ENDANGERED KANAB AMBERSNAIL USE OF NATIVE AND NON-NATIVE HOST PLANTS IN GRAND CANYON, ARIZONA

SEPTEMBER 1997 ANNUAL TECHNICAL AND ADMINISTRATIVE REPORT

NAU PROJECT NO. BIO 351Z

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Submitted To:

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April 1997 Kanab Ambersnail Research Summary

A proposal for research on endangered Kanab ambersnail (KAS) use of native and non-native host plants in Grand Canyon, Arizona was funded by the Bureau of Reclamation in September 1996. The proposed work involves three phases: laboratory study, habitat establishment, and initial establishment of an experimental Kanab ambersnail population at Glen Canyon Dam. The U.S. Fish and Wildlife Service Recovery Plan (1995) for the Kanab ambersnail states that 10 additional Kanab ambersnail populations are to be discovered or established before the species can be downlisted, and at least one of these populations is expected to be in Arizona. Recovery activities are proceeding but will require considerable time. Meanwhile, ecosystem management of the Colorado River in Grand Canyon depends on the ability of the Bureau of Reclamation to conduct habitat building flows. Our feasibility study will help determine Kanab ambersnail habitat requirements and life cycle, as well as the feasibility of establishing an experimental population at Glen Canyon Dam.

Phase I of this project consists of five specific objectives involving literature review, host plant propagation and life cycle information, data collection on Kanab ambersnail life history and the development of a life history model, as well as an optional evaluation of the effects of parasitism on ambersnail life history. Host plant propagation in experimental KAS enclosures has been initiated, the literature review is underway, and pilot experiments involving host plant life history and growing conditions are in progress. Young ambersnails were collected in August 1997 and have been placed in experimental enclosures at NAU. The captive population of ambersnails has been monitored on a daily basis, and preliminary growth rate data has been collected. Methods for other experiments have been developed, though are subject to change pending committee evaluation.

PHASE I PROGRESS

1. Literature Review

- April 1997: A comprehensive review of all relevant literature pertaining to Kanab ambersnail, succineid ecology, parasitism of molluscs, genetic isolation, geographic speciation, autecology of the two host plant species, and host plant shifts among invertebrates has been initiated (see attached literature review).

2. Data collection and analysis regarding propagation of ambersnail host plants has been initiated, as well as growth rates, seed longevity, and plant life cycle information.

- September 1996: Both Kanab ambersnail host plants were collected at Vasey's Paradise, and have been successfully growing in an NAU greenhouse.

- February 1997: Construction of the first experimental chamber (a plexiglass plant/snail enclosure) was completed, and initial host plants were propagated.

- May 1997: Kanab ambersnail host plants were collected at Vasey's Paradise and transported down river by boat. Collected root masses were placed in existing enclosures at Northern Arizona University green house laboratory.

- May 1997 to Present: Propagation of KAS host plants was successful. Plants are continuously being monitored on a daily basis to determine basic life history processes, and optimal growing conditions. Experiments involving plant responses to varying levels of nutrients and light intensities will be initiated when enough plants are successfully propagated

3. Laboratory experiments on snail growth, preference, survivorship and fecundity.

- August 1997: Small (<4.0 mm) Kanab ambersnails were collected at Vasey's Paradise, and transported on boats down river. Snails were then transported to the Northern Arizona University green house facility, where they were measured and placed on the corresponding host plants from which they were removed.

- September 1997: Measurements have been taken on KAS 3 times since their introduction into captivity. A total of 248 snails were placed in enclosures containing each of the two host plants. This arrangement distributed 124 snails among 10 cells in each enclosure for each plant type.

TABLE 1. Preliminary data on growth rates is presented below (also see attached data sheets) measuring KAS placed on the two host plants in the original enclosures. Average size of KAS on Naof increased between measurements 970809 and 970906 then appear to average out. This can be attributed to the presence of some smaller snails (3.0 mm-5.0 mm) most likely having hatched during captivity. Sample sizes varied between measurements due to invasive nature of the snails, and limited impact to habitat during surveys. Mortality has also increased, possibly attributed to age, or survivorship curves.

