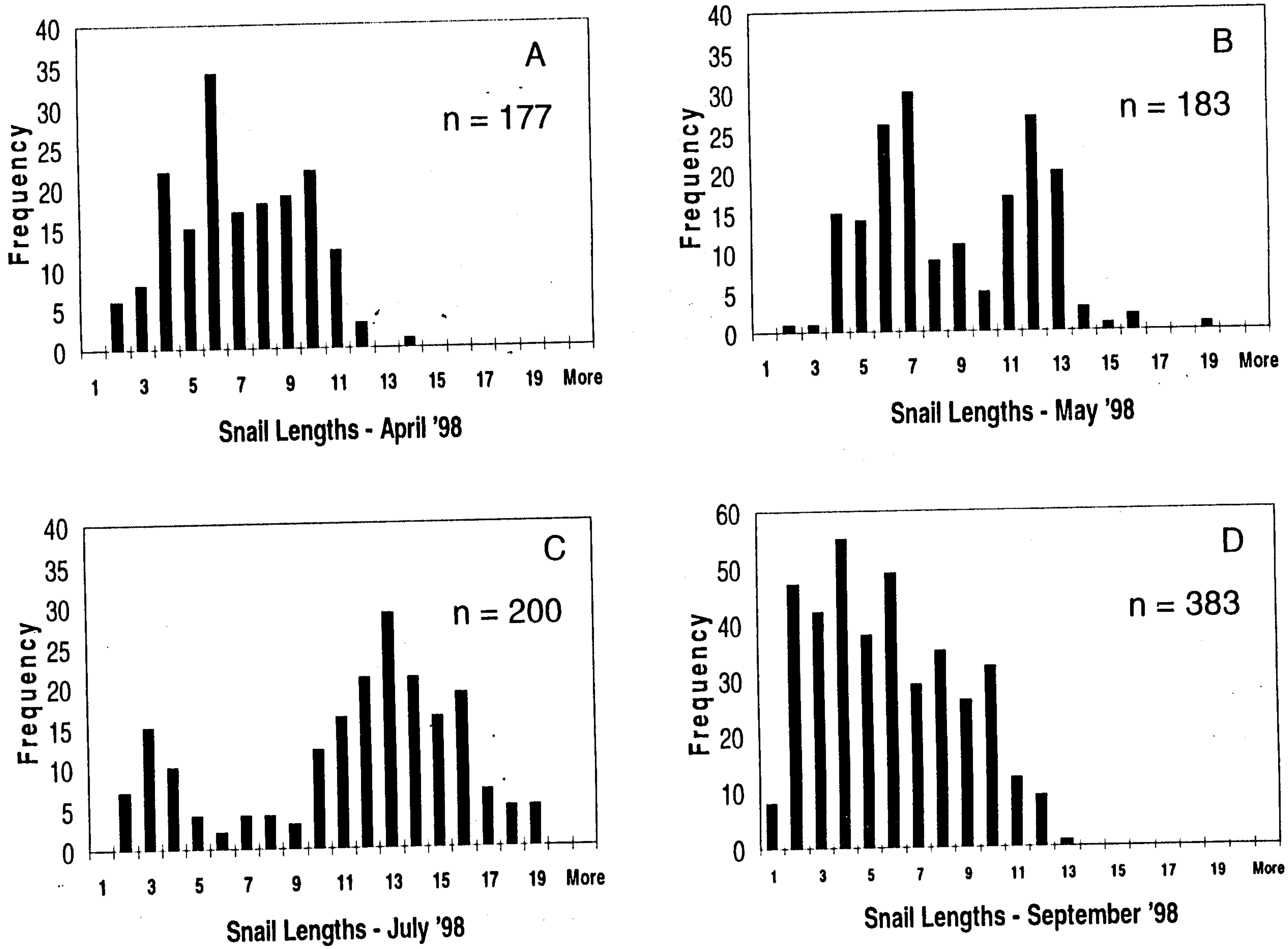

Figure 5: April - September Snail Lengths at Vaseys Paradise

Table 1. April 4-5 ambersnail and habitat survey data, 1998.
Snail estimates are corrected for areas of bare rock and open water.

