Tests in general field herbivore preference among vegetables and *Orconectes propinquus* preference among macrophytes

Bios 569- Practicum in Aquatic Biology

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Abstract

Field and laboratory experiments were performed to test general herbivore preference and feeding rates among vegetables submerged in Lake Tenderfoot, and more specifically crayfish preference among submerged macrophytes in laboratory preference tests. Lines securing six vegetable samples, *Myriophyllum alterniflorum, Isoetes braunii, Potamogeton amplifolius, Nuphar variegatum, Typha latifolia,* and filamentous green algae were submerged for 48 hours in Tenderfoot Lake and the area consumed was measured. Herbivorous organisms were observed and collected from the submerged lines to confirm herbivore consumption. The most preferred vegetables from all combined sites was kale which was closely followed by spinach. A laboratory experiment tested *Orconectes propinquus* selectivity among six macrophytes. Crayfish caused visible leaf damage among the less tough and leafy macrophytes. The most preferred macrophytes according to mean consumption were *Potamogeton amplifolius,* followed by filamentous algae and *Nuphar variegatum.*

Introduction

Aquatic plants grow along the littoral zone between the shoreline and the open waters (Carpenter and Lodge, 1986) and are a food source to herbivores such as crayfish and water beetles. This acknowledgment of an herbivory role is relatively recent since biologists once believed that macrophytes were detached from aquatic food webs (Lodge, 1991).

Terrestrial herbivores show a preference for plants with more protein (Mattson, 1980; as cited in Lodge, 1991) and higher nitrogen concentrations (Mattson, 1980; as cited in Carpenter and Lodge, 1986). Past research has traditionally focused on terrestrial plants while little is known of aquatic plant preferences. Macrophytes can obtain their nutrient requirements, which include nitrogen, from the sediments (Huebert and Gorham, 1983; Smart and Barko, 1985; as cited in Barko et al., 1986). For this reason, rooted macrophytes have been called a "living link between the sediments and the overlaying water" (Carpenter and Lodge, 1986).

Although a macrophyte may have a high nitrogen concentration, herbivore consumption may be hampered by structural characteristics such as tough cell walls, lignified structures, hairs, and spines (Howe and Westley, 1988; Lamberti and Moore, 1984; as cited in Lodge, 1991). For this reason, terrestrial herbivores prefer young tissue (Coley, 1983; as cited in Lodge, 1991). As plants age, they become tougher and produce secondary compounds, both of which may affect grazer selectivity (Lodge, 1991).

Aquatic macrophytes can also avoid consumption through various chemical defenses. Macrophyte tissue content often depends on the plant part and season (Boyd, 1968, 1971; Reimer and Toth, 1969, 1970; as cited in Lodge, 1991). These chemical defenses are found widely among terrestrial plants (Rosenthal and Janzen, 1979; Harborne, 1988; Howe and Westley, 1988; as cited in Lodge, 1991). Likewise, recent studies have suggested that secondary compounds may be more widespread among aquatic macrophytes than was once believed (Lodge, 1991).

Orconectes propinquus is an ideal crayfish species for my experiment because their availability in northern Wisconsin and their known herbivorous feeding patterns. In addition, crayfish are the largest invertebrate freshwater herbivore (Lorman and Magnuson, 1978; Lorman, 1980; Momont, 1984; as cited in Lodge and Lorman, 1987), and they feed on macrophytes by clipping shoots near the sediments (Lodge and Lorman, 1987; Lodge, 1991). Crayfish prefer eating snails and beef liver over macrophytes (Lorman, 1980; Hill et al., 1993). These results imply a preference for a more nitrogen-rich diet and may indicate a preference for macrophytes with higher nitrogen contents. *O. propinquus* normally feed on plant and detrital material (Lorman, 1975), but when given a choice of macrophytes, it is likely that *O. propinquus* will prefer those macrophytes with higher nitrogen concentrations (Lodge and Hay, 1993).

In the first half of my study, I used field experiments to test the preference of natural herbivores including O. *propinquus* among common vegetables and freshwater macrophytes. The second half of this study used laboratory experiments to test the preference of *O. propinquus* among macrophytes.

Materials and Methods

Field Experiments on Preference Among Vegetables

Experiment time

During the late spring and early summer, when macrophytes were not abundant, preliminary experiments were conducted to determine the vegetable preferences of *O. propinquus*. This time frame is ideal in that competing with existing macrophytes in feeding preference was minimized and the effects of crayfish and other grazers was observable.

Sample preparation

Six vegetable samples (cabbage, kale, lettuce, romaine lettuce, red lettuce, and spinach) were purchased from IGA foodstore in Land O' Lakes, Wisconsin and Trigg's in Minoqua, Wisconsin, refrigerated, and used within 48 hours (Table 1). Each vegetable was cut to a 525 square area (1 square=2.5mmx2.5mm) using a transparent grid, 150 squares of which was secured within the polypropylene line. One cut sample of each vegetable was secured to 1.5 m of three-strand polypropylene rope weighted at both ends and in the center (Figure 1). The lines were submerged at a depth of 1.0 m in Tenderfoot Lake which has a reasonable *O. propinquus* population (Lodge, unpublished data). The leaves were recovered 48 hours later and the area consumed was measured. This depth was selected to limit grazing activity to aquatic organisms while allowing for a variety of grazers.

Table 1. Phylogenic classification of vegetables. The phylogeny of family, genus, and species of vegetables (Fassett, 1972,Benson, 1979; Burr, 1988; and Tanaka, 1976).

Vegetable	Family	Genus	Species	Variety
cabbage	Cruciferae	*Brassica*	*oleracea*	capitata
kale	Cruciferae	*Brassica*	*oleracea*	sabellica
spinach	Chenopodiaceae	*Spinacia*	*oleracea*	
iceberg lettuce	Cichorium	*Lactuca*	*sativa*	ice cabbage
romaine lett.	Cichorium	*Lactuca*	*sativa*	longifolia
red lett.	Cichorium	*Lactuca*	*sativa*	Victoria or red boarder

Preliminary experiment

Experiment I using six lines - three in one rocky substrate and three in one muddy substrate - was performed to test herbivore grazing (Figure 2). The samples were checked every day to detect evidence of grazing, gauge grazing intensity, and observe leaf condition. This experiment determined the ideal submersion time to be 48 hours. the methods used varied from the remaining experiments and was not included.

Further experiments

Experiments II and III which were limited to cabbage, spinach, and icehead lettuce. 30 lines were placed in Tenderfoot Lake - 15 in rocky substrate (five each in three rocky areas) and 15 in muddy substrate (five each in three muddy areas) where macrophytes were expected to grow later in the season (Figure 2). This placement took into account that crayfish live in rocky substrate while macrophytes and perhaps different herbivores thrive in muddy substrate (Lodge, unpublished). Experiment IV used six vegetables (cabbage, iceberg lettuce, kale, romaine lettuce, red lettuce, and spinach) and were treated identically to experiments II and III

Protein analysis

At the initiation of the final experiment, at least 100 grams of each vegetable sample was freeze-dried and stored for protein analysis at U. of N.D.. The analysis requires one to five grams of dry matter which is obtainable from approximately 10-50 grams of wet matter (Lodge, unpublished). These analyses have not yet been done.

Laboratory Preference Experiment

Sample preparation

When the macrophytes began to grow, 10-15 macrophyte species were collected in cooperation with Katie Wissing from various UNDERC lakes (Table 2). The six selected macrophytes were refrigerated overnight. Depending on the plant's morphology, excess water was removed with either a salad spinner or blotting method. The weight of each sample was recorded to +/-0.005 grams in relation to a common standard size, secured to a rubber bathtub matting portion, and immersed in a dish pan with 5cm of well water (Figure 3).

Table 2. Phylogenic classification, origin, collection and preparation of macrophytes. The phylogeny of family, genus, and species of macrophytes for five macrophytes and the families of filamentous green algae are listed in figure A (Fassett, 1972). Lake origin, collection date, and water removal method of macrophyte samples for general preference experiment are listed in figure B. Collection of macrophytes was done with the cooperation of Katie Wissing and the UNDERC class.

A) Family	Genus	Species
Macrophytes		
Haloragidacea	*Myriophyllum*	*alterniflorum*
Isoetaceae	*Isoetes*	*braunii*
Najadaceane	*Potamogeton*	*amplifolius*
Nymphaeaceae	*Nuphar*	*variega*
Typhaceae	*Typha*	*latifolia*
Green Algae (Fassett, 1972)		
Microspora		
Spirogyra		
Cladophora		

B) Macrophyte	Source	Collection Date	Method
Algae Cladophora Microspora Spirogyra	Tenderfoot Stream	7/5/94	spin
Isoetes braunii	Roach	7/5/94	spin
Myriophyllum alterniflorum	Kickapoo	7/4/94	spin
Nuphar variegatum	West Long	7/4/9	blot
Potamogeton amplifolius	Kickapoo	7/4/94	blot

Typha latifolia	Temporary pond near maint. bldg.	7/4/94	blot

Experimental conditions

The room temperature was maintained at 22^{0}C and resulted in a water temperature of 18.5^{0}C. The water pH was 6.92. To maintain the natural feeding environment, one scrubbed rock was placed in each control and experimental pan to provide cover and each pan was partially covered to simulate nocturnal feeding. Into each of the 15 replicate pans, I added one average-sized male *O. propinquus* from Tenderfoot Creek (avg. carapace 25mm; avg. total length 51 mm) caught 48 hours beforehand and added to each of the 15 replicate experimental pans (Appendix 1). Each pan with a crayfish ("experimental") was paired with an identical pan without crayfish ("control") for an experiment duration of 90 hours.