DATE MEASURED	HOST PLANT TYPE	TOTAL SNAILS MEASURED	AVERAGE SIZE	STANDARD DEVIATION	EGG MASSES	MORTALITIES
970809	NAOF	124	3.4 mm	0.88		0
	MICA	124	3.2 mm	1.17		0
970906	NAOF	92	8.5 mm	2.21		0
	MICA	77	7.4 mm	1.33		0
970926	NAOF	89	8.4 mm	2.17		11
	MICA	76	8.5 mm	1.82	1(~12)	5

AVERAGE LENGTHS OF KAS ON EACH HOST PLANT TYPE

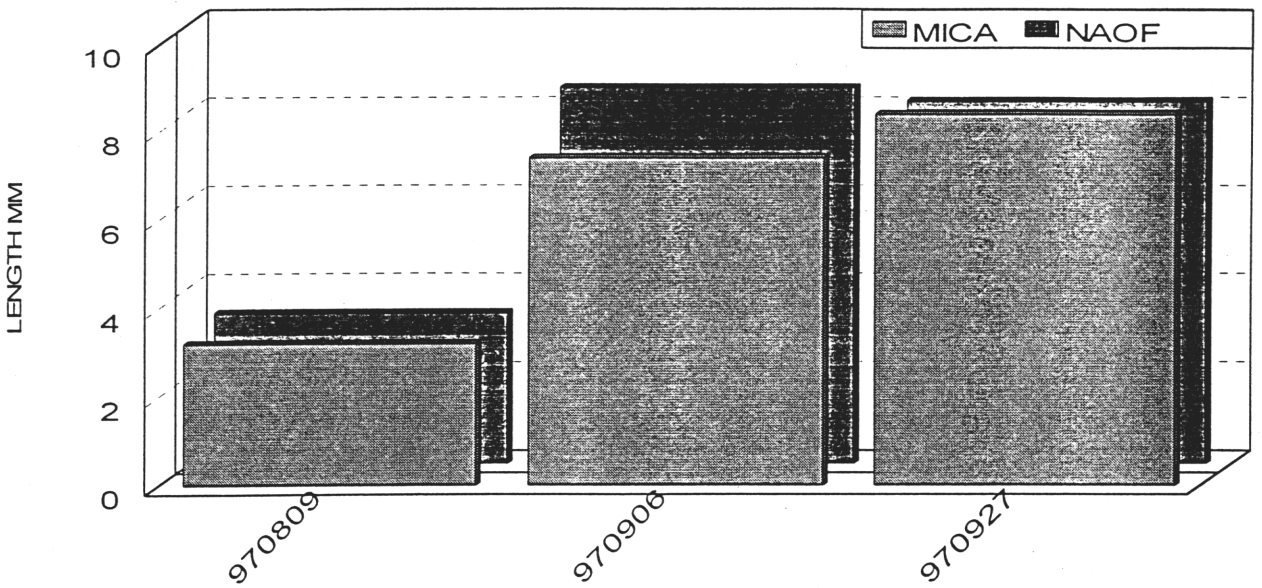

Figure 2. Graphical representation of KAS lengths measured on 3 different occasions.

- August 1997 to Present: Collection of data pertaining to snail survivorship, growth rates, fecundity, ovipositional preference on the two host plants will be initiated using the following methods:

PHASE I METHODS

2. Data collection and analysis regarding propagation of ambersnail host plants has been initiated, as well as growth rates, seed longevity, and plant life cycle information.

- Host plants have been successfully propagated, by both root mass regeneration and by seed. We are currently building a seed bank in order to test seed longevity in both the field and laboratory. Seeds will be kept in containers with hoods, to prevent direct contact with moisture, while still being influenced by abiotic factors. Seeds will then be taken out of the containers at monthly intervals and propagation success will be recorded.

- Growth rates on the Nasturtium average 5.5 cm per month. However, these rates are variable with progression of plant age (younger plants seem to grow more vigorously). Approximately half of the Nasturtium plants have flowered once since August, and will continue to be monitored.

- Growth rates on Mimulus average 2 cm per month, and need to be continuously trimmed back to a height of 30 cm. Mimulus blooms on an almost monthly basis, producing viable seeds which have propagated within the enclosures.