Patch	Patch area	N of samples	N of snails	Snail density (#/sq m)	Boot-strap 5-ile	Cal-culated Mean	Boot-strap 95-ile	N dor-mant	% of Live Vegetation			% Veg That is Live	% Cov Total Veg	Live Veg'd Area	Total Veg'd Area	Area Mica	Area Naof	Area Caaq
									Mica	Naof	Caaq							
4.5	11.19	8	3	11.9	45	133.6	223		77			81	100	9.06	11.19	8.62		
5M	38.04	12	7	18.6	198	692.2	1286		88	2		90	98	33.55	37.28	32.81	0.75	
5N	9.51	6	19	100.8	505	958.6	1413		5	95		100	100	9.51	9.51	0.48	9.03	
6NU	7.04	10	3	9.6	23	67.2	135		1	96	1	98	100	6.90	7.04	0.07	6.76	0.07
6MU	7.55	5	2	12.7	0	96.1	289		63		1	76	100	5.74	7.55	4.76		0.08
6MM	12.56	12	16	42.5	164	522.4	915	6	16	5	7	31	98	3.82	12.31	1.97	0.62	0.86
6NM	1.3	3	0	0.0		0												
6NDS	2	6	2	10.6	0	21.2	43	1	5	95		100	100	2.00	2.00	0.10	1.90	
6RMDR	29.55	3	17	180.5	1255	5223.3	9407	1			3	10	98	2.90	28.96			0.87
7L	3.93	8	0	0.0		0			8		80	87	95	3.25	3.73	0.30		2.99
7U	7.04	7	3	13.6	23	67.2	113		18	75	5	98	70	4.83	4.93	0.89	3.70	0.25
8L	14.27	10	5	15.9	39	193.0	387		56	2	10	60	85	7.28	12.13	6.79	0.24	1.21
8U	12.35	11	17	49.2	251	607.5	1001	4	38.5			71	100	8.77	12.35	4.75		
9L	0.61	all	1	1.6		1				100		100	100	0.61	0.61		0.61	
9U	0.91	5	16	101.9	24	92.7	168			98	1	100	100	0.91	0.91		0.89	0.01
11	5.78	6	0	0.0		0						31	60	1.08	3.47			
12	8.18	8	0	0.0		0					12.5	65	90	4.79	7.36			0.92
13	1.44	4	2	15.9	0	22.9	46		76.5	5		82	100	1.18	1.44	1.10	0.07	
203M	24.23	6	2	10.6	0	257.1	515		76.7			89	100	21.56	24.23	18.58		
203N	3.59	6	26	138.0	153	495.2	896		10	90		100	100	3.59	3.59	0.36	3.23	
others			38			38												
Total	201.1	131	179		4,920	9,489	14,515	12						131.3	190.6	81.57	27.80	7.25
	sq m	samples	snails		snails	snails	snails	dorm.						sq m	sq m	sq m	sq m	sq m
			counted					6.7%									w/o 6RMDR	

6MM comprises old 6POAM, 6MM, 6NM.
Vegetation in 6RMDR estimated from photographs.
37 snails were found on small *Juncus articulatus* patches in 5M. These snails are excluded from density calculations, and but are added to totals of snails counted. and mean ambersnail estimate)

Table 2. May 24-25 ambersnail and habitat survey data, 1998.
Snail estimates are corrected for areas of bare rock and open water.