Experiment calculations

At the completion of the experiment, each macrophyte was weighed in an identical manner as the initial weights. The change in plant weight in each experimental replicate was corrected according to its paired control with the following equation:

$$\frac{\text{Initial Weight(experimental)} - \text{Final Weight(experimental)}}{\text{Initial Weight(experimental)}} = A$$

$$\frac{\text{Initial Weight(control)} - \text{Final Weight(control)}}{\text{Initial Weight(control)}} = B$$

$$A - B = \text{Corrected Weight}$$

Protein analysis

When plants are collected for the laboratory experiment, additional plants were freeze-dried and collected for protein assays. Each sample of each species was weighed before and after freeze-drying to find the water content. These protein analyses have not yet been conducted.

Results

Field experiments in Herbivore Vegetable Preference

Experiment IV showed a strong preference for spinach and kale among the rocky and muddy substrates (Figs. 4 & 5). The confidence level for the muddy sites (Fig. 5) suggest that cabbage was consumed. According to the mean, iceberg lettuce was the second least preferred species (Appendix 2). Although the confidence limit ranges were wider, the higher ranges for spinach and kale suggests the strongest preference. Grazing activity on vegetables in both substrates were similar and were combined on a single graph (Fig. 5). Experiments II and III, showed cabbage to be least preferred, icehead lettuce was more preferred, and spinach was most preferred (Appendices 3 & 4) More herbivorous organisms were observed and collected among the submerged vegetables in the muddy substrate than those among the rocky substrate (Table 3). The three most prevalent herbivorous organisms found on the vegetables in both rocky and muddy substrata were *Amnicola sp.*, *Physa sp.*, and amphipoda crustacea although non-herbivorous organisms were also found on the vegetables (Table 4). Interestingly, a crayfish with a missing claw was found attached to a vegetable line in the muddy substrate in experiment III. The calculated water composition percentage was least for spinach and kale and highest for icehead lettuce (Table 5).

Table 3. Summary of herbivorous organisms found on six submerged vegetables and number of crayfish caught at each site used for vegetable preference experiments. The number of herbaceous organisms according to substrate and order (Lehmkuhl, 1979; Merrit, 1984; and Thorp, 1991). The experiment began 6/16/94 and lasted 48 hours. After the completion of the vegetable preference experiments, six crayfish traps with raw beef liver portions were placed at each experiment site for 24 hours on 6/26/94. The number, sex, and species of each crayfish caught was recorded.

Muddy	cabbage	kale	iceberg	red	romaine	spinach	TOTAL
Gastropoda							
Amnicola sp.	0	56	28	16	23	43	166
Physa sp.	12	8	8	3	5	18	54
Gyraulus parvus	0	0	0	1	0	0	1
Helisoma sp.	0	0	0	1	0	0	1
Valvata tricarinata	0	1	0	0	0	0	1
Trichoptera							
Limnephilidae goera	0	0	0	0	1	1	2
Leptocerida oecetis	1	0	1	0	0	0	2
potanyia sp.	1	0	0	0	0	0	1
					Total		228
Rocky							
Gastropoda							
Amnicola sp.	17	21	12	16	32	18	116
Physa sp.	8	16	0	0	8	7	39
Valvata tricarinata	3	3	0	0	0	6	12
Gyraulus parvus		0	0	1	0	0	1
Valvata perdepressa	1	0	0	0	0	0	1
Trichoptera							
Limnephilidae sp.	0	1	0	0	0	0	1
Leptoceridae setodes	0	70	0	0	1	0	1

Total 171

B.

site	crayfish species	sex	number
muddy			
1	*O. propinquus*	male	2 large
2	none		
3	none		
rocky			
1	*O. propinquus*	male	2 large
2	*O. propinquus*	male	1 small
	O. virilis	female	1 medium
3	none		

Table 4. Complete summary of organisms found on submerged vegetables. The number of herbivores and non-herbivores are listed according to substrate and order (Thorp, 1991 and Baker, 1928, Pennak, 1978). the experiment began 6/16/94 and continued for 48 hours. Table continued on following page.

	cabbage	kale	iceberg	red	romaine	spinach	TOTAL
Gastropoda							
Amnicola sp.	0	56	28	16	23	43	166
Physa sp.	12	8	8	3	5	18	54
Gyraulus parvus	0	0	0	1	0	0	1
Helisoma sp.	0	0	0	1	0	0	1
Valvata tricarinata	0	1	0	0	0	0	1
Trichoptera							
Limnephilidae goera	0	0	0	0	1	1	2
Leptocerida oecetis	1	0	1	0	0	0	2
potanyia sp.	1	0	0	0	0	0	1
Annelida							
Actinobdella	0	0	0	1	0	0	1
Erpododellidae	0	0	0	0	1	0	1
Crustacea							
Amphipoda	4	1	2	0	1	4	12

Gastropoda							
Promentus Exacuous	0	1	0	0	0	0	1
Rocky							
Gastropoda							
Amnicola sp.	17	21	12	16	32	18	116
Physa sp.	8	16	0	0	8	7	39
Valvata tricarinata	3	3	0	0	0	6	12
Gyraulus parvus		0	0	1	0	0	1
Valvata perdepressa	1	0	0	0	0	0	1
Trichoptera							
Limnephilidae sp.	0	1	0	0	0	0	1
Leptoceridae setodes	0	0	0	0	1	0	1
Annelida							
Actinobdella	0	1	0	0	0	0	1
Erpobdellidae	0	0	0	1	0	0	1
Glossiphonidae	0	0	3	3	3	0	9
Crustacea							
Amphipoda	3	0	0	4	6	5	18
Other							
Lestidae lestes	0	0	2	0	1	0	3
Ancylidae	0	1	0	0	0	0	1
Chironomidae sp.	1	0	0	0	0	0	1
spider mite	1	0	0	0	0	0	1

Table 5. Calculations for water composition percentage of vegetables used in general preference test. The wet and dry weights were recorded and calculated using (wet weight-dry weight)/wet weight).

Vegetable	Percent
kale	88.13%
spinach	89.53%
red lettuce	90.76%
cabbage	92.84%
romaine lettuce	93.48%
icehead lettuce	94.81%

Laboratory Experiments in Herbivore Macrophyte Preference

The confidence levels show that *Potamogeton amplifolius,* filamentous algae, and *Nuphar variegatum,* were probably all consumed in varying levels because their confidence limits all lie above zero (Appendix 5). However, *Myriophyllum alterniflorum* had a mean that was above zero, but a confidence level that lay above, at, and below zero. *Isoetes braunii* had a negative mean and a confidence level above and below zero. *Typha latifolia* had a very strong negative mean and a negative confidence level that did not include zero consumption (Fig. 6). The algae tended to separate in the water although most was recovered. There was noticeable grazer damage to the *Potamogeton amplifolius* and *Nuphar variegatum* while plant damage to *Myriophyllum alterniflorum, Isoetes bruanii*, and filamentous algae were difficult to determine due to their structure. The water concentration percentage was calculated for all macrophytes except algae. *Isoetes bruanii* and *Myriophyllum alterniflorum* contained the most water while *Potamogeton amplifolius* and *Typha latifolia* had the least water (Table 6).

Table 6. Percent water composition was calculated for five macrophytes. The calculation used was (wet weight-dry weight)/wet weight.

Macrophyte	Percent
Potamogeton amplifolius	80.13%
Typha latifolia	81.50%
Nuphar variegatum	87.03%
Myriophyllum alterniflorum	89.69%
Isoetes braunii	92.95%
filamentous algae	not freeze-dried

Discussion
Field Experiments in Herbivore Vegetable Preference

Herbivorous organisms

More herbivorous insects and higher consumption rates were expected among the muddy sites than the rocky sites due to macrophyte growth. It was expected that herbivores would prefer to live near their food source and more herbivorous insects were found on the vegetables in the muddy substrate . The most prevalent organisms in both substrates were found to be the gastropods *Amnicola sp.* and *Physa sp.* , both which were found on the submerged vegetables. Crayfish traps with beef liver were set in Tenderfoot Lake and caught five crayfish. There are crayfish present in Lake Tenderfoot which were later caught for the Laboratory experiment. A crayfish with a missing claw was found attached to a line in the muddy substrate in experiment III. This suggests that more food is available in the muddy substrate for the injured crayfish with less competition from healthy crayfish which prefer rocky substrate.

Vegetable preference

The muddy sites had higher mean consumption rates for all vegetables except for spinach and larger confidence levels for all the vegetables except kale and spinach in experiment IV. The strong preference for kale among all combined sites was unexpected considering the close phylogenic relationship to cabbage which was least preferred. The strong preference for spinach is reinforced in experiments II and III where three vegetables were used and the positive confidence levels indicate herbivore damage.

Deterrence from cabbage is due either or both to chemicals or the structural rigidity present in cabbage but lacking in kale. Both cabbage and kale are grouped in the mustard family. Egg masses were found on the cabbage which suggesting that structural rigidity, unlike that of kale may protect the eggs. The rigidity can be related to the water content, in that the most preferred vegetables, spinach and kale, had the lowest water content. The eggs were disk-shaped capsules within a gelatinous matrix which were possibly laid by Gastropods but can not be positively determined (Costello et al., 1957). The confidence levels in the rocky substrate exclude zero suggesting that some cabbage was consumed (Fig. 5). However, the average consumption of the muddy substrate and combined substrates include zero in their confidence limits allowing for the possibility that no cabbage was consumed. Interestingly, the confidence levels of each individual rocky and muddy site excludes zero in their confidence limits suggesting that cabbage was consumed. Two experiments using three vegetables included zero in their confidence level making cabbage consumption inconclusive.