3. Laboratory experiments on snail growth, preference, survivorship and fecundity.

A new snail enclosure will be built with five 1 square foot cells, which will be further divided into four smaller cells by way of sliding plexiglass walls. This new design will increase the ease and accuracy of future experimentation by allowing us to trace individual snails throughout their life history.

enclosure naof 2

cell 1	cell 2	cell 3	cell 4	cell 5

enclosure mica 2

cell 1	cell 2	cell 3	cell 4	cell 5

enclosure naof 1

cell 1	cell 2	cell 3	cell 4	cell 5

enclosure mica 1

cell 1	cell 2	cell 3	cell 4	cell 5

New experimental enclosure (each cell has removable dividers which reduce cell area by ¼)

naof ¼	mica ¼	naof	mica	naof	mica	naof	mica	naof	mica
mica ¼	naof ¼	mica	naof	mica	naof	mica	naof	mica	naof
cell 1		cell 2		cell 3		cell 4		cell 5	

Figure 1. Existing experimental enclosures, and the new "prototype enclosure" for increased ease and accuracy of KAS and host plant experiments.

Experiments in the new enclosure will adhere to the following methods:

- 6 to 10 small snails (<2mm, F_1 generation) will be placed in each cell of the new enclosures, and distributed among the two host plants in even proportions. Snails will be marked by color code when they reach approximately 4 mm to allow for the monitoring of individual snails through time. These snails will be removed from each of the two host plants on which they have hatched in the original enclosures, and placed on corresponding plants in the new enclosure, as well as the opposite plants from which they were removed in order to account for differing genotypes.

- Snails will be monitored on a daily basis, and measured on a tri-weekly basis to ensure an accurate time-line based growth chart. These snails will be observed until they are mature enough to reproduce. After reproduction has occurred, the ovipositon points of the snails on each of the two host plants will be recorded and closely monitored in order to determine a possible ovipositional preference, and any differences in the success of hatching for the offspring on each host plant type.

- During mating, snails will also be inspected to determine if any sexual-dimorphism exists with respect to snail size, color, and behavior.

- Snails in each enclosure will be followed from their introduction through oviposition, to mortality. The same protocol will also be followed for the F_1 generation of the

snails observed from hatching through mortality in the new enclosures to ensure the most accurate development of a life history model.

- To determine feeding preference, snails will be given an option of different substrates. Substrate options will include: host plant leaves(dead and alive), litter (stems), scrapings from dead stems (possible fungi), and soil, all in various stages of decomposition. These will be blended and placed on a 30cmx30cm sheet of Plexiglas in a semicircular pattern. Snails representing each size class (<2mm, 6mm, 9mm, >12mm) will be placed in the middle of the semicircle and movement towards particular substrates will be noted. During this experiment we also hope to note if snails utilize any particular taxis in their substrate choice.

- We will also place snails of each size class in an enclosure consisting of all the substrate options. Snails will be marked, and their movement to particular substrates will be mapped and recorded.

4. Kanab ambersnail parasitism studies (2nd year; optional)

- We may start these analyses in Year 2 of the project, if sufficient levels of parasitism are detected in the Vasey's Paradise population.

5. Kanab ambersnail life history model.

- Model development will take place near the end of Phase I of this research project. This will depend upon completion of the above experiments and observations with a statistically proper amount of repetitions.

PHASE II PROGRESS

1. Interagency consultation on Kanab ambersnail habitat construction at Glen Canyon Dam.

- September 1997: Discussed KAS habitat construction and snail introduction options with Dam managers. We have agreed upon a preliminary construction site and enclosure dimensions (see attached proposal).

2. Construction of habitat and establishment of host plants.

- Following final consultation with Dam operators, we plan to initiate construction of Kanab ambersnail habitat and propagation of host plants at Glen Canyon Dam. We hope to accomplish this element of the project by winter 1997.

PHASE III PROGRESS

1. Establishment of an experimental KAS population at Glen Canyon Dam.

- This element will be initiated following habitat establishment at the dam, in spring 1998.

ADMINISTRATIVE REPORT

PHASE I AND II

BUDGET	FY97	FY98	TOTAL
Research stipend for Clay B. Nelson ($13,500 per year; 1996/97 and 1997/98)	13,500	13,500	27,000
Overhead costs for Northern Arizona University(20%)	2,700	2,700	5,400
Benefits 1%	135	135	270
Equipment costs (aquarium and field supplies)	1,915	1,915	3,830
Office, graphics and page costs	750	750	1,500
Subtotal of NAU Costs	17,085	17,085	34,170
Subtotal of non-NAU costs	1,915	1,915	3,830
TOTAL PHASE I AND II	**19,000**	**19,000**	**38,000**

PHASE I AND II EXPENDITURES TO DATE (September 22, 1997)

Graduate assistant stipend	10,666
Equipment costs	1,114
TOTAL	**11,780**

LITERATURE REVIEW

Alper, J. 1993. How to save a species and its ecosystem. (efforts to restore Florida's Everglades National Park involve a controversial plan to resume water flow from Lake Okeechobee and threaten the snail kite's habitat) (About Audubon Column) Audubon v95 n1 p104(2).