Patch	Patch area	N of samples	N of snails	Snail density (#/sq m)	Boot-strap 5-ile	Cal-culated Mean	Boot-strap 95-ile	% of Live Vegetation			% Veg That Is Live	% Cov Total Veg	Live Veg'd Area	Total Veg'd Area	Area Mica	Area Naof	Area Caaq
								Mica	Naof	Caaq							
4.5	8.82	10	16	51.0	281	449.2	618	97	0	0	98	100	8.6	8.8	8.6	0.0	
5M	42.18	14	15	34.1	864	1438.5	2014	98	2	0	98	100	41.3	42.2	41.3	0.8	
5N	7.94	7	16	72.8	253	577.7	939	5	95	0	95	100	7.5	7.9	0.4	7.5	
6NU	7.81	12	9	23.9	41	182.7	346	TR	100	0	100	98	7.7	7.7	0.0	7.7	
6MU	6.56	8	0	0.0		0.0		80	0	16	95	100	6.2	6.6	5.2	0.0	1.0
6MP	7.87	8	18	71.7	181	541.1	962	25	0	50	98	96	7.4	7.6	1.9	0.0	3.8
6NDS	2.35	0	0			0.0		UNDER WATER									
6C	2.16	3	4	42.5	68	89.8	112	4		95	100	98	2.1	2.1	0.1		2.0
6RMDR	33.25	0	0		765	2286.0	4064	25	5	50	91	96	29.1	31.9	8.0	4.8	16.0
7L	4.66	6	4	21.2	43	85.0	171	5	TR	85	100	86	4.0	4.0	0.2		3.4
7U	7.16	8	4	15.9	18	68.4	120	2	95	1	100	60	4.3	4.3	0.1	4.1	
8L	15.28	12	10	26.5	138	344.5	586	85	0	10	91	85	11.8	13.0	11.0		1.3
8U	10.02	13	18	44.1	169	432.8	722	70	TR	8	97	98	9.5	9.8	6.9		0.8
9	2.37	6	8	42.5	63	100.6	139		98	2	100	100	2.4	2.4		2.3	
11	6.27	7	1	4.5	0	27.1	82		4	25	100	95	6.0	6.0		0.2	1.5
12	20.51	6	0	0.0		0.0				30	100	60	12.3	12.3			3.7
13	1.49	3	1	10.6	0	15.8	32	97	TR	3	100	100	1.5	1.5	1.4		
203M	14.28	8	27	107.5	796	1534.0	2387	98	1		100	100	14.3	14.3	14.0	0.1	
203N	9.18	8	30	119.4	220	1095.7	2484	2	98		100	100	9.2	9.2	0.2	9.0	
203A	1.72	3	0	0.0		0.0		5			91	100	1.6	1.7	0.1		
others			3			3.0											
Total w/o 6RMDR	178.63 sq m	142 samples	184 snails counted		5,431 snails	6,986 snails	8,740 snails						157.7 sq m	161.2 sq m	91.4 sq m	31.8 sq m	17.5 sq m
Total w/ 6RMDR	211.88					9,269							186.8	193.2	99.4	36.6	33.5

6RMDR vegetation composition extrapolated, in part from 6MP.

Table 3. July 20, 21 ambersnail and habitat survey data, 1998.
Snail estimates are corrected for areas of bare rock and open water.