Macroscopically, iceberg lettuce contained more water mass than red and romaine lettuces which were preferred over icehead lettuce according to mean area consumption but for which the confidence levels overlap. These macroscopic observations were confirmed by the high water percentage. The most preferred vegetables, kale and spinach, had the lowest water percentage. Experiments II and III confirm that icehead lettuce preference lies between that of cabbage and spinach (Appendices 3 & 4). Observations of leaf damage on the lettuces was simpler to determine than spinach and kale. The grazers tended to remove circular pieces within the leaf interior and feed along the edges while the spinach and kale edges were not as discriminate.

Leaf breakage

The vegetables were checked for breakage after being placed in Tenderfoot Lake. However, breakage occurred when the lines were removed but was recovered. This suggests that some breakage may have occurred during the experimental period. This is probable because the lines were found closer to shore, particularly after a storm. The kale and spinach were prone to bacterial decomposition due to unseasonably warm temperatures. Errors due to breakage and decomposition could have been found by using control lines enclosed by some barrier in the lake.

Future recommendations

It is recommended that further experimentation include a random vegetable order on each line. Some vegetables were difficult to distinguish and should be recorded in some manner. The area of the vegetables increased at the experiment's end due to water absorption. For greater accuracy, it is recommended that the vegetable leaves be soaked in water overnight so maximum area can be measured. The freeze-dried vegetables should be treated in the same manner to account for area increase and possible protein leakage. This procedure is suggested because the vegetables are presented to herbivores in aqueous conditions and not with the water concentration in which it was purchased.

Laboratory Experiments in Herbivore Macrophyte Preference

Macrophyte consumption

Potamogeton amplifolius had the highest mean weight consumption which was evident by visible grazing patterns on the leaf. The confidence level did not include zero suggesting that consumption occurred with 95% confidence (Fig. 6).

Filamentous algae and *Nuphar variegatum* followed with decreasing mean consumption which may be related to *Nuphar variegatum's* thicker leaf composition . Like, *Potamogeton amplifolius*, the confidence limits both lay above zero indicating that both macrophytes were consumed. The algae was found to separate during the experiment even though it was rolled into a ball. Most algae was recovered with a sieve and the remaining loss was accounted for by the controls. *Nuphar variegatum* was also consumed and had visible leaf destruction.

Myriophyllum alterniflorum followed the above macrophytes in terms of its positive mean consumption and the wide confidence levels include positive values and zero. The negative confidence values indicate that weight may have increased. From this information, it is not possible to determine if consumption actually occurred and visual evidence of grazing activity was not observed. *Isoetes braunii* also had a wide confidence level similar to *Myriophyllum alterniflorum*,. The mean for *Isoetes braunii* was negative suggesting that weight may have increased. This can not be positively determined from the confidence levels. The structure of *Isoetes braunii* was tougher than *Myriophyllum alterniflorum* and expectedly, *Isoetes braunii* had a lower mean consumption although grazing activity was not detected.

Typha latifolia was the least preferred macrophyte with a negative mean and a negative confidence limit that excluded zero. This unusual confidence limit suggests that weight was gained. All macrophytes were soaked in water prior to being cut and measured. Even if maximum water was not absorbed, it was assumed that the paired controls account for any weight gain. The negative mean probably resulted from all the controls and all the experimentals being weighed together rather than each control and corresponding experimental pair weighed alternately. The other macrophytes did not experience this because they were completely submerged and lacked a vast difference in their osmotic concentration gradients. The *Typha latifolia* used was from the middle stalk which lay above the vernal pond's water level. Due to this, a large osmotic gradient probably existed when *Typha latifolia* was submerged in water. In addition to this weight gain, Typha latifolia was structurally the toughest of the six macrophytes and probably is not a preferred food source.

Similar to the vegetables, the water composition of more preferred species were lower. This was true of Potamogeton amplifolius but not of Typha latifolia possibly because the shoots grow above the water and the thick structure is intended to prevent water loss. Myriophyllum alterniflorum and Isoetes bruanii both had higher water percentages which correspond to the vegetable results suggesting that higher water concentrations are less preferred. Water abundance may be representative of rigid plants and lower protein concentration.

The laboratory preference test suggests that crayfish prefer less rigid macrophytes and is reinforced by the vegetable preference tests. Further experimentation is recommended to find whether chemical deterrence of nutrient composition play a role in herbivore selectivity.

Acknowledgments

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References Cited

Baker, F.C. 1928. The Freshwater Mollusca of Wisconsin. Part 1 Gastropoda. Wisconsin Academy of Sciences, Arts, and Letters, Madison, WI.

Barko, J.W. , M.S. Adams, and N.L. Clesceri. 1986. Environmental factors and their consideration in the management of submerged aquatic vegetation: a review. J. Aquat. Plant Manage. 24: 1-10.

Benson, L. 1979. Plant Classification 2nd ed. D.C. Heath & Co., Massachusetts.

Boyd, J.D. 1968. Freshwater plants: a potential source of protein. Economic Botany. 22: 359-368.

Burr, F. !988. The field and Garden Vegetables of America. The American Botanist, Booksellers, Chillicothe, Illinois.

Carpenter, S.R., and D.M. Lodge. 1986. Effects of Submerged macrophytes on ecosystem processes. Aquat. Bot. 26: 341-370.

Costello, D.P., M.E. Davidson et al. 1957. Methods for Obtaining and Handling Marineeggs and Embryos. Lancaster Press, Inc., Lancaster, Pennsylvania.

Fassett, N.C. 1972. A manual of Aquatic Plants. University of Wisconsin Press, Wisconsin.

Hill, A.M., D.M. Sinars, and D.M. Lodge. 1993. Invasion of an occupied niche by the crayfish *Orconectes rusticus*: potential importance of growth and mortality. Oecologia. 303-306.

Holdich D.M., and R.S. Lowery. 1988. Freshwater Crayfish; Biology, Management,and Exploitation. Timber Press, Portland, Oregon.

Lehmkuhl, D.M. 1979. How to Know the Aquatic Insects. Wm. C. Brown Co., Dubuque, Iowa.

Lodge, D.M. 1991. Herbivory on freshwater macrophytes. Aqu. Bot. 195-224.

Lodge, D.M., and M.E. Hay. 1993. Collaborative research: herbivory on freshwater macrophytes: quantifying plant damage and mechanisms of plant resistance. Unpublished NSF proposal. 1-31.

Lodge, D.M. , and J.G. Lorman. 1987. Reductions in submerged macrophyte biomass and species richness by the crayfish *Orconectes rusticus*. Can. J. Fish. Aquatic. Sci. 44: 591-597.

Lorman, J.G. 1975. Feeding and activity of the crayfish *Orconectes rusticus* in a northern Wisconsin lake. M.S. thesis, University of Wisconsin, Madison, Wisconsin.

Lorman, J.G. 1980. Ecology of the crayfish *Orconectes rusticus* in northern Wisconsin. Ph.D. thesis, University of Wisconsin, Madison, Wisconsin.

Merrit, R.W., and K.W. Cummins. 1984. An Introduction to the Aquatic Insects of North

America 2nd ed. Kendall/Hunt Pub. Co., Dubuque, Iowa.

Pennak, R.W. 1978. Freshwater Invertabrates of the United States, 2nd Ed. John Willey & Sons, New York.

Tanaka, T. 1976. Tanaka's Cyclopedia of Edible Plants of the World. Keigaku Pub.Co., Tokyo, Japan.

Thorp, J.H., and A.P. Covich. 1991. Ecology and Classification of North American Freshwater Invertebrates. Academic Press, Inc., New York.

Figure 1. Diagram of submerged polypropylene line for vegetable preference tests. Each line consisted of three cans weighted with gravel and tied to the rope. These lines were submerged in 1.0m water with cabbage, icehead lettuce, kale, red lettuce, romaine lettuce, and spinach to determine grazer selectivity.

Figure 2. Map of Lake Tenderfoot showing six sites for vegetable preference tests and two sites for experiment I. The lines were submerged at 1.0m for 48 hours. Muddy and rocky sites are indicated by "m" and "r" and Experiment I sites are indicated by "p". The site numbers correspond to other figures and appendices.

Figure 3. Diagram of laboratory experiment conditions. To simulate the natural feeding environment, a rock was scrubbed in hot water and placed in the pan for shelter, the pan was covered to simulate night feeding preferences, and the room temperature was raised to 18.5 degrees Celcius. Each macrophyte was attached to a piece of bathtub matting and was randomly arranged in a semi-circle around the rock. The only difference between each experimental and control pan was the addition of one crayfish which was allowed to feed for an experimental duration of 90 hours.

Figure 4. Mean preference of six vegetables and their 95% confidence limits for three muddy and three rocky sites. Each number corresponds to a specific vegetable as specified in the figure. Cabbage and icehead lettuce had a consistently low consumption rate. Romaine and Red lettuce varied among sites while spinach and kale were consistently high. For data, see appendix 2.

Figure 5. Mean preference of six vegetables and their 95% confidence limits for three rocky sites combined and three muddy sites combined and all sites combined for experiment III. Each number corresponds to a specific vegetable indicated in the figure which were submerged for 48 hours from 6/16/94 to 6/18/94. Both rocky and muddy sites (A & B) had high consumption of spinach and kale, moderate consumption of red and romaine lettuces, and low consumption of spinach and kale. In C, kale had a high consumption rate which is unusual due to the close phylogenic relationship with cabbage. Spinach was also preferentially consumed while red and romaine lettuces were moderately consumed. Icehead lettuce and cabbage had low consumption rates. For data see appendix 2.

Fig 6. *O. Propinquus* consumption of selected macrophytes in grams with 95% confidence limits. Each number corresponds to a specific macrophyte indicated in the figure. The *Potamogeton amplifolius*, filamentous algae, and *Nuphar variegatum* were found to be consumed while *Myriophyllum alterniflorum*, *Isoetes* braunii, and *Typha latifolia* were unable to be determined. The experiment duration was 90 hours and was conducted 7/6/94 to 7/10/94. For data, see appendix 5.