Baur, B. 1992. Random mating by size in the simultaneously hermaphroditic land snail Arianta arbustorum: experiments and an explanation. Animal Behaviour v43 n3 p511(8).

Baur, B. 1994. Inter-population differences in propensity for egg cannibalism in hatchlings of the land snail Arianta arbustorum. Animal Behaviour v48 n4 p851(10).

Bayne, C.J., and T.P. Yoshino. 1989. Determinants of compatibility in mollusc-trematode parasitism. (Symposium: Phylogeny of Immune Defense Mechanisms in Parasitic Infections) American Zoologist v29 n2 p399(9).

Beardsley, T.M. 1990. Snail tale; growth strategy protects a snail from its predators. Scientific American v262 n5 p32(2).

Burnham, L. 1988. The hard shell; heat stress, not camouflage, controls color in an adult snail. Scientific American v259 n3 p26(2).

Burger, R., and M. Lynch. 1995. Evolution and extinction in a changing environment: a quantitative genetic analysis. Evolution 49: 151-163.

Booth, D.T. 1995. Oxygen availability and embryonic development in sand snail (Polinices sordidus) egg masses. Journal of Experimental Biology v198 p241(7).

Coley, P.D., J.P. Bryant, and I.F.S. Chapin. 1985. Resource availability and plant herbivore defense. Science 230: 895-899.

Couper , J. M., and E. M. Leise 1996. Serotonin injections induce metamorphosis in larvae of the gastropod mollusk Ilyanassa obsoleta. The Biological Bulletin v191 n2 p178(9).

Cowie, R.H. 1995. Variation in species diversity and shell shape in Hawaiian land snails: in situ speciation and ecological relationships. Evolution v49 n6 p1191(12).

Crowl, T.A., and A.P. Covich. 1990. Predator-induced life-history shifts in a freshwater snail. Science v247 n4945 p949(3).

DeWitt, T.J. 1996. Gender contests in a simultaneous hermaphrodite snail: a size-advantage model for behavior. Animal Behaviour v51 n2 p345(7).

Elliott, A.C., and B.A. Pierce. 1992. Size, growth rate, and multiple-locus heterozygosity in the land snail (Otala lactea). The Journal of Heredity v83 n4 p270(5).

Emberton, K.C. 1995. Sympatric convergence and environmental correlation between two land-snail species. Evolution v49 n3 p469(7).

Esch, G.W., and J.C. Fernandez. 1994. Snail-trematode interactions and parasite community dynamics in aquatic systems: a review. The American Midland Naturalist v131 n2 p209(29).

Feeney, P. 1976. Plant apparency and chemical defense. In: Wallace, J.W., Mansell, R.L. (eds) Biochemical interaction between plants and insects. Recent advances in Phytochemistry 10. Plenum Press, New York, NY, pp 1-41.

Feeney, P. 1977. Defensive ecology of the Cruciferae. Annals of the Missouri Botanical Garden 64: 221-234.

Fernandez, J., T.M. Goater, and G.W. Esch. 1991. Population dynamics of Chaetogaster limnaei (Oligochaeta) as affected by a trematode parasite in Helisoma anceps (Gastropoda). The American Midland Naturalist v125 n2 p195(11).

Foster, B.A., and A.E. Stiven. 1994. Effects of age, body size and site on reproduction in the southern Appalachian land snail Mesodon normalis (Pilsbry, 1900). The American Midland Naturalist v132 n2 p294(8).

Foster, B. A., A.E. Stiven 1996. Experimental effects of density and food on growth and mortality of the southern Appalachian land gastropod, Mesodon normalis (Pilsbry). The American Midland Naturalist v136 n2 p300(15).

Fox, J., A. Mark, F. Dybdahl, Jukka Jokela, and C.M. Lively 1996. Genetic structure of coexisting sexual and clonal subpopulations in a freshwater snail (Potamopyrgus antipodarum). Evolution v50 n4 p1541(8).