Patch	Patch area	N of samples	N of snails	Snail density (#/sq m	Boot-strap 5-ile	Cal-culated Mean	Boot-strap 95-ile	% of Live Vegetation			% Veg That Is Live	% Cov Total Veg	Live Veg'd Area	Total Veg'd Area	Area Mica	Area Naof	Area Caaq
								Mica	Naof	Caaq							
4.5	11.71	6	12	63.7	0	745.5	1491	92			100	100	11.7	11.7	10.8		
5M	38.81	20	18	28.7	666	1089.6	1574	99	TR	TR	100	98	38.0	38.0	37.7		
5N	9.57	10	33	105.1	687	985.1	1284	10	90		96	98	9.0	9.4	0.9	8.4	
6NU	10.41	11	33	95.5	679	974.2	1299	10	80	5	100	98	10.2	10.2	1.0	8.2	0.5
6MU	15.29	8	1	4.0	0	60.8	183	80		10	100	100	15.3	15.3	12.2		1.5
6NP	1.44	3	4	42.5	46	61.1	77		100		100	100	1.4	1.4		1.4	
6P	20.3	9	4	14.2	72	287.2	575		2	55	100	100	20.3	20.3		0.4	11.2
6ND	1.64	5	11	70.1	74	114.8	157		99	1	100	100	1.6	1.6		1.6	0.0
6C	2.33	4	0	0.0	0	0	0	5		95	100	100	2.3	2.3	0.1		2.2
6RMDR	8.59	not counted				122		10		50	100	100	8.6	8.6	0.9		4.3
7L	4.89	6	0	0.0	0	0	0	10		85	100	95	4.6	4.6	0.5		3.9
7U	8.87	8	4	15.9	35	138.3	243	2	98	TR	100	98	8.7	8.7	0.2	8.5	
8L	13.75	8	7	27.9	94	325.5	559	90		5	100	85	11.7	11.7	10.5		0.6
8U	15.17	6	23	122.1	805	1851.0	2978	73		15	100	100	15.2	15.2	11.1		2.3
9	3.27	8	34	135.4	287	442.4	599		98	1	100	100	3.3	3.3		3.2	0.0
11	7.35	6	2	10.6	0	76.4	230			12	100	98	7.2	7.2			0.9
12	21.33	8	0	0.0	0	0	0			38	100	60	12.8	12.8			4.9
13	3.43	not counted				102		88	2	10	100	100	3.4	3.4	3.0	0.1	0.3
203M	15.67	5	7	44.6	391	684.3	978	100			100	98	15.4	15.4	15.4		
203N	7.13	7	8	36.4	62	246.4	493	95	5		95	95	6.5	6.8	6.4	0.3	
203A	1.66	3	0	0.0	0	0	0	10			92	100	1.5	1.7	0.2		
Total w/o 6RMNDR or 13	222.61 sq m	141 samples	201 snails counted		6,541 snails	8,083 snails	9,702 snails						200.1 sq m	201.0 sq m	109.9 sq m	32.2 sq m	28.3 sq m
w/6RMNDR and 13						8306.6											

Vegetation in 6RMDR extrapolated, in part, from 6MP.

Table 4. Sep 27, 28 Ambersnail and habitat survey data, 1998.
Snail estimates are corrected for areas of bare rock and open water.