Figure 1. Experimental design for field experiments in general herbivore preference among vegetables.

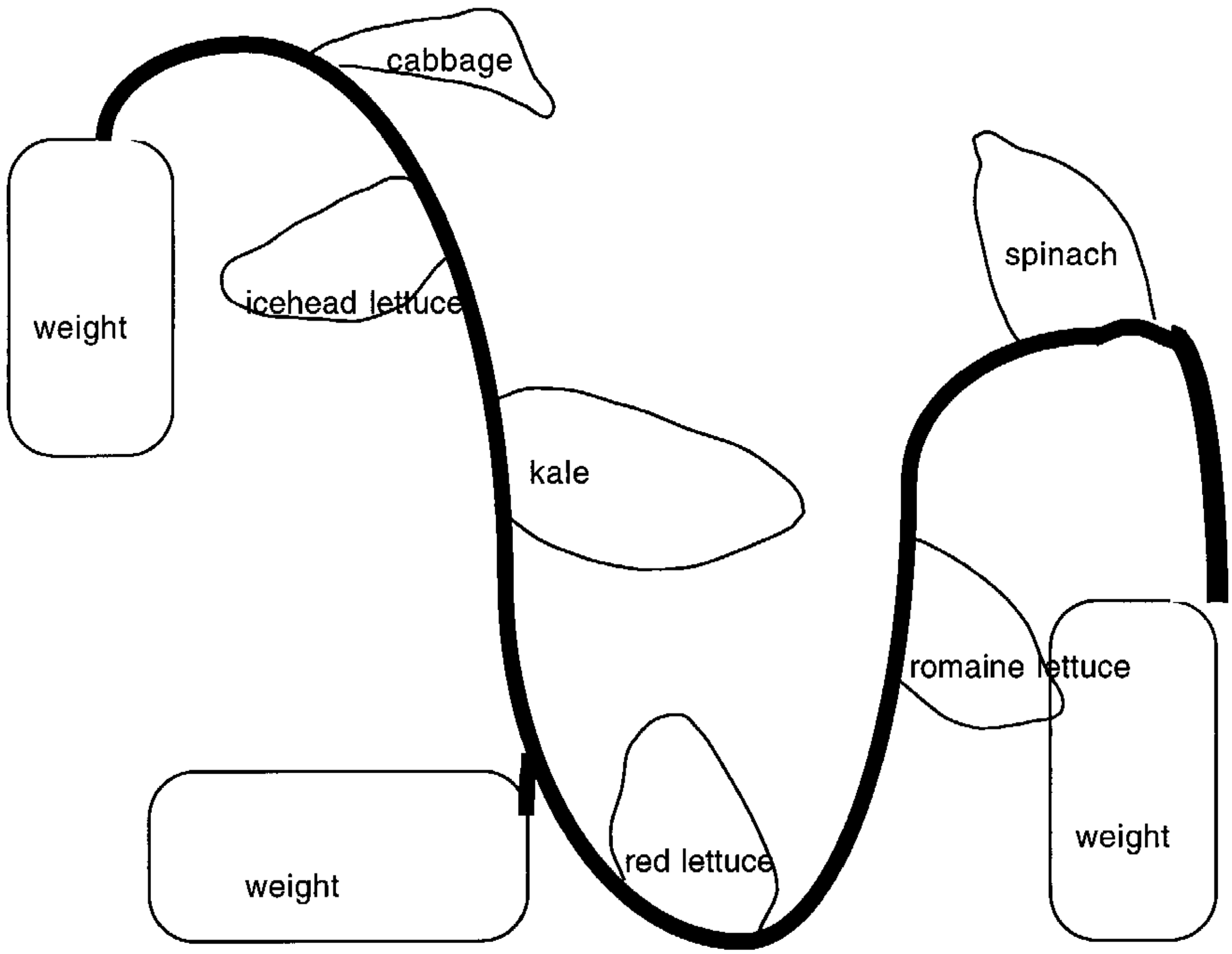


Figure2. Map of Tenderfoot Lake showing six sites for vegetable experiments II, III, and IV and two sites for experiment I.

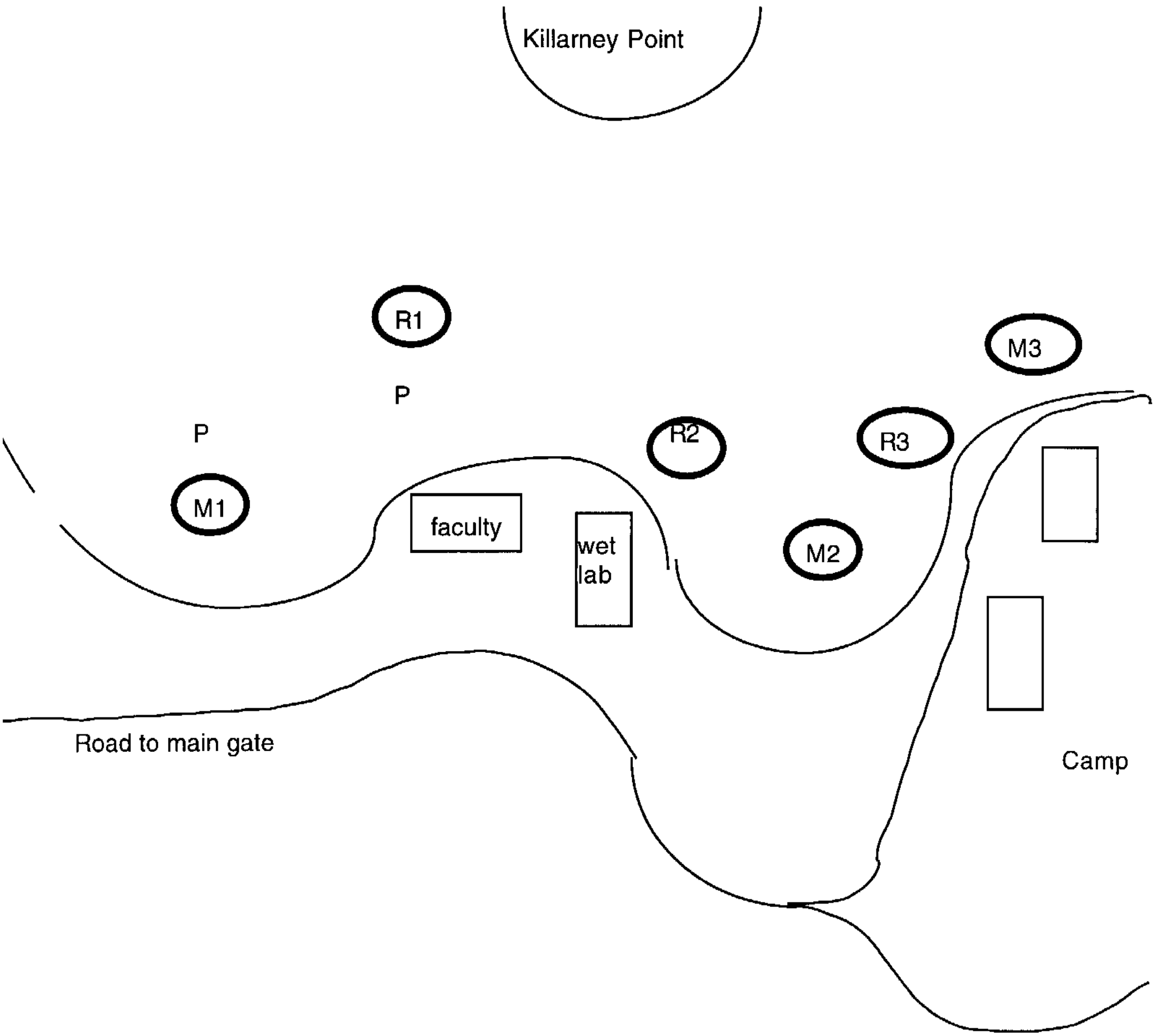


Figure 3. Diagram of laboratory experiment testing for *O. propinquus* macrophyte preference.