Greenwood, J.J.D. 1992. In the pink (and yellow). (evolutionary genetics and natural selection of land snails) Nature v357 n6375 p192(1).

Goodfriend, G.A., and R.M. Mitterer. 1993. A 45,000-yr record of a tropical lowland biota: the land snail fauna from cave sediments at Coco Ree, Jamaica. The Geological Society of America Bulletin v105 n1 p18(12).

Goodfriend, G. A., and S. J. Gould 1996. Paleontology and chronology of two evolutionary transitions by hybridization in the Bahamian land snail Cerion. Science v274 n5294 p1894(4).

Harper, John L. 1981. The Meaning of Rarity. Pages 189-203 in Hugh Synge, editor. The Biological aspects of Rare Plant Conservation. John Wiley and Sons, New York, New York, USA.

Hermann, P.M., A. Ter Maat, and R.F. Jansen. 1994. The neural control of egg-laying behaviour in the pond snail Lymnaea stagnalis: motor control of shell turning. Journal of Experimental Biology v197 p79(21).

Hermes-Lima, M., K.B. Storey 1995. Antioxidant defenses and metabolic depression in a pulmonate land snail. The American Journal of Physiology v268 n6 pR1386(8).

Hill, W., R.M., G. Ryon, and E.M. Schilling 1995. Light limitation in a stream ecosystem: responses by primary producers and consumers. Ecology v76 n4 p1297(13).

Hillis, D.M., M.T. Dixon, and A.L. Jones. 1991. Minimal genetic variation in a morphologically diverse species (Florida tree snail, Liguus fasciatus).The Journal of Heredity v82 n4 p282(5).

Holomuzki, J.R., N. Hemphill 1996. Snail-tadpole interactions in streamside pools. The American Midland Naturalist v136 n2 p315(13).

Johannesson, K., B. Johannesson, and U. Lundgren. 1995. Strong natural selection causes microscale allozyme variation in a marine snail. Proceedings of the National Academy of Sciences of the United States v92 n7 p2602(5).

Johannesson, K., E. Rolan-Alvarez, and A. Ekendahl 1995. Incipient reproductive isolation between two sympatric morphs of the intertidal snail Littorina saxatilis. Evolution v49 n6 p1180(11).

Johnson, J. 1991. Biologists plot revenge in war of the snails. (Moorea's native Partula snails to be reintroduced in the island following disastrous experiment in trying to control the African land snail) New Scientist v131 n1783 p14(1).

Kelly, D. 1989. Control of mortality and fecundity. (Demography of short-lived plants in chalk grassland, part 2) The Journal of Ecology v77 n3 p770(15).

Lafferty , K.D., D.T. Sammond, and A.M. Kuris. 1995. Analysis of larval trematode communities. Ecology v75 n8 p2275(11).

Lande, R, and S Shannon. 1996. The role of genetic variation in adaptation and population persistence in a changing environment. Evolution v50 n1 p434-437.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241: 1455-1460.

Levri, E.P., and C.M. Lively 1996. The effects of size, reproductive condition, and parasitism on foraging behaviour in a freshwater snail, Potamopyrgus antipodarum. Animal Behaviour v51 n4 p891(11).

Lively, C.M. 1989. Adaptation by a parasitic trematode to local populations of its snail host. Evolution v43 n8 p1663(9).

Miller, J.A. 1984. Pass-along sperm, a snail sex option. Science News v125 p277(1).

Newman, R.M., W. C. Kerfoot, and Z. Hanscom III. 1996. Watercress allelochemical defends high-nitrogen foliage against consumption: effects on freshwater invertebrate herbivores. Ecology v77 n8 p2312(12).

Newman, R.M., Hanscom, Z., Kerfoot, C.W. 1992. The watercress glucosinolate-myrosinase system: feeding deterent to caddisflies, snails and amphipods. Oecologia 92: 1-7.

Pease, C.M., Lande, R., Bull, J.J. 1989. A model of population growth and evolution in a changing environment. Ecology 70: 1657-1664.

Pilsbury, H.A. 1948. Land mullusca of North America. The Academy of Natural Sciences of Philadelphia Monographs II(2):xivi, 521-1113.

Pilsbury, H.A. and J.H. Ferris. 1911. Mollusca of the southwestern states, V: the Grand Canyon and northern Arizona, Proceedings of the Academy of Natural Sciences of Philadelphia 63: 174-199.