Patch	Patch area	N of samples	N of snails	Snail density (#/sq m)	Boot-strap 5-ile	Cal-culated Mean	Boot-strap 95-ile	% of Live Vegetation Mica	% of Live Vegetation Naof	% of Live Vegetation Caaq	% Veg That Is Live	% Cov Total Veg	Live Veg'd Area	Total Veg'd Area	Area Mica	Area Naof	Area Caaq
4.5	11.86	7	15	68.2	428	808.9	1175	85			99	100	11.7	11.9	10.1	0.0	0.0
5M	38.81	15	22	46.7	1223	1793.7	2691	100			98	99	37.7	38.4	38.4		
5N	9.57	7	34	154.7	1132	1479.5	1872	10	90		100	100	9.6	9.6	1.0	8.6	
6NU	5.05	11	107	309.8	1006	1516.7	2113	5	70	25	100	97	4.9	4.9	0.2	3.4	1.2
6MU	9	9	14	49.5	191	445.6	733	92		4	100	100	9.0	9.0	8.3		0.4
6NMX	3.35	6	43	228.2	427	764.2	1156	10	60		100	100	3.4	3.4	0.3	2.0	
6P	4.5	5	24	152.9	316	687.5	1118	TR	10	TR	100	100	4.5	4.5		0.5	
6RMDR	57.77	13	27	66.1	1981	3819.1	5800			80	100	100	57.8	57.8		0.0	46.2
7U	9.94	6	30	159.2	633	1582.0	2532.0	1	99	TR	100	100	9.9	9.9	0.1	9.8	
7L	4.29	6	9	47.8	43	190.5	339	7	7	75	100	93	4.0	4.0	0.3	0.3	3.0
7LL	0.28	2	3	47.8	0	11.4	23				100	85	0.2	0.2			
8U	15.28	8	27	107.5	894	1608.6	2324	90			100	98	15.0	15.0	13.5		
8L	15.45	7	4	18.2	66	261.3	458	95		3	100	93	14.4	14.4	13.7		0.4
9	1.06	6	4	21.2	5	19.1	34		50	40	100	85	0.9	0.9	0.0	0.5	0.4
11	6.96	6	1	5.3	0	36.9	111		TR	5	55	100	3.8	7.0			0.3
12	15.48	8	5	19.9	93	231.0	370			48	100	75	11.6	11.6			5.6
13	2.73	5	3	19.1	0	51.1	103	98	TR	2	100	98	2.7	2.7	2.6		0.1
203M	18.25	7	8	36.4	332	663.9	996	100			100	100	18.3	18.3	18.3		
203N	3.94	2	2	31.8	0	119.1	239	20	80		100	95	3.7	3.7	0.7	3.0	
203A	2.11	3	0	0.0		0.0		5			100	99	2.1	2.1	0.1		
Total	235.68 sq m	139 samples	382 snails counted		13,570 snails	16,090 snails	18,695 snails						225.1 sq m	229.1 sq m	107.6 sq m	28.1 sq m	57.6 sq m

Median snail estimate was 16,043.

Table 5. 1998 Peromyscus crinitus mark-recapture data.

PIT tag #	Age Class	Sex	Ap 4	Ap 5	May 24	May 25	July 20	July 21	Sep 28	Sep 29
028518796	ad	M	ds - up							
028515558	ad	M	ds - mid	ds - up						
028560510	ad	M	8L							
028550847	ad	M	8L	8U	P100	6C		ds - low	ds - mid	
028577839	ad	M	5M us	5M us						
028582826	ad	F		ds - mid	ds - mid	ds - up				
028582628	ad	M		ds - low						
028582344	ad	F		7U	6NUS	8L				
028590277	ad	F		8L						
028518019	imm	M			ds - up					
028551320	imm	M			7L					
028521573	ad	F			4.5	5M us	203	4.5	dead, 203	
028550824	ad	F			5M					
028545573	imm	M				5M ds				
028382825	imm	M					203			
028123774	imm	M					5M	4.5		
028588868	ad	M					ds - up		ds - up	ds - up
028127877	imm	F					203		203, ad	4.5
028302848	subad	M							ds - low	7U
028568364	ad	M							ds - low	
028512594	ad	F							4.5	
082588523	subad	M							8U	8L
028119828	subad	F							8L	
028588868	subad	M							ds - up	
028379263	ad	M								203
			5 caps	7 caps	7 caps	5 caps	5 caps	3 caps	9 caps	5 caps
				3 recaps	3 recaps	4 recaps	1 recap	3 recaps	3 recaps	4 recaps
			38 traps	38 traps	42 traps	42 traps	41 traps	41 traps	30 traps	30 traps

April:	May:	July:	September:
9 indivs	8 indivs	6 indivs	10 indivs
12 caps	12 caps	8 caps	14 caps
3 recaps	7 recaps	4 recaps	7 recaps
43% recap	58% recap	50% recap	50% recap
16% succ	14% succ	10% succ	23% succ

OVERALL		
302 trap/nights		
25 indivs	16 us	9 ds
46 caps	29	18
21 recaps	13	9
46% rcap	22	50
15% succ		

	Immature	Subadult	Adult	RT
F	1	1	6	8
M	5	3	9	17
CT	6	4	15	GT = 25

FIGURES