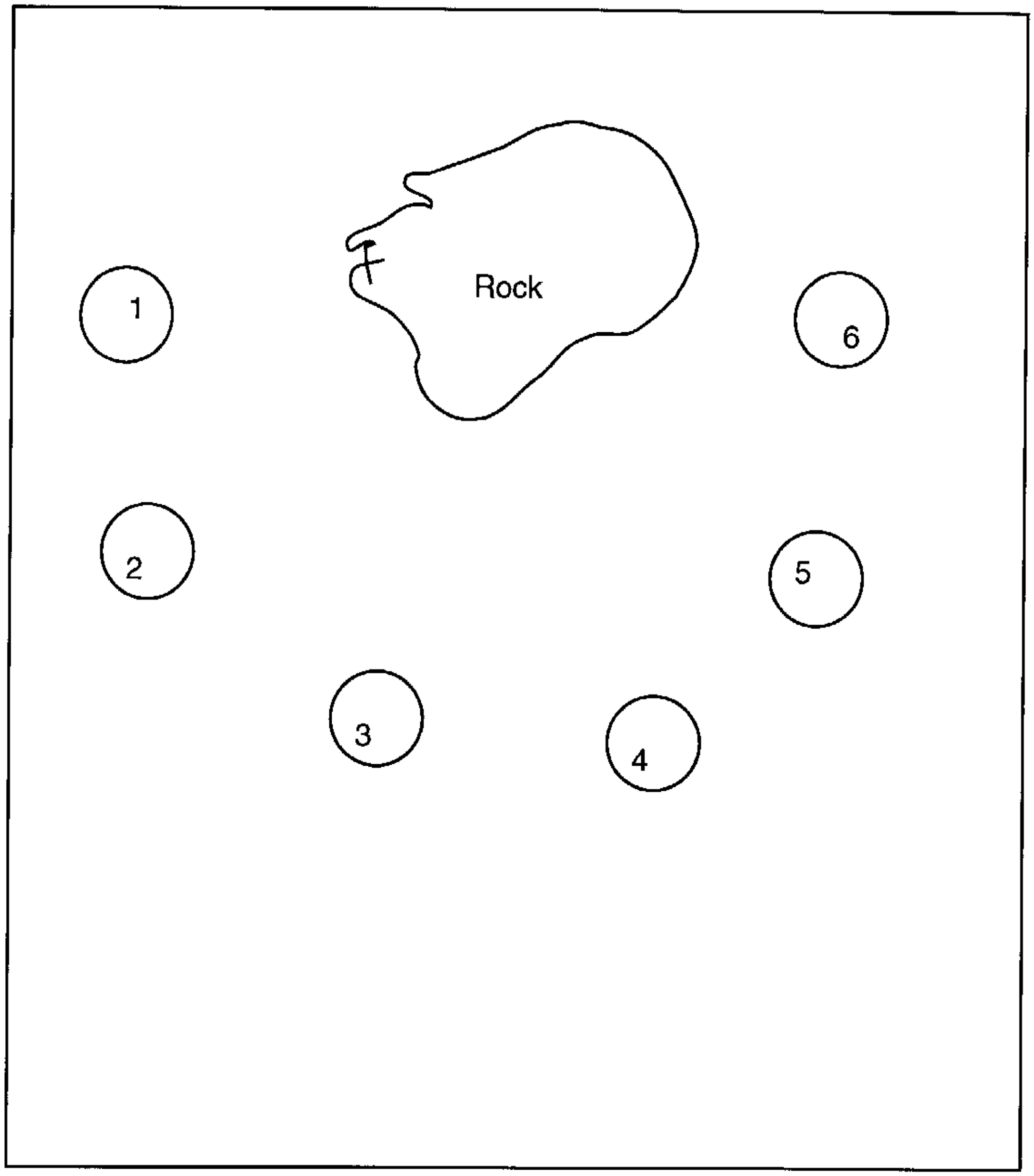


Figure 4. Comparison of number of squares consumed among six individual muddy and rocky sites in experiment IV. All sites are located in Tenderfoot Lake. Data from appendix 2. Key: CAB=cabbage, ILE=iceberg lettuce, KAL=kale, RLE=red lettuce, ROM=romaine lettuce, and SPI=spinach.

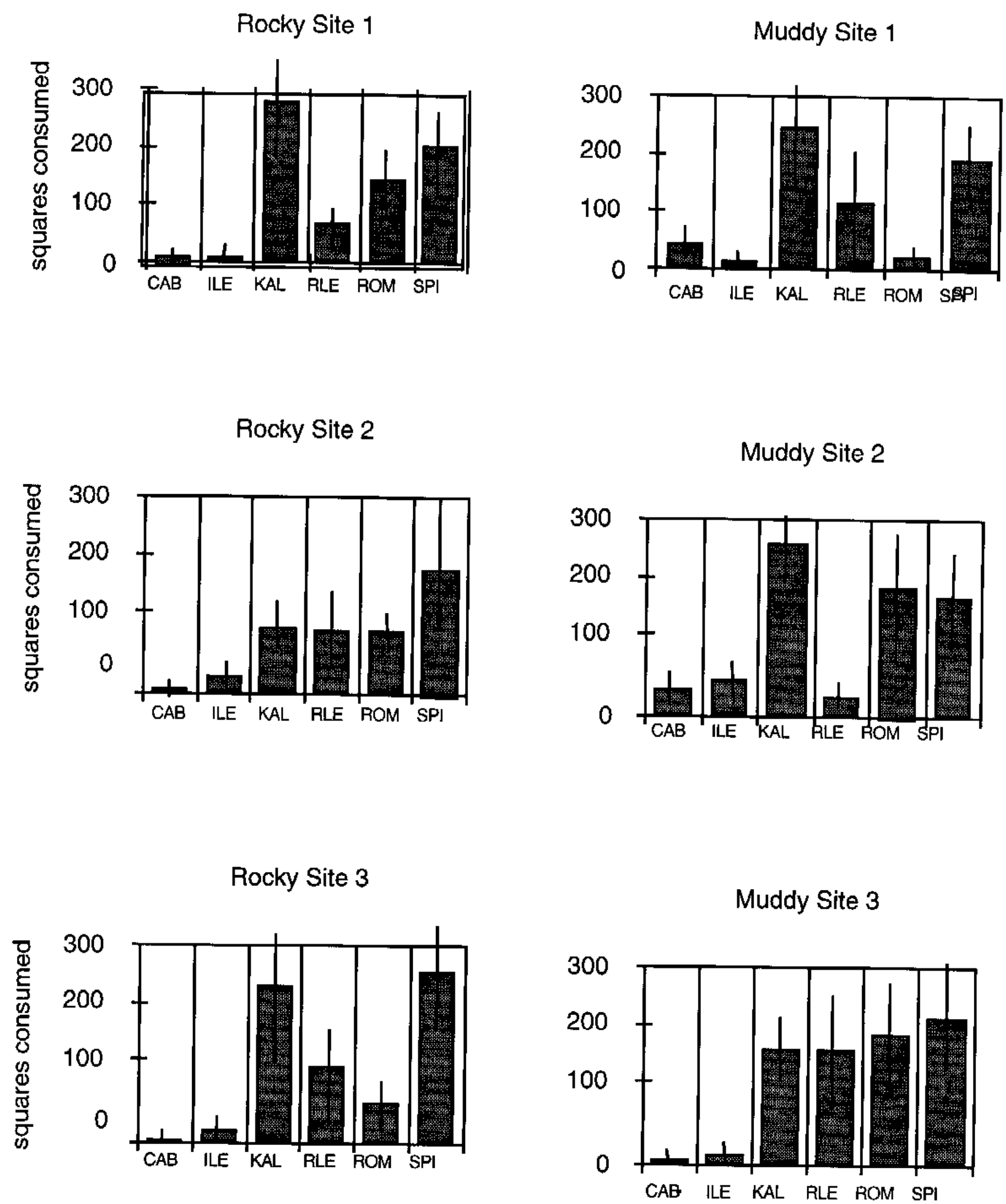


Figure 5. Comparison of mean number of squares consumed and confidence limits in separate and combined muddy and rocky substrates. Comparison between vegetables was determined by number of 2x2mm squares consumed. Data from appendix 2. Key: CAB=cabbage, ILE=icehead lettuce, KAL=kale, RLE=redlettuce,ROM=romainelettuce,SPI=spinach.