Rabinowitz, Deborah. 1981. Seven Forms of Rarity. Pages 205-217 in Hugh Synge, editor. The Biological aspects of Rare Plant Conservation. John Wiley and Sons, New York, New York, USA.

Rees, B.B., and S.C. 1993. Hand. Biochemical correlates of estivation tolerance in the mountainsnail Oreohelix (Pulmonata: Oreohelicidae). The Biological Bulletin v184 n2 p230(13).

Robertson, R. 1993. The coiling directions of gastropods. Research & Exploration Wntr v9 n1 p104(16).

Rosemond, A.D., P.J. Mulholland, and J.W. Elwood. 1993. Top-down and bottom-up control of stream periphyton: effects of nutrients and herbivores. Ecology v74 n4 p1264(17).

Sapp, K.K., and G.W. Esch. 1994. The effects of spatial and temporal heterogeneity as structuring forces for parasite communities in Helisoma anceps and Physa gyrina. The American Midland Naturalist v132 n1 p91(13).

Schmitt, R.J. 1996. Exploitation competition in mobile grazers: trade-offs in use of a limited resource. Ecology v77 n2 p408(18).

Schrag, S.J., A.O. Mooers, G. Tata Ndifon, and A.F. Read. 1994. Ecological correlates of male outcrossing ability in a simultaneous hermaphrodite snail. The American Naturalist v143 n4 p636(20).

Schrag, S., J. G. Tata Ndifon, and A.F. Read. 1994. Temperature-determined outcrossing ability in wild populations of a simultaneous hermaphrodite snail. Ecology v75 n7 p2066(12).

Small, D.L., and C.E. Morris 1995. Pore properties of Lymnaea stagnalis neuron stretch-activated K+ channels. Journal of Experimental Biology v198 p1919(11).

Sousa, W.P. 1993. Interspecific antagonism and species coexistence in a diverse guild of larval trematode parasites. Ecological Monographs v63 n2 p103(26).

Spamer, E.E. and A.E. Bogan. 1993. Mollusca of the Grand Canyon and vicinity, Arizona: new and revised data on the diversity and distributions, with notes on Pleistocene-Holocene mollusks of the Grand Canyon. Proceedings of the Academy of Natural Sciences of Philadelphia 144:21-68.

Stanton, W. 1991. Discovery at a snails pace. (research on snail holes in limestone) New Scientist v130 n1766 p63(1).

Stevens, L.E., V.M. Meretsky, F.R. Protiva, D.M. Kubly, and J. Peterson. 1995. The ecology of the Kanab ambersnail (Succineidae: *Oxyloma haydeni kanbensis* Pilsbury, 1948) at Vaseys Paradise, Grand Canyon, Arizona:1995 Draft Final Report. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Program Report, Flagstaff, AZ.: 1995.

Stiven, A.E., B.A. Foster 1996. Density and adult size in natural populations of a southern Appalachian low-density land snail, Mesodon normalis (Pilsbry). The American Midland Naturalist v136 n2 p287(13).

Stone, J.R. 1996. Computer-simulated shell size and shape variation in the Caribbean land snail genus Cerion: a test of geometrical constraints. Evolution v50 n1 p341(7).

Uslabar, K. 1989. Snail stats. (paleontology lesson). The Science Teacher v56 n7 p33(2).

Visser, D., A. Ter Maat, and C. Zonneveld. 1994. Energy budgets and reproductive allocation in the simultaneous hermaphrodite pond snail, Lymnaea stagnalis (L): a trade-off between male and female function. J.A.G.M. The American Naturalist v144 n5 p861(7).

Vitousek, P. M. Stopping biological invasions before they do lasting damage. 1997. The Chronicle of Higher Education Jan 17, 1997 v43 n19 pB4(2).

Weimer, R.A., and T.P. Thorpe. 1995. Snail Growth rate and quality variation of homoepitaxial diamond grown at elevated temperatures. Journal of Applied Physics v77 n2 p641(5).

Wells, S. 1988. Snails going extinct at speed. (carnivorous snail in French Polynesia prefers endangered endemic snail to snail it was imported to control) New Scientist v117 n1599 p46(3).

Wethington, Amy R., Robert T. Dillon Jr.Gender choice and gender conflict in a non-reciprocally mating simultaneous hermaphrodite, the freshwater snail, Physa.. Animal Behaviour May 1996 v51 n5 p1107(12).

Yoshida, M., and M. Kobayashi. 1995. Modulation of the buccal muscle contraction by identified serotonergic and peptidergic neurons in the snail Achatina fulica. Journal of Experimental Biology v198 p729(10).

NORTHERN ARIZONA UNIVERSITY KANAB AMBERSNAIL PROPAGATION AND EXPERIMENT DATA SHEET

ENLOSURE	SNAIL TOTALS/ENCLOSURE									10					15					20					25	AVG(mm)	STDEV	TOTAL
N1A	8.0	7.0	6.0	6.0																						6.8	0.96	4
N1B	8.0	8.0	6.0	6.0	5.0	4.5	4.5	5.0	5.0	5.0	3.0															5.5	1.49	11
N1C	9.0	9.0	10.0	12.0	10.0	9.0	8.0	10.0																		9.6	1.19	8
N1D	11.0	10.0	10.5	14.0	8.5	9.0	3.0	2.0																		8.5	4.06	8
N1E	7.0	8.0	8.0	7.0	8.0	9.0	7.0	6.0	7.0	9.0	6.0	6.0	6.5	6.0	7.0	8.0	6.0	6.0	7.0	5.0	6.0	7.0				6.9	1.05	22
N2A	6.0	6.0	6.0	8.0	7.0	5.0	7.0	7.0	7.0	7.0	8.0	6.0	7.0	7.0	7.0	5.0										6.6	0.89	16
N2B	9.0	10.0	10.0	10.0	11.0																					10.0	0.71	5
N2C	9.0	9.0	11.0	10.0																						9.8	0.96	4
N2D	8.5	9.0	10.0	10.0	10.0	10.0	10.0	9.0																		9.6	0.62	8
N2E	11.5	9.0	11.0																							8.8	1.64	3
MORTALITIES	9.5	8.0	9.0	8.0	7.0	8.0	10.0	9.0	8.0	5.0	9.5																	
NAOF TOTAL	measured 970927																									**8.2**	**2.10**	**89**
M1A	9	8	9	8.5	10	9	4	5	4	4	7															7.0	2.35	11
M1B	10	11	12	12	12																					12.0	0.89	5
M1C	10	10	10	6	7	9	10																			8.0	1.68	7
M1D	8	10.5	8	8	6	4	6	8	1	1	1	1														4.0	3.47	12
M1E	6	8	8	10																						8.0	1.63	4
M2A	7	9	9	9.5	8.5	7	9	9	8	5																8.1	1.39	10
M2B	11	9	8	9	9.5	9.5																				9.0	0.98	6
M2C	11	9.5	9	9	9	8																				9.3	0.99	6
M2D	9	10	9.5	9	8.5	8	8	9	12	9																9.2	1.16	10
M2E	9	9	8	8.5	9	9.5	6	8	8																	9.0	2.02	9
MORTALITIES	13	13	8.5	7																						**10.4**		**4**
MICA TOTAL																										**8.4**	**2.48**	**80**