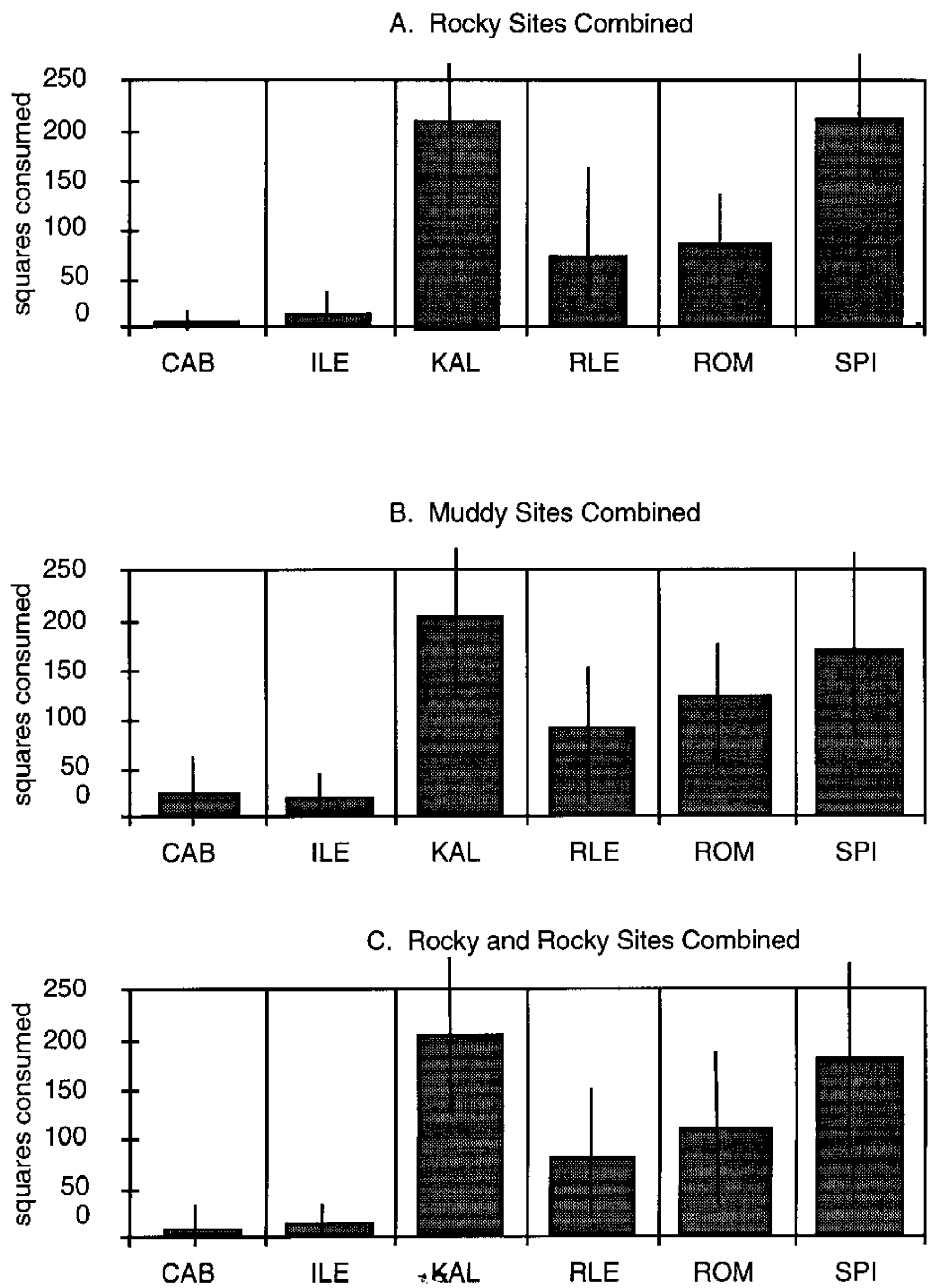
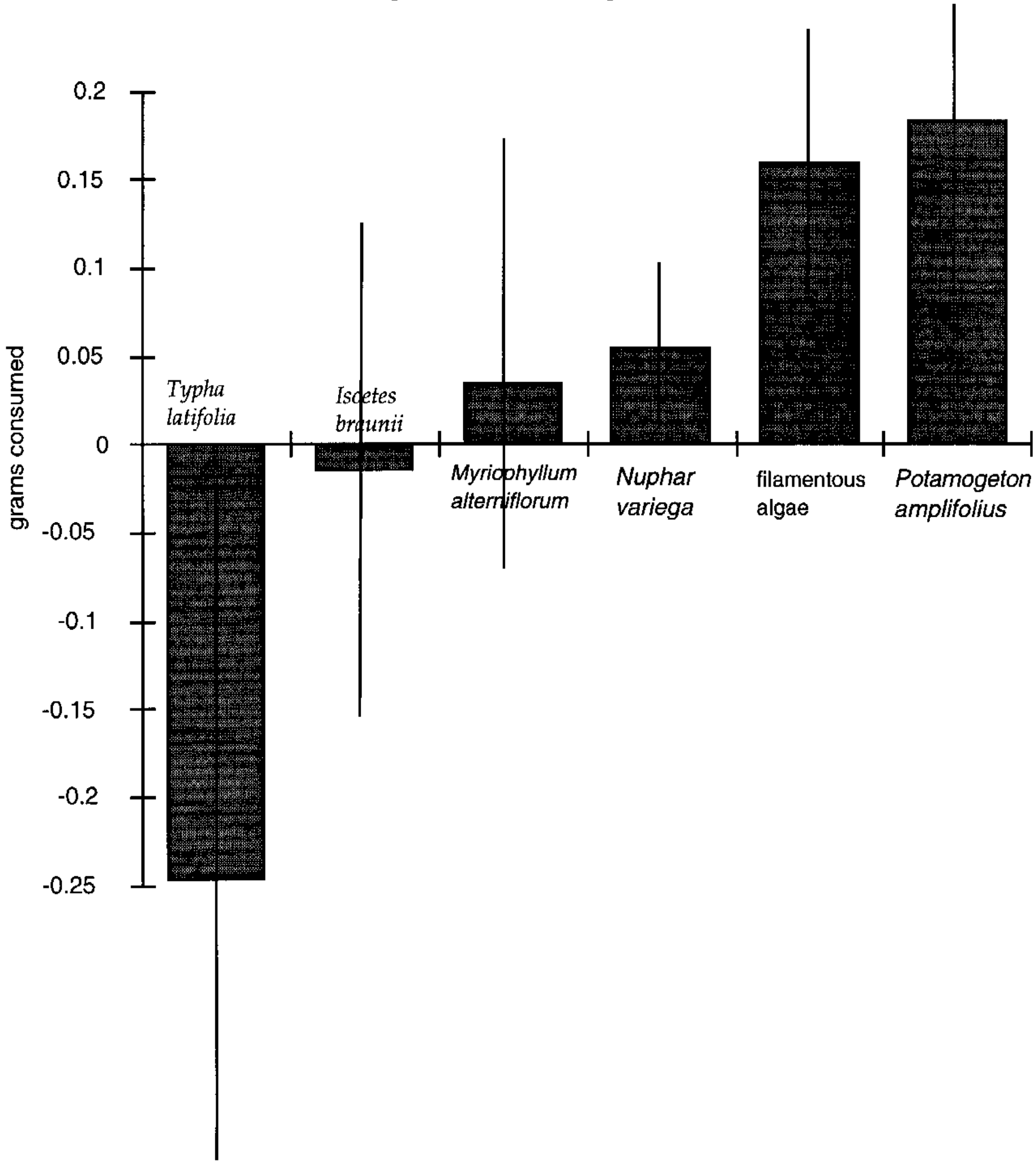


Figure 6. Results of laboratory preference tests. The experiment duration was 90 hours from 7/6/94 to 7/10/94. The mean consumption is measured in grams with 95% confidence limits.



Appendix 1. Size of *O. propinquus* used for each experimental pan. Additional information about crayfish is included where applicable. Crayfish chosen had sturdy, hard carapace with light markings and those that recently or would soon molt during the experiment were not used. Crayfish were caught 48 hours before experimentation which began 7/6/94.

Number	Carapace Length (mm)	Total Length (mm)
1	31	66
2	26	58
3	35	58
4	26	55
5	25	50
6	26	50
7	23	50
8	26	53
9	24	47
10	23	49
11	22	45
12	25	48
13	22	43
14	20	40
15	26	50-died during experiment
Average	25mm	51mm

Appendix 2. Comparison of submerged vegetables among muddy and rocky sites for experiment IV. Six vegetables were cut into a square with 375 2x2mm square area exposed and a 150 square area secured to a 1.5m polypropylene rope. The experiment duration was 48 hours from 6/16/94- 6/18/94 Consumption was measured in number of squares consumed.

Rocky

Site 1

#	Cabbage	Iceberg	Kale	Red	Romaine	Spinach
1	0	38	375	3	18	375
2	0	1	77	20	59	35
3	2	4	370	125	123	50
4	0	1	220	90	360	172
5	3	1	360	103	164	375
Mean	1	9	280.4	68.2	144.8	201.4
Variance	1.6	211.6	13666.64	2297.36	14118.96	22349.84
Std. Dev.	1.2649111	14.546477	116.9044054	47.93078343	118.8232301	149.4986288
Std. Err.	0.3643537	4.1900671	33.67394658	13.80631154	34.22665799	43.06261019
C.L.	0.7870039	9.0505448	72.73572461	29.82163292	73.92958126	93.015238

Site 2

#	Cabbage	Iceberg	Kale	Red	Romaine	Spinach
6	4	4	57	35	35	100
7	6	5	165	90	90	375
8	3	40	23	117	117	55
Mean	4.3333333	16.333333	81.66666667	80.66666667	80.66666667	176.6666667
Variance	1.5555556	280.22222	3664.888889	1164.222222	1164.222222	20005.55556
Std. Dev.	1.2472191	16.739839	60.53832579	34.12070079	34.12070079	141.4409967
Std. Err.	0.3592576	4.8218581	17.43787449	9.828360631	9.828360631	40.7416346
C.L.	0.7759963	10.415214	37.6658089	21.22925896	21.22925896	88.00193074

Site 3

#	Cabbage	Iceberg	Kale	Red	Romaine	Spinach
9	10	11	275	15	53	375
10	0	10	11	40	4	38
11	3	14	365	15	65	375
12	4	7	29	375	95	375
13	0	37	350	35	29	40
Mean	3.4	15.8	206	96	49.2	240.6
Variance	13.44	117.36	24026.4	19564	962.56	27095.44
Std. Dev.	3.6660606	10.833282	155.0045161	139.8713695	31.02515109	164.6069257
Std. Err.	1.0559972	3.1204928	44.64856372	40.28950841	8.936697268	47.41450765
C.L.	2.280954	6.7402646	96.44089764	87.02533816	19.3032661	102.4153365

All rocky sites combined

Mean	2.6923077	13.307692	205.9230769	81.76923077	93.23076923	210.7692308
Variance	8.0591716	202.8284	21039.45562	8825.869822	7874.177515	24278.48521
Std. Dev.	2.838868	14.241784	145.0498384	93.94610062	88.73656245	155.8155487
Std. Err.	0.817727	4.102301	41.78115011	27.06087904	25.56028794	44.88217912
C.L.	1.7662903	8.8609702	90.24728423	58.45149873	55.21022195	96.94550689

Muddy

Site 1

	Cabbage	Iceberg Lettuce	Kale	Red Lettuce	Romaine Lettuce	Spinach
1	3	35	375	26	22	11
2	160	6	375	4	35	360
3	30	7	43	8	19	35
4	3	10	83	150	4	270
5	0	1	350	370	11	220
Mean	39.2	11.8	245.2	111.6	18.2	179.2
Variance	3766.96	142.96	22374.56	19576.64	110.16	18336.56
Std. Dev.	61.375565	11.956588	149.5812823	139.9165466	10.49571341	135.4125548
Std. Err.	17.679039	3.4440576	43.08641827	40.30252152	3.023257263	39.00516085
C.L.	38.186724	7.4391645	93.06666345	87.05344649	6.530235689	84.25114744

Site 2

6	103	8	220	28	39	200
7	4	12	350	34	68	116
8	5	120	150	15	375	98
9	45	38	152	17	350	20
10	14	38	375	24	22	375
Mean	34.2	43.2	249.4	23.6	170.8	161.8
Variance	1404.56	1632.96	9225.44	49.04	24778.16	14637.76
Std. Dev.	37.47746	40.4099	96.04915408	7.00285656	157.4108001	120.9866108
Std. Err.	10.795265	11.639945	27.66665698	2.017150824	45.34168629	34.84981303
C.L.	23.317771	25.14228	59.75997908	4.357045781	97.93804238	75.27559614