MEASUREMENTS TAKEN 970927

NORTHERN ARIZONA UNIVERSITY KANAB AMBERSNAIL PROPAGATION AND EXPERIMENT DATA SHEET

ENLOSURE	SNAIL TOTALS/ENCLOSURE									10						15					20					25	AVG(mm)	STDEV	TOTAL
N1A	3	3	4	4	2	3	4	3	3	3.5	4																3.3	0.64	11
N1B	3.5	3.5	3.5	3	3	3	4	4.5	3	3	3	4															3.4	0.51	12
N1C	3	3	3	5	4.5	4	3	3	3	5	3.5	4	4														3.7	0.78	13
N1D	4.5	3	2	3	3	2	4	2.5	2	3	4	2.5															3.0	0.84	12
N1E	2	2.5	3	3	3	2.5	2	2	2	3	3	5															2.8	0.84	12
N2A	4	4	3.5	4	4	4	3	4	4	3	2	3	5														3.7	0.75	13
N2B	3.5	3.5	2	4	3	2	5	4.5	2.5	4	4.5	5	4														3.7	1.03	13
N2C	4	3	3	5	4	2	4	3.5	3	5	3.5	3.5	3.5														3.6	0.82	13
N2D	6	4.5	3	4	4	3.5	4	2	6	5	3	4	5														4.2	1.16	13
N2E	3	4	3	4	3	3	3	3	4	4	2	3															3.3	0.62	12
NAOF TOTAL	measured 970809																										**3.4**	**0.88**	**124**
M1A	4	2.5	3.5	3	4	4	2	4	1	3	4.5	4															3.3	1.03	12
M1B	1	2	1.5	3	2	6	2	1	3	4	5	2.5	4														2.8	1.53	13
M1C	4	3.5	1	4	3	2	2	2	2.5	5	1	2.5															2.7	1.23	12
M1D	4	2	2	2	1.5	3.5	1	2	5	2	3	4															2.7	1.21	12
M1E	2	3.5	4	5	2.5	5	2	2	2	2	4	4															3.2	1.21	12
M2A	5	1.5	2.5	1.5	2	4.5	5	3	2.5	3	4	5	3.5														3.3	1.30	13
M2B	4	2	2	3.5	2.5	3	3	2	3	2.5	3	3	3														2.8	0.60	13
M2C	5	4	3.5	4	3.5	3.5	4	2	1	4.5	4																3.5	1.13	11
M2D	3	4	4	3.5	3	3	1.5	3	4	4	4	4.5	5														3.6	0.89	13
M2E	5	5	3	3	4.5	4	5	4	4	4	4	3	5														4.1	0.77	13
MICA TOTAL	measured 970809																										**3.2**	**1.17**	**124**

MEASUREMENTS TAKEN 970809

NORTHERN ARIZONA UNIVERSITY KANAB AMBERSNAIL PROPAGATION AND EXPERIMENTAL DATA SHEET

ENLOSURE	SNAIL TOTALS/ENCLOSURE										10					15					20					25	AVG(mm)	STDEV	TOTAL
N1A	6.0	7.0	6.0	7.0	8.0	8.0	6.0	6.0	7.0	7.0	5.5	5.0															6.5	0.94	12.0
N1B	9.5	9.5	9.0	8.0	8.0	7.5	7.0	7.5	7.0	7.0	7.5	6.0	8.0														7.8	1.03	13
N1C	10.0	9.0	10.0	9.5	11.0	10.0	12.0	10.0	10.0	9.0	8.0																9.9	1.05	11
N1D	15.0	8.0	11.0	11.0	10.0	9.0	8.0	8.0																			10.0	2.39	8
N1E	11.0	8.0	10.0	10.0	7.0	8.0	8.5	7.0	7.5	7.5	7.0	7.5	7.0														8.2	1.34	13
N2A	6.0	5.0	7.0	8.0	7.0	8.5	8.5	8.5																			7.3	1.31	8
	4.5	5.5	5.0	6.0	6.0	5.0	5.0	5.0	5.0	4.0	5.0	4.0	3.0	4.0	4.0	3.5	3.5	3.0	2.5										
N2B	9.0	9.5	12.0	10.5	8.5	7.0	10.0																				9.5	1.58	7
N2C	7.0	7.0	7.0	7.5	7.5	7.0	8.0	7.0																			7.3	0.38	8
N2D	9.0	6.0	10.0	9.0	9.5	10.0	8.0	9.0	11.0	8.5																	9.0	1.35	10
N2E	8.5	11.5																									10.0	2.12	2
NAOF TOTAL	measured 970906																										**8.5**	**2.21**	**92.0**
M1A	5.5	9	7	8	7	6.5	7.5																				7.2	1.11	7
M1B	9	10	9.5	9.5	8																						9.2	0.76	5
M1C	8	6	9	8	6	8	5.5	8																			7.3	1.28	8
M1D	7	6	6	5	10	10	5																				7.0	2.16	7
M1E	8	5	7.5	5	8	9.5	6																				7.0	1.71	7
M2A	7.5	8	9	6	6	7	8	7																			7.3	1.11	8
M2B	6	7.5	6	7	7.5	7																					6.8	0.61	6
M2C	7	5	6	7	8	7.5	8	10	9																		7.5	1.59	9
M2D	8	7	5.5	7	7	6.5	7	9	9.5	8																	7.5	1.19	10
M2E	9	7	6	7.5	7	7	7.5	8	8	8																	7.5	0.82	10
MICA TOTAL	measured 970906																										**7.4**	**1.33**	**77**

MEASUREMENTS TAKEN 970906