Site 3

11	4	12	375	375	375	375
12	2	5	40	42	33	80
13	1	7	82	375	112	48
14	8	4	126	12	18	375
15	5	32	180	12	375	160
Mean	4	12	160.6	163.2	182.6	207.6
Variance	6	107.6	13652.64	30026.16	25698.64	20013.04
Std. Dev.	2.4494897	10.373042	116.8445121	173.2805817	160.3079536	141.4674521

Std. Err.	0.7055678	2.9879221	33.6566945	49.912927	46.17620225	40.74925499
C.L.	1.5240265	6.4539118	72.69846011	107.8119223	99.74059686	88.01839077

All muddy sites combined

Mean	25.8	22.333333	218.4	99.46666667	123.8666667	182.8666667
Variance	1967.6267	845.55556	16757.57333	19872.24889	22468.24889	18018.78222
Std. Dev.	44.357938	29.078438	129.4510461	140.9689643	149.8941256	134.2340576
Std. Err.	12.777165	8.3759527	37.287967	40.60566714	43.17653181	38.66569844
C.L.	27.598676	18.092058	80.54200872	87.70824102	93.26130871	83.51790863

All rocky and muddy sites combined

Mean	15.071429	18.142857	212.6071429	91.25	109.6428571	195.8214286
Variance	1190.6378	567.40816	18784.30995	14821.47321	15925.87245	21118.71811
Std. Dev.	34.505619	23.820331	137.0558643	121.743473	126.1977514	145.3228066
Std. Err.	9.9392352	6.8613715	39.478511	35.06782479	36.35086568	41.85977773
C.L.	21.468748	14.820562	85.27358376	75.74650155	78.51786987	90.4171199

Appendix 3. Consumption of submerged vegetables among rocky and muddy substrates for experiment II. Three vegetables purchased from IGA in Land O' Lakes, Wisconsin. were cut into rectangles with 375-2x2mm squares exposed and 150 squares secured to a 1.5m polypropylene rope. Vegetable consumption was measured in number of squares. The experimental period began 6/8/94 and continued for 48 hours until 6/10/94.

Rocky	Site 1			Muddy	Site 1		
#	Cabbage	Iceberg	Spinach		Cabbage	Iceberg Lett	Spinach
1	1	217	52	1	0	208	322
2	1	268	114	2	5	176	295
3	3	8	18	3	4	140	18
4	1	2	150	4	2	18	290
5	1	30	145	5	1	27	284
Mean	1.4	105	95.8	Mean	2.4	113.8	241.8
Variance	0.64	12951.2	2732.16	Variance	3.44	6028.16	12690.56
Std. Dev.	0.8	113.80334	52.27006792	Std. Dev.	1.854723699	77.64122616	112.6523857
Std. Err.	0.2304375	32.780694	15.0562288	Std. Err.	0.534247333	22.36431119	32.44916566
C.L.	0.497745	70.806299	32.5214542	C.L.	1.153974239	48.30691218	70.09019784
Site 2				**Site 2**			
6	56	18	296	6	375	375	72
7	2	375	300	7	0	0	12
8	4	296	43	8	375	105	168
9	0	3	310	9	2	375	290
10	3	95	239	10	4	375	312
Mean	13	157.4	237.6	Mean	151.2	246	170.8
Variance	464	22745.04	10083.44	Variance	33392.56	26064	13826.56
Std. Dev.	21.540659	150.81459	100.4163333	Std. Dev.	182.7363128	161.4434886	117.5863938
Std. Err.	6.2047192	43.441668	28.92460924	Std. Err.	52.63662061	46.50328952	33.87039119
C.L.	13.402193	93.834003	62.47715596	C.L.	113.6951005	100.4471054	73.16004497
Site 3				**Site 3**			
11	0	94	290	11	2	9	300
12	1	47	6	12	1	12	280
13	1	8	6	13	3	375	290
14	2	6	18	14	3	375	300
15	2	375	300	15	17	375	28
Mean	1.2	106	124	Mean	5.2	229.2	239.6
Variance	0.56	19118	19523.2	Variance	35.36	31887.36	11248.64
Std. Dev.	0.7483315	138.26786	139.7254451	Std. Dev.	5.946427499	178.5703223	106.0596059
Std. Err.	0.2155545	39.827621	40.24747534	Std. Err.	1.712849753	51.43662014	30.55013616
C.L.	0.4655978	86.027662	86.93454673	C.L.	3.699755467	111.1030995	65.98829411

All rocky sites			All muddy sites			
Mean	5.7692308	134.15385	133.6923077	Mean	52.93333333	196.3333333	217.4
Variance	211.25444	20480.899	13934.8284	Variance	15973.26222	24779.42222	13675.17333
Std. Dev.	14.534595	143.11149	118.0458741	Std. Dev.	126.3853719	157.4148094	116.9408968
Std. Err.	4.1866443	41.222816	34.00274307	Std. Err.	36.40490918	45.34284115	33.6844578
C.L.	9.0431516	89.041282	73.44592502	C.L.	78.63460382	97.94053688	72.75842885

Muddy & rocky sites			
Mean	31.03571429	167.4642857	178.5357143
Variance	9208.46301	23745.32015	15538.53444
Std. Dev.	95.96073682	154.0951659	124.6536579
Std. Err.	27.64118867	44.38662826	35.90609442
C.L.	59.70496752	95.87511705	77.55716395

Appendix 4. Consumption of submerged vegetables among rocky and muddy substrates for experiment III. Three vegetables were purchased from IGA foodstore in Land O' Lakes, Wisconsin, cut into rectangles with 375-2x2mm squares exposed, and 150 squares secured to a 1.5m polypropylene rope. Vegetable consumption was measured in number of squares. Experimental period started 6/10/94 and continued for 48 hours until 6/12/94.

Rocky	**Site 1**			**Muddy**	**Site 1**		
#	Cabbage	Iceberg	Spinach		Cabbage	Iceberg Lett	Spinach
1	2	3	13	1	1	8	5
2	1	5	280	2	6	375	268
3	375	2	375	3	11	100	26
4	1	2	375	4	2	4	32
5	25	3	4	5	2	18	10
Mean	80.8	3	209.4	Mean	4.4	101	68.2
Variance	21722.56	1.2	28118.64	Variance	13.84	20004.8	10078.56
Std. Dev.	147.38575	1.0954451	167.6861354	Std. Dev.	3.720215048	141.4383258	100.3920316
Std. Err.	42.454003	0.3155395	48.30146431	Std. Err.	1.071596253	40.74086525	28.91760919
C.L.	91.700646	0.6815654	104.3311629	C.L.	2.314647906	88.00026893	62.46203585
Site 2				**Site 2**			
6	1	22	121	6	1	375	300
7	3	18	375	7	50	19	37
8	8	32	19	8	1	47	290
9	2	39	95	9	3	22	375
10	0	29	75	10	8	70	375
Mean	2.8	28	137	Mean	12.6	106.6	275.4
Variance	7.76	54.8	15286.4	Variance	356.24	18352.24	15498.64
Std. Dev.	2.7856777	7.4027022	123.6381818	Std. Dev.	18.87432118	135.4704396	124.493534
Std. Err.	0.8024057	2.1323251	35.61358971	Std. Err.	5.4366889	39.02183438	35.85997122
C.L.	1.7331963	4.6058222	76.92535378	C.L.	11.74324802	84.28716226	77.45753783
Site 3				**Site 3**			
11	1	7	9	11	1	12	375
12	2	14	3	12	0	22	375
13	375	8	375	13	4	59	280
14	12	63	8	14	1	16	315
15	1	44	375	15	1	0	290
Mean	78.2	27.2	154	Mean	1.4	21.8	327
Variance	22039.76	502.96	32564.8	Variance	1.84	397.76	1666
Std. Dev.	148.45794	22.42677	180.4571971	Std. Dev.	1.356465997	19.94392138	40.81666326
Std. Err.	42.762843	6.4599605	51.98012852	Std. Err.	0.390725767	5.744783876	11.75711158
C.L.	92.367741	13.953515	112.2770776	C.L.	0.843967658	12.40873317	25.39536101

	All rocky sites			All muddy sites		
Mean	62.076923	17.153846	179.3846154	Mean	6.133333333	76.46666667	223.5333333
Variance	17846.84	328.59172	29118.54438	Variance	146.3822222	14417.71556	21589.04889
Std. Dev.	133.59207	18.127099	170.641567	Std. Dev.	12.0988521	120.0737921	146.9321234
Std. Err.	38.480775	5.2214539	49.15276709	Std. Err.	3.485036326	34.58687847	42.32333639
C.L.	83.118474	11.27834	106.1699769	C.L.	7.527678463	74.70765749	91.41840659

Muddy and rocky sites			
Mean	32.10714286	48.92857143	203.0357143
Variance	9142.881378	8751.352041	25569.6773
Std. Dev.	95.61841547	93.54866135	159.9052135
Std. Err.	27.54258408	26.94639791	46.06019421
C.L.	59.49198161	58.20421948	99.49001949

Appendix 5. Data from laboratory experiments in herbivore macrophyte preference. Data is listed according to specific macrophyte for all 15 replicates. Initial and final mass for each experimental and control is listed along with statistical calculations for each macrophyte. The experiment began 7/6/94 and continued for 90 hours until 7/10/94.

Appendix 15.1. Data for filamentous algae preference in grams.

#	Initial Mass	Final Mass	Initial Control	Final Control	A	B	A-B
1	0.595	0.075	0.6	0.177	0.87394958	0.705	0.16894958
2	0.602	0.204	0.604	0.255	0.66112957	0.57781457	0.083315
3	0.595	0.098	0.605	0.351	0.83529412	0.41983471	0.41545941
4	0.596	0.251	0.6	0.29	0.57885906	0.51666667	0.06219239
5	0.602	0.221	0.596	0.316	0.63289037	0.46979866	0.16309171
6	0.605	0.071	0.602	0.27	0.88264463	0.55149502	0.33114961
7	0.598	0.127	0.599	0.308	0.78762542	0.48580968	0.30181574
8	0.601	0.102	0.595	0.167	0.83028286	0.71932773	0.11095513
9	0.603	0.232	0.604	0.217	0.61525705	0.64072848	-0.0254714
10	0.604	0.248	0.595	0.375	0.58940397	0.3697479	0.21965607
11	0.601	0.147	0.595	0.309	0.75540765	0.48067227	0.27473539
12	0.601	0.204	0.603	0.338	0.66056572	0.43946932	0.2210964
13	0.6	0.242	0.596	0.176	0.59666667	0.70469799	-0.1080313
14	0.597	0.126	0.605	0.276	0.78894472	0.54380165	0.24514307
15	0.599	0.202	0.595	0.16	0.66277129	0.73109244	-0.0683212
						MEAN	0.15971571
						VARIANCE	0.01878323
						STD. DEV.	0.14575786
						STD. ERR.	0.04198509
						C.L.	0.0906878

Appendix 5.2. Data for *Isoetes braunii* preference in grams

#	Initial Mass	Final Mass	Initial Control	Final Control	A	B	A-B
1	0.319	0.241	0.317	0.342	0.24451411	-0.0788644	0.32337846
2	0.32	0.345	0.319	0.361	-0.078125	-0.1316614	0.05353644
3	0.316	0.224	0.316	0.331	0.29113924	-0.0474684	0.33860759
4	0.316	0.321	0.32	0.31	-0.0158228	0.03125	-0.0470728
5	0.32	0.261	0.319	0.338	0.184375	-0.0595611	0.24393613
6	0.313	0.291	0.316	0.312	0.07028754	0.01265823	0.05762931
7	0.313	0.338	0.315	0.331	-0.0798722	-0.0507937	-0.0290786
8	0.319	0.279	0.317	0.255	0.12539185	0.1955836	-0.0701917
9	0.318	0.37	0.316	0.384	-0.163522	-0.2151899	0.05166786
10	0.311	0.345	0.317	0.307	-0.1093248	0.03154574	-0.1408705
11	0.314	0.41	0.316	0.299	-0.3057325	0.05379747	-0.35953
12	0.317	0.255	0.318	0.292	0.1955836	0.08176101	0.11382259
13	0.311	0.4	0.313	0.33	-0.2861736	-0.0543131	-0.2318605
14	0.311	0.346	0.318	0.214	-0.1125402	0.32704403	-0.4395842
15	0.313	0.378	0.315	0.351	-0.2076677	-0.1142857	-0.093382
						MEAN	-0.0152661
						VARIANCE	0.05023719
						STD. DEV.	0.21754058
						STD. ERR.	0.06266188
						C.L.	0.13534966

Appendix 5.3. Data for *Myriophyllum alterniflorum* preference in grams.

#	Initial Mass	Final Mass	Initial Control	Final Control	A	B	A-B
1	0.357	0.335	0.362	0.501	0.06162465	-0.3839779	0.44560255
2	0.366	0.399	0.357	0.467	-0.0901639	-0.3081232	0.21795931
3	0.357	0.443	0.361	0.456	-0.2408964	-0.2631579	0.02226154
4	0.364	0.337	0.363	0.482	0.07417582	-0.3278237	0.40199952
5	0.362	0.45	0.366	0.412	-0.2430939	-0.1256831	-0.1174109
6	0.366	0.488	0.367	0.407	-0.3333333	-0.1089918	-0.2243415
7	0.366	0.421	0.358	0.436	-0.1502732	-0.2178771	0.06760387
8	0.365	0.454	0.365	0.407	-0.2438356	-0.1150685	-0.1287671
9	0.364	0.486	0.367	0.507	-0.3351648	-0.3814714	0.04630655
10	0.366	0.467	0.363	0.416	-0.2759563	-0.1460055	-0.1299508
11	0.367	0.396	0.365	0.444	-0.0790191	-0.2164384	0.13741928
12	0.364	0.459	0.36	0.435	-0.260989	-0.2083333	-0.0526557
13	0.366	0.363	0.368	0.402	0.00819672	-0.0923913	0.10058803
14	0.366	0.457	0.362	0.42	-0.2486339	-0.160221	-0.0884129
15	0.365	0.449	0.365	0.388	-0.230137	-0.0630137	-0.1671233
						MEAN	0.03540524
						VARIANCE	0.03694538
						STD. DEV.	0.19342233
						STD. ERR.	0.05571469
						C.L.	0.12034374

Appendix 5.4. Data for *Nuphar variegatum* (submerged) preference in grams.

#	Initial Mass	Final Mass	Initial Control	Final Control	A	B	A-B
1	0.112	0.123	0.11	0.118	-0.0982143	-0.0727273	-0.025487
2	0.109	0.113	0.107	0.119	-0.0366972	-0.1121495	0.07545229
3	0.11	0.104	0.112	0.128	0.05454545	-0.1428571	0.1974026
4	0.107	0.099	0.108	0.12	0.07476636	-0.1111111	0.18587747
5	0.103	0.108	0.104	0.11	-0.0485437	-0.0576923	0.00914862
6	0.111	0.122	0.108	0.12	-0.0990991	-0.1111111	0.01201201
7	0.112	0.129	0.104	0.12	-0.1517857	-0.1538462	0.00206044
8	0.11	0.117	0.103	0.114	-0.0636364	-0.1067961	0.04315975
9	0.112	0.121	0.109	0.132	-0.0803571	-0.2110092	0.13065203
10	0.106	0.11	0.107	0.115	-0.0377358	-0.0747664	0.03703051
11	0.112	0.119	0.106	0.106	-0.0625	0	-0.0625
12	0.108	0.115	0.105	0.114	-0.0648148	-0.0857143	0.02089947
13	0.108	0.117	0.111	0.13	-0.0833333	-0.1711712	0.08783784
14	0.108	0.112	0.106	0.117	-0.037037	-0.1037736	0.06673655
15	0.108	0.117	0.107	0.12	-0.0833333	-0.1214953	0.03816199
						MEAN	0.05456297
						VARIANCE	0.00524434
						STD. DEV.	0.07009942
						STD. ERR.	0.02019192
						C.L.	0.04361454

Appendix 5.5. Data for *Potamogeton amplifolius* preference in grams.

#	Initial Mass	Final Mass	Initial Control	Final Control	A	B	A-B
1	0.059	0.074	0.059	0.113	-0.2542373	-0.9152542	0.66101695
2	0.056	0.054	0.057	0.071	0.03571429	-0.245614	0.28132832
3	0.058	0.055	0.061	0.085	0.05172414	-0.3934426	0.44516676
4	0.058	0.057	0.061	0.064	0.01724138	-0.0491803	0.06642171
5	0.054	0.052	0.06	0.07	0.03703704	-0.1666667	0.2037037
6	0.059	0.059	0.058	0.069	0	-0.1896552	0.18965517
7	0.058	0.05	0.06	0.063	0.13793103	-0.05	0.18793103
8	0.057	0.056	0.06	0.069	0.01754386	-0.15	0.16754386
9	0.059	0.059	0.058	0.061	0	-0.0517241	0.05172414
10	0.054	0.055	0.061	0.079	-0.0185185	-0.295082	0.27656345
11	0.06	0.064	0.059	0.067	-0.0666667	-0.1355932	0.06892655
12	0.058	0.06	0.061	0.067	-0.0344828	-0.0983607	0.0638779
13	0.06	0.057	0.057	0.062	0.05	-0.0877193	0.1377193
14	0.061	0.068	0.053	0.052	-0.1147541	0.01886792	-0.133622
15	0.055	0.055	0.059	0.064	0	-0.0847458	0.08474576
						MEAN	0.18351351
						VARIANCE	0.03399392
						STD. DEV.	0.18006791
						STD. ERR.	0.051868
						C.L.	0.11203487

Appendix 5.6. Data for *Typha latifolia* preference in grams.

#	Initial Mass	Final Mass	Initial Control	Final Control	A	B	A-B
1	0.172	0.28	0.176	0.268	-0.627907	-0.5227273	-0.1051797
2	0.177	0.351	0.173	0.254	-0.9830508	-0.4682081	-0.5148428
3	0.18	0.363	0.176	0.239	-1.0166667	-0.3579545	-0.6587121
4	0.177	0.441	0.173	0.297	-1.4915254	-0.716763	-0.7747624
5	0.173	0.343	0.18	0.266	-0.982659	-0.4777778	-0.5048812
6	0.171	0.376	0.18	0.355	-1.1988304	-0.9722222	-0.2266082
7	0.177	0.416	0.176	0.321	-1.3502825	-0.8238636	-0.5264188
8	0.172	0.343	0.173	0.366	-0.994186	-1.1156069	0.12142089
9	0.176	0.386	0.175	0.328	-1.1931818	-0.8742857	-0.3188961
10	0.177	0.383	0.178	0.366	-1.1638418	-1.0561798	-0.107662
11	0.181	0.316	0.172	0.369	-0.7458564	-1.1453488	0.39949248
12	0.18	0.318	0.173	0.368	-0.7666667	-1.1271676	0.36050096
13	0.172	0.353	0.177	0.354	-1.0523256	-1	-0.0523256
14	0.176	0.398	0.171	0.314	-1.2613636	-0.8362573	-0.4251063
15	0.175	0.379	0.176	0.314	-1.1657143	-0.7840909	-0.3816234

MEAN	-0.247707
VARIANCE	0.12148111
STD. DEV.	0.33861976
STD. ERR.	0.09753836
C.L.	0.21068286